Addressing Psychosocial and Lifestyle Risk Factors to Promote Primary Cancer Prevention: an integrated platform to promote behavioural change (IBeCHANGE)

Project Number: 101136840

D2.2 – Psychosocial support and behavioural change interventions and techniques to be included in the iBeChange system

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Disclaimer

Table of Contents

List of Abbreviations

Abbreviation	Explanation
BCT	Behaviour change technique
BCTT	Behaviour change technique taxonomy
HAPA	Health Action Process Approach
HBM	Health Belief Model
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomised controlled trial
SCT	Social Cognitive Theory
SDT	Self-Determination Theory
TCM	Traditional Chinese Medicine
TPB	Theory of Planned Behaviour
TTM	Transtheoretical Model

List of Tables

List of Figures

Executive Summary

The current deliverable (D2.2) reflects the work carried out under Work Package 2 (WP2) of the iBeChange project. Specifically, the reported results relate to Task 2.3 - “Behavioural change interventions and techniques inventory” and Task 2.4 - “Psychosocial support and interventions inventory”. The activities conducted in D2.2 aimed to establish the theoretical and methodological framework for identifying and integrating effective psychosocial interventions and behavioural change techniques into the iBeChange platform.

In Task 2.3, a systematic review was conducted to identify the **most effective Behaviour Change Techniques** (BCTs) for targeting behavioural risk factors, such as physical activity, nutrition, alcohol consumption, cigarette smoking, and weight management. This review was guided by the **BCT Taxonomy** (BCTT; Michie et al., 2013), providing a standardized framework for classifying the specific content of complex Behaviour Change interventions.

For Task 2.4, a systematic review was performed to evaluate digital psychological interventions addressing psychosocial risk factors, including emotional distress, anxiety, depression, and lack of social support. The findings highlighted effective digital tools and interventions that can both identify psychosocial risks and promote tailored psychological interventions, fostering participants’ engagement and adherence.

The findings from D2.2 will contribute to define the content for the Behavioural Change (BC) and Emotional Wellbeing (EW) support tools (T2.7) and provide critical input for the development of the knowledge base for recommendation systems (T4.3). This deliverable discusses the following topics in detail:

i) the methodologies and study designs adopted;

ii) the results of the systematic reviews;

iii) the implications for the development of the iBeChange platform’s tools and content.

1. Introduction

This deliverable presents the findings from the systematic reviews conducted within Tasks 2.3 and 2.4 of WP2 of the iBeChange project. The primary objectives of WP2 include identifying candidate and effective BCTs, evaluating digital psychological interventions, and developing tools to support behavioural change and emotional wellbeing. The activities carried out within WP2 will provide crucial information for the design and implementation of the iBeChange platform.

Task 2.3 focused on identifying the most used and effective BCTs to address behavioural risk factors, such as physical inactivity, poor nutrition, smoking, and harmful alcohol consumption. Promoting sustainable behavioural change is essential for reducing the risk of breast, lung, and colorectal cancers, as long-term adoption of healthy behaviours significantly lowers cancer risk and improves overall health. A systematic review was conducted to assess interventions targeting these behavioural risk factors, guided by the BCTT (Michie et al., 2013). This approach provided a standardized framework to classify and evaluate the specific content of behavioural interventions. The insights gained from this review offer evidence-based recommendations for designing and implementing effective Behaviour Change support tools within the iBeChange platform.

Task 2.4 aimed to identify the most effective digital psychological intervention and psychoeducational support tools to target the psychosocial risk factors for cancer onset identified in the previous umbrella review (Task 2.2; D1.2). For this reason, we conducted a systematic review including Randomized Clinical Trials (RCTs) on available digital psychological interventions.

Together, the findings from Tasks 2.3 and 2.4 provide a comprehensive understanding of effective behavioural change techniques and psychosocial interventions. These results will directly inform the design of automatic and digital support tools that empower individuals to adopt sustainable behaviours and manage psychosocial risks, forming a cornerstone of the iBeChange platform.

2. Systematic Review of Behavioural Change Techniques (BCTs) for Promoting Healthy Lifestyles

This section presents aims, methodologies and results of a systematic review aimed at identifying commonly used BCTs to promote healthy lifestyle behaviours and evaluating their effectiveness of BCTs in promoting behavioural change, specifically targeting physical activity, diet, smoking, alcohol, and weight management. This review builds upon the findings from Deliverable D2.1 of the iBeChange project, which focused on the identification of lifestyle risk factors and their influence on cancer prevention. By focusing on the implementation of BCTs, the current review seeks to offer evidence-based recommendations for designing automatic and effective interventions to reduce cancer risk, particularly for breast, colorectal, and lung cancers.

As stressed in D2.1, promoting healthy lifestyles is critical in primary cancer prevention, as lifestyle choices have a profound impact on the onset of various types of cancer. For breast, colorectal, and lung cancers, adopting preventive measures such as engaging in physical activity, following a balanced diet, refrain from smoking, reducing alcohol, and maintaining a healthy weight, can substantially lower the risk of cancer development. Clinical guidelines and expert recommendations consistently highlight the importance of these lifestyle modifications, stressing the need for effective behavioural interventions to encourage their adoption and long-term maintenance.

