# The effectiveness of fully automated digital interventions to promote mental well-being in the general population: A systematic review and meta-analysis

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# Abstract

## Background

Recent years have highlighted the increasing need to promote mental well-being in the general population. This has led to a rapidly growing market of fully automated digital mental well-being tools. Although many individuals have started using these tools in their daily lives, evidence on the overall effectiveness of digital mental well-being tools is currently lacking.

## Objective(s)

The objective of the current study was therefore to review evidence on the effectiveness of fully automated digital interventions to promote mental well-being in the general population.

## Methods

Following preregistration of the systematic review protocol on PROSPERO (registration: CRD42022310702), searches were carried out in: Medline, Web of Science, Cochrane, PsychINFO, PsychEXTRA, Scopus and ACM Digital (initial searches in February 2022; updated in October 2022). Studies were included if they contained a general population sample and a fully automated digital intervention that exclusively employed psychological mental well-being promotion activities. Two reviewers, blinded to each other’s decisions, conducted data selection, extraction and quality assessment of the included studies. A narrative synthesis and a random-effects model of Per Protocol (PP) data were adopted.

## Results

A total of 7,243 participants in 19 studies were included. These studies contained 24 fully automated digital mental well-being interventions of which 15 were included in the meta-analysis. Compared with no intervention, there was a significant small effect of fully automated digital mental well-being interventions on mental well-being in the general population (SMD = 0.19, 95% CI ranging from 0.04 to 0.33). Specifically, mindfulness, acceptance & commitment, and compassion-based interventions significantly promoted mental well-being in the general population; insufficient evidence was available for positive psychology and Cognitive Behavioural Therapy (CBT)-based interventions; and contraindications were found for integrative approaches. Overall, there was substantial heterogeneity which could partially be explained by the intervention duration, comparator and study outcome. Risk of bias was high and confidence in quality of the evidence very low (GRADE), primarily due to the high rates of study dropout (averaging 37%, ranging from 0-85%) and suboptimal intervention adherence (averaging 40%).

## Conclusion

In conclusion, this study provides a novel contribution to knowledge regarding the effectiveness, as well as the strengths and weaknesses of fully automated digital mental well-being interventions in the general population. Future research and practice should take these findings into account when developing fully automated digital mental well-being tools. Additionally, research should aim to investigate positive psychology and CBT-based tools as well as further strategies to improve adherence and reduce dropout in fully automated digital mental well-being interventions. Finally, it should aim to understand when and for whom these interventions are particularly beneficial.

## Keywords

*Mental well-being; promotion; intervention; digital; online; web-based; apps.*

# Background

## General background

Mental well-being is commonly defined as a complex construct that includes a subjective experience (subjective well-being which is often referred to as ‘happiness’) [1], and a process of self-realisation (psychological well-being) [2,3]. Traditionally, it was thought that mental well-being would arise in the absence of mental illness - as they were considered opposite ends of one continuum [4]. However, the absence of mental illness was found to be insufficient to produce good mental well-being [5]. The dual-continuum model has identified that mental well-being and mental illness are two distinct but related continua instead [6], both of which could be considered part of mental health [7]. It is important to focus on effective promotion of mental well-being exclusively [8], as only a small proportion of the general population have optimal levels of mental well-being [7,9].

Additionally, mental well-being in the general population is crucial in allowing society, and the individuals within it, to thrive. Mental well-being is linked to enhanced productivity, growth, quality of life, social cohesion, more satisfying and enduring relationships, and reduced risk of disease, mental illness, and longevity [5,7,10,11]. Promoting mental well-being in the general population is therefore considered a fundamental goal by the World Health Organisation (WHO), as described in the Mental Health Action Plan 2013-2030 [12]. Mental well-being promotion interventions provide “various activities or practices that aim to promote, build on, increase or foster primarily individuals’ strengths, resourcefulness or resiliency” [10].

Evidence suggests that a variety of psychological approaches are effective at promoting mental well-being; including Acceptance & Commitment Therapy (ACT), compassion, Cognitive Behavioural Therapy (CBT), mindfulness, positive psychology, and multi-theoretical interventions [7]. These psychological approaches were found to have small to moderate effects on mental well-being in the general population, whereby Mindfulness Based Interventions (MBIs) and multi-component Positive Psychology Interventions (PPIs) were particularly efficacious [7,13]. Further meta-analyses focusing on PPIs, MBIs and ACT-based interventions separately, also found similar effects on mental well-being [14-16].

However, these systematic reviews do not focus on fully automated digital interventions. Fully automated digital interventions are interventions that are delivered entirely by the technology itself, not requiring any form of human support (by clinicians or non-clinicians) [17]. Although fully automated digital interventions might be less effective, since recent research has found that any form of human support enhances the effectiveness of interventions [18], fully automated digital interventions allow for great scalability, and are highly cost-effective and accessible [19]. Therefore, fully automated digital interventions provide a particularly pertinent way to promote mental well-being in the general population.

Overall, there’s a need to systematically review the evidence on the effectiveness of fully automated digital mental well-being interventions to improve mental well-being (which includes subjective and psychological well-being) in the general population. Furthermore, an understanding of what psychological approaches work when delivered fully automated digitally, and for whom (as one approach does not suit all) [20], is needed.

## Main objective

The current systematic review aims to understand the effectiveness of fully automated digital interventions to promote mental well-being in the general population.

## Secondary objectives

Furthermore, it aims to explore the effectiveness of fully automated digital mental well-being interventions across psychological approaches and population subgroups.

# Methods

## Study protocol

The systematic review protocol was registered on PROSPERO (registration: CRD42022310702). The Cochrane handbook was used when designing and conducting the systematic review [21], and PRISMA guidance was followed for reporting of the systematic review [22].

## Eligibility criteria

Studies were included if they employed a fully automated digital intervention that aimed to promote mental well-being in the general population.

The study needed to include adults, meaning the population needed to be aged 18 or over. General population was further defined as any adult population subgroup that was not a clinical population and was not specifically recruited due to (expected) lower mental well-being baseline scores by the researchers.

