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Influences on uptake of and engagement with health and wellbeing smartphone apps: a systematic review.

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Abstract

Background: The public health impact of health and wellbeing digital interventions is dependent upon sufficient real-world uptake and engagement. Uptake is currently dependent largely on popularity indicators (e.g. ranking and user ratings on app stores), which may not correspond with effectiveness, and rapid disengagement is common. Therefore, there is an urgent need to identify factors that influence uptake and engagement with health and wellbeing apps to inform new approaches that promote the effective use of such tools.

Objective: To synthesise what is known about influences on the uptake of and engagement with health and wellbeing smartphone apps amongst adults.

Methods: A systematic review of quantitative, qualitative and mixed-methods studies. Studies conducted on adults were included if they focused on health and wellbeing smartphone apps reporting on uptake and engagement behaviour. Studies identified through a systematic search in MEDLINE, EMBASE, CINAHL, PsychINFO, Scopus, Cochrane library databases, DBLP and ACM Digital library were screened, with a proportion screened independently by two authors. Data synthesis and interpretation was undertaken using a deductive iterative process. External validity checking was undertaken by an independent researcher. A narrative synthesis of the findings was structured around the components of the COM-B behaviour change model and the Theoretical Domains Framework.

Results: Out of 7640 identified studies, 41 were included in the review. Identified factors related to uptake (U), engagement (E) or both (B). Under 'Capability', the main factors identified were app literacy skills (B), user knowledge, including app awareness (U), available user guidance (B), health information (E), statistical information on progress (E), well-designed reminders (E), features to reduce cognitive load (E), and self-monitoring features (E). Availability at low cost (U), positive tone and personalisation (E) were identified as physical 'Opportunity' factors, while recommendations for health and wellbeing apps (U), embedded health professional support (E) together with social networking (E) possibilities were social 'Opportunity' factors. Finally, 'Motivation' factors included positive feedback (E), available rewards (E), goal setting (E) and the perceived utility of the app (E).

Conclusions:

Across a wide range of populations and behaviours, twenty-six factors relating to capability, opportunity and motivation appear to influence the uptake of and engagement with health and wellbeing smartphone apps. Our recommendations may help app developers, health app portal developers and policy makers in the optimisation of health and wellbeing apps.

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Keywords: mhealth, health app, engagement, uptake, systematic review, COM-B, TDF, digital health

Introduction

Background

Digital behaviour change interventions, such as smartphone apps, can be effective and cost-effective tools to change a range of health related behaviours [1,2]. For example, there have been promising studies of apps to deliver health prevention messages for men who have sex with men [3], to help self-manage diabetes [4] and cardiovascular diseases [5], in weight management [6-8], alcohol reduction [9-11], mental health interventions [12], and in the management of long-term conditions [13]. For certain behaviours such as alcohol reduction, they could also address the barriers experienced by health professionals when delivering brief interventions in person, such as lack of necessary training [11] and to reduce the stigma associated with the behaviour [2]. The public health implications are substantial because of their potential to have a low incremental cost and broad reach.

Despite their promise, effect sizes reported in evaluations of app-based interventions are often small. One potential explanation is the level of uptake and engagement. Uptake refers to the act of downloading and installing a smartphone app. Engagement has been defined as '(1) the extent (e.g. amount, frequency, duration, depth) of usage and (2) a subjective experience characterised by attention, interest and affect' [14]. To date, low uptake and poor engagement are commonly observed with digital interventions which is often insufficient to sustain behaviour change [15,16]. However, there is a lack of evidence as to the main factors in contributing to problem.

Systematic reviews that focussed on one specific behaviour or a certain type of health or wellbeing app suggest that the effectiveness of evidence-based smartphone apps can be improved by targeting the design and engagement features, such as user-friendly design, individualised and culturally tailored content or health professional support [17-19]. A review based on experiential and behavioural perspectives conceptualised key factors that might affect engagement with digital behaviour change interventions: the content (e.g. behaviour change techniques, social support, reminders), and how the content is delivered (e.g. professional support, personalisation, aesthetic features) [14].

To our knowledge, no systematic review that primarily seeks to identify factors that influence the uptake of and engagement with a wide range of health and wellbeing smartphone apps has yet been conducted. To narrow the focus of this review, the four public health priority behaviours related to prevention (smoking, alcohol consumption, physical activity and diet) along with mental health and wellbeing were targeted.

Theoretical framework

The COM-B (Capability, Opportunity, Motivation – Behaviour) model is a comprehensive framework that posits that individuals, in order to perform or change a behaviour, need the capability to undertake it, the opportunity to take part in and the motivation to engage with that behaviour [20]. COM-B is increasingly being applied to inform the development of digital behaviour change interventions [21-23]. The Theoretical Domains Framework (TDF) [24], has previously been successfully applied for systematic reviews in other contexts [25,26]. The 14 domains of the TDF, described elsewhere [24], offer a concise coding framework, which can be usefully conceptualised as possible targets for behaviour change interventions. The TDF, being linked to the COM-B model [24], can be used as subthemes under the components of the COM-B model (see Multimedia Appendix 1.).

Objectives

This systematic review aimed to synthesise factors identified in studies that influence the uptake of and engagement with health and wellbeing smartphone apps among adults targating public health priority behaviours (smoking, alcohol consumption, physical activity and diet) and mental health and wellbeing, and mapped these factors under the components of the COM-B model and constructs of the TDF. This could help inform stakeholders in public health and policymakers, digital behaviour change intervention developers, and providers of health and wellbeing smartphone app portals to better target uptake and engagement.

Methods

The review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) [27] (Multimedia Appendix 2.), and the protocol was registered on the International Prospective Register of Systematic Reviews (PROSPERO: CRD42019120312). The review used a mixed-methods approach to generate different, but complimentary knowledge about users' views from qualitative findings, and predictors and patterns of behaviour from quantitative findings.

Eligibility criteria

Eligible studies had to explore factors that influence uptake or engagement with health and wellbeing smartphone apps among adults. Table 1 summarises the inclusion/exclusion criteria.

Table 1. List of Inclusion/exclusion criteria.

	Inclusion criteria	Exclusion criteria
Participants	Adults aged 18 and over. Studies including individuals aged 16 and over were included if at least 70% of the participants were 18 or over.	Apps targeting health professionals.
Intervention/context	Studies investigating digital interventions using smartphone health and wellbeing behaviour change apps on the following behaviours and outcome: smoking, alcohol consumption, physical activity, diet and mental health and wellbeing.	Studies where the smartphone was not the primary intervention component.
Outcomes	Qualitative: Findings described as facilitators, barriers, determinants of uptake or engagement with health or wellbeing apps (either already existing or planned to be developed), including perceptions, beliefs, experiences, interest, etc. of the participants. Quantitative: Uptake, measured as number of downloads; engagement measured as number of logins, frequency of use or any other relevant measure that tracks user engagement.	Usability and user-testing studies, where functionality and app design were exclusively investigated for specific apps.
Study design	All study designs were included.	

Search strategy

Electronic search

A systematic literature search was developed in consultation with a specialist librarian from the University of East Anglia and a senior information scientist from Public Health England. An iterative process helped to define the final search terms while ensuring a balance between sensitivity and specificity. A systematic literature search was performed in eight electronic databases: MEDLINE, Embase, CINAHL, PsycINFO, Scopus, Cochrane library database, DBLP and ACM Digital library. The databases were searched with no data limit, no publication or geographical restriction, but limited to English language. Synonyms of three

concepts were searched: (mhealth) AND (behaviour change) AND (uptake or engagement) (see Multimedia Appendix 3. for MEDLINE search strategy). The electronic search was performed in November 2018 initially and it was updated in August 2019.

Searching for other resources

Additionally, the search also included a manual search in key journals, such as 'Journal of Medical Internet Research' (JMIR) and 'Computers in Human Behaviour', and in Google Scholar. Reference lists of all included studies were hand searched for additional studies. The search for grey literature included dissertations and theses, as well as unpublished research data and material was sought from government bodies and policy makers during stakeholder communication (Public Health England, National Health Service in England).

Identification of studies

All records identified by the search strategy were exported to Endnote X9 and deduplicated. To reduce the likelihood of reviewer selection bias and to assess how reliably the study eligibility criteria were applied, a subsample (10%) of records were additionally screened by a second reviewer (FN) during the title and abstract screening. Inter-rater reliability based on the number of eligible and ineligible studies was tested using Cohen's Kappa statistics [28], with the following cut-offs being used: 0.41-0.60 to indicate moderate agreement, 0.61-0.80 substantial agreement and 0.81-0.99 almost perfect agreement [28]. The full texts of potentially eligible studies were independently screened by DS with 20% randomly selected and double screened by FN. The exclusions of the studies were justified and recorded.

Data extraction

A data extraction proforma was developed by the first author following the existing Cochrane guidelines [29] and the subsequent data were extracted: study characteristics (author, date of publication, sample size and type, location of the study, type of the app investigated in the study, aim of the study, methodological characteristics (design, data collection, participants), main findings related to the research question of this systematic review (including participant's quotations and author's interpretations in the qualitative studies, reported results of the quantitative studies) and conclusion of each study. The data extraction was performed by one reviewer (DS) and was checked for accuracy by a second reviewer (FN).

Quality assessment

To assess the quality of the studies, critical appraisal was conducted using the latest version of the Mixed Methods Appraisal Tool (MMAT) [30]. MMAT is a unique tool [30] that was developed by pooling together the core relevant methodological criteria found in different well-known and widely used qualitative and quantitative critical appraisal tools [31-33].

The quality of all studies was assessed by the first reviewer (DS) and checked for accuracy by two other authors (FN, AJ). The tool is not intended to score the studies or to exclude papers, but to offer a guide of how to interpret findings [30].

Data synthesis and analysis

Integrative synthesis was applied to analyse the data [34,35]. The focus of the synthesis was on interpreting the data using specific concepts of the TDF as a deductive coding framework which, for ease of interpretation, is summarised under the components of the the COM-B model. Using the integrated approach, the data were pooled together by findings viewed as answering the same research questions, rather than by methods (e.g. quantitative vs qualitative) [34,35].