While these findings reported in D2.1 provide a robust foundation for the iBeChange project, the next step was to identify a set of BCTs that could be useful and effective in promoting each of the behaviours identified as relevant for the primary prevention of breast, colorectal, and lung cancers. This systematic review conducted within Task 2.3 “Behavioural change interventions and techniques inventory”, therefore, aims to evaluate and synthesize the BCTs that have been successfully applied in interventions targeting the lifestyle factors - such as physical activity, balanced diet, smoking cessation, alcohol moderation, and weight management - that are critical in reducing cancer risk.

BCTs are fundamental components of behavioural interventions designed to modify specific behaviours, such as increasing physical activity, improving dietary habits, reducing alcohol and tobacco consumption, and managing weight. These techniques are integral to various behavioural models, including the Health Action Process Approach (HAPA; Schwarzer et al., 2008), the Transtheoretical Model (TTM; Velicer et al., 1998), and the Health Belief Model (HBM; Rosenstock, 1974), which aim to address the psychological, emotional, and cognitive factors influencing behavioural change. However, these models often overlap in their terminology and lack a standardized set of BCTs that can be universally applied across different contexts.

The need for a comprehensive taxonomy of BCTs arises from the challenge of comparing, replicating, and synthesizing findings from behavioural interventions. Previous attempts at creating BCT taxonomies, such as those by Michie et al. (2012), Michie et al. (2011a), and Michie et al. (2009), identified several techniques but lacked a cohesive structure and comprehensive framework. These earlier systems often focused on specific behaviours or settings, limiting their applicability to broader intervention designs. For example, the taxonomy developed by Michie and colleagues in 2012 focused on techniques for reducing excessive alcohol consumption, while their 2011a work centered on smoking cessation. In contrast, the BCTT by Michie et al. (2013) is designed to be cross-behavioural and provides a hierarchical, empirically-based classification system that is more adaptable and universally applicable.

The BCTT developed by Michie et al. (2013) is a significant advancement over earlier systems, primarily due to its broader scope, hierarchical structure, and extensive expert consensus.

This BCTT provides a systematic approach for identifying and categorizing techniques in behavioural interventions. By using this taxonomy, researchers and practitioners can clearly specify the active components of interventions, enabling accurate reporting, replication, and synthesis of intervention studies. It also allows for the design of more effective and tailored interventions by identifying the most appropriate BCTs for each target behaviour. While the BCTT itself is not a behavioural change model, it can be effectively integrated with models such as the COM-B model to guide the selection of the most appropriate techniques for specific target behaviours. For example, the COM-B model (see, for example, Michie et al., 2011b) helps identify the specific determinants of behaviour (i.e., Capability, Opportunity, and Motivation), and the BCTT provides a comprehensive list of behaviour change techniques that can address these determinants (see, for example, Michie et al., 2014). This integration allows for a mapping process where researchers first identify the barriers and facilitators of the target behaviour using COM-B and then use the BCTT to select techniques that address these factors.

More information about the development and structure of the BCTs, including their rigorous multiphase creation process and grouping of 93 techniques into 16 clusters, can be found in Michie et al., 2013. The taxonomy groups BCTs into 16 main clusters, each representing a key mechanism of change in behaviour. These clusters include:

1. **Goals and Planning** – Techniques related to goal setting, action planning, and problem-solving.
2. **Feedback and Monitoring** – Techniques involving monitoring of behaviour and providing feedback.
3. **Social Support** – Techniques involving the provision of emotional, practical, or unspecified social support.
4. **Shaping Knowledge** – Techniques that provide instructions, information, and re-attribution to guide behaviour change.
5. **Natural Consequences** – Techniques that inform about or emphasize the natural health, social, or emotional consequences of behaviours.
6. **Comparison of Behaviour** – Techniques involving social comparison or feedback on others' behaviour.
7. **Associations** – Techniques that utilize environmental prompts or cues and associative learning to influence behaviour.
8. **Repetition and Substitution** – Techniques involving the repetition of behaviours and substitution of unwanted behaviours with desired ones.
9. **Comparison of Outcomes** – Techniques involving the comparison of potential outcomes of behaviours to encourage change.
10. **Reward and Threat** – Techniques involving rewards or threats contingent on behaviour performance.
11. **Regulation** – Techniques aimed at regulating emotions and mental resources to facilitate behaviour change.
12. **Antecedents** – Techniques that modify the environment or provide distractions to reduce exposure to cues for unwanted behaviours.
13. **Identity** – Techniques that help form a new self-identity associated with the desired behaviour.
14. **Scheduled Consequences** – Techniques involving punishments, rewards, or reinforcements contingent on behaviour.

15. **Self-Belief** – Techniques aimed at enhancing self-efficacy and confidence in behaviour change.
16. **Covert Learning** – Techniques involving the use of mental rehearsal, imagining consequences, and observing others' behaviours.

Detailed information for each of the 93 BCTs included in the 2013 Michie et al. BCTT can be found in Annex 1. This comprehensive, cross-domain BCTT provides a valuable tool for the development, evaluation, and refinement of automatic interventions within the iBeChange project, significantly contributing to the advancement of behaviour change strategies aimed at cancer prevention.