Digital interventions were defined according to the National Institute for Health and Care Excellence (NICE) [17] as interventions that are delivered through hardware and electronic devices (e.g., smartwatches and smartphones), software (e.g., computer programs and apps), and websites. The intervention needed to be fully automated, which means it should be delivered by the technology itself entirely, independent from healthcare professionals, and not containing any other form of social support [17]. For example, a digital web-based intervention whereby video content was delivered automatically would have been included, whilst a digital video call intervention whereby a healthcare professional delivered content would have been excluded. Although the content should be delivered entirely by the technology itself, elements of the study could have still been conducted by the researchers. For example, researchers could have screened, obtained measures, and obtained informed consent (digitally or in-person), after which they could have provided the participant with access to the intervention.

Furthermore, the intervention needed to employ individual mental well-being promotion, defined by the WHO as “various activities or practices that aim to promote, build on, increase or foster primarily individuals’ strengths, resourcefulness or resiliency” [10]. This should be a psychological intervention.

Interventions that included physical activity or lifestyle-related interventions were excluded. If an intervention contained elements that did not include mental well-being promotion, they would also be excluded as the detection of the effectiveness of mental well-being promotion strategies would not be possible. For example, a mindfulness-based intervention would have been included, however, a mindfulness-based intervention that included a yoga session would have been excluded.

The outcome needed to consider a validated measure of mental well-being, including psychological well-being and/or subjective well-being.

Finally, studies needed to investigate the effectiveness of this digital intervention on mental well-being. Therefore, quantitative randomised and Non-Randomised Studies of Interventions (NRSI), such as before-and-after studies, were considered appropriate as they can both provide insights into the effectiveness of interventions [23]. For further details regarding inclusion/exclusion criteria, see the protocol.

## Searches

The initial search was carried out in February 2022 and updated using a title/keyword search in October 2022. Databases searched included Medline, Web of Science, Cochrane, PsychINFO, PsychEXTRA, Scopus and ACM Digital. Combinations of the following key search terms were used: mental well-being, psychological well-being and subjective well-being in combination with digital, online, internet, web-based, app, apps, smartphone application\*, and mobile application\*. No restrictions were applied. See Multimedia Appendix 1 for the detailed searches carried out in each database.

## Study selection

Each record was double screened, and reviewers were blinded to each other’s decisions throughout the process. To ensure consistency and quality of the screening process, the lead author (JG) screened all records, and double screening was conducted by MB, ET, and MZ. After screening 10% of the records, inter-reviewer reliability was calculated which ranged from moderate to substantial agreement (Cohen’s Kappa ranging from 0.54 – 0.79) [24]. Inconsistencies in the screening process were discussed and conflicts were resolved through discussion. If conflicts remained, additional discussion with a third, senior reviewer (BA) took place. Upon completion of screening, inter-reviewer reliability was recalculated (Cohen’s kappa ranging from 0.42 – 0.80) and conflicts were again resolved using the same process. This process was then repeated for full-text screening.

## Data extraction

Prior to data extraction, the Cochrane data collection form was adapted and pre-piloted for the current review. Data extraction included information regarding the study population, participant demographics, and setting; details of the intervention and control conditions (such as duration, frequency, timing, and activities); study methodology; recruitment and study completion rates; outcomes, outcome measures, and times of measurement; and information for assessment of the risk of bias. Two reviewers (JG, AM) independently extracted all relevant data from the included studies and held meetings to discuss any discrepancies in data extraction. When conflicting views on the data extraction occurred, a third, senior reviewer (BA) advised on how to resolve this. Missing data was sought by contacting the lead author of the study via email, identified through the journal paper.

## Risk of bias assessment

Risk of bias was assessed independently by two reviewers (JG & AM) using the RoB 2.0 tool for Randomised Controlled Trials (RCTs) [25]. No standardised tools were available for non-controlled before-after studies, therefore, the National Institutes of Health (NIH) tool ‘Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group’ was used as guidance to provide an indication of the risk of bias in these studies [26]. However, it was taken into consideration that these studies would provide a lower quality of evidence. Following risk of bias assessments discussions were held to discuss conflicts and any remaining disagreements were resolved through verbal discussion with a third reviewer (BA).

## Data synthesis & meta-analysis

Means (Ms), Standard Deviations (SDs) and total number of participants (No) were extracted for each post-intervention mental well-being outcome in the study-arms that met the inclusion criteria of digital mental well-being intervention and control group. Effect estimates were averaged where studies included multiple study outcomes. This method was also adopted for multi-arm studies as it was considered meaningful to combine the intervention effects, since the interventions all adopted digital mental well-being interventions. In addition, this avoided double counting participants in the control group. The Standardised Mean Differences (SMDs) were used in a random-effects model.

Initially both Per protocol (PP) and Intention to Treat (ITT) data was extracted. However, only PP was included in the meta-analysis as high dropout (ranging up to 85%) led to ITT data being less meaningful.

Visual inspection of the forest plot, X2 and I2 tests were used to assess heterogeneity. For which > 50% was considered to represent substantial heterogeneity. Heterogeneity was explored, interpreted and contextualised.

# Results

## Description of studies

An initial search yielded 12,672 records. Following deduplication, a total of 7,764 records were screened in Covidence. 7,526 records were excluded following title/abstract screening, and 238 records were sought for retrieval for full-text screening. 230 full-text records were screened leading to exclusion of another 213 records. Most common reasons for exclusion were the population being a clinical population, intervention not solely employing mental well-being promotion, intervention not being fully automated digital, or study still ongoing. For full details on the study selection process see Figure 1.

**Figure 1.**

PRISMA Flowchart

**Identification of studies via databases and registers**

Records identified from:

Medline (n = 2,138)

Web of Science (n = 3,147)

Cochrane (n = 741)

PsychINFO (n = 1,820)

PsychEXTRA (n = 95)

Scopus (n = 4,669)

ACM Digital (n = 62)

Total (n = 12,672)

Duplicate records removed *before screening*:

Endnote (n = 2,354)

Covidence (n = 2,554)

**Identification**

Records screened

(n =7,764)

Records excluded

(n = 7,526)

Reports sought for retrieval

(n = 238)

Reports not retrieved

(n = 8)

**Screening**

Reports excluded:

Participants under 18 (n = 15)

Clinical population (n = 33)

Intervention not mental well-being promotion (n = 38)

Intervention not fully automated digital (n = 38)

Outcome not mental well-being (n = 10)

Wrong study design (n = 9)

Study still ongoing (n = 45)

Study report not available in English (n = 7)

Duplicate (n = 18)

Reports assessed for eligibility

(n = 230)

Studies included in review

(n = 17)

Reports of included studies

(n = 16)

**Included**

*Note*. PRISMA Flowchart of search strategy outcomes. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analysis.

