



A systematic review of interventions to improve breast cancer screening health behaviours

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ABSTRACT

Whilst breast cancer screening has been implemented in many countries, uptake is often suboptimal. Consequently, several interventions targeting non-attendance behaviour have been developed. This systematic review aims to appraise the successes of interventions, identifying and comparing the specific techniques they use to modify health behaviours.

A literature search (PROSPERO CRD42020212090) between January 2005 and December 2020 using PubMed, Medline, PsycInfo, EMBASE and Google Scholar was conducted. Studies which investigated patient-facing interventions to increase attendance at breast cancer screening appointments were included. Details regarding the intervention delivery, theoretical background, and contents were extracted, as was quantitative data on the impact on attendance rates, compared to control measures. Interventions were also coded using the Behavioural Change Techniques (BCT) Taxonomy.

In total fifty-four studies, detailing eighty interventions, met the inclusion criteria. Only 50% of interventions reported a significant impact on screening attendance. Thirty-two different BCTs were used, with 'prompts/cues' the most commonly incorporated (77.5%), however techniques from the group 'covert learning' had the greatest pooled effect size 0.12 (95% CI 0.05-0.19, $P < 0.01$, $I^2 = 91.5\%$). 'Problem solving' was used in the highest proportion of interventions that significantly increased screening attendance (69.0%). 70% of the interventions were developed using behavioural theories.

These results show interventions aimed at increasing screening uptake are often unsuccessful. Commonly used approaches which focus upon explaining the consequences of not attending mammograms were often ineffective. Problem solving, however, has shown promise. These techniques should be investigated further, as should emerging technologies which can enable interventions to be feasibly translated at a population-level.

1. Introduction

Breast cancer is now the most common cancer worldwide, with screening programmes playing a key role in asymptomatic detection (WHO, 2021). In the UK alone, breast cancer screening is estimated to save 1300 lives annually (Cancer Research UK, 2015). Moreover, serial participants have been shown to have an estimated 49% lower risk of breast cancer mortality than serial non-participants (Duffy et al., 2021). Despite this, substantial geographical disparities in screening rates between, and within, different countries exist. For example Finland often reports attendance above 75%, however in 2017, 8 European Union countries had rates below 50% (European Commission, 2021a). Whilst

this can be attributed to the relative infancy, or lack of public programmes in these nations, countries such as Germany, which has had a programme since 2005, still has suboptimal participation rates of approximately 50% (OECD/European Union, 2018; Kaucher et al., 2020). Moreover, within countries such as the US, Canada and UK, the accessibility of breast screening services has been reported to vary amongst different population subgroups (Crawford et al., 2015; Kim et al., 2019). Addressing these issues has therefore become a prime public health concern, forming a central principle within the EU's recent 'Beating Cancer Plan' and UK's Richard's Review (European Commission, 2021b; Richards, 2019).

The urgency to find a solution has recently increased due to the

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impact of COVID-19, in which health services such as in Canada, suspended screening to reduce potential transmission. Consequently, millions of women worldwide have missed mammograms, leading to significantly increased pressures upon breast cancer services (Yong et al., 2021; Maringe et al., 2020). Furthermore, the pandemic is likely to raise new barriers to access services, and exacerbate existing inequalities (EBCC, 2020). There is therefore a growing need to understand what interventions are most effective at increasing uptake of breast screening.

In a review on existing screening interventions, Duffy et al. classified these into 5 broad groups: reminders, endorsement, interventions in non-participants, varying invitation materials and direct contact interventions. Whilst they found physician endorsement, pre-screening and personalised reminders were amongst the most effective interventions, they acknowledged the search was not exhaustive, recommending a formal systematic review (Duffy et al., 2017). Furthermore, they made few comparisons between the intervention types, limiting the utility for policy makers looking to increase mammography rates. This may be given the arbitrary groupings, which include a mix of delivery methods, behavioural techniques and target populations. Similar issues are also seen in reviews classifying according to scale, such as individual or community-based interventions (Agide et al., 2018). In order to draw inferences as to the effectiveness of differing interventions a more defined method is required.

The Behavioural Change Technique (BCT) Taxonomy is a validated cross-domain classification of 93 techniques to change behaviour, categorised into 16 higher groups. Developed through an expert consensus, the taxonomy provides definitions and examples of how the ‘active ingredients’ of interventions bring about behavioural changes. For example, the BCT *social comparison* is defined as an intervention that “draws attention to others’ performance to allow comparison with the person’s own performance”. This provides standardised language to classify interventions and allows replication of techniques in research and practice (Michie et al., 2013). As the focus of the definition is upon the technique this also facilitates the descriptions of interventions from different contexts, allowing conclusions to be drawn about the most effective intervention components. Moreover, many interventions use theoretical frameworks such as the Health Belief Model (HBM) or Transtheoretical Model (TTM), as theory-based interventions are said to be more effective (Rosenstock, 1974; Prochaska and Velicer, 1997; Glanz and Bishop, 2010). Understanding how effective interventions translate these frameworks into practical tools is important in guiding future development. Not all interventions use these constructs, however, and the BCT taxonomy enables comparison irrespective of the theories employed.

The aim of this review is to comprehensively and systematically evaluate the effectiveness of interventions to increase breast cancer screening uptake. In order to achieve this aim, this review will identify and compare the behavioural content of the interventions, the context they are delivered in, and biases within the existing literature. In this way, insights into the components of successful interventions may be elicited to inform the development of tools to improve breast screening uptake.

2. Methods

This systematic review was prospectively registered with PROSPERO (CRD42020212090) and conducted in accordance with PRISMA guidelines (Page et al., 2021).

A literature search of PubMed, Medline, PsycInfo, EMBASE and Google Scholar databases was conducted to include articles published from January 1st 2005, up to and including December 31st 2020. Studies which detailed the use of one or more patient-facing interventions to increase the uptake of breast cancer screening invitations were elicited. Appropriate MeSH descriptors included: *mass screening, population surveillance, mammography, breast cancer, breast neoplasms, patient compliance and health behaviour*. Searches were combined with all

field free-text entries: *breast malignancy, screening program*, cancer screening, asymptomatic screening, mobile screening, uptake, attendance, coverage and intervention*. These were used in various combinations in conjunction with standard Boolean operators AND/OR.

Identified studies were uploaded to the Cochrane supported software, Covidence (Melbourne, Australia). Abstracts were screened for suitability by two authors (AA and VS), blinded to each other’s assessment. Discrepancies were discussed, and resolved through consensus. Included studies were then reviewed for full-text evaluation.

All studies comparing the effect of an intervention on breast screening attendance in relation to a control were included. The primary outcome of interest was the difference between trial arms upon either self-reported or health record documented attendance at any time point. Given that usual care practices vary between healthcare systems, the control standard was not stipulated, and included printed appointment reminders, breast cancer educational materials, general health advice or no contact.

No restrictions on the type of interventions were placed, whether it was multi-modal or phased, or if it targeted specific sub-groups. Eligible studies were either observational or randomised controlled trials (RCTs). Whilst studies describing opportunistic screening (i.e. not a part of an organised program) were not excluded, the exclusion criteria included interventions targeting healthcare professionals (e.g. reminding a physician to opportunistically organise screening or ask patients to screen). Other exclusion criteria include protocols and studies regarding intervention development. Studies using outcomes as proxies for attendance such as intention to screen, were also excluded.

Study design, population demographics, behavioural theories, intervention details and uptake outcomes were extracted from available full-text articles.

To contrast the techniques utilised by interventions, The Behavioural Change Technique taxonomy was used. This cross-domain, cross-discipline classification defines the individual ingredients that change behaviour, or Behavioural Change Techniques (BCTs) (Michie et al., 2013). The taxonomy includes 93 BCTs categorised into 16 higher groups, each with examples of usage. An intervention may contain multiple BCTs, some of which may be unintended. The content of each intervention was classified using the BCT Taxonomy v1 by one author (AA). Mapping involved comparing the components of interventions within each study, to the descriptions given of each BCT in the taxonomy (Supplementary Material). A second independent author (GJ), blinded to the assessment, validating this evaluation in 20% of studies, in keeping with similar systematic reviews (Rhoon et al., 2020). Both authors had previously undertaken online training or had practical coding experience with the taxonomy (No name, 2021), which facilitated a high initial agreement of 83.6%. In studies, where discrepancies were found these were discussed until an agreement was found. When the intervention was inadequately described, protocols and pilot studies were reviewed, with authors contacted occasionally to garner the required information. The frequency of BCT use in effective and ineffective interventions was extracted when used in more than three studies.

The Revised Cochrane risk-of-bias tool for randomised trials (RoB 2) was also used to evaluate the literature (Sterne et al., 2019). This tool uses signalling questions to assess biases in five domains: randomisation, adherence to the intervention, missing outcomes, measurement of outcomes, and reported result selection. Non-randomised studies were appraised using an analogous method: the Risk Of Bias In Non-Randomised Studies of Interventions (ROBINS-I) (Sterne et al., 2016). Both frameworks are endorsed by Cochrane for their use in the assessment of internal validity. Assessment was undertaken by one author (AA), and validated independently by another (VS), with disagreements resolved by discussion.

2.1. Data analysis

To determine which BCTs were the most effective, interventions

were grouped according to whether they contained BCTs from each of the 16 higher taxonomical groups. Within each study, data regarding the proportional difference in screening attendance between the intervention and controls was extracted. A meta-analysis based upon these proportional differences was undertaken using the inverse-variance, random-effects model described by DerSimonian and Laird (DerSimonian and Laird, 1986). This model was used to determine a pooled effect size for each higher-level BCT group. When only one study contained BCTs from a particular group, no analysis was undertaken.

The I^2 statistic was used to estimate the degree of heterogeneity between studies, with higher values indicating greater heterogeneity. A Chi-Squared test was used to associations of categorical variables such as behavioural model use with positive attendance outcomes. All analyses were undertaken using Stata version 15 (StataCorp, Texas, USA).

2.2. Ethical compliance

As this constituted a review of existing original articles, no ethical review was required.