2.1 Aim

The aim of this subtask within the iBeChange project is to conduct a systematic review to identify the most commonly used and effective BCTs targeting specific behavioural risk factors, including physical activity, diet, alcohol consumption, cigarette smoking, and weight management. This review focuses on randomized controlled trials (RCTs) and quasi-experimental studies with at least one control group, using the BCTT (Michie et al., 2013) to classify and report the specific components of the assessed interventions.

The goal of this systematic review is to analyse and identify the most frequently used and effective BCTs in interventions aimed at promoting healthy behaviours. By leveraging the BCTT, a standardized and consensus-based framework for classifying complex behaviour change interventions, we aim to gain insights into which BCTs are most effective for each specific lifestyle risk factor, and to understand how these techniques contribute to behaviour change outcomes.

The results of this task will contribute to the iBeChange project by:

- Identifying the BCTs that have been proven effective in promoting positive lifestyle changes related to physical activity, diet, smoking cessation, alcohol moderation, and weight management.
- Informing the design of Behaviour Change support tools (T2.7) and enhancing the development of the knowledge base for evidence-based recommendations (T4.3).
- Providing a comprehensive understanding of the active ingredients in successful interventions, which will guide the development of automatic and tailored interventions which will be delivered by the iBeChange platform

2.2 Methods

A systematic review was conducted to identify relevant studies evaluating interventions targeting lifestyle risk factors, including physical activity, diet, alcohol consumption, smoking, and weight management. The active ingredients of the assessed interventions were classified using the BCTT (Michie et al., 2013), which provides a standardized framework for identifying and reporting the BCTs used in the interventions.

The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search was conducted in two primary databases: PubMed and Scopus, in late October 2024. The search strategy was designed to identify studies related to physical activity, dietary habits, smoking, alcohol consumption, and weight management, using terms aligned with these lifestyle factors. Specifically, the search targeted studies that examined behaviours such as aerobic activities, sedentary lifestyles, diet, cigarette smoking, alcohol use, and weight loss or

obesity. Importantly, only studies that cited the BCTT (Michie et al., 2013) were included in the review, ensuring that all selected studies reported detailed information on the BCTs used in their interventions.

To ensure the relevance and rigor of this systematic review, clear inclusion and exclusion criteria were established. These criteria were designed to identify studies that align with the objectives of evaluating BCTs using the BCTT (Michie et al., 2013) in interventions targeting lifestyle risk factors.

Inclusion Criteria:

- Studies that explicitly cite the BCTT (Michie et al., 2013) and provide detailed information on BCTs used.
- Randomized controlled trials (RCTs) or quasi-experimental studies with at least one control group.
- Interventions targeting healthy populations or individuals without severe clinical conditions.
- Studies focused on behaviours related to physical activity, dietary habits, smoking, alcohol consumption, or weight management.
- Publications in English.
- Studies published within the last 10 years.
- Studies that include outcome measures related to behaviour change (self-reported or objective).

Exclusion Criteria:

- Studies that do not explicitly reference the BCTT or fail to report the active BCTs used in interventions.
- Observational studies, qualitative studies, or reviews.
- Studies targeting populations with severe clinical conditions or focusing on rehabilitation.
- Non-English publications.
- Studies published before 2013.
- Interventions not addressing the specified lifestyle behaviours (physical activity, diet, smoking, alcohol, or weight management).

All identified studies were screened for relevance based on titles and abstracts. The screening and management of the articles were performed using Rayyan software (Ouzzani et al., 2016), which facilitated the collaborative review process. Duplicates were identified and removed, and eligibility was assessed by two independent reviewers. Any conflicts were resolved through discussion. Full-text articles were subsequently screened for eligibility, and data extraction was carried out by one reviewer and validated by a second reviewer to ensure accuracy. Key data extracted included the study's authors, year of publication, title, BCTs used, total number of BCTs, targeted behaviours, models used, sample size (randomized), age range/mean age, gender (% female), outcome type, description of the intervention, main results description, intervention type, and intervention duration.

2.3 Results

Our search and screening process identified 17 full papers that met the inclusion criteria.Figure 1 reports a detailed log of the screening procedure.