An updated title/keyword search in October 2022 yielded another 525 records. Following deduplication, 366 articles were screened in Covidence. 347 articles were excluded and full texts of 19 articles were obtained. A further 17 articles were excluded following full-text screening.

## Narrative summary

A total of 18 records containing 19 studies were included in the current systematic review, containing 17 RCTs and 2 non-randomised before-after trials.

### Setting & Participants

Studies mainly took place in Western countries; samples were primarily female and highly educated; and study populations were students, employees, mothers and other general population samples, see Table 1.

**Table 1.**

*Characteristics of Included Studies*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Study** | **Population** | **Setting** | **Comparator** | **Outcome** |
| Avey, 2022; Study 3 [27] | Employees | US & Australia | Unknown | PWB |
| Bakker, 2018 [28] | General population | Australia | Waitlist control | MWB |
| Brazier, 2022 [29] | Trainees | UK | Waitlist control | MWB |
| Champion, 2018 [30] | Employees | UK & US | Waitlist control | SWB |
| Chung, 2021 [31] | Students | Australia & UK | Waitlist control | MWB |
| Di Consiglio, 2021 – Study 1 [32] | Students | Italy | Active control | PWB |
| Di Consiglio, 2021 – Study 2 [32] | Students | Italy | None | PWB |
| Eisenstadt, 2021 [33] | Real-world app users | UK | None | MWB |
| Gammer, 2020 [34] | Mothers of infants under 1 year | UK | Waitlist control | MWB |
| Liu, 2021 [35] | Students | China | Placebo | SWB |
| Ly, 2017 [36] | General population | Sweden | Waitlist control | PWB; SWB |
| Mak, 2018 [37] | General population | China | Active control | MWB |
| Manthey, 2016 [38] | General population | Germany | Active control | SWB |
| Mitchell, 2009 [39] | Adults | Australia | Placebo | PWB |
| Neumeier, 2017 [40] | Employees | Germany & Australia | Waitlist control | SWB |
| Pheh, 2020 [41] | General population | Malaysia | Active control | MWB |
| Schulte-Frankenfeld, 2021 [42] | Students with a part-time job | Germany | Waitlist control | SWB |
| Shin, 2020 [43] | Students | US | Placebo | SWB |
| Walsh, 2019 [44] | Students | Canada | Active control | PWB |
| *Note.*  MWB = Mental Well-Being; PWB = Psychological Well-Being; SWB = Subjective Well-Being.  **MWB outcomes included:** 5 item mental well-being index (WHO-5) [45]; Warwick-Edinburgh Mental Well-Being Scale (WEMWBS version 1) [46].  **SWB outcomes included:** Satisfaction With Life Scale (SWLS) [47]; Positive And Negative Affect Schedule (PANAS) [48]; Satisfaction with Life and happiness [49]; Subjective happiness scale [50]; Single item life satisfaction & affect measure [40].  **PWB outcomes included:** Psychological Well-Being (PWB) [51]; Psychological Well-Being Scale (PWBS) [52]; Personal Well-being Index (Adult) scale (PWI-A) [53]; Flourishing scale [36]. | | | | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Psychological approaches Several different psychological approaches were employed, including: 1) mindfulness, Acceptance & Commitment Therapy (ACT) and self-compassion, 2) positive psychology, 3) Cognitive Behavioural, and 4) Integrative, see Table 2. The most frequently employed psychological approach was mindfulness, ACT and self-compassion. General intervention activities and Behaviour Change Techniques (BCTs), such as well-being tips and BCTs to form habits, were adopted across psychological approaches and in the majority of interventions.  The intervention content was primarily developed by the study researchers and clinical psychologists, however, some studies collaborated with companies or digital labs to develop the digital aspect of the intervention.  **Table 2.**  *Description of Intervention Characteristics*   |  |  |  | | --- | --- | --- | | **Psychological approach underpinning the intervention** | **Activities and/or practices** | **Studies adopting the approach** | | **Mindfulness, ACT & Self-compassion** | * Meditation: Awareness of inner experiences, present moment & acceptance * Overcoming obstacles in mindfulness meditation * Body scan * Increasing awareness through biofeedback * Being mindful in daily life * Loving-Kindness Meditation * Compassionate journaling, breaks * Self-kindness activities | [30,31,34,37,41,42,44] | | **Positive psychology** | * Gratitude (gratitude diary, and letter) * Positive future imagination * Best possible self * Counting blessings * Random acts of kindness * Replaying positive experiences * Using strengths * Savouring the moment * Wearing a smile * Brainstorming meaningfulness | [35,38-40,43] | | **Cognitive Behavioural approach** | * Mood related activities (e.g. mood tracker, mood diary and mood improvement activities) * Challenging thoughts and behaviours * Problem solving * Goal setting (SMART-goals, planning) * Committed actions * Journaling | [28,39] | | **Integrative approach** | A combination of intervention activities and/or practices of these psychological approaches. | [27,29,32,33,36] | | **General intervention components adopted across interventions:**   * Psychoeducation (e.g. on emotions, needs, values, mental illness) * Support seeking information * Well-being tips   **Behaviour Change Techniques (BCTs) adopted across interventions [54]:**   * Habit formation * Goal setting * Action planning (e.g., implementation intentions) * Prompts/cues * Self-monitoring of behaviour/of outcome of behaviour * Self-assessment of affective consequences * Feedback on behaviour * Material/non-specific reward | | |   *Note.* For a more detailed intervention description, see Multimedia Appendix 2. Intervention delivery A total of 24 fully automated digital mental well-being interventions were included. The interventions were app-based (10), web-based (11), both app and web-based (2), and text-message (1) interventions, see Table 3. Intervention duration, frequency and timing The duration participants were expected to use the intervention for varied substantially across interventions, ranging from one single session to 10 months, and there didn’t appear to be a clear end strategy across interventions. Most commonly, intervention usage was recommended daily for up to 30 days, weekly for up to 8 weeks, and fortnightly for up to 10 months. Participants were often encouraged to use and access the intervention content for 5-15 minutes at a time, irrespective of the duration of the intervention.  **Table 3.**  Intervention characteristics and dropout   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Study** | ***N*** | **Intervention** | **Duration** | **Frequency** | **Mode of delivery** | **Dropout *N* (%)** | | Avey, 2022; Study 3 | 102 | Resilience intervention | 10 weeks | Weekly | App-based | 3 (2.9%) | | Bakker, 2018 | 226 | Moodkit; Moodprism | 30 days | Daily | App-based | 108 (47.8%) | | Brazier, 2022 | 279 | ‘Dear Doctor’ | 10 months | Fortnightly | Text-message | 126 (45.2%) | | Champion, 2018 | 74 | Headspace | 30 days | Daily | App-based | 12 (16.2%%) | | Chung, 2021 | 427 | Brief MBI | 6 weeks | Weekly | Web-based | 280 (65.6%) | | Di Consiglio, 2021 – Study 1 | 24 | Noibene | 3 months | 4 times | Web-based | 0 (0%) | | Di Consiglio, 2021 – Study 2 | 178 | Noibene | None | None | Web-based | 119 (66.9%) | | Eisenstadt, 2021 | 115 | Paradym | 2 weeks | Daily | App-based | 81 (70.4%) | | Gammer, 2020 | 206 | Kindness For Mums Online (KFMO) | 5 weeks | Weekly | Web-based | 80 (38.8%) | | Liu, 2021 | 1,000 | Positive Psychology Intervention (PPI) | 1-3 days | Twice | Web-based | 132 (13.2%) | | Ly, 2017 | 30 | Shim | 2 weeks | Daily | App-based | 3 (10%) | | Mak, 2018 | 2,282 | Mindfulness-based program; Self-compassion program | 28 days | Daily | App & web-based | 1,933 (84.7%) | | Manthey, 2016 | 666 | Best possible self; gratitude | 8 weeks | Weekly | Web-based video | 112 (16.8%) | | Mitchell, 2009 | 160 | Strengths intervention; Problem solving intervention | 3 weeks | Daily | Web-based | 111 (77.6%) | | Neumeier, 2017 | 431 | PERMA programme & Gratitude programme | 7 days | Daily | App-based | 128 (29.7%) | | Pheh, 2020 | 206 | Brief MBI | 1 day | Once | Web-based | 100 (48.5%) | | Schulte-Frankenfeld, 2021 | 99 | Balloon | 8 weeks | Daily | App-based | 35 (35.4%) | | Shin, 2020 | 630 | Gratitude writing | 20 minutes | Once | Web-based | 49 (7.8%) | | Walsh, 2019 | 108 | Wildflowers | 3 weeks | Daily | App-based | 22 (20.4%) |   *Note.* This Table represents general characteristics of the studies included in the systematic review. Only interventions of the studies that met the inclusion criteria are presented in the current Table. Dropout rates are calculated from randomisation to final assessment. N considers the number of participants randomised in the study, irrespective of whether people conducted baseline and/or follow-up assessments. |