3. Results

1666 articles were retrieved through the search, with abstracts screened to meet the inclusion criteria and relevance to the current study. The study diagram is shown in Fig. 1. Fifty-four full text articles met the inclusion criteria. Of these, 45 were RCTs and 9 were quasi-

experimental (including pre-post studies) (Abood et al., 2005; Ahmed et al., 2010; Allen and Bazargan-Hejazi, 2005; Beauchamp et al., 2020; Bodurtha et al., 2009; Bowen et al., 2017; Carney et al., 2005; Chambers et al., 2016; Champion et al., 2006; Champion et al., 2007; Champion et al., 2016; Champion et al., 2020; Chan et al., 2018; Cuellar et al., 2017; Cohen and Azaiza, 2010; DeFrank et al., 2009; Dietrich et al., 2006; Fernández et al., 2009; Goldzahl et al., 2018; Han et al., 2009; Hegenscheid et al., 2011; Highfield et al., 2015; Icheku and Arowobusoye, 2015; Kearins et al., 2009; Kerrison et al., 2015; Kregting et al., 2020; Kreuter et al., 2005; Lakkis et al., 2011; Larkey et al., 2012; Lee et al., 2014; Lee et al., 2017a; Lee et al., 2017b; Luckmann et al., 2018; Marshall et al., 2016; Merrick et al., 2015; Michielutte et al., 2005; Mishra et al., 2007; Moskowitz et al., 2007; Nanda et al., 2020; Nguyen et al., 2009; Page et al., 2006; Paskett et al., 2006; Phillips et al., 2011; Puschel and Thompson, 2011; Russell et al., 2010; Sadler et al., 2011; Schapira et al., 2019; Secginli and Nahcivan, 2011; Slater et al., 2017; Tuzcu et al., 2016; Vernon et al., 2008; Vidal et al., 2014; Wang et al., 2012; Wu and Lin, 2015). Various measures of attendance were reported by studies, with 42.3% using health record data, 44.4% self-report measures, 9.3% a combination of the two, and 3.7% not stating how attendance was derived. Across the studies 468,381 women were included (220,309 in the control and 248,072 in the intervention arms). 14.8% of the studies focussed upon low-income populations, whilst 33.3% of studies targeted minority ethnic groups (11.1% on African Americans, 3.7% on Chinese Americans, 3.7% on Hispanic, 1.9% on Israeli-Arabs, 9.3% on Korean Americans, 1.9% on Samoans, and 1.9%

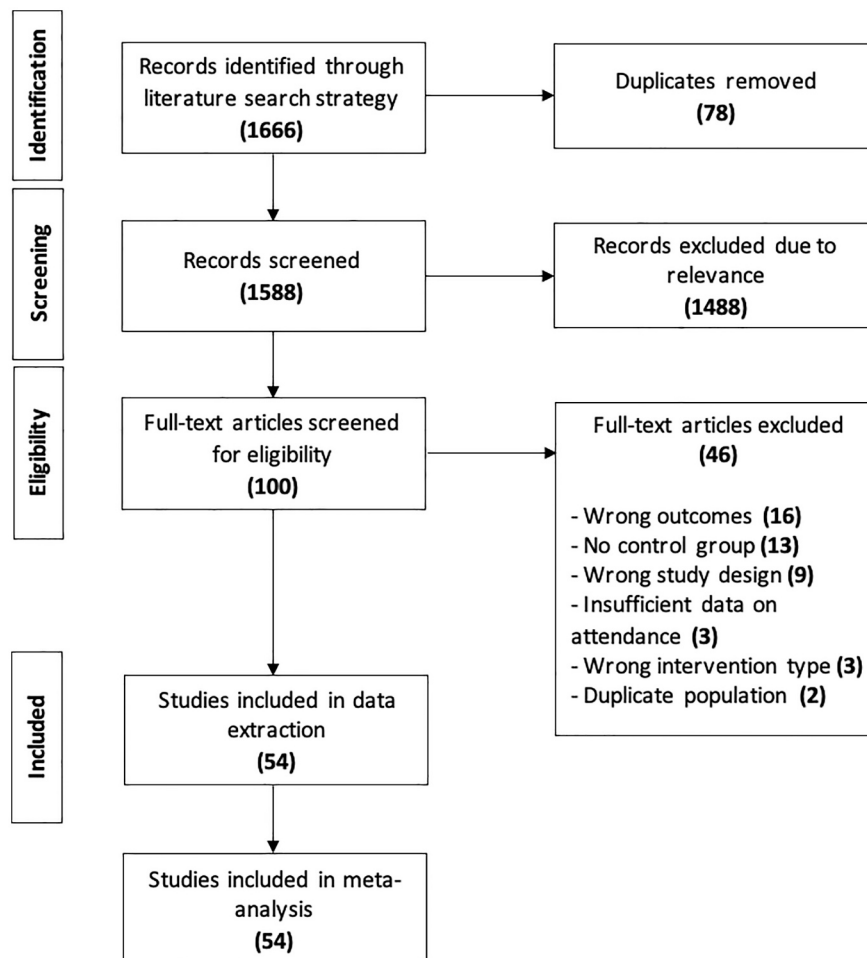


Fig. 1. Diagram demonstrating literature search strategy. Duplicate publication represents two studies that report results in the same group (either as interim results or subgroup analysis). In these cases the more formative or earlier studies were excluded.

Vietnamese Americans). Study characteristics are shown in [Table 1](#).

The 54 included studies described 80 different interventions. In 71.3% a singular delivery method was used, whilst the remainder used a combination of strategies. In 48.8% of the interventions, a print medium was employed either alone (28.8%) or in combination (20.0%) with other means. App-based mobile, web or computer resources were used in 8.8% of cases. The remainder of studies used in-person (3.8%), SMS (5.0%), telephone (20.0%), video (5.0%), or a mixture of non-print methods (8.8%).

Interventions applied 32 of the 93 techniques described in the BCT taxonomy. Of the 80 interventions, 40 reported a significant increase in screening attendance compared to control measures. The median number of BCTs included in interventions was five (inter-quartile range three). Using a higher number (>5) compared a low number of BCTs (≤ 5) was not associated with a greater proportion of effective interventions (42.9% v. 53.8% effective $\chi^2 = 0.88$ $P = 0.35$). [Fig. 2](#) demonstrates the frequency of BCTs utilised by interventions, and the proportions of which led to positive outcomes. ‘Prompts/cues’ was the most common BCT, with 77.5% of interventions employing the technique, of which 51.6% reported a significant effect. Of the four interventions that used prompts alone, three were effective (75%), compared to 29 of the 58 (50%) interventions combining prompts with other BCTs. Techniques highlighting the ramifications of non-attendance to the individual, whilst commonly used, were not often effective. These included ‘information on health consequences’ (43 interventions, 39.5% effective), ‘pros/cons’ (24 interventions, 37.5% effective), and ‘salience of consequences’ (22 interventions, 31.8% effective). 69.0% of 29 interventions using ‘problem solving,’ however, led to significantly improved uptake. This was the highest proportion of any BCT used in more than three studies. ‘Instruction on how to perform’ (65.6% effective) and ‘credible source’ (65.0% effective) also performed well.

Whilst BCTs from 15 of the 16 higher-level groups were represented, no BCT from the group ‘scheduled consequences,’ was coded. Weighted random effects analysis demonstrated the higher groups ‘covert learning’, which includes the BCTs ‘vicarious consequences’, ‘imaginary reward’, and ‘punishment’, had the highest pooled effect size (ES) 0.12 (95% CI 0.05–0.19, $P < 0.01$) ([Table 2](#)). The heterogeneity was, however, high ($I^2 = 91.5\%$), and only three interventions included BCTs from this group. ‘Self-belief’ (ES 0.11, 95% CI 0.07–0.15, $I^2 = 97.2\%$) and ‘social support’ (ES 0.11, 95% CI 0.03–0.29, $I^2 = 99.2\%$), had a similar effect size, but were more extensively studied. Again, however, levels of heterogeneity were high. The group ‘associations,’ which contains the BCT ‘prompts/cues,’ had the lowest pooled ES 0.05 (95% CI 0.05). The high heterogeneity precluded further sub-group analysis. Full BCT coding for studies, and Forest plots for the meta-analysis can be found in the Supplementary Data.

The majority of studies (70%) described the use of one or more named theories to underpin intervention development. The Health Belief Model (HBM) was the most commonly cited, used in 55.4% of theory-based interventions (31 interventions in 21 studies). Of the theory-based interventions, fewer than half were reported as effective. This did not significantly differ to the proportion of effective non-theory-based interventions (46.4% v. 58.3%, $\chi^2 = 0.95$, $P = 0.33$). When comparing individual theories to no theory, no significant differences were found ([Table 3](#)).

The RoB-2 and ROBINS-1 evaluation of the literature is shown in [Fig. 3](#). This analysis was undertaken in parallel to the primary outcome of impact on attendance to demonstrate the standard of the current literature. As the intended meta-analysis incorporating BCT effects was precluded due to heterogeneity, the effect of bias was described through summarizing risk of bias for the outcome measure within each study, as opposed to stratification of forest plots. This full assessment for included studies is shown in the (Supplementary Material). 35.6% of RCTs were judged to contain ‘moderate’ or ‘severe’ biases compared to 77.8% of observational studies. The risk due to deviation was found to be

‘moderate’ or ‘severe’ in two-thirds of these non-randomised studies. These deviations include the exposure of the comparison groups to unplanned breast cancer campaigns during the study period, as with Moskowitz et al. ([Moskowitz et al., 2007](#)) This could have impacted upon screening behaviours, and as such a ‘serious’ risk of bias was coded. Whilst RCTs demonstrated lower risk of bias compared to non-randomised studies, inclusion was not restricted to randomised studies. This was because only 22% of non-randomised studies (or 7.4% of all studies) had a high risk of overall bias, thus the conclusions drawn were unlikely to be impacted by this minority of studies. Moreover, these studies often involved pragmatic evaluations amongst diverse populations within existing screening services, and therefore, gave important information regarding real-world effectiveness of interventions.