Deductive thematic synthesis, a methodology designed to enhance the transparency of synthesising qualitative data [36], was used to conduct the data synthesis of the findings of the qualitative studies and the qualitative component of the mixed-methods studies. Using line-by-line coding, the findings were coded deductively into the domains of the TDF. The coding was conducted by the first author, and a randomly selected 10% of the coding was checked for accuracy by another author (FN). Regular coding meetings took place to maintain consistency. Expert opinion of an independent researcher with extent experience in systematic reviewing was sought on data synthesis. The integrative approach includes interpretation of the quantitative findings by ‘qualitizing’ [35], which refers to the textual interpretation of the findings of the quantitative studies (regardless of the interpretation of the author) so they can be combined narratively with the qualitative data [35].

Results

Included studies

A total of 7633 studies were initially retrieved, with a further six identified through manual search and reference check. An additional unpublished research report was received from stakeholders as part of grey literature searching process. No non-English papers were identified. A total of 2138 duplicates were removed. Further 5429 studies were excluded based on the review on their titles and abstracts (Figure 1).

PRISMA 2009 Flow Diagram

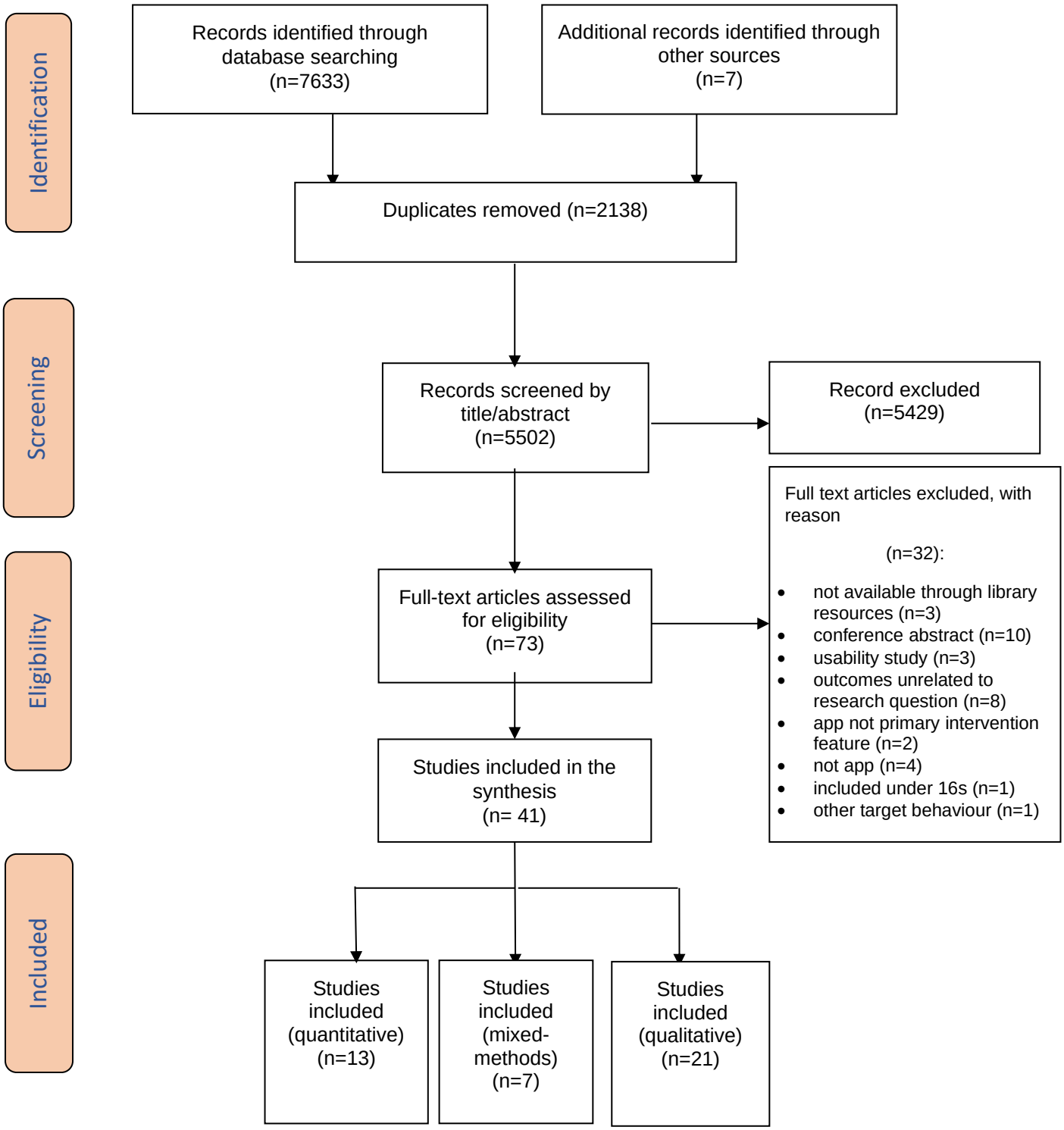

Figure. 1. PRISMA flowchart illustrating the inclusion and exclusion of the studies [27].

During title and abstract screening ‘substantial’ agreement was achieved between the two independent reviewers (Kappa = 0.63) [28]. There were two types of disagreements identified (one reviewer included studies that targeted app used in conjunction with a connected device, and purely user research studies) that limited agreement between the reviewers during the selection process, which were resolved through discussion and with the consultation with another author (AJ). After disagreements were resolved and the eligibility criteria updated accordingly, seventy-three studies were identified as potentially meeting the inclusion criteria. All remaining titles and abstracts of records were assessed by one reviewer (DS). From these, 41 studies were included in the review [37-77], out of which thirteen were quantitative [41-44,49,53,55,63-65,68,76,77], seven were mixed-methods [38,47,59,62,73,74,78] and twenty-one were qualitative studies [37,39,40,45-47,50-52,54,56-58,60,61,66,67,70-72,75].

Description of included studies

The study characteristics are summarised in Table 2. The end users of the studies were described as the general public [37,39,42,44,46,47,50-54,56-59,65,71,72,75,76], college students [48], existing app users [38,43,46,49,55,63,67,77,78], male workers of male-dominated industry [60], LBGTQ+ communities [40], , rural communities [57], Asian ethnic minorities [41], pregnant women [73], patients in primary care [45,61,74], adult cancer survivors [62], adults with diabetes [57], those infected with HIV [64], those with chronic disease [68] and bipolar disorder [69]. The focus of some studies was very specific and targeted a certain health behaviour or condition, including alcohol reduction [38,46,54,58,59,64], smoking cessation [40,58,67,72,77], increasing physical activity [39,45,48,49,53,62,65,68], weight management [47,48,51,53,63,65,66,71,78], depression [52,61], mindfulness [50], diabetes management [57], health management in pregnancy [73]. Other studies were less specific and targeted a more general mental health app [43,60,70], and a more general health app [37,41,42,44,55,56,74-76]. Fifteen studies were investigating factors influencing one particular app [38,39,43,45,46,49,50,54,55,63,65,67, 70, 72,77]. The remaining twenty-seven studies examined users’ perceptions of a wide range of apps or of a hypothetical app not yet developed.

The studies were published between 2011 and 2019 and were carried out in Australia [37,49,60,61,70], Belgium [69], Canada [40,51,55,67], China [68,73,76], Czech Republic [65], Ireland [45], Italy [39], New Zealand [47], Norway [75], Sweden [52], the United Kingdom [38,46,50,54,58,59,62,66,71,72,74], the United States [41-44,48,53,56,57,63,64,77].

Table 2. Characteristics of the studies included in the review.

Studies	Location	Study aim	App used (name if applicable)	Participants	Methods or design, and analytic approach
Anderson et al., 2016 [37]	Australia	To explore experiences of health app users	Non-specific health apps	Adults in the general population; N = 22, female = 15; age groups: 18-25 n=4, 26-35 n=13, 46-55 n=2, 55 and over n=1	Semi-structured interviews; thematic analysis
Attwood et al., 2017 [38]	UK	To examine patterns of app usage over time and to explore app users' views of the app	Alcohol reduction (Drinkaware)	App users; N = 119713 (interview N = 21); % female = 59.3% (interview: 12%); age groups: 31% 35-44	Mixed-methods approach (Secondary data analysis of Drinkaware database and semi-structured interviews); ANOVA, regression, t-test, framework analysis
Baretta et al., 2019 [39]	Italy	To examine user's need and preferences regarding their engagement with physical activity apps	Physical activity (Runtastik, Edumondo, Runkeeper)	N = 20, % female = 45%; mean age (SD) = 39.8 (7)	Longitudinal, single-arm design with think-aloud methodology and interview techniques; thematic analysis.
Baskerville et al., 2016 [40]	Canada	To explore LGBTQ+ communities' perception of a smoking cessation app	Smoking cessation	LGBTQ+ youth and adults; N focus groups = 204; 39% female, 26.6% male, 3.7% trans female, 6.9% trans male, 4.1% two spirit, 14.7% queer, 0.5% intersex, 4.6% other Age groups: 8.8% 16-18, 91.2% 18-29	Focus groups (n = 24); framework analysis
Bender et al., 2014 [41]	US	To examine factors predicting uptake with health apps among ethnic minorities	Non-specific health apps	Ethnic minorities in US (Caucasians, Latinos, Koreans); N = 904; % female = 64.3%; Mean age (SD) = 44 (16.1)	Cross-sectional survey; descriptives, regression
Bhuyan et al., 2016 [42]	US	To explore the use of mhealth apps for heath seeking behaviour among US adults	Non-specific health apps	Adults in the general population; N = 3677; female = 51.7%; age groups: 30.8% under 35, 17.2% 35-44, 18.9% 45-54, 15.8% 55-64, 17.4% over 65	Secondary data analysis of a nationally representative sample (Health Information National Trends Survey - cycle 4); descriptives, regression
Bidargaddi et al., 2018 [43]	US	To assess the effectiveness of push notifications on engagement	Wellbeing app (JOOL)	App users; N = 1255; % female = 63.97%; age groups: 28.86% under 30, 42.44% 30-50, 28.70% over 50	Micro-randomized trial; regression
Carroll et al., 2017 [44]	US	To describe sociodemographic characteristics with health app use, predictors of health app use	Non-specific health apps	Adults in the general population; N = 3519; % female = 51.62%; age groups: 65.62% 18-44, 34.38% 45 and over	Secondary data analysis of a nationally representative sample (Health Information National Trends Survey - cycle 4); regression
Casey et al., 2014 [45]	Ireland	To explore patients views of using smartphone app to promote physical activity in primary care	Physical activity (SMART MOVE)	Adult patients in primary care; N = 1255; % female = 75%; mean age = 42 (range 17-62)	Semi-structured interviews; framework analysis