### Level of automation of interventions

Access was generally automated with instant, sequential or weekly access to content, see Table 4. The majority of digital content was delivered in a standard way, tailoring and dynamic delivery of content occurred in only two mental well-being interventions [36,44].

**Table 4.**

Level of automation and engagement of intervention

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Intervention** | **Frequency of content release** | **How access to intervention content was provided** | **Tailoring of content to improve/maintain engagement** | **Other intervention strategies to improve/ maintain engagement** | **Actual engagement with intervention contenta** |
| Avey, 2022; Study 3 | Resilience intervention | Unknown | Unknown | None | None | Unknown |
| Bakker, 2018 | Moodkit | Instant access | N/A | N/A | None | Unknown |
| Bakker, 2018 | Moodprism | Instant access | N/A | Feedback on mental well-being | None | Unknown |
| Brazier, 2022 | Dear doctor | Fortnightly | Automated text-message | None | None | Unknown |
| Champion, 2018 | Headspace | Sequential access | Automated access upon completion of step/content in app | None | None | M = 20.7% |
| Chung, 2021 | Brief MBI | Fortnightly/ weekly | Unknown | None | Notifying of new content | Unknown |
| Di Consiglio, 2021 – Study 1 | Noibene | Instant access | N/A | None | None | M = 100% |
| Di Consiglio, 2021 – Study 2 | Noibene | Instant access | N/A | None | None | Unknown |
| Eisenstadt, 2021 | Paradym | Unknown | Unknown | None | Push notification | M = 32.1% |
| Gammer, 2020 | Kindness For Mums Online | Weekly | Unknown | None | None | Unknown |
| Liu, 2021 | Positive Psychology Intervention | Sequential access | Unknown | None | None | Unknown |
| Ly, 2017 | Shim | Upon opening of app | Automated by digital conversationing agent | Based on individual and external factors (e.g. time of day) | None | M = 126.5% |
| Mak, 2018 | Mindfulness-Based Program | Weekly | Unknown | None | Sticker earning; alarm feature | M = 29.5% |
| Mak, 2018 | Compassion-based Program | Weekly | Unknown | None | Sticker earning; alarm feature | M = 32.2% |
| Manthey, 2016 | Best possible self | Weekly | Automated email | None | None | Unknown |
| Manthey, 2016 | Gratitude | Weekly | Automated email | None | None | Unknown |
| Mitchell, 2009 | Strengths intervention | Instant access | N/A | None | Interactive features; automated email reminders | Unknown |
| Mitchell, 2009 | Problem-solving intervention | Instant access | N/A | None | Interactive features; automated email reminders | Unknown |
| Neumeier, 2017 | PERMA programme | Sequential access | Automated access upon completion of step/content in programme | None | None | Unknown |
| Neumeier, 2017 | Gratitude programme | Sequential access | Automated access upon completion of step/content in programme | None | None | Unknown |
| Pheh, 2020 | Brief MBI | Instant access | N/A | None | None | Unknown |
| Schulte-Frankenfeld, 2021 | Balloon | Sequential access | Automated access upon completion of step/content in app | None | A reminder was sent if a session was missed. | M = 40.2% |
| Shin, 2020 | Gratitude writing | Instant access | N/A | None | None | M = 100% |
| Walsh, 2019 | Wildflowers | Sequential access | Automated access upon completion of step/content in app | Based on mood/stress levels recommendations were made for meditations | None | M = 77.7% |
| Note:  aActual engagement with content is based on the requested/expected frequency of engagement with the intervention (e.g., daily for 2 weeks = 14 days = 100%) compared to the actual frequency of engagement in the intervention (e.g., on average participants engaged with the intervention on 5 days = 35.7%). | | | | | | |