4. Discussion

This study has demonstrated the variable performance of the interventions aimed at increasing breast cancer screening uptake, and the breadth of approaches explored. Only half of the interventions in this review led to a significant increase in screening attendance compared to usual care. ‘Prompts/cues’ were most commonly used, however, ‘problem solving’ was more commonly associated with effective interventions. Pooled analysis demonstrated that BCT groups such as ‘self-belief’, ‘social support’ and ‘covert learning’ may have a greater effect upon screening attendance, than individual consequence-based strategies. Although, ‘covert learning’ was only studied in three interventions, limiting the conclusions that can be drawn. Contrary to some literature, no significant differences were found in the reported effectiveness of interventions underpinned by theoretical frameworks ([Glanz and Bishop, 2010](#)). This may indicate the difficulty in translating general constructs to address specific behaviours. This is of particular importance, as the interventions were used in a variety of different contexts, including a number targeting minority ethnic or low-income populations.

This review has also shown the standard of the reporting literature is sub-optimal. Whilst the overall risk of bias was low in 64.4% of the RCTs, a lack of detail regarding randomisation and allocation meant only 53.3% of these studies rated as low risk in this regard. In addition, handling of missing data constituted a moderate or serious risk in 24.4% of RCTs and 44.4% of quasi-experimental studies. This was partially due to the use of self-reported mammography as an outcome with 24 of the 54 studies. This relies upon participation in follow-up interviews, and therefore, data can be skewed by attrition, as well as response biases. Further, the validity of these measures in mammography is contentious due to the potential for telescoping and inconsistent interpretation in minority ethnic groups ([Levine et al., 2019](#)).

Despite an increasing need for measures to overcome the low uptake and disparities associated with breast cancer screening, existing interventions are often unsuccessful. There was a tendency for research to rely upon similar techniques, potentially due to interventions being based upon well-cited barriers, such as poor healthcare access ([Lee et al., 2017b](#); [Nanda et al., 2020](#)). One method that was commonly used were reminders. Prompts (or reminders) were the most commonly used BCT in both effective and ineffective interventions. The pooled effect of interventions that used techniques from the higher order group ‘associations’ (which included prompts), was 0.05. This is equivalent to the 5% increase in uptake quoted by screening services that incorporate reminders. Moreover, our findings are in keeping with the review by Duffy et al. which showed reminders were the second most commonly used technique but also consistently increased participation by 3–10 percentage points ([Richards, 2019](#); [Duffy et al., 2017](#)). However, the use of reminders has been already established in the outpatient setting, including several screening programmes ([Fors et al., 2019](#)). This is particularly important given that countries such as the UK and Finland have had breast screening programmes established since the 1980’s

Table 1
Extracted information from included studies.

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
					Description (n)					
Abood et al. (2005)	USA	Quasi-experimental	Aged 50–64, Under-/Uninsured	Telephone call to schedule a mammogram (992)	Scripted loss-framed messages (112)	Tel.	NS	HR at 6 months	+11.9 ^a	Loss-framed communication strategy seems associated with increased mammography utilisation.
Ahmed et al. (2010)	USA	RCT	Aged > 40	Usual care including monthly newsletters on health topics including breast screening and access outreach workers (786)	Usual care and received a reminder letter signed by the medical director endorsing screening (785)	Print	IDT, SLT	NS	+3 ^a	The stepwise intervention significantly increased mammography, more so than the simple intervention which also led to significant higher rates than controls.
					Received the director's letter, if no mammogram at 3 months then a personalised letter from primary care physician. If no appointment at 6 months then an outreach worker conducted counselling tailored to barriers. (785)	In-person/Print	IDT, SLT	+14 ^a		
Allen and Bazargan-Hejazi (2005)	USA	RCT	Aged > 40	Telephone calls to enquire about mammogram receipt only (169)	Barrier counselling tailored using a survey delivered by Latina/African American workers. Focus was upon importance of screening and scheduling a low-cost test. Mailed appointment reminders and brochures. (185)	Print/Tel.	AM, HBM PT, SLT TPB, TTM	SR at 6 months	+7.8 ^a	Tailored counselling increased screening mammogram rate by 8% compared controls.
Beauchamp et al. (2020)	Australia	RCT	Aged 50–74, identified Italian or Arabic as preferred language	English reminder letter with breast cancer stats, purpose of screening and booking information (460)(100)	Single reminder in their preferred language, as well as English. The translation was simplified and included a photo and quote from an Italian or Arabic GP (572)	Print	NS	HR at 14 days	–1.5	Sending letters in preferred language showed no different to letters in English. Telephone call to women in their preferred language was 10 times more effective than usual care.
					A reminder call in their preferred language, lasting 4–8 min. Participants could book the appointment during the call. (95) ^b	Tel.	NS	+58.2 ^a		
Bodurtha et al. (2009)	USA	RCT	Aged > 40	General print information on breast cancer prevention not tailored to risk level (450)	5-yr and lifetime breast cancer risk calculated using the Gail Model described in handouts. These also addressed barriers, severity of breast cancer and benefits of mammograms. Instructions on scheduling a mammogram were included (449)	Print	HBM	SR/HR at 18 months	–2	A brief intervention in the waiting room did not increase mammography rates, but was associated with improved rates in those most worried about breast cancer.
Bowen et al. (2017)	USA	RCT	Aged 18–74 (>40 for mammo.), internet access at home	No website access received standard programme invitation and information (338)	Access to website with personal stories, messages about breast cancer tailored to an individual's risk and exploration of this risk with a health counsellor. Participants were also given the chance to make commitments and address their concern. A risk calculator, and genetic counselling was available. (334)	Web	SR	SR at 12 months	+12 ^a	The multi-faceted intervention significantly increased screening behaviour. The effects were stronger in those whose knowledge increased and worry decreased due to the intervention.
Carney et al. (2005)	USA	RCT	Aged > 50, 1 or more previous mammograms	General print information on breast cancer and state	Educational and counselling calls to identify barriers, means to overcome them and stage of readiness change.	Tel.	TTM	SR at 15 months	+13 ^a	Tailored counselling influenced women's behavioural stage relative to obtaining

(continued on next page)

Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion	
Chambers et al. (2016)	UK	RCT	Aged > 50	Letter sent from the local breast screening Centre to remind individuals to attend (217)	screening services sent twice. (132)					mammography leading to greater number of women being up to date with screening compared controls. A simple telephone intervention doubled the uptake compared a letter alone, but there no additional effect of telephone support or anticipated regret.	
					Two sessions were given 1 y a part, each lasting on average 6 mins. (126)	Within 2 weeks of letter, received a telephone reminder (212) ^a	Tel.	HBM, TPB	SR at 3 months	+9.6 ^a	
					Within 2 weeks of letter, received telephone support addressing barriers and concerns identified (213)	Tel.	HBM, TPB		+4.4		
Champion et al. (2006)	USA	RCT	Aged 41–75, African American, low income	Educational pamphlets targeting African American women, encouraging attendance and giving a list of local screening facilities. (71)	Within 2 weeks of letter, received telephone support addressing barriers and concerns identified including two questions on anticipated regret (214) ^a	Tel.	HBM, TPB		+6.2 ^a		
					Interactive tutorial narrated by local African American celebrity, asking questions regarding the beliefs and knowledge on cancer screening. Tailored responses from storytellers persuaded participants to re-evaluate negative beliefs. Videos demonstrated mammography, a spiritual perspective on mammography and a doctor giving factual information. Lasted 20 to 40 mins. (138)	Computer	EPPM, HBM, TTM	SR at 6 months	+7.9	Interactive computer module was more effective at increasing mammography adherence than the targeted video but not the pamphlet. Interactive measures were more effective than non-interactive tools.	
					A target video that was a linear representation of the computer program using the same local narrators and storytellers. The tone promoted self-efficacy, reduced fatalism and moderated threat. Video lasted 20 mins (135)	Video	EPPM, HBM, TTM		-7.5	Attendance in the video and computer groups was not significantly different from that in the pamphlet group	
Champion et al. (2007)	USA	RCT	HMO member	Usual care which incorporates breast cancer screening written reminder from some health providers (294)	Mailed newsletter with tailored information from interviews on participants' risk, benefits and barriers. If self-efficacy was low this was added as secondary page. If a participant had not had a previous mammogram a supplementary page on how to arrange one was included. A physician-signed cover letter addressing age, family history and stage of adoption was included (329)	Print	HBM, TTM	HR at 4 months	+9 ^a	A combination tailored print and telephone intervention was the most effective intervention for 4-month adherence. Adding print materials appeared to have an additive effect on adherence. All 3 interventions outperformed controls	
					Counsellors delivered tailored information covering the topics included in the newsletter and answered specific non-medical questions from clients. (314)	Tel.	HBM, TTM		+6 ^a		
					Received print letter and a counsellor's call within a week of the newsletter. (308)	Print/Tel.	HBM, TTM		+12 ^a		