Crane et al., 2017 [46]	UK	To understand the usability of the app	Alcohol reduction (Drink Less)	Adult excessive drinkers and users of the Drink Less app; N = 24; % female = 50%; mean age - think-aloud = 42; mean age - interviews = 40	Think-aloud and semi-structured interviews; thematic analysis
Gorton et al., 2011 [47]	New Zealand	To explore a potential weight loss management intervention on smartphone	Weight management	Adults in the general population; N = 306 (focus groups N = 54); % female = 77% (focus group: 76%); age groups survey: 20% 16-30, 51% 31-50, 28% 51 and over; age groups focus group: 35% 16-30; 50% 31-50; 15% 51 and over.	Mixed-methods approach (cross-sectional survey and focus groups (n=10)); descriptives, thematic analysis
Gowin et al., 2015 [48]	US	To describe the use of health apps among students	Weight management and/or physical activity.	College students; N = 27; % female = 78%; age groups: 70% 18-20, 22% 21-23, 8% 24-26	Semi-structured interviews; grounded theory
Guertler et al., 2015 [49]	Australia	To examine the engagement with physical activity promotion app, identify sociodemographic factors of non-engagement	Physical activity (10000 steps)	App users, N = 1451 % female = 72.43%; mean age (SD) = 38.3 (11.1)	Secondary data analysis of the '10000 Steps' database; ANOVA, Chi square, regression
Laurie & Blandford, 2016 [50]	UK	To understand users' experiences with mindfulness app	Mindfulness (Headspace)	Adults in the general population; N = 16; % female = 68.75%; mean age = 32.5 (range 25-38)	Semi-structured interviews; grounded theory
Lieffers et al., 2018 [51]	Canada	To understand the experiences of adults who have used nutrition app previously	Weight management	Adults in the general population; N = 24; % female = 79%; age groups: 63% 18-30, 25% 31-50, 13% 51-70	Semi-structured interviews; content analysis
Ly et al., 2014 [52]	Sweden	To explore participants' views of a mental health app	Depression	Adults with major depression; N = 12; % female = 50%; mean age = 37.9 (range 21-59)	In-dept interviews; thematic analysis
Mackert et al., 2016 [53]	US	To determine the association between health literacy and app engagement	Fitness and weight management	Adults in the general population; N = 4974; % female = 57.74%; mean age (SD) = 43.5 (16.7)	Cross-sectional survey; Cross-tabulation analysis, regression
Milward et al., 2018 [54]	UK	To understand 1) why and how participants engaged with the app, 2) facilitators and barriers to engagement with app, 3) how the app impacted drinking behaviour, (4) to identify typologies of users (engagement)	Alcohol reduction (BRANCH)	Participants of a randomised controlled trial; N = 20, % female = 80%; mean age (SD) = 24 (3)	Semi-structured interviews; framework analysis

Mitchell et al., 2017 [55]	Canada	To evaluate uptake with a loyalty points-based health app and to describe sociodemographic characteristics of the users	Multipurpose health app (Carrot Rewards)	App users; N = 57885; % female = 62.96% Age groups: 2.4% 13-17, 20.65% 18-24, 33.69% 25-34, 20.11% 35-44, 1317% 45-54, 7.22% 55-64, 2.74% over 65	Process evaluation; descriptives
Peng et al., 2016a [56]	US	To better understand a more diverse pool of users' perception of health apps	Non-specific health apps	Adults in the general population; N = 44; % female = 65%; mean age (SD) = 37.2 (15.7)	Focus groups (n = 6) and interviews (n = 5); thematic analysis
Peng et al., 2016b [57]	US	To explore the perception of rural adults with diabetes regarding apps to manage their condition	Non-specific health apps	Adults with diabetes; N = 18; % female = 72.2%; mean age (SD) = 54 (12.7)	Focus groups (n = 4); thematic analysis
Perski et al., 2017 [58]	UK	To explore participants' choices of health apps and to identify important features of engagement	Smoking cessation and alcohol reduction	Adults in the general population; N = 20; % female = 60%; mean age (SD) = 29.7 (9.2)	Think-aloud and semi-structured interviews; thematic analysis
Perski et al., 2018 [59]	UK	To explore the more important features of engagement	Alcohol reduction	Adults in the general population; N = 132 (focus group: n = 9); % female = 49.2% (focus group = 77.8%); Age groups survey: 10.6% 18-24, 24.2% 25-34, 34.1% 35-44, 21.2% 45-54, 6.8% 55-64, 3% 65 and over. Age groups focus group: 44.4% 18-24; 33.3% 25-34; 0% 35-44; 22.2% 45-54; 0% 55-64, 0% 65 and over.	Mixed-methods approach. (Online survey and focus groups (n=3)); interclass correlation coefficient, thematic analysis.
Peters et al., 2018 [60]	Australia	To explore participants' preferences of a mental health app	Wellbeing	Adult workers of male-dominated industry; N = 60 % female = 8%; Mean age = 47 (range 26-65)	Participatory study - workshops (n = 6); thematic analysis
Pung et al., 2018 [61]	Australia	To explore mobile app use among patients with depressive symptoms	Depression	Patients of primary care presenting depressive symptoms; N = 16; % female = 58%; age groups: 19% under 25, 44% 25-44, 38% 45-65	Semi-structured interviews; thematic analysis
Puszkiewitz et al., 2016 [62]	UK	To assess cancer survivors' attitudes towards a physical activity app, to understand how the app could be adapted to their needs, how to increase their physical activity level using the app	Physical activity	Adult cancer survivors; N = 11; % female = 89%; mean age (SD) = 45 (9.4)	Mixed-methods approach (One arm pre-post design and semi-structured interviews); Wilcoxon sign rank test. thematic analysis

Serrano et al., 2017 [63]	US	To explore features of the app that influences engagement and to describe the characteristics of the users	Weight loss app (Lose it!)	App users; N = 1011008	Secondary data-analysis of a cross-sectional data; CART analysis, descriptives, regression
Sharpe et al., 2018 [64]	US	To determine factors associated with uptake of an alcohol reduction app among persons living with HIV	Alcohol reduction	Adult population living with HIV; N = 757; % female = 35%; age groups: 18% 18-34, 20% 35-44, 41% 45-54, 21% 55 and over	Secondary data analysis of a cross-sectional survey data of a longitudinal cohort study (Florida Cohort Study); descriptives, regression
Smahel et al., 2017 [65]	Czech Republic	To reveal characteristics regarding use of heath apps	Fitness and weight management	Adults of the general population; N = 406; % female = 86.9%; mean age (SD) = 23.8 (5.3)	Cross-sectional survey; descriptives, regression
Solbrig et al., 2016 [66]	UK	To explore experiences and wishes regarding weight management using apps	Weight management (FIT)	Adults of the general population; N = 24; % female = 79.2%; mean age = 30 (range 19-70)	Focus groups (n = 6); thematic analysis
Struik et al., 2018 [67]	Canada	To understand the interaction and experiences with the app	Smoking cessation (Crush the Crave)	App users; N = 31; % female = 42%; mean age (SD) = 24 (2.72)	Semi-structured interviews; framework analysis.
Sun et al., 2017 [68]	China	To investigate the current usage, willingness to use and barriers to use physical activity app	Physical activity	Adult patients with chronic disease; N = 218; % female = 61%; mean age = 44.6 (range 20-69)	Cross-sectional survey; descriptives, Chi-square.
Switsers et al., 2018 [69]	Belgium	To examine needs of adults with bipolar disorder regarding apps	Mental health	Adults with bipolar disorder; N = 16;% female = 56.3%; mean age = 41.8 (range 21-69)	Focus groups (n = 7); thematic analysis.
Taki et al., 2019 [70]	Australia	To examine how app characteristics influence engagement.	Weight management (Growing Healthy GH)	Female app users; N = 18, mean age = 30.9 (range 21-38)	Semi-structured interviews; thematic analysis
Tang et al., 2015 [71]	UK	To explore young adults' experiences of using apps	Weight management	Adults of the general population; N = 19; % female = 47.37%; age range: 19-33	Semi-structured interviews; thematic analysis
Tudor-Sfetea et al., 2018 [72]	UK	To explore individuals' perceptions of different smoking cessation apps	Smoking cessation (Quit Genius and NHS Smokefree)	App users; N = 15 (Quit Genius) and N = 14 (NHS Smokefree); % female = 13.3%/14.3%; mean age = 25.07/24.21	Semi-structured interviews; thematic analysis
Wang et al., 2018 [73]	China	To explore app engagement and to understand people's views about app containing health information	Pregnancy health apps	Pregnant women from secondary care; Focus groups N = 28, mean age (SD) = 29.6 (3.1); Survey N = 535, mean age (SD) = 30.6 (3.6)	Survey and focus groups (n=4); descriptives, logistic regression, thematic analysis

Webcredible Report, 2016 (unknown authors) [74]	UK	To understand why people use health apps, hoe they choose them, what factors influences their choice and engagement	Non-specific health apps	Adults in the general population; N = 300 (focus group: n = 12); % female (focus group) = 42%, Age range (focus group): 33-60	Mixed-methods approach. (Online survey and focus groups (n=2)); analysis used unreported.
Woldaregay et al., 2018 [75]	Norway	To explore motivational factors of user engagement with health apps	Non-specific health apps	Adults of the general population; N = 16; % female = 50%; Age range: 21-55	Semi-structured interviews; thematic analysis
Xie et al., 2018 [76]	China	To examine the prevalence, extent, demographics of health app use	Non-specific health apps	Adults of the general population; N = 633; % female = 48.5%; age groups: 24.6% 18-29, 25% 30-44, 24.6% 45-59, 25% 60 and over	Cross-sectional survey; descriptives, regression
Zeng et al., 2015 [77]	US	To examine demographical, psychological and behavioural predictors of the use of app	Smoking cessation (SmartQuit)	App users; N = 98; % female = 53%; mean age (SD) = 41.5 (12)	Secondary data analysis of the SmartQuit trial's data (intervention arm); descriptives, regression

Quality assessment of the studies included

Based on the MMAT [30] the majority of the studies employing qualitative methodology were deemed to be of high quality. Concerns related to the sample were identified across many quantitative studies. This included issues around sampling, lack of clarity as to whether the groups were comparable at baseline or whether the sample was representative for the general population. In four non-randomised studies confounders were not accounted for by the design and analysis. Two out of seven mixed-methods studies were judged to be of low quality, out of which one is an unpublished report (grey literature) and the other one is a published short report. See Multimedia Appendix 4 for details of quality assessment for each study.