### Intervention engagement

Overall, intervention engagement was suboptimal – below the required/recommended intervention engagement levels, see Table 4. On average, participants engaged in 40.2% (median) of the recommended intervention sessions/days. Only few studies contained optimal levels of engagement – engaging in the recommended intervention sessions/days or more [32,36,43].

Studies attempted to improve intervention engagement in a variety of different ways (see Table 2 & 4), including: 1) sending automated email reminders or notifications to use the intervention, 2) increasing participant motivation (e.g., increasing awareness of potential benefits, employing in-app reward earning features), 3) increasing habit formation, and 4) tailoring intervention content based on external factors (such as time of day) or internal factors (such as suggestion of a specific activity based on someone’s mood).

Although caution should be used when interpreting the impact of these strategies on the engagement with the intervention due to the variety and inconsistency in reporting, preliminary results imply that tailored content improves engagement more than interventions that employ reminders (habit formation/prompts) or sticker earning features (non-specific rewards). Furthermore, it seems that interventions that require little engagement – engaging once/4 times in the intervention in total [32,43] – also allow for more optimal intervention engagement. This is in line with studies showing that engagement was generally highest at the start of the intervention and decreased over time.

### Study dropout and attrition

Dropout occurred at any point throughout the study period when a participant failed to complete the research protocol associated with the digital intervention [55].

On average, there was a 37% dropout rate (mean) which ranged from 0-85% in studies (see Table 3). Strategies used to reduce study dropout included monetary incentives, the intervention being a mandatory element of university courses, and follow-up of participants by sending email reminders.

There was a range of findings across studies on the association between participant demographic characteristics and dropout. Some studies found males were more likely to drop out [38], whilst others found no significant difference [29,33]; some found that participants that remained in the study were significantly older [37,40], although other studies did not find this effect [33,38]; one study found that educational level was significantly higher amongst participants that dropped out [37], whilst another study did not find this effect [40].

Several studies compared whether baseline mental well-being was associated with dropout. The majority of studies did not find any differences in baseline mental well-being levels between participants that did and did not drop out [29,31,34,37,38]. However, one study found that participants with lower levels of mental well-being, as well as anxiety, depression, and distress were more likely to drop out [32], whilst another study found participants with higher mental well-being, and lower levels of anxiety, depression, and distress were more likely to drop out [33].

Few studies excluded participants from their analysis (considered them to have dropped out) if they did not adhere at a minimum required level with the intervention content [39,44]; the majority of studies included participants with any level of intervention engagement.

### Outcomes

A variety of validated standardised questionnaires were used to measure mental well-being across studies, including the WHO-5 and WEMWBS for mental well-being; PWBS and Flourishing scale for psychological well-being; and SWLS and PANAS for subjective well-being, see Table 1. Nevertheless, some study authors created and validated their own mental well-being questionnaires which included a combination of different measures. Although not included in the current systematic review (as it is not considered the primary aim of mental well-being promotion), most studies included additional outcome measures such as distress, depression, anxiety, and stress.

## Risk of Bias

Generally, Risk of Bias (RoB) of the included studies was considered high, see Table 5. High levels of dropout and non-adherence led to a high RoB in domain 2 of the RoB-2.0 tool. This domain assesses RoB due to deviations from the intended interventions (effect of adhering to the intervention) and led to high RoB as included studies did not appropriately account for intervention non-adherence in their analysis. For example, Cochrane RoB-2.0 tool recommends using an instrumental variable analysis or inverse probability weighting to appropriately account for non-adherence, however, none of the included studies conducted these analyses.

Furthermore, Domain 4 in the RoB-2.0 tool, assessing RoB in measuring the outcome, led to high RoB due to the nature of the research being fully automated digital. Self-report measures were used to assess mental well-being digitally, however, participants were aware of the intervention they received when self-reporting their mental well-being scores as most studies included a waitlist control group. Although active controls account for this issue, these control interventions also contained high levels of dropout and therefore might not be appropriate as control group [37].

High RoB was also detected in studies due to a lack of general high-quality research practice. For example, some studies did not provide any information regarding the randomisation process, several studies did not preregister, and studies that did pre-register often did not indicate their pre-intended analysis plan.

**Table 5.**

*Risk of Bias*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Bias assessment RoB-2 Tool** | | | | | | |
| **Study ID** | **Randomisation process** | **Deviations from intended intervention** | **Missing outcome data** | **Measurement**  **of outcome** | **Selection of**  **the reported results** | **Overall RoB** |
| Avey, 2022 |  |  |  |  |  |  |
| Bakker, 2018 |  |  |  |  |  |  |
| Brazier, 2022 |  |  |  |  |  |  |
| Champion, 2018 |  |  |  |  |  |  |
| Chung, 2021 |  |  |  |  |  |  |
| Di Consiglio, 2021 – Study 1 |  |  |  |  |  |  |
| Gammer, 2020 |  |  |  |  |  |  |
| Liu, 2021 |  |  |  |  |  |  |
| Ly, 2017 |  |  |  |  |  |  |
| Mak, 2018 |  |  |  |  |  |  |
| Manthey, 2016 |  |  |  |  |  |  |
| Mitchell, 2009 |  |  |  |  |  |  |
| Neumeier, 2017 |  |  |  |  |  |  |
| Pheh, 2020 |  |  |  |  |  |  |
| Schulte-Frankenfeld, 2021 |  |  |  |  |  |  |
| Shin, 2020 |  |  |  |  |  |  |
| Walsh, 2019 |  |  |  |  |  |  |
| **Bias assessment NIH tool: before-after studies with no control group** | | | | | | **Overall RoB** |
| Di Consiglio, 2021 – study 2 |  |  |  |  |  |  |
| Eisenstadt, 2021 |  |  |  |  |  |  |

*Note.* RoB = Risk of Bias; NIH = National Institute for Health.