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
Champion et al. (2016)	USA	RCT	Aged 51–75, member of HMO	Usual care ranging from no additional materials to a post-card reminder when it was time to schedule the mammo. (537)	DVD lasting 10 mins with women of different demographics delivering messages. These were tailored to perceived risk, benefits, self-efficacy, barriers and demographics previously identified. Demonstration of mammography was included (542)	Video	HBM, TTM	SR/HR at 6 months	–5.6	Neither DVD nor telephone intervention significantly increased uptake, the effect of intervention however appeared moderated by income.
					Tailored messages (over an average 11.3 mins) to perceived risk, benefits, self-efficacy, barriers and demographics previously identified. Demonstration of mammography was included (559)	Tel.	HBM, TTM		–0.2	
Champion et al. (2020)	USA	RCT	Aged 51–75, non-adherent to both colorectal and breast screening	Usual care depended upon health care providers including receiving reminder postcards at the time to book a mammogram (177)	Tailored messages based on individual's responses regarding knowledge, risk of cancer, benefits and self-efficacy for screening. Messages simultaneously addressed the need to for both colorectal and breast screening. Video clips demonstrated mammography. (180)	Web	HBM, TPB, TTM	SR/HR at 6 months	6.8	Tailored intervention did not significantly improved rates of mammogram alone between the groups. It did significantly increase non-breast cancer screening outcomes.
					Tailored messages consistent with web-based algorithms. Participants were asked if they wanted to book an appointment. Calls lasted an average of 19 mins. (168)	Tel.	HBM, TPB, TTM		6.4	
					Completion of the tailored web program with the phone intervention delivered 2–4 weeks later. (167)	Tel./Web	HBM, TPB, TTM		4.4	
Chan et al. (2018)	Canada	RCT	Aged 51–73, enrolled in screening mammogram program	Reminder postcard with "mammograms save lives" and quotes from service workers. (2749)	A signed letter from their physician expressing concern regarding their overdue screening status in addition to the postcard (2749)	Print	NS	HR at 6 months	+10.4 ^a	A signed letter from a physician significantly increased the percentage of women who returned for screening
Cuellar et al. (2017)	USA	Quasi-experimental	Aged 40–64, member of employee wellness program	No explicit financial reward, but promotional materials for the Wellness Programme (160789)	Employee wellness Programme offering a \$0–\$75 reward for receipt of mammogram or other preventative measures recorded by score card (maximum annual incentive between \$250–900) (160789)	NS	NS	NS	+2.7 ^a	Financial incentives increase their impact upon preventative care services with a 5–7% increase in mammogram rates. Modest financial incentives, even below federally approved levels can drive behaviours
Cohen and Azaiza (2010)	Israel	RCT	Aged 40–65	Usual care materials including invitations (14)	Social worker explored stage of contemplation, individual risk-based recommendations, beliefs and barriers addressing them with a culturally tailored approach (26)	Tel.	HBM, TTM, CCA	SR at 6 months	+17.1	Cultural-based interventions increased mammography attendance but not significantly. Social and exposure barriers were lowered through this approach.
DeFrank et al. (2009)	USA	RCT	Aged 40–75, stage health plan	Mailed reminder with last mammogram date, screening benefits, and contact information (799)	Telephone reminder with last mammogram date, benefits of screening, guidelines and contact information. Call lasted 69 s and had a female voice. (1259)	Tel.	NS	SR/HR at 14 months	+5.5 ^a	The automated telephone reminder was the most effective strategy to increase adherence, but enhanced print reminders performed similarly to usual care.

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
					Letter reminder contained the same information as the telephone call, as well as a booklet incorporating figures regarding severity and susceptibility of breast cancer. (1269)	Print	HBM		+2.7	
Dietrich et al. (2006)	USA	RCT	Aged 50–69, overdue 1 cancer screening, attended migrant health Centre	1 call where screening queries were answered and advice to obtain needed screening (694)	A series of support calls over 18 months facilitating screen process, addressing barriers and detail explanations of screening. Aimed to prioritise screening and gave motivational support. Written recommendations, patient activation cards and reminders were also sent. (696)	Print/Tel.	NS	HR at 18 months	+10 ^a	Telephone support can improve screening rates in those visiting migrant health centres.
Fernández et al. (2009)	USA	Quasi-experimental	Aged > 50, Hispanic farmer status	Initial invitation no other outreach or educational activity (257)	Lay health workers held sessions lasting 1 to 2 h using bilingual pamphlets, breast models and videos to educate and motivate to screen. A further contact at 2 weeks to assist booking.(207)	In-person/Tel.	LR	SR at 6 months	+5	A higher percentage of women in the intervention group than in the control group reported screening although this did not reach statistical significance.
Goldzahl et al. (2018)	France	RCT	Aged 50–74	Printed invitation letter that explains process and rationale to screen (5277)	Addition of 3 official logos of the National Insurance Funds onto control letter (5296) Simplified letter preferred by a sample of eligible women (5315) Logo and simple Letter (5300) Letter with social norms information (5307)	Print Print Print Print	LR LR LR LR	HR at 24 months	–1.1 –0.8 –0.7 –0.5	No treatment led to a significant increase in mammography receipt including amongst first time and low-income subgroups. This may be due to many women not opening the letters or understanding them
Han et al. (2009)	USA	Quasi-experimental	Aged > 40, Korean American	Standard reminder untailored to cultural values (93)	2-h education sessions in the community using a curriculum including case presentations and barriers to screening. Individually tailored follow up to counsel participants, identifying benefits and barriers to screening. (93)	In-person/Tel.	HBM, TTM	SR at 6 months	+31.9 ^a	The multifaceted intervention led to significant increase in attendance, and was considered a highly acceptable by participants. It did not improve screening knowledge.
Hegenscheid et al. (2011)	Germany	RCT	Aged 50–69	Written reminder to attend mammogram (2952)	Counsellor used study data to reduce an individual's barriers and increase facilitators to screening. They used preformulated facts to include cancer risk, use of mammograms and recommendations. (2455)	Tel.	CM, HBM, TTM	HR at 3 months	+3.6 ^a	The telephone counselling group had significant higher attendance rate compared controls. The intervention was effective and well accepted by participants.
Highfield et al. (2015)	USA	Quasi-experimental	Aged 35–64, African American, uninsured	Telephone reminder with scan details and location (151)	6–10 min tailored telephone counselling reminder using salient barriers from local African American women and active listening. (88)	Tel.	TTM	HR at NS	+25 ^a	The evidence-based intervention significantly increased attendance in a real-world context
Icheku and Arowobusoye (2015)	UK	Quasi-experimental	Aged 50–70	An NHS trust headed invitation letter signed by GP lead (1452)	SMS reminder messages sent 1 week prior to appointments following invitation letter. (552)	SMS	LR	HR at 6 months	+8 ^a	Letter intervention combined with SMS reminders were the most effective in improving breast screening uptake
Kearins et al. (2009)	UK	Quasi-experimental	Aged 53–64		A call to persistent non-attenders following the invitation letter to	In-person/Tel.	NS	HR at NS	+3.1 ^a	

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
				An invitation from screening service to a timed scan (5180)	ascertain intention and answer queries. A reminder call was made 24 h prior to the appointment. If no phone contact, a personal visit was undertaken (476)					Enhanced activity of phone calls led to moderate increases in screening uptake
Kerrison et al. (2015)	UK	RCT	Aged 47–53, invited to first routine screen	Printed invitation but no reminder (435)	Reminder 48 h prior to appointment (456)	SMS	NS	HR at 1st appointment	+5.3 ^a	Sending a reminder before first routine breast screening appointment significantly increased attendance.
Kregting et al. (2020)	Netherlands	RCT	Aged 49–75	Standard invitation and information leaflet (457)	Additional leaflet using simple text to increase gist knowledge regarding screening process, outcomes, benefits and harms. (531)	Print	NS	HR at appointment	+2	The leaflet did not lead to increased attendance but did lead to more knowledge and positive explicit attitudes towards screening.
Kreuter et al. (2005)	USA	RCT	Aged 40–65, African American	Received no printed materials during the study but did receive them at the end. (55)	Received 6 magazines over 18 months. Magazines promoted mammography using tailored stories, was personalised to the recipient and used local African American artists' works. The magazine was tailored to cancer knowledge, risk, perceived barriers and use of screening and readiness to act. (48)	Print	LR	SR at 18 months	+10.1	Integrating culture into behavioural interventions may enhance their effectiveness for African Americans. Those who had behavioural and cultural stories were 2.6 times more likely than controls to attend mammograms.
					Received 6 magazines over 18 months. Magazines promoted mammography using culturally tailored stories and was personalised to the recipient. The magazine was tailored to 2 of 4 cultural constructs (religiosity, collectivism, racial pride, time orientation), that they scored high on the pre-study survey. (44)	Print	LR		+9.1	Using magazines tailored on culture or knowledge alone did not significantly increase attendance compared controls
					Magazine contained both behavioural and cultural tailored stories (45) ^a	Print	LR		+21.1 ^a	
Lakkis et al. (2011)	Lebanon	RCT	Aged 40–75, Health insurance	SMS general invitation +3 reminder messages (192)	In addition to the invite and 3 reminders at 4-week intervals, an SMS regarding the benefits of mammograms was sent (193)	SMS	NS	HR at 6 months	+0.9	The addition of an SMS about benefits did not improve mammogram rates compared to the usual SMS invite
Larkey et al. (2012)	USA	RCT	Aged > 18 (>40 for mammo.) self-identified as Hispanic/Latina	Individual sessions with a <i>promotora</i> only and didactic teaching (402)	6 group-based sessions regarding screening with group exercises and interaction. Materials were designed to create interaction (604)	In-person	NS	SR at 3 months	–11.4	No significant difference in achievement of screening behaviour between groups but high attrition was noted.
Lee et al. (2014)	USA	RCT	Aged > 40, Korean American immigrants and married to a Korean American	Education session and DVD on improving diet (217)	A 30 mins DVD culturally tailored messages on screening to change health beliefs and increase spousal support. Group discussion with couple on the main messages and a home exercise for couples to do. (211)	In-person/ Video	HBM, MoI	SR at 15 months	+14 ^a	Women in the intervention group were more than twice as likely to have a mammogram within 15 months.