Data analysis and thematic-synthesis

While not all the studies presented data for all the aspects of this review, all studies presented some data that could be included in the synthesis. Evidence that was considered weakly explained, or was judged to be unclear, was not included in the summary of findings. An overview of the identified factors, the level of influence (uptake, engagement or both) along with a brief description of each factor can be found in Table 3. Examples of supporting evidence are provided in textboxes.

Table 3. Factors identified in the systematic review.

COM-B component	TDF construct	Identified factor (source)*	Uptake engagement, or both	Short description of the factor
Physical capability	Skills	App literacy [46,50,57,61,65]	Both	Technological competency
Psychological Capability	Knowledge	App awareness [54,56,57,61,75]	Uptake	Knowledge of the existence of health and wellbeing apps
		User guidance [37,39,46,50,59,72]	Both	Instructions on how to effectively use the app
		Health Information [47,51,53,54,56-58,62,69,72,75,78]	Engagement	Educational information related to health and wellbeing aspects
		Statistical information [37-39,46,52,54,57,66,67,71,72,75]	Engagement	A visual or numerical summary of progress
	Memory, Attention and Decision Processes	Well-designed reminders [37-40,43,46,48,51,52,54,56-58,62,66,67-69, 71,78]	Engagement	The ability to customize reminders
		Less cognitive load [37,39,46,48,50,51,54,56-58,60,66,69, 71, 72,75]	Engagement	The app is not too time consuming, easy to use and requires minimal input
		Coping games [40,60,67,72]	Engagement	Distraction activities within the app
	Behavioural Regulation	Self-monitoring (36, 38-40, 45, 48, 51, 52, 55, 57, 59, 60)	Engagement	The ability of the app to help self-regulation of the target behaviour
		Established routines [38,48,50,54,66]	Engagement	Regularity in using the app
		Safety netting [37,61,66,73]	Engagement	Retaining the app for a potential precipitating event in the future
Physical Opportunity	Environmental Context and Resources	Availability/accessibility [37,40,45,49,52,57,72,78]	Uptake	The ability to use a smartphone anytime anywhere
		Low cost [37,40,47,48,56,68,72,74]	Uptake	The price of the app
		Interactive and positive tone [46,51,57-60,69, 71, 72]	Engagement	Encouraging communication style
		Personalisation to needs [37,38,40,47,50,52,56,57,60-62,69,71, 72,75,78]	Engagement	The possibility to use an app that is tailored to a user's needs
Social Opportunity	Social influences	Recommendations [56-58,61,74]	Uptake	Suggestions received from other users
		Health practitioner support [37,40,51,52,57,59,62,67,69,72,73]	Engagement	Possibility to get in touch with health professionals and practitioner within the app
		Community networking [37,39,40,47,56,59,62,66,67-73,75]	Engagement	Social interaction with users with similar needs within the app or within their community
		Social media [39,40,48,54,56,58,61,66,67,71,72,75,78]	Engagement	A choice to connect to social media platforms
		Social competition [37,39,48,56,59,66,67]	Engagement	Competitive nature of the app with others or with themselves

		Personification of the app [39,45,47,48,50,56]	Engagement	Applying human attributes to the app
Automatic Motivation	Reinforcement	Feedback [37,39,45-48,51,52,54,56,58,62,67,72]	Engagement	Feedback regarding the user's performance
		Rewards [37,40,45,46,56-59,66,69,71,75]	Engagement	Tangible and intangible reward in response to the user's effort
	Emotions	Curiosity [38,52,54,61]	Uptake	Desire to acquire knowledge and skills to use a behaviour change tool
Reflective Motivation	Goals	Goal setting [38,39,45,48,51,54,56,58,59,66,71,74]	Engagement	Establishing what the user would like to accomplish
	Beliefs about consequences	Perceived utility of the app [37,46,52,59,61,74]	Engagement	Discrepancy of what the users are looking for and what the app offers

*Source: studies where the factor was identified

Physical Capability

TDF domain: Skills.

Skills refer to one's ability to perform an action, and include constructs such as competencies, interpersonal skills, skill development and practice (Textbox 1). App literacy [46,50,57,61,65], defined as technological competency to use a smartphone app, was reported by participants as being of high importance for both uptake and engagement. A basic level of app literacy is required to be able to download and initiate engagement with an app (see Quote 1 (Q1)), whilst adequate app literacy skills would enhance users' intentions to engage with an app (Q2) [46,50]. In a cross-sectional study, advanced app literacy was associated with the increased use of the social functions of an app, such as networking, but not with the functions that target action planning and goal management [65]. This suggests that app literacy might be an important aspect for successful uptake, but this alone might not be enough to maintain engagement. In contrast, users have reported that lack of app literacy skills could trigger negative emotions towards themselves (e.g. self-blame, disappointment of not being able to use an app) [46,50,61], and could contribute to their perceived low self-confidence in using technology [61].

Textbox 1. Illustrative quotes (Q) (Q1-2) for factors mapped onto Physical Capability subcomponent of the COM-B model and coded under the TDF domain: Skills.

Uptake and engagement

App literacy

- Quote 1: "I'd be happy to do it if I knew how to do it [but] I don't know how to download apps...I need help with technology. Like, I'm 58 and I didn't grow up in a technological age and so do find that I lack confidence with technology." [61]
- Quote 2: "I've never used it [these apps] because I never got it to work the way I wanted it to." [57]

Psychological Capability

TDF domain: Knowledge.

There were multiple factors identified under the TDF domain that covers rational, procedural and other types of knowledge, information and awareness of the existence of something (Textbox 2). App awareness [54,56,57,61,75], such as information on the existence of health and wellbeing apps, would positively influence uptake of health and wellbeing smartphone apps (Q3). It was suggested that many participants were not aware of the availability of such

tools, and some found the disorganised nature of the commercial app stores confusing, and represented a barrier for uptake [61].

User guidance [37,39,46,50,59,72], namely instructions on how to effectively use an app, such as how to create achievable goals, influenced uptake and initial engagement. It was proposed that by having a guide on how to use an app could positively affect the users' intention to be engaged with it, and hence users might be able to better regulate their behaviour (Q4) [46,59]. However, the presence of a guide was reported off-putting and unnecessary for long-term engagement by producing negative emotions (e.g. annoyance) once the knowledge regarding app functionality has been gathered (Q5) [59].

Available health information within the app was perceived by users as beneficial and positively influenced their engagement in several studies (Q6, Q7) [47,51,53,54,56-58,62,69,72,75,78]. Depending on the target behaviour, end users wished to: 1) access advice on exercise routines [39,56,62,66]; 2) seek nutritional education [39,51,56,57,66,70]; 3) widen their knowledge of health consequences [58,67,72]; 4) find out more about healthy living whilst living with a medical condition [62,73]; 5) know more about the condition they are living with [69,73,75]; 6) improve their health literacy [75]; 7) demystify myths [72]; 8) receive health news updates, such as on smoking taxes and bans [72]; 9) better understand alcohol units (UK) [54].

However, the quality of information was identified as potentially affecting engagement [72]. Some users wanted a credible source, a trustworthy and evidence-based guide with references to the information they receive (Q8) [62, 70, 73]. Health information that focuses on negative aspects of the past behaviour that cannot be modified (e.g. smoking or alcohol consumption) would trigger negative emotions (e.g. regrets) [58]. It was suggested that better quality of information would increase the likelihood of maintaining users' engagement with an app and consequently they would better self-monitor their behaviour [56,67]. This could be achieved by providing a wide range of information that everyone could relate to rather than facts that are already known (Q9) [72]. For example, one qualitative study suggested the use of health quizzes to promote engagement [75]. Health quizzes were also found promising by a large study that evaluated the uptake of a loyalty points-based health app conducted in Canada [55]. One of the intermediate objectives of that study was to improve the Canadian population's health literacy by using health information related to quizzes. The app usage data included quiz completion rates, and the results showed that 60% of the users were highly engaged with the app by having more than 75% of health quizzes completed. Furthermore, better health literacy might enhance beliefs about consequences (e.g. health outcome expectancies) [67,72] and the users' intention to stay engaged with an app and subsequently with the behaviour they target to change [72,75].

Mackert and colleagues also found that adequate heath literacy was associated with increased engagement with fitness and nutrition apps [53].

Users valued available statistical information [37-39,46,52,54,57,66,67,71,72,75], that was a visual or numerical summary of progress or a trend in their behaviour. This included features like step counting [71,75], the number of calories consumed [54,71], number of days spent abstinent from smoking [67], the amount of money saved by quitting smoking [72] or by reducing drinking [54], a trend in their alcohol consumption and how is it changing over time [38,46,54], as well a way to allow analysis of user data [37,75]. Being able to check their progress helped users better monitor their behaviour (Q10) [37-39,71,72] and for some individuals, a positive trajectory acted as a behavioural reinforcement (Q11) [46,67]. In two studies, participants reported that a lack of visual representation of progress led to disengagement with the alcohol reduction app (Q12) [38,46], and one study on smoking cessation reported negative emotions associated with progress viewing during 'a few bad days', suggesting discouragement (Q13) [67].