RoB of the studies included in the meta-analysis have been highlighted in green. Non-highlighted studies are only presented narratively.

## Intervention effects

All studies included fully automated digital mental well-being interventions in the general population and were therefore considered sufficiently homogeneous for a meta-analysis. Methodological homogeneity was also considered, which led to a comparison across RCTs only, as these were considered sufficiently homogeneous for a meta-analysis. Considering the incredibly high range of missing values, a meta-analysis based on ITT data was considered inappropriate; therefore, we conducted a meta-analysis based on PP data instead. Nevertheless, this does increase the risk of underestimating or overestimating the real effect which should be considered when interpreting the meta-result. Full PP data was available for a subset of 12 studies. A random-effect model was applied as different measures were used to measure the same multidimensional construct ‘mental well-being’. Average effect estimates were calculated for each study, reverse scoring ‘negative affect’ scores to ensure a higher score in each study indicated higher levels of mental well-being. Standardised Mean Differences (SMDs), 95% confidence intervals (95% CIs) and two-sided p-values were calculated.

### Outlier

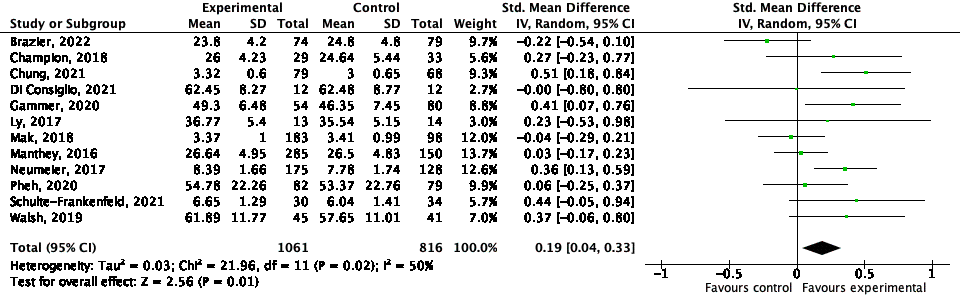
During data extraction, the negative affect score in the intervention group of one study [35] was flagged by both reviewers as unexpectedly high and further information was sought to identify what could potentially explain this unusually large result. Normative data for negative affect is *M* = 14.8, *SD* = 5.4 [56], however, the negative affect score in the waitlist control group in this study was *M* = 26.98, *SD* = 5.19. When further exploring this data, no methodological or clinical differences could reliably explain this result in our opinion. Additionally, when included in the meta-analysis, confidence intervals were entirely outside of the range of any other study and heterogeneity was incredibly high (92%) (see Multimedia Appendix 3). Removing this study from the meta-analysis changed the overall heterogeneity from 92% to 50%. Therefore, the study was considered an outlier and was excluded from the meta-analysis.

### Main effect

The pooled SMD, for the 12 trials, calculated using a random‐effects model was 0.19 (95% CI 0.04 to 0.33), indicating a small clinical effect in favour of digital mental well-being interventions, see Table 6. There was substantial heterogeneity (I² = 50%).

**Table 6.**

*PP meta-analysis of fully automated digital interventions compared to control groups on mental well-being in the general population.*



*Note.* Some studies did not provide per protocol data and were therefore not included in the main analysis [27,28,39,43]. One study was excluded as this study was considered an outlier [35]. Two studies did not contain a control group and were therefore not included in this meta-analysis [32,33].

## Subgroup analysis

An a-priori subgroup analysis was planned to detect the effect of digital mental well-being interventions across individual differences (e.g. age, gender, educational level). Nevertheless, insufficient data was available for a meaningful comparison to be made.

Another a-priori subgroup analysis was planned to identify the effectiveness across psychological approaches. Mindfulness, ACT and self-compassion interventions were the most common. Seven studies were included in this subgroup. A small significant effect was found for fully automated digital mindfulness, ACT and self-compassion interventions to promote mental well-being in the general population (SMD 0.26, 95% CI 0.08 to 0.44), with moderate levels of heterogeneity (I 2 = 44%), see Table 7. The positive psychology intervention subgroup only included two studies, and there were significant levels of heterogeneity (I2 = 78%). Studies investigating CBT-based interventions did not contain any PP data and could therefore not be included as a subgroup in the analysis. The final subgroup included an integrative approach; three studies contained sufficient PP data to be included. There was no significant level of heterogeneity in this subgroup (I2 = 0%), however, integrative approaches did not have a significant effect on mental well-being in the general population.

Overall, no significant subgroup difference was found when comparing the effect of mindfulness, ACT and self-compassion, positive psychology, and integrative interventions on mental well-being.

**Table 7.**

*Subgroup analysis of different psychological approaches to promote mental well-being.*

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Description automatically generated**

*Note.* Cognitive behavioural interventions were not included as a separate subgroup due to a lack of per protocol data.

## Sensitivity analyses

As there was substantial heterogeneity (I2 = 50%), sensitivity analyses were performed to explore, interpret and contextualise heterogeneity. Firstly, intervention duration was explored using subgroups of interventions lasting up to 2 weeks (short), 2 to 6 weeks (medium) and over 6 weeks (long).

A small significant effect was found for short interventions (SMD 0.24, 95% CI 0.04 to 0.45) and medium interventions (SMD 0.29, 95% CI 0.05 to 0.52), but no effect was found for long interventions (SMD 0.02, 95% CI -0.22 to 0.26), see Multimedia Appendix 4 Table 1. No significant levels of heterogeneity were found in any of the subgroups, and the subgroups substantially reduced the overall level of heterogeneity (I2 = 28.6%).