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
					Description (n)					
Lee et al. (2017a)	USA	RCT	Aged > 40, Korean American immigrants and married to a Korean American	Received standard materials from healthcare provider (32)	Culturally tailored messages on screening to change health beliefs and increase spousal support, with a summary of the main messages and a home exercise for couples to do and report to study team by phone (23)	Web	HBM, MoI	SR at 2 months	+9.2	Greater uptake of mammography although the difference was not significant. This may be due to the short follow up and small sample size.
Lee et al. (2017b)	USA	RCT	Aged 40–79, Korean-American immigrant	Printed materials in Korean with details of a health navigator (60)	Application to send culturally tailored messages to increase education and motivation, as well as an in-app reward system, clinic information and an online health navigator to address logistical barriers (60)	Mobile app	FBM, HBM	SR at 6 months	+45 ^a	Intervention received mammograms at a significantly higher rate. The app can positively influence health behaviours
Luckmann et al. (2018)	USA	RCT	Aged 40–84, members of Fallon health clinic	Letter reminder only informing them of outstanding mammogram (10063)	Reminder calls 2 weeks after the control letter, with the offer to schedule one (10043) Further reminder letter 2 weeks after the initial letter and educational booklet, if no mammogram scheduled. This was followed by a counselling call to identify and overcome barriers and support screening 1 week later (10054)	Print/Tel.	NS	HR at 24 months	+2.2 ^a	Reminder calls were more effective than counselling calls and letters, with the largest difference in those aged 40–49 years. No difference in adherence between counselling calls and letters.
						Print/Tel.	PAPM		0	
Marshall et al. (2016)	USA	RCT	Aged > 65, self-identified as African American and in fee-for-service Medicare	Printed educational materials on cancer and preventive services by Medicare (720)	Patient navigation services discussing printed control materials, risks for cancer and barriers. Also helped arrange appointments and accompanied patients to appointments (638)	In-person/ Tel.	NS	SR at 24 months	+5.8 ^a	Patient navigation increased mammography utilisation, with the effect stronger on those not up to date
Merrick et al. (2015)	USA	RCT	Aged 42–69 with network-model plan coverage	Standard reminder letter encouraging contact providers with medical questions and help finding a mammography facility. (1102)	Control letter offering a \$15 gift card if receipt of mammography (1100) Control letter offering a lottery for 1 of 5 \$250 gift cards if receipt of mammography (1118) Control letter to indicate their preference of gift card or entering lottery, or person-centred incentive (1107)	Print	NS	HR at 4 months	–0.2	None of the incentives led to a significant increase in mammogram rates but the subset who had a mammogram most recently may be responsive to person-centred incentives
						Print	NS		+0.2	
						Print	NS		+1.5	
Michielutte et al. (2005)	USA	RCT	Aged > 65, private healthcare	Educational materials regarding skin cancer, in same frequency as intervention. Physician-facing skin cancer information. (914)	Simply written pamphlet on mammography for older patients, with key points such as coverage guidelines highlighted. Physician-facing materials were also sent. (997) Received initial pamphlet, and 4 months later were mailed educational materials and a fact sheet based upon HBM. The sheet emphasized age as a risk factor, the law for insurance companies and benefits of screening. (997)	Print	NS	HR at 4 months	–0.8	No overall effect across all three stages of the intervention, although printed education materials (the second phase) appeared to lead to significant increase in attendance.
						Print	HBM		+3.5	
						Print/Tel.	HBM, TTM		+2.7	

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
Mishra et al. (2007)	USA	RCT	Aged > 42, Samoan ancestry	Print materials regarding screening from healthcare providers (385)	4 months after receiving initial and secondary educational materials, contacted by a counsellor who identified her stage of change. Aim was to note why patient had not screen and the most important barriers addressed. (997) Multicomponent, involving educational booklets with Samoan artwork, idioms, and addressing culture-specific myths. Samoan health educators conducted sessions, approaching delicate discussions and religious sensitivities in skill exercises and role play. The sessions aimed at increasing knowledge, planning mammograms and addressing barriers. (391)	In-person/ Print	AM, Freire's pedagogy,	SR at 8 months	+8	Despite implementation of a theoretically driven, culturally competent programme, no overall effect of the intervention was seen.
Moskowitz et al. (2007)	USA	Quasi-experimental	Aged > 50, Korean American	English language materials from providers (214)	Educational workshops in Koran American churches, incorporation of <i>tell a friend</i> materials, media campaigns and \$15 incentive (205)	In-person	NS	SR at 48 months	+10.8	The multi-faceted intervention did not affect community-level screening practice
Nanda et al. (2020)	USA	RCT	Aged 50–65, primary care patients	Usual care using printed letters and ad-hoc reminding (445)	Participants called to inform them they are due for a mammogram and opportunity to schedule in real-time (445)	Tel.	NS	HR at 6 months	+11 ^a	The telephone call with access-enhancement significantly increased uptake compared usual care practice
Nguyen et al. (2009)	USA	RCT	Aged > 40, Vietnamese American	Community-wide breast cancer media campaign addressing stigma, knowledge and encouraging screening. (546)	In addition to media education, lay health workers two sessions of 90 mins for 3–10 women. The first concerned breast cancer. Mammography facts and motivation. Some used fear-based messages while others used positive messages. The second session 2 months later re-emphasized the benefits. Calls were conducted to help access screening (543)	In-person/ Tel.	NS	SR at 24 months	+6.5 ^a	Use of lay health workers with media education was significantly more effective than education-alone at receipt of mammography and breast cancer knowledge.
Page et al. (2006)	Australia	RCT	Aged 50–54	A personalised invitation letter for a free mammo. At a local service (786)	Two personalised letters 6 weeks a part (785) A personalised letter with a follow-up telephone call at 6 weeks (785)	Print Print/Tel.	NS NS	HR at 3 months	+3 ^a +2.3	All interventions increased screening rate compared with no intervention. While 2 letters outperformed 1 letter, there was no difference between the letter and phone call and the 1 letter group
Paskett et al. (2006)	USA	RCT	Aged > 40, from a low-income, rural white, native American, African American area	Printed brochure and invitation on cervical screening at 6 months, and one regarding breast screening at 9 months (418)	Local native American and African American lay health workers delivered an educational program in 3 visits over a 9 – 12 month period. They provided materials about individual risk, addressed barriers and helped schedule mammograms. Two phone calls between the first 2 sessions were made to discuss	In-person/ Print/Tel.	CBM, MHCM, SLT, TTM	SR/HR at 12 months	+15.2 ^a	Intervention group had higher mammography rates at follow-up than comparison group, this was for all three racial groups.

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
Phillips et al. (2011)	USA	RCT	Aged 51–70, assigned primary care provider	Provider based care materials (2078)	barriers and determine stage of change. This was used to inform tailoring of mailing sent to each woman and postcards. (433) Trained patient navigators used a barrier-focussed culturally tailored approach with 3 calls over 2 weeks. They identified and addressed ways overcome barriers (1817)	Tel.	CMM	HR at 9 months	+11 ^a	Mammogram adherence was higher in the intervention compared controls. Barrier counselling by patient navigators improved rates for low income, minority populations.
Puschel and Thompson (2011)	Chile	RCT	Aged 50–70	Usual care including ad-hoc advice and information from primary physician (333)	In addition to ad-hoc advice and a mail contact with a letter from the primary care physician, mammogram ordering information and a booklet with messages aimed to explore barriers/facilitators and containing reinforcing factors. (167)	Print	PERM	HR at 6 months	+45.8 ^b	Mailed intervention alone or with personal contact increased rate of mammography compared standard care. Personal contact plus mail had a greater effect than mail alone.
					A telephone/home contact if no appointment 6 weeks after mail. Messages aimed to explore barriers/facilitators and reinforced factors such as clear information about the procedure (167)	Print/Tel.	PERM	+64.1 ^a		
Russell et al. (2010)	USA	RCT	Aged 41–75, African American, <250% federal poverty level	Culturally appropriate pamphlet on screening, and a mailer on nutrition 3 times. (90)	Combined intervention using a computer program with African American story tellers and demonstration of mammogram. A lay health advisor gauged understanding addressed individual barriers identified and gave service information. They contacted participants 3 times to provide further counselling, and encouragement. A tailored mailed postcard was sent out. (89)	In-person/ Print/Tel.	EPPM, HBM, SLT, TTM	SR at 6 months	+32.8 ^a	Compared to the low-dose intensity comparison group, the intervention significantly increased adherence, mediated through progress in the stage of screening.
Sadler et al. (2011)	USA	RCT	Aged > 20 (>40 for mammo.) African American, attend specific salons	Received a training program on diabetes (120)	Trained cosmetologist led education to encourage clients to attend screening, with laminated mirror challenges posted in the salon, information from Black celebrities and breast models to demonstrate (112) ^a	In-person	HBM	SR at 6 months	+21 ^a	Participants in the intervention group had significantly higher frequency of mammogram than controls, associated with a shift in health behaviour.
Schapira et al. (2019)	USA	RCT	Aged 39–48	Breast cancer risk assessment questionnaire following randomisation (102)	Decision aid that ascertained individual breast cancer risk, introduced decision problems, guidelines, comparisons of mortality reduction due to screening and pictographs comparing the outcomes of screening. (102)	Web	ET	HR at 12 months	-1	No significant difference in use of the decision aid and uptake of mammography despite increased knowledge
Secginli and Nahcivan (2011)	Turkey	RCT	Aged > 41, local to health Centre	Received general health information from health	Nurse-led health promotion program including small group teaching on susceptibility, benefits and barriers	In-person/ Print/ Video	LR, HBM	SR at 6 months	+5.8	No significant difference in mammography rates between the groups, but the program increased

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
Slater et al. (2017)	USA	RCT	Aged 65–84, Medicare beneficiaries	Usual care practice from the health provider (4266)	centres but not about breast screening (93)	Print/Tel.	LR, TTM	HR at 12 months	+1.3 ^a	perceived susceptibility, benefits of screening and confidence to screen, as well as decreasing perceived barriers to mammography. Significantly higher attendance was noted in those receiving mail and incentives than mail alone. Both groups had higher rates than controls
					to screening, instruction on self-examination, an educational booklet, a calendar to give salient points and allow planning, as well as a card designed as a cue to action (97)					
Tuzcu et al. (2016)	Turkey	RCT	Aged > 20, (>40 for mammo.) Migrant women	Received a standard program for women by the Family Health Centre (100)	Two mailers 1 month a part with a prompting card with a loss framed/high-efficacy message with contact details of screening navigation services with \$25 on receipt of mammogram (4256)	Print/Tel.	LR, TTM	SR at 6 months	+3.4 ^a	Following the intervention, the rates of mammography significantly increased, it was also associated with positive health beliefs (lower perceived barriers and high motivation)
					A presentation including breast cancer screening facts, barriers and messages regarding benefits of screening. A film displaying mammogram technique, and training for self-examination on a model. Two reminder cards on the importance of screening and inviting participants to a free specified mammogram (100)					
Vernon et al. (2008)	USA	RCT	Aged > 52, US veteran	Undertook an initial questionnaire including questions on screening history only. (1840)	Printed booklets developed from focus groups incorporating testimonials from veterans and how to access services. Messages were tailored to stages of change and aimed at leading to progress through the cycle. An exercise to encourage reflection and a letter to aid discussion with a doctor. (1857)	Print	LR, TPB, TTM,	SR at 15 months	+2.8	The tailored and targeted intervention did not result in higher mammography rates than targeted-only intervention, and there was limited support of either over the usual care group.
					Letter with messages addressing each individual's response to the theoretical constructs in the pre-study survey. The letter included feedback on decisional balance, gave motivational messages and suggested activities to help change. A reminder regarding the next mammogram was included. Two rounds of the intervention were undertaken. The group also received the targeted materials (1803)					
Vidal et al. (2014)	Spain	Quasi-experimental	Aged 50–69	Letter invitation only. Had to phone to change appointment time (9067)	After the letter received SMS reminder 72 h before the appointment, with an ability to reply to the SMS to change the appointment time. (3719)	SMS	NS	HR at appointment	+9.9 ^a	SMS reminders increased participation in a cost-effective manner, especially amongst those who had not previously participated in screening