Textbox 2. Illustrative quotes (Q3-13) for factors mapped onto Psychological Capability subcomponent of the COM-B model and coded under the TDF domain: Knowledge.

App awareness

- Quote 3: "I didn't realize that they had an app." [57]

<u>Engagement</u>

User guidance

- Quote 4: "I want something to tell me "Do number 1 first, then number 2. When you've done this go here" so I don't have to think too much about it. Once I've got it up and running I'm fine." [46]
- Quote 5: "Just at the beginning of the app, when you've downloaded it and you're using it for the first time, it should tell you what to do. But not every time. You don't need guidance how to use it and where things are, because I think it would just be annoying." [59]

Health information

- Quote 6: '[It is] important and really helps me to learn about bipolar disorder and read about stuff'. [67]
- Quote 7: "I... enjoy learning something new. It's quite informative and makes you think about what you're doing. [QG] helps you to understand a bit more about what's going on...what could go wrong by continuing [to smoke]." [72]

- Quote 8: “I personally am scared of getting lymphedema, and still don’t know sometimes what exercises are good to prevent it, so I think that maybe educating people about […] consequences of not exercising from a really good NHS source would be helpful.” [62]
- Quote 9: “I think everyone has heard that information many times. It’s actually quite patronizing...shallow stuff, not hard-hitting useful facts. It obviously isn’t a tailored app to each person, but it gives enough information that each person can relate to it in a tailored way. I find it really engaging, I suppose that’s why I stuck with it.” [72]

Statistical information

- Quote 10: “I like the numbers. I like to track stuff and have some figures behind it rather than just like, oh, I’ll go for a run today. I’ll be like, well, I’ll go for a run today but what’s my time from last time and how can I beat it? And I think that’s why this kind of app appeals to me. If I just put the drinks in and it just said you’re drinking too much but didn’t give any numbers behind it, I’d probably delete it within a few days.” [38]
- Quote 11: “It was like a visual of my day of smoking. And every day, you’d look at it, it went down and down and down, like it got better every day. So it was like a motivational thing to just look, like positive reinforcement.” [67]
- Quote 12: “I couldn’t find any graph that’s reflected the mood so therefore I didn’t see the point of having to fill that part out and I stopped filling it out.” [46]
- Quote 13: “If you're having a bad day or a couple of bad days, seeing it on [the app] as a reflection [of your bad days] just like kicks you in the face even more, you know?” [67]

TDF domain: Memory, Attention and Decision Processes.

Under the domains that focus on the ability to retain and select information, including aspects of attention, memory, decision making and cognitive overload (Textbox 3). Reminders [37-40,43,46,48,51,52,54,56-58,62,66,67, 69-71] to engage with an app were reported as being useful for people with busy schedules, and for those who tend to forget engaging with the app and, therefore, with the target behaviour [37,39,43,56,67]. Individuals described being inclined to check their phones when receiving a notification [37,38,40]. Reminders positively affected behavioural regulation by prompting engagement with self-monitoring and the tracking features of the app (Q14) [37,39,40,51,54,62, 67, 69-71], as well as reinforcing the users by reminding them about their positive progress [40,48,51]. A micro-

randomised trial found that a push notification that contained a tailored health message resulted in a small increase in the engagement with a health app [43]. A large study conducted on engagement with a weight loss app found that 16% of the most engaged group used reminders, compared to 1% of the least engaged group [64]. However, not all users found reminders useful [37,39,51,56-58,66]. In case of behaviours that are associated with stigma (e.g. alcohol consumption), reminders would threaten the users' social identity when these are received at an inappropriate time or wrong place (Q15) [38,46,54]. Therefore, the timing of when the reminders sent, as well as the language used, appeared to be important conditions. If these conditions were not met, users were more likely to turn the notifications off [37,38,69] or ignore them (Q16) [56,66,67].

Regarding attention and decision processes, the findings of the studies included in the review proposed that cognitive overload should be avoided to maintain engagement with an app. An app that is less time-consuming, requires minimal input, is easy to use and log into was preferred (Q17) [37,39,46,48,50,51,54,56-58,60,66,69,71,72,75]. Additional functions that decrease the time spent on a task using an app were highly appreciated [37,39,48,50,54,56,71,72,75]. The automatization of data collection, for example, by linking apps to wearables [37] or by using the camera function for scanning the barcodes to input calories [71] was found particularly useful for physical activity and weight management apps. An app that is easy to use and does not require extra effort would increase the intention to engage with it [39,46,48,54,56,57,74], and would improve users' self-monitoring and self-management strategies [48,51,66,75]. Conversely, using a difficult and time-consuming app would affect the users' perceived competence in engaging with it (Q18) [50]. Such an app often would be deleted or replaced with another one that is perceived to be easier to use [46,48,56,66,71]. Only one study found that users who are highly committed to change behaviour (in this case to reduce alcohol consumption) would be willing to overcome this barrier [54].

Including coping games [40,60,67,72] as distraction activities was suggested as a helpful way to cope with cravings (smoking) [40,67,72] or with distress [60]. Some users indicated that by using their hands and minds, they expected to be preoccupied, instead of engaging with the undesirable behaviour, while keeping them engaged with the app itself (Q19-20).

Textbox 3. Illustrative quotes (Q14-20) for factors mapped onto Psychological Capability subcomponent of the COM-B model and coded under the TDF domain: Memory, Attention and Decision Processes.

Engagement

Well-designed reminders

- Quote 14: “I found it was almost like having my girlfriend there, in a good way. So you’re like, oh I haven’t done this in two days, I didn’t even realize, but my phone just reminded me. Better keep it going.” [67]
- Quote 15: “I think because they were just pinging… and I was just thinking, I don’t really want to read this right now. Obviously, and I don’t know whether they do but I guess most people check their phone when something pings in and you can be with your friends and actually maybe you wouldn’t want to be saying to your friends, I’ve just got a notification from Drinkaware”. [38]
- Quote 16: “I completely ignored them [notifications]. Actually, I’m pretty sure I had the notifications that were from the app all turned off. It just felt like a pop up, like another thing for me to click close on throughout the day. I completely paid no attention to it.” [67]

Less cognitive load

- Quote 17: “I really loved it [Couch to 5K], there was no excessive login, it was really easy you just downloaded and start you have to have your email, no password, no nothing like that, they don’t send you a bunch emails that annoy the crap out of me. Nothing.” [48]
- Quote 18: “What I’m thinking is, this better be easy, because otherwise I’m probably not going to do it. If there are too many obstacles in the way I won’t. Even though I know I need to do this, I probably won’t.” [46]

Coping games

- Quote 19: “If there was a bunch of games on the app that were there to distract you from smoking, (you could) go play five minutes of a quick game instead of smoking.” [40]
- Quote 20: “Maybe if they had prior to like some type of like a mini game or something in there that would keep the mind occupied rather than telling you, “Don't smoke.” [72]

TDF domain: Behavioural Regulation.

Behavioural regulation refers to managing, monitoring or changing actions or behaviour (Textbox 4). Self-monitoring, the ability of an app to help monitor and regulate the target behaviour (36, 38-40, 45, 48, 51, 52, 55, 57, 59, 60), was found to be important to support behaviour change. A self-monitoring feature was able to raise awareness on the number of

cigarettes smoked [40,58], the amount of alcohol consumed [58], the number of steps they made [45], the mood they have [60], or on users calorie intake (Q21) [48,56]. It also enhanced users intention to engage with an app [51,52,58], provided 'self-reinforcement' [52], helped increase self-efficacy (Q22) [56,61,71], and evoked feelings of 'control, security, health, empowerment and autonomy' [54].

An established routine or regularly using an app [38,48,50,54,66] positively affected the intention to engage with an app [50] and to maintain the engagement (Q23). Further, safety netting [37,61,66,73] defined as the ability of an app to provide 'aftercare' [66] and an option to retain an app for a potential precipitating event in the future and for relapse prevention, was found useful to maintain the behaviour, even when the target behaviour has been achieved (Q24).

Textbox 4. Illustrative quotes (Q21-24) for factors mapped onto Psychological Capability subcomponent of the COM-B model and coded under the TDF domain: Behavioural Regulation.

Engagement

Self-monitoring

- Quote 21: "You get a chance to see what you do on a daily basis, something you're probably not aware of." [56]
- Quote 22: "Because I can see I'm getting better, I use the app now, but I can see myself in the future not having to use it. Kind of like a stepping stone I guess." [71]

Routines

- Quote 23: "Because, I've got a couple of other little apps that I look at on a daily, not all apps, but a little regime of four or five, you know, I check the weather and I look at my drink app, and various things like that, a little routine, so pretty much daily." [38]

Safety netting

- Quote 24: "I think the migraine one's probably outlived its usefulness for me, but the back pain one, I could still go back to that at any time. If I started to need to monitor my pain again in a systematic way, I'd still go back to it." [37]

Physical Opportunity

TDF domain: Environmental Context and Resources.

This domain refers to the circumstances of an individual's situation or environment that positively or negatively affects the uptake of or engagement with health and wellbeing smartphone apps (Textbox 5). Availability and accessibility of a smartphone [37,40,45,49,52,57,72,78] facilitates both uptake and engagement by having a behaviour change device in close proximity (Q25). Although a smartphone or tablet enhances portability and accessibility of health apps, the development of an accompanied website was suggested to reduce the inequality for those who might not have the opportunity to own a smartphone (Q26) [40]. Furthermore, the results of a digital behaviour change intervention study examining engagement and non-usage attrition with a physical activity programme suggest that when the app was used together with the accompanying website, a higher engagement rate was observed versus those who used the app only or the web only versions [49].