Another sensitivity analysis was performed exploring methodological heterogeneity across studies based on the comparator. We argue that placebo controls are not feasible in psychological interventions, considering the difficulty isolating intervention components in psychological interventions [57]. Therefore, we’ve grouped placebo controls under active controls in the current review. A small significant effect was found in studies using a waitlist control as comparator (SMD 0.28, 95% CI 0.07 to 0.50), but no significant effect was found in studies using a placebo or active control as comparator (SMD 0.05, 95% CI -0.08 to 0.18), see Multimedia Appendix 4 Table 2. No significant levels of heterogeneity were present in either of the two subgroups, although substantial heterogeneity remained in studies using a waitlist control comparator (I2 = 53%).

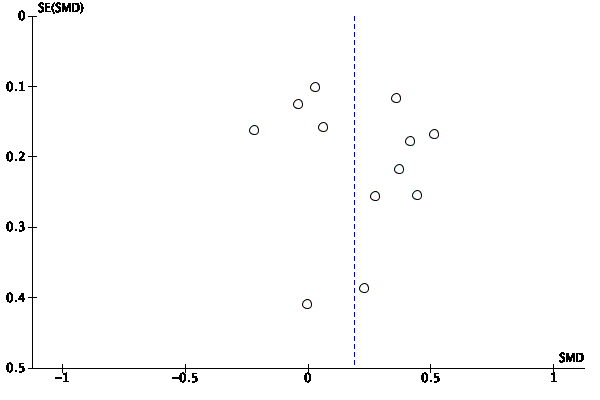
Finally, a sensitivity analysis was performed based on the outcome mental well-being, psychological well-being, and subjective well-being. A small significant effect was found on subjective well-being (SMD 0.23, 95% CI 0.04 to 0.42). However, no significant effect was found on mental well-being (SMD 0.14, 95% CI –0.12 to 0.40) or psychological well-being (SMD 0.26, 95% CI –0.08 to 0.59), see Multimedia Appendix 4 Table 3. Despite reducing heterogeneity in subjective well-being and psychological well-being, substantial heterogeneity was found in mental well-being (I 2 = 72%).

## Reporting bias

Visual inspection of the funnel plot, which appeared asymmetrical, indicates evidence of a reporting bias, see Figure 2. Few smaller studies were found, and larger random variation would be expected within smaller studies; this is potentially due to a publication bias, although other aspects such as heterogeneity can also cause asymmetrical funnel plots.

**Figure 2.**

*Funnel plot*



*Note.* Asymmetrical plot in the presence of publication bias or due to low methodological quality studies. The funnel plot only represents studies that were included in the main per protocol meta-analysis.

## Certainty of body of evidence (GRADE)

The certainty of body of evidence was assessed using GRADE [59]. The evidence was downgraded due to high RoB (effect of adhering to the intervention, see Table 5), inconsistency (heterogeneity was considered substantial, see Table 6), imprecision (wide CIs and insufficiently small sample sizes were observed, see Table 6), and publication bias (visual asymmetry in the funnel plot, see Figure 2). Thus, we consider there to be very low confidence in the quality of evidence of the main PP meta-effect, see Table 6, meaning we are very uncertain about the estimate of the effect.

# Discussion

## Main effect

The aim of the current systematic review and meta-analysis was to understand the effectiveness of fully automated digital interventions to promote mental well-being in the general population. We evaluated 24 fully automated digital mental well-being interventions lasting from a single session up to 10 months, with daily, weekly, and biweekly delivery. At post-intervention, we found a small significant effect of fully automated digital mental well-being interventions compared to control groups on mental well-being in the general population.

The effect found in the current meta-analysis of fully automated digital interventions (SMD = 0.19), was smaller than the effect found in previous meta-analyses of non-automated mental well-being interventions (effect sizes ranging between 0.26 and 0.42) [7,15,16]. This could highlight the importance of nonspecific psychological factors, such as the therapeutic relationship and social support, in the effectiveness of these psychological interventions. On the other hand, this could also indicate the importance of social support in the adherence to mental well-being interventions. Previous research found that improved adherence was linked to better mental well-being outcomes, and that adherence tended to be higher in non-automated interventions [18,55]. As suboptimal intervention adherence was observed in the current review, with average engagement in 40% of intervention content, it is likely that the reported effectiveness in the current review is an underestimation of the potential effectiveness of fully automated digital interventions that could be achieved when reaching optimal levels of engagement (the level of engagement recommended by the researchers). Nevertheless, recommended engagement levels differed tremendously between studies and most studies lacked a clear end strategy.

## Exploratory findings

We found that short (< 2 weeks) and medium (< 6 weeks) interventions were effective at promoting mental well-being in the general population, but long (> 6 weeks) interventions were not. This could be further related to intervention adherence, as (in line with previous research findings) intervention adherence reduced over time [55]. It does appear that the optimal intervention duration might also depend on the outcome that is being targeted. Research found that short interventions led to a bigger effect on subjective well-being, whilst long interventions had a bigger effect on psychological well-being [59]. As the majority of studies in the current review included a subjective well-being outcome, this might explain why shorter interventions were found to be effective in the current review.

In contrast to prior research, our exploratory analysis showed no significant effect on general mental well-being outcomes (e.g., WEMWBS) [7,15]. Measures of general mental well-being may not be sensitive enough to detect the small change that occurs in mental well-being in the general population, as measures of mental well-being are concise whilst including both subjective- and psychological well-being [46]. Previous research includes a clinical population alongside a general population, and non-automated interventions alongside fully automated digital mental well-being interventions [7,14,15]. Both of these factors increase the effectiveness of mental well-being interventions, which could lead to a sufficiently large effect to detect using a general mental well-being measure.

Furthermore, we found a small significant effect when comparing a fully automated digital mental well-being intervention to a waitlist control group, though no significant effect was found when comparing it to an active or placebo control group. The effect when comparing to an active and placebo control is expected to be smaller than the effect when comparing to a passive control [60]. This indicates that the effects between mental well-being interventions and other psychological interventions (e.g., active control) on mental well-being do not currently differ.