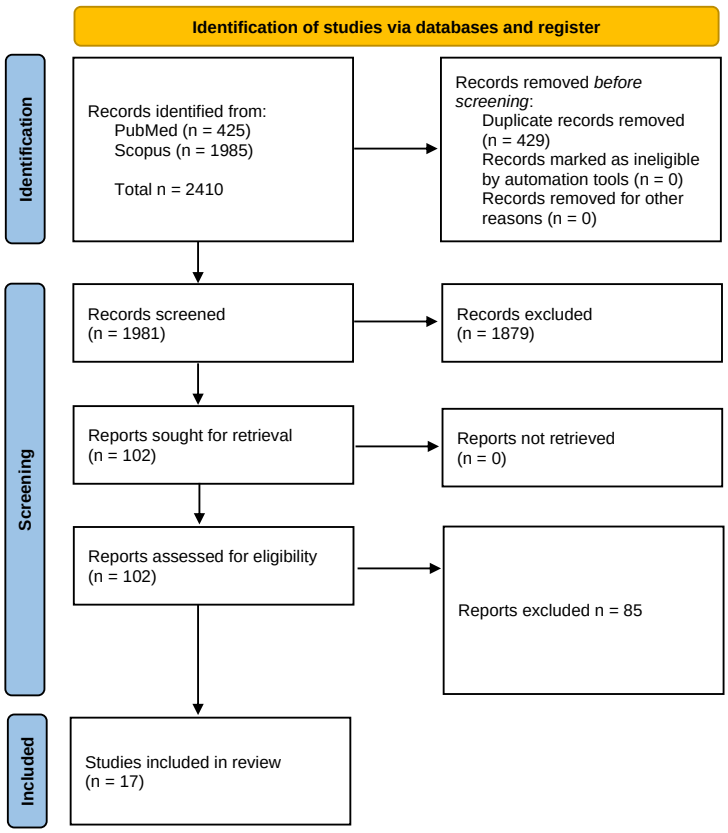


Figure 1. PRISMA 2020 flow diagram for this systematic review

As reported in Table 1, the studies considered in this analysis cover various health interventions and outcomes, published between 2013 and 2024. These studies primarily focus on promoting healthier behaviours and addressing lifestyle-related risk factors. Only one study (i.e., Chung et al., 2023) target multiple behavioural change by focusing simultaneously on diet, physical activity and weight management. Other studies predominantly target physical activity (7/17; 41.2%), diet (6/17; 35.3%), smoking (1/17; 5.9%), and weight management (2/17; 11.8%) No study targeted alcohol consumption. The interventions included are diverse, with a significant portion utilizing text messages/booklet (47.5%), in-person interactions (23.5%), SMS (17.7%), mobile apps (11.8%), web-based content (11.8%), videos (11.8%) and consumer-graded wearables (11.8%).

Table 1: Main results of the Task 2.3 systematic review

Authors	Year	BCTs	Total BCTs	Intervention Type	Targeted Behaviours	N	Age (M; range)	Gender (% Female)	Outcome Type	Description of Outcomes	Main Results Description
Chung et al.	2023	1.1. Goal setting (behaviour), 1.3. Goal setting (outcome), 1.6. Discrepancy between current behaviour and goal, 1.7. Review outcome goal(s), 2.2. Feedback on behaviour, 2.3. Self-monitoring of behaviour, 2.4. Self-monitoring of outcome(s) of behaviour, 2.7. Feedback on outcome(s) of behaviour, 3.1. Social support (unspecified), 5.1. Information about health consequences, 6.2. Social comparison, 7.1. Prompts/cues, 9.1. Credible source, 10.2. Material reward (behaviour), 10.3. Non-specific reward, 10.4. Social reward, 10.10. Reward (outcome), 15.3. Focus on past success	18	Mobile app	Diet, Physical activity, Weight	121	M= 58; NA - NA	53%	Self-report	BMI, dietary behaviour (i.e., Dietary Approaches to Stop Hypertension, measured with dietary behaviour questionnaire) and physical activity (measured with the International Physical Activity Questionnaire)	- BMI: Results indicated that the traditional Chinese medicine mHealth app group showed a significant decrease in BMI at T3 compared to that in the control group. However, there were no significant differences in the change in BMI between the traditional Chinese medicine and ordinary mHealth app group - Dietary behaviour: Results showed no significant differences in dietary behaviour among the three groups over time - Physical activity: Results showed no significant differences in the total physical activity among the three groups over time

Harada	2022	1.1. Goal setting (behaviour), 1.2. Problem solving, 1.4. Action planning, 1.5. Review behaviour goal(s), 2.3. Self-monitoring of behaviour, 3.1. Social support (unspecified), 3.2. Social support (practical), 3.3. Social support (emotional), 5.1. Information about health consequences, 9.2. Pros and cons, 15.3. Focus on past success	11	Text messages/booklets	Physical activity	393	M= 74; NA - NA	58%	Self-report	Exercise behaviour (i.e., weekly exercise time), measured by asking participants to report frequencies and durations of exercise in a typical week.	Results demonstrated that exercise behaviour increased after intervention in both immediate and delayed intervention groups
Landais et al.	2022	1.1. Goal setting (behaviour), 1.2. Problem solving, 1.3. Goal setting (outcome), 1.4. Action planning, 1.6. Discrepancy between current behaviour and goal, 4.1. Instruction on how to perform the behaviour, 5.1. Information about health consequences, 5.6. Information about emotional consequences, 9.2. Pros and cons, 13.4. Valued self-identify	10	Web-based	Physical activity	964	M= 49; NA - NA	64%	Self-report	- Physical activity, assessed through the short form of the International Physical Activity Questionnaire - Sitting time, assessed through the short form of the International Physical Activity Questionnaire	Physical activity and sitting time did not significantly differ between groups over time.
Lithopoulos et al.	2020	1.1. Goal setting (behaviour), 1.2. Problem solving, 1.4. Action planning, 2.3. Self-monitoring of behaviour, 4.1. Instruction on how to perform the behaviour, 5.1. Information about health consequences, 5.6. Information about emotional consequences, 7.1. Prompts/cues	8	In person, Text messages/booklets	Physical activity	116	M= 43; NA - NA	58%	Self-report	Average hours of sitting time per day at work, measured using an adapted version of the sitting assessment portion of the International Physical Activity Questionnaire.	Controlling for baseline sitting, overall, the affective group sat for less time than the instrumental and self-regulation groups. Also, at week 4, the affective group sat for less time than the instrumental and self-regulation groups and, at week 8, the affective group sat for less time than the self-regulation and control groups. There were no differences between the groups at week 12.