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Table 1 (continued)

Study	Country	Study design	Inclusion criteria	Control description (n)	Intervention(s) Description (n)	Delivery method	Theory used	Outcome measure	Difference in attendance compared control (%)	Conclusion
Wang et al. (2012)	USA	RCT	Aged > 40, Chinese American	Chinese breast cancer printed fact sheet with information on Asian women's risk, screening guidelines as well as information on local services (222)	A generic video with soap opera conversation involving common issues across differing ethnic groups such as knowledge, beliefs, barriers and risk. General incidence data presented by a non-Asian physician. (217)	Video	HBM	SR at 6 months	+7.4	The use of a culturally guided or generic video increased screening to a similar extent. Neither video was significantly superior to the print condition. The culturally-target approach seemed to more efficacious in increasing amongst those of the lowest acculturation level.
					Cultural video of Chinese breast cancer survivor telling their story to reframe ideas regarding risk and fatalism. A Chinese physician provides Asian breast cancer data and uses a model to demonstrate. (225)	Video	HBM		+9.2	
Wu and Lin (2015)	USA	RCT	Aged > 41, self-identified Chinese/Taiwanese American	Pamphlet on breast health, role of mammograms and the importance of screening (97)	Counselling tailored to baseline interviews including cultural issues, barriers and self-efficacy lasting up to 1 h. Calls delivered in Cantonese/Mandarin/English (96)	Tel.	HBM	SR at 4 months	+7	No differences between print materials and counselling groups indicating that counselling was no more effective than the pamphlet. The intervention was well accepted, feasible and culturally appropriate.

RCT: Randomised controlled trial. AM: Adherence Model. CBM: Communication-Behaviour Model. CCA: Cultural Competence Approach. CM: Conflict Model of Decision Making. CMM: Care Management Model. EPPM: Extended Parallel Process Model. ET: Exemplification Theory. FBM: Fogg Belief Model. HBM: Health Belief Model. IDT: Innovation Diffusion Theory. LR: Literature Review. MHCM: Minority Health Communication Model. MoI: Kleinman's Model of Illness. PAMP: Precaution Adoption Process Model. PERM: Predisposing, Enabling Reinforcing Model. PT: Prospect Theory. SLT: Social Learning Theory. SRM: Levanthal's Self-Regulation Model. TPB: Theory of Planned Behaviour. TTM: Trans-Theoretical Model. Tel: Telephone. Mammo: Mammogram. HR: Health record mammogram. SR: Self-reported mammogram. NS: Not stated.

^a Intervention led to significant change in outcome.

(OECD/European Union, 2018). As such, successful reminder interventions have already been incorporated, and would constitute 'usual care' in these nations. This may explain why in comparison to usual care; therefore, many interventions showed no additional increase in screening attendance. These interventions, however, could be potentially effective in cases where the use of reminders is not the norm. Furthermore, as any contact with participants by researchers may act as an inadvertent reminder to screen, the true effect size of prompts may be underestimated in the research setting (Merrick et al., 2015).

Augmenting reminders with other techniques, appeared to lead to diminishing returns (DeFrank et al., 2009; Lakkis et al., 2011; Luckmann et al., 2018). This may be because more complicated reminders place a greater cognitive demand upon recipients (Rakowski et al., 2003), which could explain why incorporating high numbers of BCTs was not associated with effectiveness. With prompts, these additional techniques may detract from the underlying *gist* of the reminder (Reyna, 2012). This would explain why 75% of interventions that used prompts alone were effective, compared to 50% using them in combination with other techniques. It may, therefore, be worthwhile for studies to examine techniques to work in parallel to simple prompts. As opposed to using strategies highlighting individual consequences, which performed poorly, these adjuncts to prompts could use covert learning, or self-belief techniques. Although less commonly tested, these demonstrated amongst the highest effect sizes. Further investigation into their utility is needed, especially given the heterogeneity demonstrated across studies. Furthermore, delivering these techniques, in a way that does not overly complicate interventions, would also need consideration.

At present, printed materials are the most common delivery method used. Incorporating more complex BCTs into print may prove difficult and worsen the aforementioned issue of distracting recipients. Although print needs to be maintained to avoid exacerbating the digital divide (Hong et al., 2017), resources such as social media, may overcome traditional problems. These versatile multimedia platforms have the capacity to deliver a wider range of BCTs to large populations, and target information to relevant groups. The rise of 'medical influencers' has already demonstrated the effectiveness of such measures at providing endorsement (Stokel-Walker, 2020). As seen with cervical screening, credible source, or endorsement, is an important means of improving attendance (Huf et al., 2017). In this review, 65% of the interventions that used credible source significantly increased attendance, with the majority using written testimonials. Whilst this is a lower proportion than existing literature in which print-based endorsement led to typical increases of 2–3% attendance, these reviews incorporate medical endorsement only, whilst the present study also included endorsement from cultural leaders (Duffy et al., 2017). The role of non-medical endorsement however is an important consideration, as evidenced by the increase in BRCA testing following Angelina Jolie's risk-reducing bilateral mastectomy (Liede et al., 2018). Social media may enable this same endorsement, but in conjunction with complex BCTs such as feedback or repetition. These combinations have been used effectively in non-screening research (Simeon et al., 2020), but have been poorly investigated within the current review, each only used once. However, the effect of social media interventions upon actual attendance, as opposed to engagement metrics such as *likes*, requires examination (Plackett et al., 2020). Findings from an unpublished project from the Good Things Foundation, suggests these benefits may translate into uptake. Using a Facebook page and online posts, they reported a 12.9% increase in local mammogram attendance, which clearly warrants investigation. Furthermore, they also managed to improve user-experience of the service, which is important in facilitating serial participation (NHS Digital, 2021).

Emerging technologies may also improve the translation of effective interventions into differing contexts. A high number of interventions were targeted to people of a similar ethnicity or level of deprivation, and designed to meet specific needs within a population. To achieve this, theoretical frameworks are often used to guide barrier identification,

and subsequently, map interventions. Contrary to some literature however, we have found no association of theory-based interventions with effectiveness (Naz et al., 2018). Whilst this may be attributed to a lack of information provided by authors on which theories they used, it may also represent issues in the fidelity of the mapping process. In order to identify barriers, surveys and interviews are used, both of which are subject to response and sampling biases (Hagger and Weed, 2019). Furthermore, some interventions assume subgroup homogeneity, where responses from a limited sample are assumed to represent the entire group. This then impacts upon the effectiveness of these interventions on a wider scale (Barrer et al., 2013). This is particularly relevant with interventions such as financial incentives or disincentives. These rely upon a person's value of the proposed incentive in the context of their biases, and so can vary greatly between individuals. They may also have unintended consequences such as inducing fear. This would explain why only 33% of included interventions using this technique succeeded, mirroring the variable successes of incentives in other screening services (Vlaev et al., 2019; Judah et al., 2017). It may also explain why the BCT, problem solving, which can be tailored to meet individual needs, was used in the highest proportion of effective interventions. Scaling individualised processes, however, can be expensive. Web-applications can automate barrier identification, circumventing the expenses of training lay health workers, increasing feasibility (Behavioural Insight Team, 2020). Furthermore, the use of A/B testing, allows randomised online experiments to be run at scale, so multiple differing techniques can be evaluated, and interventions iteratively refined to meet the needs of a population (Kohavi et al., 2020).

Consequently, important recommendations can be drawn from this review to guide future research and intervention development. Firstly, focus research upon the use of novel Behavioural Change Techniques which have shown promise such as self-belief, moving away from the use of prompts which have been established. Secondly, investigate newer resources such as web-based messaging and social media, to enable interventions using successful techniques such as problem solving or credible source to be scaled. Analogue methods must also be maintained to prevent exacerbating inequalities. Additionally, develop means of more effectively translating existing successes into differing contexts. This may be through the use of automated barrier identification, or using A/B testing to iteratively refine an intervention to meet the needs of a local population. Finally, intervention content should be clearly described to facilitate learning from the results of the research. Through these principles the authors feel future priorities can be set, and the demands upon breast screening services globally can be met.

Despite using a robust methodology, this review must be considered in relation to its limitations. For example, the data extraction was reliant upon the information given by authors, with insufficient detail provided on several of the interventions. This was mitigated by reviewing study protocols, references and, in some circumstances, contacting authors, however not all information could be discerned. This could limit the accuracy of the conclusions made regarding these interventions, and the BCT coding. Furthermore, the data extracted did not lend itself to meta-analysis. Whilst not a primary outcome of this review, a pooled evaluation of the effectiveness of individual intervention BCTs was planned to provide further evidence. This, however, was precluded by the significant heterogeneity determined statistically. This heterogeneity will also influence the generalisability of the conclusions that can be drawn from this review.