The low cost of an app was found to be an influential factor for uptake [37,40,47,48,56,68,72,74]., so that low income individuals would be able to afford them (Q27) [47]. In a questionnaire study in China, one of the top barriers of using a health app was the extra cost, having a total of 83% of patients reporting that they would not be willing to pay for a health app [68]. Nevertheless, a few participants expressed their willingness to pay a small extra fee (i.e. under $5) if this way they would unlock unique features otherwise not available with the free version (Q28) [37,48,56,74].

Numerous studies found that interactivity and positivity of tone may be efficacious for engagement, especially when attempting to change behaviours associated with self-blame (e.g. weight management) (Q29) [46,51,57-60,69,71,72]. Three studies provided evidence that an encouraging rather than condescending tone was important [46,58,69]. Evidence from one study suggested shame should be avoided and praise emphasised [51], and another study provided evidence that a relaxed tone may be beneficial and may include jokes [46]. Several studies suggested that demanding or annoying language would be ignored (Q30) [57-59], although a study of nutrition apps reported the occasional need for a tougher attitude to achieve goals (Q31) [51]. Nevertheless, careful selection of the terminology used to understand the app and what it does, such as using simple and clear language, was suggested to make a noteworthy difference in the effectiveness of the content [60,72]. Terminology around certain behaviours might make a difference. For example, it was reported that using 'non-smoker' label as opposed to an 'ex-smoker' label would increase people's self-confidence [72]. It was suggested that unsupportive language would

evoke negative emotions (e.g. guilt, regret) and that would affect the intention to engage with an app [46,59,71].

A personalised app was highly valued for engagement [37,38,40,47,50,52,56,57,60-62,69-72,75]. Users would want to have control over the app (Q32) [59,66,69]. They would like to switch off features they do not use [37], use external incentives, such as uploaded photos or quotes [66,67], to personalise their goal and how to achieve it [40]. Users would also like to choose a level where to start using a particular app. For example, a more experienced user would want to have the possibility to start a mindfulness practice at the intermediate level rather than at the beginner level [50]. Users were seeking to receive more personalised information about their current behavioural habits, demographic characteristics, long term effect of the current behaviour [38,56,60,78], and recommendations based on their tracked data [57]. Personalisation can be extended to their identity as well (Q33). Participants were looking for an app that is tailored to their culture and social identity, such as LGBTQ+ people or cancer survivors, or other patients, who are predisposed to have other struggles and mental health issues (Q34) [40]. Personalisation to user's needs and preferences suggested better engagement [58,59,61], while lack of flexibility in content was found to be a reason to stop engagement [52], and in some cases created frustration [71]. Furthermore, a large study found that 30% of the most frequently engaged group customised the app more, for example, uploaded pictures, than the least engaged group (2%) [63].

Textbox 5. Illustrative quotes (Q25-34) for factors mapped onto Physical Opportunity subcomponent of the COM-B model and coded under the TDF domain: Environmental Context and Resources.

<u>Uptake</u>

Availability

- Quote 25: "It was real easy you just put it in your pocket and off you go and… you could do it at your own pace." [45]
- Quote 26: "I feel like there would need to be a website equivalent with it (for) people who don't have access to smartphones but do have access to public libraries. A lot of smokers are LGBTQ and a lot of LGBTQ are in poverty and homeless. The people that you want to access might not be able to access the program." [40]

Low cost

- Quote 27: "I wouldn't pay money for an app. I think that's kinda stupid." [48]

- Quote 28: “I'm prepared to pay for applications. As well as being in the software industry, I understand that it's people's livelihoods are attached to this. I use some free applications, but I often will pay for the upgraded or the purchased option.” [37]

Engagement

Positive tone

- Quote 29: “I had a chocolate bar today and It would say, this chocolate bar contained this much saturated fat and... I just feel really guilty now.” [71]
- Quote 30: “I think I’m more likely to listen to practical advice rather than finger wagging…” [58]
- Quote 31: “I just see it as a way to help me monitor what I’m doing and maybe give me a little kick in the pants every now again to be like, ‘By the way, that donut had five hundred calories in it. Maybe make a better choice at dinner.’” [51]

Personalisation

- Quote 32: “The more I would be able to manipulate the app to be and do what I wanted or needed, for my own circumstances, the more likely I am to use it.” [59]
- Quote 33: “It must be very personalized, it's easy to find things on the Internet, but it's mostly for normal people.” [75]
- Quote 34: “Assuming that it’s customised to LGBTQ (and) it incorporates the kinds of struggles that we’ve lived through, it wouldn’t be any average quit-smoking app. The fact that it’s specific to a community... the fact that it’s LGBTQ-specific, that would help us more than if it was just a general quit-smoking app.” [40]

Social Opportunity

TDF domain: Social Influences.

Social influences are interpersonal influences (received from other individuals) that could impact on the individual’s behaviours, decisions, thoughts and feelings (Textbox 6). In five studies, recommendations to use an app [56-58,61,74], received from health care practitioners or trusted providers [57,61,74], friends and families [56,60,74], or by reading user reviews [56,58,74], positively affected the uptake of health and wellbeing apps (Q35-37).

Connections between an app and health practitioner support were highly valued [37,40,51,52,57,59,62,67,69,72,73]. Participants reported that counselling services should

be linked to an app [40,67,69], such as an ‘emergency button’ feature [69], while others have emphasised the importance to link an app to their health care provider (Q38-40) [37,62]. Health practitioner support could i) help overcome potential barriers caused by lack of skills, such as app literacy [52], ii) enhance self-monitoring [52,62] and iii) act as reinforcement [52], having the potential to enhance intentions to engage with the app (Q40) [52,62,72].

The possibility for community networking within apps with other users or other people with similar needs was identified in multiple studies [37,39,40,47,56,59,62,66,67,69-73,75]. It was considered important social support by reinforcing behaviour change [47,56,59,62,69,72,73] and by sharing knowledge and experiences [37,69,73,75]. This was found to increase their intention to engage with the app and subsequently, the behaviour (Q41-42) [62]. A large study found that the most engaged group had a mean number of 24 friends within the app, as opposed to the least engaged group (1 friend) [64]. The users’ potential social role or group identity, and personal preference should be taken into consideration. For instance, individuals from the LGBTQ+ community [40] and cancer survivors [62], would wish to interact with people who face similar challenges (Q41). Also, some users would not want to share information with strangers due to fear of social comparison [39,59] or social stigma [54], while others were more open to connecting with strangers rather than with friends or family (Q42-44) [56].

Evidence for the importance of embedded social media for engagement was mixed [39,40,48,54,56,58,61,66,67,70,71,72,75]. It largely depends on the individual’s attitude towards these channels and as well as on the target behaviour. Some users found this reinforcing (Q46) [40,61,71,75], while others did not want to engage with such features due to social stigma (e.g. smoking, alcohol consumption or weight management) (Q46-47) [39,48,54,56,58,67,72].

Social competition [37,39,48,56,59,66,67] includes the possibility for individuals to compete with themselves (i.e. their previous achievements or breaking their own records), or with others app users (Q48-49). Five studies suggest that the reinforcing nature of social competitions might increase the intention to engage with an app [37,48,56,59,66]. The increased engagement was anticipated when the competition is based on support by receiving encouragement from others [39,67], rather than on defeating each other, which might prompt discouragement to use the app (Q50) [67].

Several studies described that some participants felt apps can impersonate a little person [39,45,47,48,50,56] which increased the intention to use the app (Q51-52) [45,48,50]. It was also suggested that if the app is too impersonal, it would not offer the social support the

users need [47]. In contrast, in two studies the participants were concerned about having a machine telling them what to do (Q53) [47,56].

Finally, personal experience related to noncommunicable diseases might increase the chances of the uptake of apps. One study conducted on Latino and Asian subgroups in the US found that the odds of downloading a health app was twice as high for those who had a family history of heart attack (OR 2.02, 95% CI 1.16-3.51), compared to those who have not [41].

Textbox 6. Illustrative quotes (Q35-53) for factors mapped onto Social Opportunity subcomponent of the COM-B model and coded under the TDF domain: Social influences.

Uptake

Recommendations

- Quote 35: “I’d rather ask a counsellor or a doctor what they would recommend.” [61]
- Quote 36: “Most of mine [my apps] are friend recommendations, people with similar activities.” [56]
- Quote 37: “…if an app has a good rating, despite the one or two people who are not satisfied, I think it would mean that it works for the majority of people.” [58]

Engagement

Health practitioner support

- Quote 38: “It would help in times of crisis to be able to be in touch with a professional, or if I needed to ask health questions related to alcoholism.” [59]
- Quote 39: “I want to let others know when I’m not well, the app would help me.” [69]
- Quote 40: “The therapist helped me to find my motivation every now and then, and then I was on top of it for about a week or so, and eventually the application sort of became a part of my everyday life. Then it was pretty obvious that I would use it and then I didn't even think about whether it was hard to use it, I just did it.” [52]

Community networking

- Quote 41: “It is so important to get in touch with people who went through the same thing as you have. […] I think that if an app for cancer survivors had a forum on it as a part of the application to motivate each other, that would be amazing.” [62]

- Quote 42: “I don't think I would share on the social media, but within the app community I think it is important to like inspire and be motivated by others.” [66]
- Quote 43: “So having some sort of platform where everyone can just say, “This is how I stopped” or “This is how I'm trying to stop” and then other people giving feedback saying, “This is good” or, “This is not”.” [72]
- Quote 44: “Being able to exchange feedback with strangers with the same goal could be supportive but non-judgemental as you will probably not know the other users.” [59]

Embedded Social media

- Quote 45: “Integrating it with the social media is definitely a great thing to do because they can always fall back to Facebook, Twitter, etc. And through this, people can get to share their experiences and keep an update and tell whatever experiences they may have to share. So it’s like ongoing support.” [40]
- Quote 46: “Yeah you can share on Facebook and stuff, but I hate that. I hate when apps sync to like every form of social media. I’m like really weird about social media, so, no I don’t want to share it.” [48]
- Quote 47: “Don't want to share progress on social media in case you fail.” [72]

Social competition

- Quote 48: “Whenever we do a weekend challenge, you always have a look at what the other person's doing and [their] competitive side. I just want to beat the other people I see on there, so [using the app] is quite a good motivator.” [37]
- Quote 49: “It made me want to exercise more just, as like, kinda like, a competition to see how many calories because it takes your calories off whenever you exercise so I’m like let’s see how many I can get off this time.” [48]
- Quote 50: “Someone whose successful and quit smoking isn’t any better than someone that’s struggling with it. Like, no, I didn’t-I don’t like that aspect… it just makes someone feel bad.” [67]

Impersonated app

- Quote 51: “It’s like a “little boss in my pocket”… that’s sort of saying “you know you need to get out and do this”.” [45]
- Quote 52: “It’s like your own little motivator, in a way. And it definitely, it’s like, okay it’s like a little person, but it doesn’t talk, but it’s like, you shouldn’t eat that, or it’s like you should. So I don’t know it’s, I like it—I mean, I think it’s cool. It’s like my own little motivation.” [48]

- Quote 53: “I don’t want an electronic device telling me what to do.” [56]

Automatic motivation

TDF domain: Reinforcement.