Patel et al.	2022	1.1. Goal setting (behaviour), 1.2. Problem solving, 1.4. Action planning, 2.2. Feedback on behaviour, 2.3. Self-monitoring of behaviour, 8.1. Behavioural practice/rehearsal, 8.2. Behaviour substitution, 12.5. Adding objects to the environment	8	Text messages/booklets	Physical activity	59	M= 37; NA - NA	63%	Self-report, Objective	- Frequency and duration of breaks during a typical workday, measured through the workplace sitting breaks questionnaire - Occupational sedentary periods or physically demanding tasks of office workers during workdays in the last 7 days, measured through the Occupational sitting and physical activity questionnaire - Estimated VO2max, measured with a submaximal step test	Results did not demonstrate difference in the sedentary behaviour outcomes (active time percentage, breaks during sitting) or estimated VO2max between groups over time
Sersli et al.	2019	4.1. Instruction on how to perform the behaviour, 5.1. Information about health consequences, 6.1. Demonstration of the behaviour, 8.1. Behavioural practice/rehearsal, 8.7. Graded tasks	5	In person	Physical activity	178	M= NA; NA - NA	nan%	Self-report	Bicycling for three purposes for commuting (i.e., “to work or school”), for errands (i.e., “for errands or shopping”), and for leisure (i.e., “outdoors for fun or exercise”), measured through an ad-hoc self-report measure asking participants to report how many days in the past month they bicycled.	Results did not find increases in overall bicycling or for commuting or errands, compared to the control group. Results found modest increases at one month follow up in leisure bicycling among those who completed the intervention, although increased bicycling was not sustained over one year.
Suorsa et al.	2022	2.2. Feedback on behaviour, 2.3. Self-monitoring of behaviour, 5.1. Information about health consequences, 7.1. Prompts/cues	4	Consumer-graded wearable	Physical activity	231	M= 65; NA - NA	83%	Objective	Sedentary time was measured using a wrist-worn triaxial ActiGraph wGT3X-BT accelerometer, initialized to collect data at a sampling frequency of 80 Hz. Participants were instructed to wear the accelerometer on their nondominant wrist 8 consecutive days and nights at all times, including during water-based activities, but to remove the accelerometer while showering or having a sauna.	Results showed that the use of an activity tracker did not reduce daily total or prolonged sedentary time over 12 months. No differences between the intervention and control groups over 3 months were found, but a tendency for a greater decrease in prolonged sedentary time in the intervention group over 6 months was seen.
Warner et al.	2016	1.1. Goal setting (behaviour), 1.3. Goal setting (outcome), 1.4. Action planning, 1.5. Review behaviour goal(s), 2.3. Self-monitoring of	10	In person, Text messages/booklets	Physical activity	360	M= 70; 64 - 92	75%	Self-report, Objective	- Self-reported physical activity, measured through the index of the validated PRISCUS-PAQ - Objective physical activity, measured through the GENEActiv accelerometers worn	Neither self-reported nor objective physical activity measure increased in the intervention groups as compared to the other groups at any point in time

		behaviour, 5.1. Information about health consequences, 6.1. Demonstration of the behaviour, 12.2. Restructuring the social environment, 15.3. Focus on past success, 16.3. Vicarious consequences								around the left wrist for ten days at T1 and T3	
Carfora et al.	2017a	2.3. Self-monitoring of behaviour	1	SMS	Diet	244	M= NA; NA - NA	nan%	Self-report	Red meat consumption, measured through an online food diary	Results showed that the intervention was effective in reducing red meat consumption
Carfora et al.	2017a	2.3. Self-monitoring of behaviour, 5.5. Anticipated regret	2	SMS	Diet	124	M= NA; NA - NA	nan%	Self-report	Processed meat consumption, measured through an online food diary	Results showed that a daily messaging intervention, controlling for participants’ past behaviour, reduced self-reported consumption of processed meat
Caso et al.	2024	5.1. Information about health consequences, 5.2. Salience of consequences, 6.3. Information about others’ approval, 9.1. Credible source, 13.4. Valued self-identify	5	Unknown	Diet	832	M= 32.4; 18-63	55%	Self-report	Adherence to the Mediterranean diet using the MEDI-LITE score	No change in behaviour was found
Domke et al.	2021	1.4. Action planning, 15.2. Mental rehearsal of successful performance	2	Unknown	Diet	206	M= 32; NA - NA	77%	Self-report	Fruit and vegetable consumption, measured through diaries using a 24-hr recall food frequency questionnaire.	Results showed a significant between-condition differences of the phase effect, indicating that participants from the planning condition (vs. control condition) showed an enhanced fruit and vegetable consumption immediately following the intervention. The nonsignificant post-intervention day trend × planning condition interaction indicated that there were no between-condition differences in fruit and vegetable consumption changes following the intervention.
Tapper et al.	2014	1.1. Goal setting (behaviour), 1.4. Action planning, 1.5. Review	23	Web-based	Diet	100	M= 39;	83%	Self-report, Objective	- Intake of (1) saturated fat, (2) added sugar, and (3) fruit and vegetables, measured through	Results showed a significant interaction for fruit and vegetable consumption; the intervention