In addition, as there was no restriction on the control standard, there was heterogeneity in the comparator used between studies. Whilst this enabled a breadth of interventions to be included from studies based in different healthcare systems and over time, it may reduce the understanding of the true impact of the interventions. For example, as previously mentioned, in some countries with longstanding programmes, the use of reminders has become the usual practice. An intervention in this context may not be shown to be effective, however, when trialled in a country that does not use a reminder system, the comparative effect

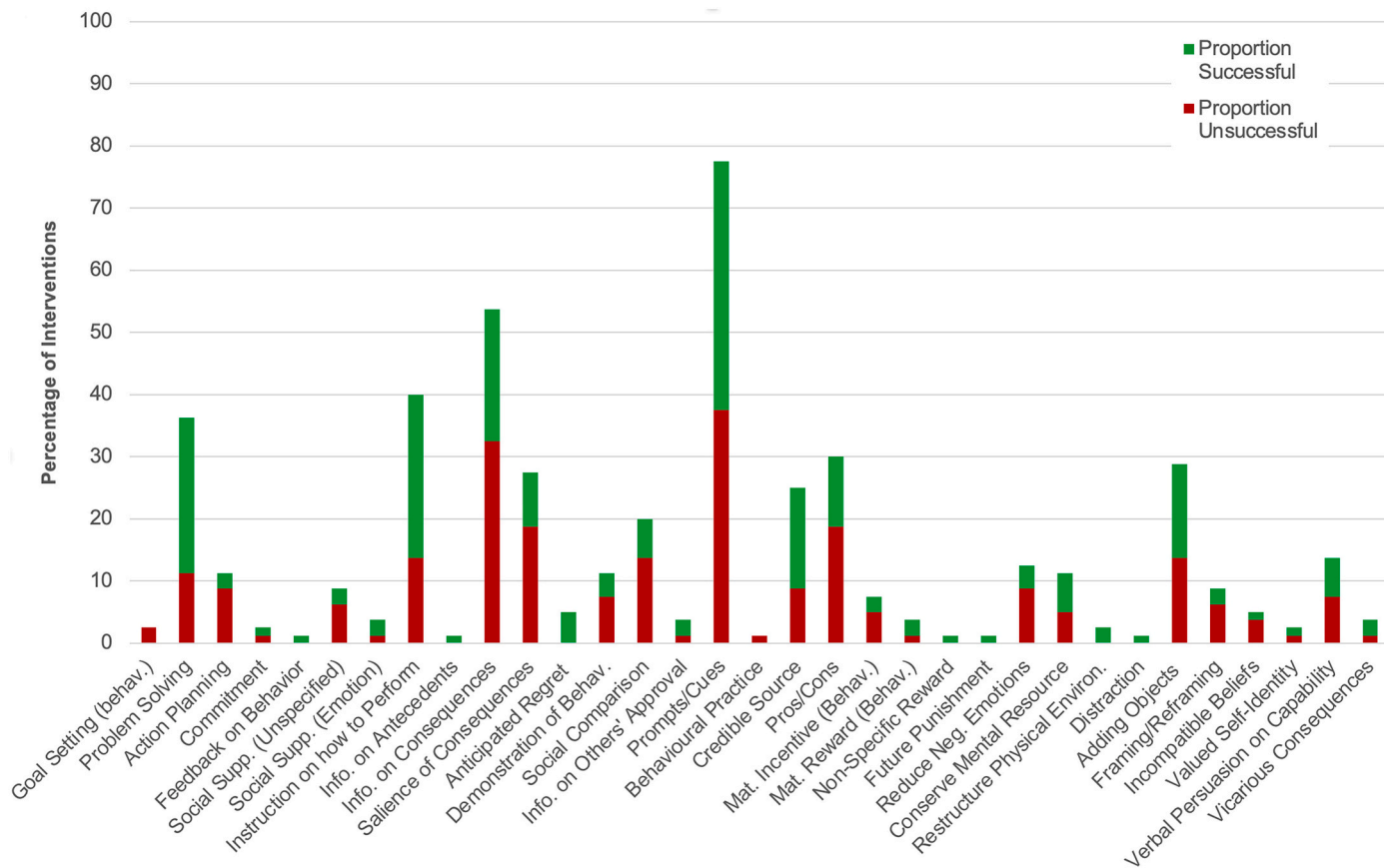


Fig. 2. Use of Behavioural Change Techniques (BCTs) across the interventions showing the proportion used in successful interventions. Successful interventions are those in which a reported significant increase in attendance was reported compared to the control measure. Behav. Behaviour. Environ. Environment. Info. Information. Mat. Material. Neg. Negative. Supp. Support.

Table 2
Results from random effects analysis demonstrating pooled effect sizes of interventions compared to controls on mammogram attendance.

BCT higher group	Interventions including BCT (n)	Reference	Pooled effect size	95% confidence interval	I squared statistic
Goals and planning	35	Ahmed et al. (2010), Allen and Bazargan-Hejazi (2005), Bodurtha et al. (2009), Bowen et al. (2017), Carney et al. (2005), Chambers et al. (2016), Champion et al. (2006), Champion et al. (2007), Cohen and Azaiza (2010), Dietrich et al. (2006), Goldzahl et al. (2018), Han et al. (2009), Hegenscheid et al. (2011), Highfield et al. (2015), Kreuter et al. (2005), Larkey et al. (2012), Lee et al. (2017b), Luckmann et al. (2018), Marshall et al. (2016), Michielutte et al. (2005), Mishra et al. (2007), Paskett et al. (2006), Phillips et al. (2011), Russell et al. (2010), Secginli and Nahcivan (2011), Slater et al. (2017), Tuzcu et al. (2016), Vernon et al. (2008), Wu and Lin (2015)	0.07*	0.06–0.07	99.2
Feedback and monitoring	1	Vernon et al. (2008)	NA	NA	NA
Social support	8	Larkey et al. (2012), Lee et al. (2014), Lee et al. (2017a), Luckmann et al. (2018), Marshall et al. (2016), Mishra et al. (2007), Moskowitz et al. (2007), Russell et al. (2010)	0.11*	0.03–0.20	99.2
Shaping knowledge	32	Allen and Bazargan-Hejazi (2005), Beauchamp et al. (2020), Bodurtha et al. (2009), Carney et al. (2005), Champion et al. (2007), Champion et al. (2016), DeFrank et al. (2009), Dietrich et al. (2006), Fernández et al. (2009), Han et al. (2009), Hegenscheid et al. (2011), Kearins et al. (2009), Kregting et al. (2020), Larkey et al. (2012), Luckmann et al. (2018), Marshall et al. (2016), Mishra et al. (2007), Moskowitz et al. (2007), Nanda et al. (2020), Paskett et al. (2006), Phillips et al. (2011), Puschel and Thompson (2011), Russell et al. (2010), Secginli and Nahcivan (2011), Tuzcu et al. (2016)	0.10*	0.08–0.11	99.6
Natural consequences	46	Abood et al. (2005), Ahmed et al. (2010), Bodurtha et al. (2009), Bowen et al. (2017), Carney et al. (2005), Chambers et al. (2016), Champion et al. (2006), Champion et al. (2007), Champion et al. (2016), Champion et al. (2020), DeFrank et al. (2009), Fernández et al. (2009), Goldzahl et al. (2018), Han et al. (2009), Highfield et al. (2015), Kregting et al. (2020), Kreuter et al. (2005), Marshall et al. (2016), Michielutte et al. (2005), Mishra et al. (2007), Moskowitz et al. (2007), Nguyen et al. (2009), Paskett et al. (2006), Russell et al. (2010), Sadler et al. (2011), Schapira et al. (2019), Secginli and Nahcivan (2011), Slater et al. (2017), Tuzcu et al. (2016), Vernon et al. (2008), Wang et al. (2012)	0.06*	0.06–0.07	98.9
Comparison of behaviour	21	Bowen et al. (2017), Champion et al. (2006), Champion et al. (2016), Champion et al. (2020), Kearins et al. (2009), DeFrank et al. (2009), Fernández et al. (2009), Goldzahl et al. (2018), Kreuter et al. (2005), Lee et al. (2014), Mishra et al. (2007), Russell et al. (2010), Sadler et al. (2011), Tuzcu et al. (2016), Wang et al. (2012)	0.08*	0.07–0.10	98.3
Associations	59	Ahmed et al. (2010), Allen and Bazargan-Hejazi (2005), Beauchamp et al. (2020), Bodurtha et al. (2009), Bowen et al. (2017), Carney et al. (2005), Chambers et al. (2016), Champion et al. (2020), Chan et al. (2018), Dietrich et al. (2006), Fernández et al. (2009), Goldzahl et al. (2018), Han et al. (2009), Highfield et al. (2015), Kearins et al. (2009), Kerrison et al. (2015), Kregting et al. (2020), Kreuter et al. (2005), Lakkis et al. (2011), Lee et al. (2014), Lee et al. (2017a), Lee et al. (2017b), Luckmann et al. (2018), Merrick et al. (2015), Michielutte et al. (2005), Nanda et al. (2020), Page et al. (2006), Paskett et al. (2006), Phillips et al. (2011), Puschel and Thompson (2011), Russell et al. (2010), Vernon et al. (2008), Secginli and Nahcivan (2011), Slater et al. (2017), Tuzcu et al. (2016), Vernon et al. (2008), Vidal et al. (2014), Wu and Lin (2015)	0.05*	0.05–0.05	99.5
Repetition and substitution	1	Mishra et al. (2007)	NA	NA	NA
Comparison of outcomes	37	Ahmed et al. (2010), Beauchamp et al. (2020), Bodurtha et al. (2009), Champion et al. (2006), Champion et al. (2007), Champion et al. (2020), Chan et al. (2018), DeFrank et al. (2009), Fernández et al. (2009), Goldzahl et al. (2018), Han et al. (2009), Hegenscheid et al. (2011), Icheku and Arowobusoye (2015), Kregting et al. (2020), Kreuter et al. (2005), Lakkis et al. (2011), Lee et al. (2017a), Luckmann et al. (2018), Nguyen et al. (2009), Puschel and Thompson (2011), Russell et al. (2010), Secginli and Nahcivan (2011), Tuzcu et al. (2016), Vernon et al. (2008), Wu and Lin (2015)	0.06*	0.05–0.07	99.3
Reward and threat	8	Cuellar et al. (2017), Lee et al. (2017b), Merrick et al. (2015), Moskowitz et al. (2007), Nguyen et al. (2009), Slater et al. (2017)	0.06*	0.03–0.08	99.9
Regulation	18	Allen and Bazargan-Hejazi (2005), Beauchamp et al. (2020), Bowen et al. (2017), Champion et al. (2006), Champion et al. (2016), Cohen and Azaiza (2010), DeFrank et al. (2009), Dietrich et al. (2006), Lee et al. (2014), Lee et al. (2017a), Nanda et al. (2020), Nguyen et al. (2009), Puschel and Thompson (2011), Schapira et al. (2019), Vernon et al. (2008)	0.11*	0.08–0.13	99.0
Antecedents	25	Allen and Bazargan-Hejazi (2005), Bodurtha et al. (2009), Cohen and Azaiza (2010), Dietrich et al. (2006), Highfield et al. (2015), Kearins et al. (2009), Kreuter et al. (2005), Lee et al. (2014), Lee et al. (2017a), Lee et al. (2017b), Luckmann et al. (2018), Marshall et al. (2016), Moskowitz et al. (2007), Nguyen et al. (2009), Phillips et al. (2011), Russell et al. (2010), Sadler et al. (2011), Moskowitz et al. (2007), Vernon et al. (2008), Wang et al. (2012)	0.10*	0.08–0.12	99.6
Identity	11	Chambers et al. (2016), Champion et al. (2007), Cohen and Azaiza (2010), Kreuter et al. (2005), Luckmann et al. (2018), Puschel and Thompson (2011), Vernon et al. (2008), Wang et al. (2012)	0.11*	0.08–0.13	99.2