Reinforcement is a process or action of encouragement of a pattern of behaviour (Textbox 7). Users reported better engagement when positive feedback was received (Q54) [37,39,45-48,51,52,54,56,58,62,67,72]. Visual feedback of progress made users aware of their advancement of reaching their goal (Q55) [37,45,46], while auditory feedback was seen as encouraging during physical activity (e.g. running) [37,48]. For some, instant feedback on their progress, even if it is of a positive nature, was perceived to cause pressure and potential disappointment if they were not able to reach their goal (Q56) [45,56].

Offering rewards [37,40,45,46,56-59,66,69,71,75] was found to be a useful way to increase engagement. Participants suggested including gamification elements in apps to enhance engagement [37,56,69,71,75]. Some users found intangible rewards (e.g. badges), motivating (Q57) [46,56,58,59,66,71], while others would want to receive tangible rewards instead (e.g. free t-shirt, gift cards, cash, reduction in health insurance or vouchers provided by hospitals, doctor’s office) (Q58-59) [40,56,58,66]. This has been partly supported by two quantitative studies. In one study having health insurance was associated with uptake of, but not with the engagement with health apps [42]. Another study found that when offering loyalty points, engagement increased for at least three months [55].

Textbox 7. Illustrative quotes (Q54-59) for factors mapped onto Automatic Motivation subcomponents of the COM-B model and coded under the TDF domains: Reinforcement and Emotions.

Engagement

Feedback

- Quote 54: “I liked how it gave notifications, like every day I've got a notification saying; You're on day four of your smoking quitting history. You could do this, don’t give up. Stay loyal and stuff like that. That was quite impressive.” [72]
- Quote 55: “The big green continue at the bottom and when it moves on to the next thing I feel great, I’ve achieved something, I’ve filled something in correctly. I like that. And a nice little noise which made me think, Oh, I’m not an idiot.” [46]
- Quote 56: “The progress I didn’t make—it shows [and thus is demotivating].” [56]

Rewards

- Quote 57: “Earning badges [was] important when I was doing it…We learned as a kid, to consider [it] as [an] accomplishment.” [56]
- Quote 58: “Each time you try, you get the points. And if these points can be converted to something else. Because you know, you’re not really working for the badge but if the virtual badge can turn into something tangible, I would want that.” [57]
- Quote 59: “Well, both of them are a kind of ‘well done for doing this’, they’re both a reward, they both make you feel a bit better. But a badge, it’s a cool fact, but it’s not the same as having vouchers, where you can go and treat yourself to something you want.” [59]

TDF domain: Emotions

Emotions, based on previous experiences and behaviour, are a complex reaction by which people tend to respond to a personally important event or matter. Curiosity [38,52,54,61] would positively influence uptake of health and wellbeing smartphone apps (Q60). However, in two studies, both targeting alcohol consumption reduction, this factor was only relevant for a specific user type: for those who were characterised as ‘low risk’ drinkers [38] and ‘noncommitters’ (i.e. users who did not commit to engage with the app, hence did not gain any benefit from it) of the app [54].

Textbox 8. Illustrative quote (Q60) for factors mapped onto Automatic Motivation subcomponent of the COM-B model and coded under the TDF domain: Emotion.

Uptake

Curiosity

- Quote 60: “It was more like seeing an ad and just, okay I should try this — and then I found it on the internet and signed up. It was more like a fun thing. We'll see if it works. More like that.” [52]

Reflective motivation

TDF domain: Goals.

Goals are outcomes that an individual would like to achieve in order to change a certain behaviour (Textbox 9). Goal setting [38,39,45,48,51,54,56,58,59,66,71,74] was related to sustained engagement with health and wellbeing apps (Q61). Some users chose to set a goal and mostly this was only one goal at a time, so their focus would remain on one single aspect of change of the behaviour (Q62), while others were more reluctant to use this

feature due to fears of not being able to achieve their set goal and to avoid disappointing themselves (Q63) [38]. In general, the studies suggest that users were more determined to engage in behaviour change when they had set goals [45] and believed they had successfully achieved or could achieve their goals with the help of an app by increasing their intention to use the app and by better monitoring the target behaviour (Q64-65) [48,54,56,58,59].

Textbox 9. Illustrative quotes (Q61-65) for factors mapped onto Reflective Motivation subcomponent of the COM-B model and coded under the TDF domain: Goals.

Engagement

Goal setting

- Quote 61: “I’m not good at self-discipline and exercise, so maybe this [goal setting in the app] can help me get to my goal.” [56]
- Quote 62: “I only set one goal because I was very keen to kind of remain focused on one thing. I didn’t want to come and get lost in the app using it like a game. You know, I wanted to use it for one very specific thing... I think I set it to drink probably within guidelines.” [38]
- Quote 63: “No, it didn’t appeal - probably because I thought if I put some goals in I’m probably not going to stick to it, which probably makes me sound a bit naughty.” [38]
- Quote 64: “If you set those manageable goals, so you could achieve it, if you feel like you’re actually progressing, getting something, then you’re more likely to go back.” [58]
- Quote 65: “It would encourage me to open the app on a daily basis.” [59]

TDF domain: Beliefs about consequences.

This domain includes aspects related to outcome expectancies. (Textbox 10.) Perceived utility of the app [37,46,52,59,61,74] refers to where there is a discrepancy between what the users are looking for and what an app actually offers. It was suggested that the unmet expectations of an app would lead to disengagement and frustration with the app (Q66-68).

Textbox 10. Illustrative quotes (Q66-68) for factors mapped onto Reflective Motivation subcomponent of the COM-B model and coded under the TDF domain: Beliefs about consequences.

Engagement

Perceived utility of the app

- Quote 66: “I do have some apps I don't use often, mainly because they've kind of bored me in a way. I'll just do an example: one fitness app shows you how to lose weight, but the way it's describing it, it's not what I'm after. It's one of those free apps I bought that—I thought [the fitness app] would be great, but when you actually use it, it's not the same.” [37]
- Quote 67: “I think that’s where it let itself down for me. Once I’d played with it, once I tried the game, done the identity and whatnot, there wasn’t much else there for me.” [46]
- Quote 68: “It [mindfulness app] didn’t add anything...I guess it didn’t detract, it didn’t make anything worse, but it didn’t add anything to my armoury, I guess, my tool kit, as keeping myself sane, I suppose, it didn't add.” [61]

Other factors

There were a number of sociodemographic factors that did not fit clearly under the components of the COM-B model.

Sociodemographic factors

Apps were more frequently downloaded by women than men, with the percentage ranging from 59% to 74% [38,41,49,53,55,63] though one study found that being male was associated with using an app to manage alcohol consumption [65]. Being less than 44 years old was associated with a higher level of uptake and engagement [38,41,42,44,49,53,55,63,64] than older adults. Living in an urban area [42,44,55], with better education level, such as having high school education or higher [41,42,44,64] and college degree or higher [41,53] and having a higher income [44] was also associated with better engagement with health and wellbeing apps.

Discussion

Principal findings

This is the first systematic review to conduct a theoretical analysis using the COM-B model of factors influencing the uptake of and engagement with health and wellbeing apps. Findings from this review suggest that there are 26 key factors across the constructs of capability, opportunity and motivation that influence the uptake of and engagement with these types of apps, which were found to be important for a wide range of populations and behaviours.

Our review replicates previous findings in the wider literature on digital behaviour change interventions. The core findings of our review suggest that attention should be perhaps shifted mainly on the support and guidance offered to new and existing users of health and wellbeing apps. We found that support and guidance of uptake can be targeted by increasing their awareness of health apps through, for example, recommendations received from health practitioners. In line with findings of previous reviews, help with initial engagement could be achieved by improving the users' app literacy skills and by providing knowledge [14,17]. We present knowledge in a novel way by breaking it down to: i) instructions of how to use it (i.e. user guidance), ii) advice related to the target behaviour or condition (i.e. health information), and iii) information on their progress or data (i.e. statistical information). This suggest that allowing access to users to different information that serves different purposes (e.g. health benefits vs progress data) would enhance their engagement through different channels, such as guidance, support and education.

Potentially, one of the most important factors for engagement identified in this review is health practitioner support. In line with the emerging evidence from the human-computer interaction literature, we found that an app coupled with human support [14,17] was likely to be more effective by increasing the intervention effectiveness and engagement [78,79]. Alternatively, human support can be impersonated by embedded artificial intelligence (AI) features. A recent experimental study found that a supportive artificial intelligence powered chatbot doubled the engagement with a smoking cessation app and increased its effectiveness [80]. This suggests that embedded human support or features that mimic human support might lead to greater engagement with digital behaviour change tools.