		behaviour goal(s), 1.6. Discrepancy between current behaviour and goal, 2.2. Feedback on behaviour, 3.1. Social support (unspecified), 4.1. Instruction on how to perform the behaviour, 4.2. Information about Antecedents, 5.1. Information about health consequences, 5.5. Anticipated regret, 5.6. Information about emotional consequences, 7.1. Prompts/cues, 8.2. Behaviour substitution, 8.3. Habit formation, 9.1. Credible source, 9.3. Comparative imagining of future outcomes, 10.4. Social reward, 12.1. Restructuring the physical environment, 12.3. Avoidance/reducing exposure to cues for the behaviour, 12.5. Adding objects to the environment, 12.6. Body changes, 15.2. Mental rehearsal of successful performance, 16.2. Imaginary reward					NA - NA			the Block Fat/Sugar/Fruit/Vegetable screener, a 55-item food frequency questionnaire (FFQ) - BMI, waist-to-hip ratio (WHR), heart rate variability (HRV) - Alcohol consumption, measured through a self-report questionnaire - Smoking, measured through a self-report questionnaire asking participants whether they smoked cigarettes and, if yes, the number they usually smoked either per day, per week, or per month - Physical activity, measured through the short version of the International Physical Activity Questionnaire	group increased their intake between baseline and 6 months relative to the control group. Results also showed overall reductions in saturated fat intake and added sugar intake during this period, but there were no interactions with group. There were overall reductions in BMI and WHR, but no interactions with group. The intervention did not affect alcohol consumption, physical activity, smoking, or HRV
Watson et al.	2023	1.1. Goal setting (behaviour), 1.2. Problem solving, 1.3. Goal setting (outcome), 1.4. Action planning, 1.5. Review behaviour goal(s), 2.2. Feedback on behaviour, 2.3. Self-monitoring of behaviour, 2.4.	18	In person, Text messages/booklets	Diet	54	M= 72; NA - NA	41%	Self-report	- Dietary intake, assessed using a 4-day food diary, which involved participants recording everything they ate and drank over four consecutive days (including 1 day at the weekend) to estimate mean daily nutrient and micronutrient intake, including: energy, protein, fat, sat fat, mono fat, Omega 3, Omega	The intervention group significantly increased their daily mean intake of potassium relative to the control group from baseline to 6 weeks (mean difference [95% CIs]: -452.40 [-1.61, -989.19]; p = 0.04). No other significant between-group differences in nutrient intakes across the time points were observed.

		Self-monitoring of outcome(s) of behaviour, 2.5. Monitoring of outcome(s) of behaviour without feedback, 2.6. Biofeedback, 4.1. Instruction on how to perform the behaviour, 5.1. Information about health consequences, 7.1. Prompts/cues, 8.1. Behavioural practice/rehearsal, 8.2. Behaviour substitution, 8.3. Habit formation, 8.4. Habit reversal, 9.1. Credible source								3 FA, Omega 6 FA, carbohydrate, free sugar, fiber, vitamin A, vitamin B6, vitamin B12, folate, vitamin C, vitamin D, iron, calcium, magnesium, potassium, iodine - Other health related outcomes assessed at baseline, six weeks, four months and eight months included body mass index (BMI) calculated as weight (kg) divided by height squared (m2).	
Naughton et al.	2023	1.1. Goal setting (behaviour), 1.2. Problem solving, 1.4. Action planning, 1.9. Commitment, 2.2. Feedback on behaviour, 2.4. Self-monitoring of outcome(s) of behaviour, 3.1. Social support (unspecified), 4.1. Instruction on how to perform the behaviour, 4.2. Information about Antecedents, 4.3. Re-attribution, 5.1. Information about health consequences, 5.5. Anticipated regret, 7.1. Prompts/cues, 7.8. Associative learning, 8.4. Habit reversal, 12.1. Restructuring the physical environment, 12.3. Avoidance/reducing exposure to cues for the behaviour, 12.4. Distraction, 15.1. Verbal	21	Mobile app	Smoking	209	M= 51; 18 - 61	56%	Self-report, Objective	- Self-reported abstinence in the previous 6 months allowing for no more than five cigarettes and not smoking in the previous week biochemically validated by a saliva cotinine concentration of less than 10 ng/ml39,40 and for those using any nontobacco nicotine substitution, an anabasine concentration of less than 0.2 ng/ml.40. - We also measured 7-day point prevalence abstinence at 6 weeks (self-report) and 6 months (self-report and biochemically verified).	- At T2, higher abstinence rate in the Quit Sense arm (11.5%; 12/104) compared to the usual care arm (2.9%; 3/105) (unadjusted OR: 4.44, 95% CI 1.21, 16.21, p = .024) - At T3, because of imbalanced saliva sample return rates between arms, a post hoc sensitivity analysis was only undertook for the primary smoking outcome but using self-reported prolonged abstinence only. The findings favoured the Quit Sense arm, though the between-arm difference was not statistically significant (Quit Sense 24.0%; usual care 15.2%, OR: 1.76, 95% CI 0.88, 3.53, p = .11). - Other smoking outcomes at 6 months also favoured Quit Sense over usual care, although this was only statistically significant for validated 7-day point prevalence.