## Subgroup effects

It was not possible to analyse the effects of digital mental well-being promotion across population subgroups (based on age, gender, socioeconomic status, and educational level), due to a lack of studies reporting these results separately.

Nevertheless, studies did provide exploratory findings into the relation between individual differences and dropout in fully automated digital mental well-being interventions. These exploratory findings indicated largely conflicting evidence on whether and how individual differences were related to dropout, which is in line with previous research findings [55].

A subgroup analysis comparing psychological approaches adopted in fully automated digital mental well-being interventions indicated a small significant effect of fully automated digital mindfulness, ACT and compassion-based interventions on mental well-being in the general population, with the majority of studies adopting this psychological approach. The effectiveness of fully automated digital positive psychology and CBT-based approaches remains largely unknown. A potential explanation for this is the large focus in CBT-based interventions on symptom reduction rather than mental well-being improvement [61]. Furthermore, positive psychology interventions have been criticised recently due to the limited ability of studies to replicate positive psychology results [62], potentially leading to fewer studies investigating positive psychology interventions.

Finally, although some studies adopted an integrative approach, we did not find an effect of fully automated digital integrative approaches on mental well-being in the general population. This contradicts previous meta-analytic findings that did find a significant effect of multi-theoretical interventions on mental well-being in the general population [7]. Nevertheless, this meta-analysis also found a smaller effect for multi-theoretical interventions compared to mindfulness-based interventions [7], indicating that these interventions might generally be less effective. This might explain why no effect of integrative approaches was found in fully automated digital interventions.

## Limitations

Several methodological limitations should be recognised however, as they could have impacted the findings of this systematic review. First, the specific search terms adopted in this systematic review limit the findings. Whilst searches should aim to be as comprehensive as possible, it is necessary to balance sensitivity and specificity when conducting searches [63]. The specificity adopted in the systematic review may not have allowed for the searches to be comprehensive as the literature uses many different terms to describe fully automated digital mental well-being interventions. Secondly, inclusion criteria in this systematic review are ambiguous and require judgement [63]. This subjectivity could lead to lower reproducibility of the findings and random error/bias [64]. Finally, the review adopts an exclusive focus on mental well-being (which includes subjective and psychological well-being). Although improving mental well-being could be considered the primary aim of digital mental well-being promotion [10], the exclusive focus on mental well-being does not allow the review to provide insights into indirect positive, or negative, intervention effects.

In addition to methodological limitations, we observed several limitations to the included studies lower confidence in the quality of evidence (GRADE). We saw high RoB in the included studies, due to 1) missing outcome data – although it is unknown what impact the dropout has on the overall effect (e.g., underestimation or overestimation) as reasons for dropout remain largely unknown; 2) the effect of adherence - suboptimal adherence might lead to an underestimation of the effectiveness; and 3) measurement of the outcome – due to the use of self-report measures whilst participants are aware of their allocated intervention, potentially leading to overestimation of the effectiveness. Alongside this, we also found a lack of general high-quality research practice in studies. Several studies were underpowered, did not provide sufficient information regarding randomisation, and did not pre-register and/or contain a prespecified analysis plan.

Furthermore, we detected a publication bias of the studies included in the meta-analysis. This publication bias indicated that smaller studies with a larger random variation were largely missing - perhaps since they are less likely to get published.

Finally, the fully automated digital mental well-being interventions were primarily delivered in a Western context, and typically included a sample that was highly educated and female which might limit the generalisability of the findings. Particularly given evidence that females and highly educated individuals might engage with and therefore benefit from these interventions differently.

## Recommendations for future research

The systematic review findings lead to several implications for future research. Firstly, future research should aim to focus in more detail on supporting engagement and reducing dropout in fully automated digital mental well-being interventions – by understanding the impact of behavioural strategies such as habit formation and non-specific rewards [54], but also by examining what is considered ‘effective engagement’ - the target level of intervention engagement needed for change [65]. This will allow for evidence-based recommendations of the level of intervention engagement in future research and practice and for studies to adopt effective end strategies.

Secondly, future research should look to understand how automated digital interventions can be ‘tailored’ to deliver relevant content according to the preferences of the user, and whether tailoring is necessary to ensure intervention effectiveness and acceptability can be ensured across different populations (e.g., Western vs. non-Western) and intervention types (e.g., positive psychology vs. mindfulness and ACT).

Finally, we recommend that future research strictly follows high-quality research recommendations, such as the CONSORT statement [66], when investigating fully automated digital mental well-being interventions to allow for higher confidence in the quality of the evidence.

# Conclusions

Overall, this review provides a novel insight into the effectiveness of fully automated digital mental well-being interventions in the general population. It shows that fully automated digital mental well-being interventions can effectively promote mental well-being in the general population (particularly when adopting a mindfulness, ACT and self-compassion based approach), despite low levels of intervention adherence and high study dropout.

# Additional information

## Acknowledgements

We are grateful for the support of the librarians at the University of Bath, and advice from Emma Fisher in conducting the meta-analysis.

## Contributions of authors

Study design, protocol and methodology: JG, BA, MB, CC and TT.

Study selection: JG, MB, ET, MZ, BA.

Data extraction and quality assessment: JG, AM, BA.

Data analysis: JG, BA, MB, CC.

Write-up and editing: JG, BA, MB, CC, AM, TT, MB, ET, MZ.

## Declarations of interest

There was no conflict of interest in conducting this study.

## Multimedia Appendices

Multimedia Appendix 1: [Search strategy per database]

Multimedia Appendix 2: [Table with detailed intervention description]

Multimedia Appendix 3: [Main PP analysis including outlier]

Multimedia Appendix 4: [Exploring heterogeneity]

## Differences between protocol and review

RoB-2 and ROBINS-1 were identified at protocol stage as the main risk of bias tools we would adopt to investigate risk of bias in RCTs and NRSIs. However, the study also identified non-randomised before-after interventions for which neither of these tools was considered appropriate. Therefore, we also used the ‘NIH Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group’ to assess risk of bias. Nevertheless, the same characteristics identified at protocol stage were considered for risk of bias assessment.

## Funding

This study was funded as part of PhD funding by the Economic and Social Research Council (ESRC), and Cyberlimbic Systems Ltd, United Kingdom.

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