Behaviour change techniques, widely reported by others previously [14,17-19], were also identified as important factors to sustain engagement, including self-monitoring, feedback, goal setting, reminders, rewards, social support. Although, we found that not all of these have a positive effect. Reminders and social support factors (embedded social media and social competition) are not universally useful and might cause disengagement or even harm by triggering negative emotions. One plausible explanation is that the participants of the studies included may or may not have real life experience with health and wellbeing apps. Some of the included studies examined the participants' perceptions about a hypothetical app or an app that was planned to be developed. These studies relied on the participants' opinion of what they think it would be important for them in terms of uptake of and engagement with health and wellbeing apps, rather than sharing their lived experiences with such tools. For example, reminders were found useful in all the studies targeting a hypothetical app, as opposed to those that were researching engagement with an app that had been used by the participants, where opinions about reminders were mixed, with some

users finding them annoying. Another explanation is that the importance of these factors might be dependent on the target behaviour. For example, people using apps that target mental health might not want to engage with social competition feature or to share their progress or experiences on social media. This suggests that some of the identified factors in this review might be behaviour-dependent.

Another interesting finding, not identified in previous literature, is the safety netting characteristic of an app. This characteristic could promote long-term engagement, rather than short goal-oriented engagement. The user could disengage at any time and re-engage at a later stage when needed. This feature might be particularly useful for addiction research targeting relapse prevention strategies.

No factors were coded directly under four out of fourteen TDF domains (optimism, social identity, beliefs about capabilities, intentions). However, two of these were highlighted in this review. We described how several factors coded under different domains affect intentions (e.g. having adequate app literacy skills, user guidance provided to the user, etc.), in the similar way of how emotions, other than curiosity, affect engagement with an app (e.g. lack of app literacy skills triggers negative emotions, some found reminders annoying, or some fear of social comparison related to sharing on social media, etc.). We also found that aspects of the factor 'personalisation to needs' also include social identity aspects. Some communities (LGBTQ+, cancer patients) prefer an app that is personalised to their social identity. Although social identity, in this case, was judged to be a weak factor to list it independently. In terms of the other two absent domains, factors under beliefs in their capabilities and optimism might be less relevant for uptake and engagement with health apps, or the studies may have missed them out, or, potentially, we failed to identify them from the included studies.

The importance of promoting equality and embracing cultural diversity was partially identified previously [18]. Several studies in this review reported that apps should be provided at low cost to users. It was suggested that multiculturalism should be embraced, and regional languages added. The concern of inequality for those who do not own a smartphone was also raised in this review [40]. An accompanying website was suggested as an alternative for homeless people who would not have access to a smartphone but may have access to the internet through non-profit organisations, charities or community libraries.

Strengths and Limitations

One major strength of this paper is that it adhered to the best practice processes for undertaking reviews by following the PRISMA guidance and Cochrane handbook [27,29]. By

including all study designs we were able to pool together and triangulate evidence and provide a novel and powerful synthesis of different study designs.

The use of theoretical frameworks is another strength. Other theoretical models were considered for this review, including the technology acceptance model [81] and the human-computer interaction models and theories [82]. However, the COM-B and TDF present advantages by their dynamic nature and by explaining the influences between components as they were developed from, and to represent, all theoretical components in behaviour change-related models and theories. COM-B was explicitly developed to inform behaviour change interventions through its connection to the Behaviour Change Wheel (BCW) [83], a tool that provides guidance on designing behaviour change interventions. The factors identified under the components of the COM-B model allow easy identification of the intervention functions to target increased uptake of and engagement with health and wellbeing smartphone apps.

The review has several limitations. The review focused on four major behaviours related to prevention (smoking, alcohol consumption, physical activity, diet) and mental health and wellbeing and could not capture other prevention type behaviours (e.g. fall prevention). Factors relating to the uptake and engagement of apps focusing on other behvaiours or conditions may differ from those found in this review and warrant further investigation.

Although we captured a wide range of populations, most of the studies included were carried out in high income countries. Therefore, the findings might not be transferable to low- and middle-income countries or to other cultures. The quality of the studies was mixed. In some qualitative studies, the authors provided interpretations of their findings without an explicit quotation to support them. These interpretations were handled with care and often ignored when no further explanation was provided about a concept. This might have led to losing some potentially important factors, not identified otherwise.

Policy and Practice: Recommendations and Implications

The findings of this review can inform app developers and researchers on how to develop health and wellbeing smartphone apps to better support behaviour change and manage and monitor different physical and mental health conditions in adults.

This review may also have implications for policies that target prevention using digital technologies. Apps are an easy way to provide health-promoting behaviours and may play an important role in prevention strategies. For example, the UK government has recently published a Green Paper entitled ‘Advancing our health: prevention in the 2020s’ which shifted their focus from ‘cure to prevention’ committing to encourage the population to live a healthier life [84]. Additionally, the ‘Long Term Plan’ policy document of the National Health

Service (NHS) in the UK dedicates an entire chapter to prevention programmes and includes plans on digitally delivered methods to improve access to information, education and intervention [85].

As part of prevention and health management strategies, the NHS and partners have created a pool of health and wellbeing apps for the individuals to access (the NHS Apps Library). This research could help people access effective apps that people will remain engaged with, though to extent to which the population is open to use these portals for uptake is yet unknown, and something worth investigating in the future.

A number of important themes are described in the projects and policy documents mentioned above. Some relate to digital health, for example with an aim to reduce health inequalities [84] or to improve population health with personalised content and tailored lifestyle advice [85]. Our findings might offer a solution for these. For example, our review suggests that app literacy skills are important for uptake. Enhancing app literacy skills for the elderly (e.g. drop-in sessions in community settings) might be a feasible way to reduce health inequalities. Furthermore, some of the engagement-related factors might suggest use of tailored lifestyle advice to address health behaviours. For example, by receiving personalised content within the app, and online or offline help or advice from health practitioners, as well as receiving recommendations for health apps from their healthcare professionals and GP practices.

Therefore, our findings could inform stakeholders in public health and policymakers, and providers of health and wellbeing smartphone app portals to provide additional support for the uptake of and engagement with these digital interventions for adults.

Recommendations for stakeholders in public health and policy makers, and health and wellbeing app developers derived from the findings of this review can be found in Table 4.

Table 4: Recommendations for stakeholders in public health and policy makers, industry and health care, and health and wellbeing app developers

Policy makers/industry/health care providers might want to consider:	App developers might want to consider:
Capability	
• Improving app literacy skills • Increasing awareness of effective health and wellbeing apps, by advertising offline (e.g. GP	• Promoting less cognitive load by enabling automatization of data collection • Including user guidance that can be deactivated once the functionality of

practices) and online (e.g. social media)	the app has been achieved (e.g. help button) • Including content that targets education, health prevention, and health consequences related to the behaviour that is targeted to change • Including statistical information (e.g. graphs, percentages, numbers), about the user's progress • Including well-designed reminders where the user can choose the time and frequency of receiving it • Including self-monitoring feature that enables users to create routines • To provide long term use of an app, a 'safety netting' feature that allows users to fall back on, even though the target behaviour has been achieved
Opportunity	
• Providing online or offline health practitioner support • Providing recommendations for health and wellbeing apps by health care professionals • Offering apps for free or at low-cost	• Allowing the provision of health professional support within the app • Allowing community networking within the app with other users • Organising competition and challenges for users to opt in to • Avoiding automatic synching with the embedded social media (when applicable) • Personification of the app, by designing human-type attributes • Offering apps for free or at low-cost • Offering personalisation of the app according to their demographics, individual and cultural needs

<table>
<tr><th colspan="2">Motivation</th></tr>
<tr><td>Offering tangible rewards, such as points that could be used as a discount in pharmacies or at other health and wellbeing related domains, or health insurance providers</td><td>Providing positive, non-judgemental, constructive and informative feedback
Include gamification elements and offering rewards
Including goal setting features (when applicable)</td></tr>
<tr><td colspan="2">Providing a meaningful title and clear description of what the app does and what can offer, and how can help the user</td></tr>
</table>

Future research

While some of the factors identified and presented in the results section appear to provide a positive influence on uptake and engagement, there are mixed findings that might benefit from further investigation, such as reminders, embedded social media, and social competition. In the studies included in the review, descriptions of notification-type-messages, such as reminders, feedback, push-notifications and other notifications, were used interchangeably and it was not always clear which were being referred to. Consistent terminology would help eliminate doubt around these concepts in the future. Issues around equality and diversity were highlighted in a few studies as something future research should address. Further work is also needed to aid our understanding as to how to avoid digital health widening inequalities through the exclusion of individuals that face a financial barrier to owning a smartphone or one with a relatively up to date operating system or to purchasing an app, or who do not possess the skills to use one.

Conclusions

This is the first systematic review to investigate factors that influence uptake of and engagement with health and wellbeing smartphone apps. We identified twenty-six factors that are relevant to a wide range of populations and different behaviours. These have clear implications for improving population health and targeting health inequalities. We provide a list of recommendations built on the identified factors to guide app developers, health app portal developers and policy makers when commissioning, developing and optimising health and wellbeing smartphone apps. These can help with addressing the issues of suboptimal uptake and engagement which currently constrain the public health benefit of apps.

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Authors' contributions

Initial concept developed by DS, TC and FN. DS wrote the study protocol with contributions from FN, AJ, TC, JB. DS undertook data collection (literature search, screening, data extraction, quality appraisal), data analysis, interpretation and report writing. FN double checked the study selection, data extraction, data coding. FN and AJ double assessed the

quality of the included studies. DS prepared the manuscript. All authors read, commented and contributed on the final manuscript.

Conflicts of interests

All authors declare that they have no conflict of interest.

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Abbreviations

mhealth: mobile health
COM-B model: Capability, Opportunity, Motivation – Behaviour model
TDF: Theoretical Domains Framework
BCW: Behaviour Change Wheel
HCI: human-Computer Interaction
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO: International prospective register of systematic reviews
MMAT: Mixed Methods Appraisal Tool
LGBTQ+: Lesbian, Gay, Bisexual, Transgender, Queer and other spectrum of sexuality and gender
MSM: Men who have Sex with Men
HIV: Human Immunodeficiency Virus
UK: United Kingdom
NHS: National Health Service
PHE: Public Health England

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