		persuasion about capability, 15.2. Mental rehearsal of successful performance, 15.4. Self-talk									
Graham et al.	2024	1.1. Goal setting (behaviour), 1.2. Problem solving, 1.4. Action planning, 1.5. Review behaviour goal(s), 1.6. Discrepancy between current behaviour and goal, 2.3. Self-monitoring of behaviour	6	Videos, Text messages/booklets	Weight	122	M= 52; NA - NA	86%	Self-report	- Mean difference in weight through a photo - Physical activity behaviours (moderate to vigorous physical activity (MVPA) minutes/week) through the Exercise Vital Signs Questionnaire (EVSQ) - Quantity and frequency of ten different foods consumed each week through an ad-hoc self-report measures	- The mean difference in weight from baseline to follow-up between the intervention and comparator groups was -1.1 kg (95% CI − 1.7 to − 0.4), favouring the intervention group - There was no difference in the MVPA minutes/week (− 26.1 min, 95% CI − 83.2 to 31.0) between the groups at follow-up - There was no difference in the dietary behaviour scores (− 1.9, 95% CI − 4.3 to 0.5) between the groups at follow-up
Young et al.	2015	1.1. Goal setting (behaviour), 1.3. Goal setting (outcome), 2.3. Self-monitoring of behaviour, 2.4. Self-monitoring of outcome(s) of behaviour, 3.1. Social support (unspecified), 3.2. Social support (practical), 3.3. Social support (emotional), 8.7. Graded tasks, 10.2. Material reward (behaviour)	9	SMS, Videos, Text messages/booklets, Consumer-graded wearable	Weight	92	M= 49; 27 - 65	0%	Self-report, Objective	- Time spent in moderate-to-vigorous physical activity, measured through a slightly modified version of the Godin Leisure Time Exercise Questionnaire - Total energy from discretionary foods, measured through the Australian Eating Survey - Weight, measured in light clothing, without shoes on a digital scale	Results revealed no significant group-by-time differences in behaviours during the intervention.

The average number of BCTs per study is approximately 8, though the number varies widely across individual studies, with some using as few as 3 BCTs and others incorporating over 20. Table 2 provides a list of the most frequently used BCTs, ordered from most to least used. . The ranking reflects which techniques are most commonly employed in behavioural interventions, providing insight into the strategies that may be considered particularly effective or essential for influencing behaviour change. It is interesting to note that techniques like **goal setting (behaviour)**, **self-monitoring of behaviour**, and **information about health consequences** are at the top, suggesting that clear, structured approaches to goal setting, as well as providing individuals with information about their health, are foundational in many interventions.

Table 2: Percentage and frequency of BCTs used in reviewed studies

BCT	Percentage	Frequency
1.1. Goal setting (behaviour)	64.7%	11/17
2.3. Self-monitoring of behaviour	64.7%	11/17
5.1. Information about health consequences	64.7%	11/17
1.4. Action planning	58.8%	10/17
1.2. Problem solving	41.2%	7/17
2.2. Feedback on behaviour	35.3%	6/17
4.1. Instruction on how to perform the behaviour	35.3%	6/17
7.1. Prompts/cues	35.3%	6/17
1.3. Goal setting (outcome)	29.4%	5/17
1.5. Review behaviour goal(s)	29.4%	5/17
3.1. Social support (unspecified)	29.4%	5/17
1.6. Discrepancy between current behaviour and goal	23.5%	4/17
2.4. Self-monitoring of outcome(s) of behaviour	23.5%	4/17
9.1. Credible source	23.5%	4/17
5.5. Anticipated regret	17.6%	3/17
5.6. Information about emotional consequences	17.6%	3/17
8.1. Behavioural practice/rehearsal	17.6%	3/17
8.2. Behaviour substitution	17.6%	3/17
15.2. Mental rehearsal of successful performance	17.6%	3/17
15.3. Focus on past success	17.6%	3/17
3.2. Social support (practical)	11.8%	2/17
3.3. Social support (emotional)	11.8%	2/17
4.2. Information about Antecedents	11.8%	2/17
6.1. Demonstration of the behaviour	11.8%	2/17
8.3. Habit formation	11.8%	2/17
8.4. Habit reversal	11.8%	2/17
8.7. Graded tasks	11.8%	2/17
9.2. Pros and cons	11.8%	2/17
10.2. Material reward (behaviour)	11.8%	2/17
10.4. Social reward	11.8%	2/17
12.1. Restructuring the physical environment	11.8%	2/17
12.3. Avoidance/reducing exposure to cues for the behaviour	11.8%	2/17
12.5. Adding objects to the environment	11.8%	2/17
13.4. Valued self-identity	11.8%	2/17