(continued on next page)

Table 2 (continued)

BCT higher group	Interventions including BCT (n)	Reference	Pooled effect size	95% confidence interval	I squared statistic
Scheduled consequences	0	NA	NA	NA	NA
Self-belief	11	Champion et al. (2006), Champion et al. (2007), Champion et al. (2016), Cohen and Azaiza (2010), Fernández et al. (2009), Highfield et al. (2015), Russell et al. (2010), Sadler et al. (2011), Wu and Lin (2015)	0.11*	0.07–0.15	97.2
Covert learning	3	Kreuter et al. (2005), Nguyen et al. (2009)	0.12*	0.05–0.19	91.5

Interventions were grouped according to the higher domains the BCTs they contained belonged. NA. Not applicable due to insufficient numbers. *P < 0.05.

Table 3

Proportion of interventions using individual theories which report a positive (effective) outcome or otherwise (ineffective).

Theory used	Interventions using theory (n)	% Effective	% Ineffective	Chi squared	P value
None	24	58.33	41.67	Ref	Ref
Theory	56	46.43	53.57	0.95	0.33
AM	2	50.00	50.00	0.05	0.82
CBM	1	100.00	0.00	NA	NA
CCA	1	0.00	100.00	NA	NA
CM	1	100.00	0.00	NA	NA
CMM	1	100.00	0.00	NA	NA
EPPM	3	33.33	66.67	0.68	0.41
ET	1	0.00	100.00	NA	NA
FBM	1	100.00	0.00	NA	NA
HBM	31	48.39	51.61	0.54	0.46
IDT	2	100.00	0.00	NA	NA
LR	14	28.57	71.43	3.14	0.08
MHCM	1	100.00	0.00	NA	NA
MoI	2	50.00	50.00	0.05	0.82
PAPM	1	0.00	100.00	NA	NA
PERM	2	50.00	50.00	0.05	0.82
PT	1	100.00	0.00	NA	NA
SLT	5	100.00	0.00	NA	NA
SRM	1	100.00	0.00	NA	NA
TPB	9	66.67	33.33	0.19	0.66
TTM	23	52.17	47.83	0.18	0.67

Chi Squared statistic compares proportion of effective interventions using each theory to the 'none' group. AM: Adherence Model. CBM: Communication-Behaviour Model. CCA: Cultural Competence Approach. CM: Conflict Model of Decision Making. CMM: Care Management Model. EPPM: Extended Parallel Process Model. ET: Exemplification Theory. FBM: Fogg Belief Model. HBM: Health Belief Model. IDT: Innovation Diffusion Theory. LR: Literature Review. MHCM: Minority Health Communication Model. MoI: Kleinman's Model of Illness. PAPM: Precaution Adoption Process Model. PERM: Predisposing, Enabling Reinforcing Model. PT: Prospect Theory. SLT: Social Learning Theory. SRM: Levanthal's Self-Regulation Model. TPB: Theory of Planned Behaviour. TTM: Trans-Theoretical Model. Ref Reference. NA: Not applicable due to zero error.

may be significant. Furthermore, historic interventions which were already found not to be successful by established programmes, prior to the inclusion cut-off, would not be included. This effect may be reduced by including all interventions trialled across breast screening programmes, including those prior to 2005. However, the aim of this review is to build upon existing reviews and inform future interventions. It would, therefore, be inappropriate to re-examine early interventions in selected countries, especially given the changes in the incidence and outcomes of breast cancer over the past decade (Cancer Research UK, 2015). Furthermore, included studies only estimated attendance at specific screening services. Several countries, however, have hybrid models of healthcare in which private providers can offer mammography in parallel. These alternative providers can decrease attendance in publicly funded programs, and would impact upon the calculated attendance rates (Walsh and Silles, 2011). This should be considered when assessing the impact of interventions in this study, however, in a randomised trial one would expect this effect to be balanced across trial arms. Nevertheless, the review has underlined common trends in the

existing literature and areas for further exploration. Furthermore, it constitutes a thorough assessment of studies in breast cancer screening over a significant period of time, using validated frameworks to compare the interventions described.

5. Conclusion

Breast cancer screening services are under growing pressure to redress falling uptake. Only half of reported interventions, however, were successful. Prompts, which are already well-established, were the most used BCT. Highlighting individual consequences was also a common strategy, yet less than half of interventions using this technique were effective. Interventions based upon techniques including self-efficacy, however, did show promise. Future work should examine these techniques to provide a greater evidence base for health policy. Application of new technologies to deliver BCTs promoting more individual tailoring (e.g. problem solving) may facilitate the scalable use of those effective techniques, so they can be adopted more widely. Furthermore, technological advances also have the potential to improve the user-experience including facilitating access to screening services. This could encourage serial participation with breast cancer screening, which warrants further investigation.

Ethical compliance

As this constituted a review of existing original articles, no ethical review was required.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contributions

AA and VS undertook the literature search, and full-text data extraction. AA and GJ evaluated the interventions from studies, including the Behavioural Change Technique appraisal. HA completed statistical analysis and data validation with AA. AA,GJ,HA all had input into the writing, editing and submission of the manuscript. AD oversaw the conduct of the project, providing guidance, supporting funding acquisition and infrastructure that enabled the study to be completed.

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Competing interests

The authors declare no conflict of interests.

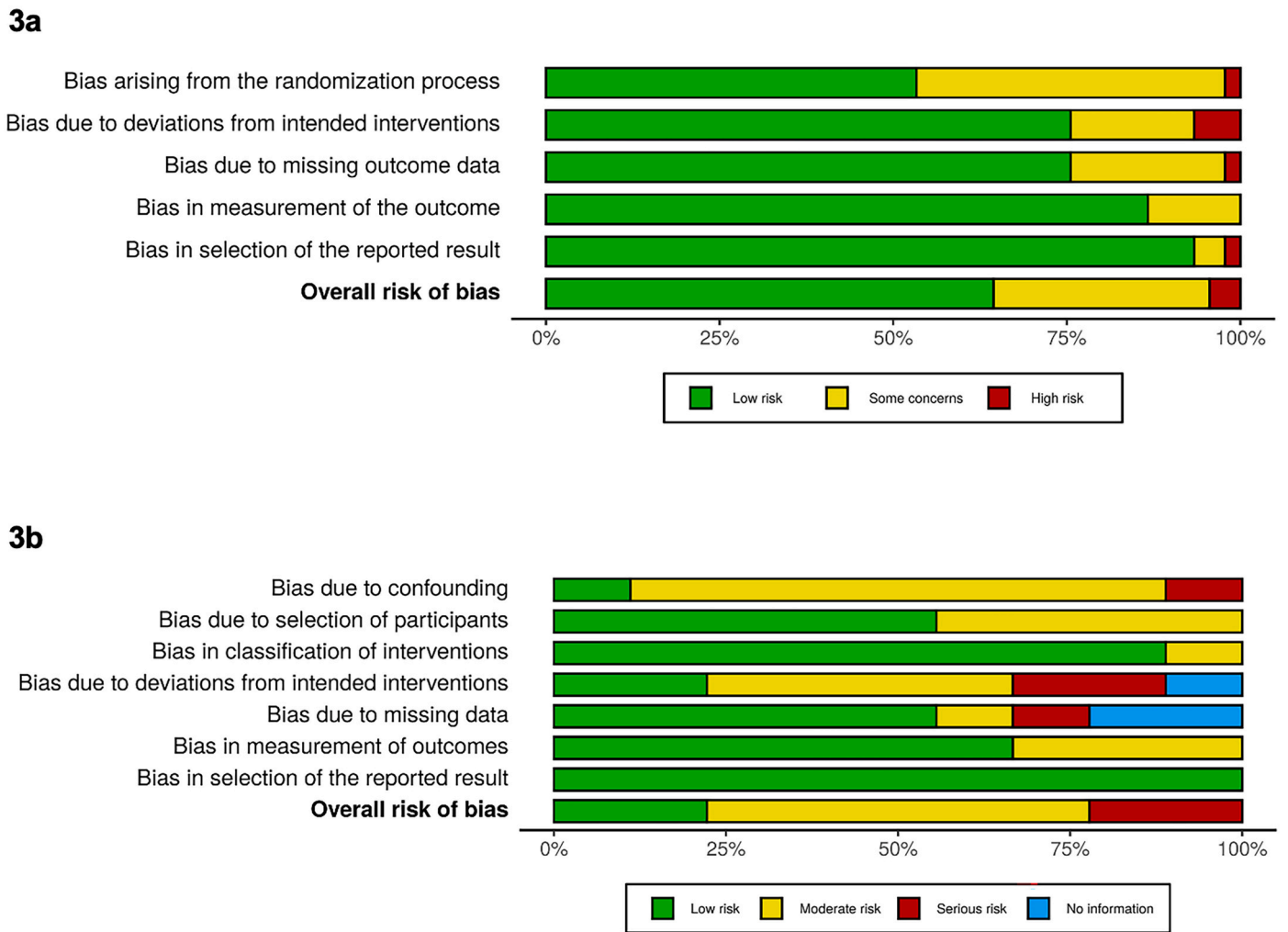


Fig. 3. (a) Summary of Risk of Bias (ROB2) evaluation of randomised studies. (b) Summary of Risk of Bias (ROBINS-I) evaluation of quasi-experimental studies.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ypmed.2021.106828>.

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