1.7. Review outcome goal(s)	5.9%	1/17
1.9. Commitment	5.9%	1/17
2.5. Monitoring of outcome(s) of behaviour without feedback	5.9%	1/17
2.6. Biofeedback	5.9%	1/17
2.7. Feedback on outcome(s) of behaviour	5.9%	1/17
4.3. Re-attribution	5.9%	1/17
5.2. Salience of consequences	5.9%	1/17
6.2. Social comparison	5.9%	1/17
6.3. Information about others’ approval	5.9%	1/17
7.8. Associative learning	5.9%	1/17
9.3. Comparative imagining of future outcomes	5.9%	1/17
10.3. Non-specific reward	5.9%	1/17
10.10. Reward (outcome)	5.9%	1/17
12.2. Restructuring the social environment	5.9%	1/17
12.4. Distraction	5.9%	1/17
12.6. Body changes	5.9%	1/17
15.1. Verbal persuasion about capability	5.9%	1/17
15.4. Self-talk	5.9%	1/17
16.2. Imaginary reward	5.9%	1/17
16.3. Vicarious consequences	5.9%	1/17

In terms of study outcomes, most studies rely on self-reported data (94.1%), while a significant portion (35.3%) includes objective measures. Five (i.e., 29.4%) out of the seventeen considered studies adopted a mixed approach including both self-reported and objective measures to assess behaviour change outcomes.

The following list presents the behaviour change models most frequently used to inform interventions, based on the provided data. These models guide interventions by offering frameworks for understanding the factors that drive behaviour and shaping strategies to facilitate change. Notably, “unspecified” is the most common, suggesting that in many cases, interventions are not strictly adhering to a particular model. Among the more structured approaches, Theory of Planned Behaviour (TPB; Ajzen, 2011), Social Cognitive Theory (SCT; Bandura, 2013), Self-Determination Theory (SDT; Deci & Ryan, 2012), and Health Action Process Approach (HAPA; Schwarzer et al., 2008) are all heavily represented, each providing unique insights into the motivation, cognitive processes, and environmental influences that affect behaviour. The COM-B model (Michie et al., 2014) and Transtheoretical Model (TTM; Velicer et al., 1998) also appear, though they seem less frequently employed. Table 3 reports the list of the most frequently used behaviour change models, ordered from most to least used.

Table 3: Percentage and frequency of behaviour change models used in studies

Model	Percentage	Frequency
Unspecified	23.5%	4/17
Theory of Planned Behaviour (TPB)	17.6%	3/17
Social Cognitive Theory (SCT)	17.6%	3/17
Self-Determination Theory (SDT)	17.6%	3/17
Health Action Process Approach (HAPA)	17.6%	3/17
Self-Regulation Theory (SRT)	17.6%	3/17
Transtheoretical Model (TTM)	5.9%	1/17
COM-B	5.9%	1/17
Cognitive Behavioural Theory (CBT)	5.9%	1/17
Behaviour Change Wheel (BCW)	5.9%	1/17

This list emphasizes the broad array of models used in behavioural interventions, revealing a strong preference for well-established theories that consider a range of psychological, social, and environmental factors influencing behaviour.

2.3.1 Interventions targeting multiple behaviours

Chung et al. (2023) is the only study in our data targeting multiple behavioural changes. The study focused on diet, physical activity, and weight management. Specifically, Chung et al. (2023) conducted a RCT to assess the effectiveness of a Traditional Chinese Medicine (TCM)-based mobile health (mHealth) app for individuals with prediabetes. The study included three arms: the TCM mHealth app group, an ordinary mHealth app group, and a control group. All participants received standard care, which included 15-20 minutes of health education on diet and exercise. The ordinary app is a mobile health app that supports prediabetes management through tracking health metrics, providing educational resources, setting health goals, and enabling user engagement via chatrooms and gamificationThe TCM mHealth app included additional TCM-based content, such as personalized dietary and physical activity advice based on body constitution.

The intervention included 18 BCTs to promote healthy behaviours. Participants engaged in **goal setting (behaviour)** by defining objectives for diet and physical activity, while **goal setting (outcome)** focused on measurable targets like blood sugar and weight. The app highlighted **discrepancy between current behaviour and goal** using charts to compare actual and desired behaviours and encouraged users to **review outcome goals** based on progress in weight and blood sugar levels. Feedback mechanisms included **feedback on behaviour**, with text updates and behaviour charts, and **feedback on outcome(s) of behaviour**, using pop-ups to flag out-of-range metrics. Participants practiced **self-monitoring of behaviour** by logging activities and **self-monitoring of outcome(s)** by tracking weight, BMI, and blood sugar. **Social support (unspecified)** was fostered through chatrooms and researcher encouragement, while **information about health consequences**

emphasized the impact of behaviours on health. Motivation was enhanced through **social comparison** via leaderboards, **prompts/cues** with reminders and notifications, and credible guidance aligned with ADA and USDA standards. Rewards included **material rewards** (virtual gold for prizes), **non-specific rewards** (gamified points), **social rewards** (encouraging messages), and **reward (outcome)** for achieving goals. Finally, **focus on past success** allowed users to compare current progress with past behaviour through charts.Regarding efficacy, the TCM mHealth app led to significant improvements in glycated haemoglobin (HbA1c, a common measure of long-term blood sugar level), BMI, and body constitution (i.e., a concept in TCM referring to an individual's condition that influences susceptibility to specific health conditions), but no significant changes in fasting plasma glucose (FPG) or dietary behaviour (i.e., adherence to broader dietary guidelines such as the Dietary Approaches to Stop Hypertension diet (Campbell, 2017), which emphasizes vegetables, fruits, and whole grains, and low-fat, low-sodium, and high-fiber foods). Both the TCM and ordinary app groups showed significant improvements in quality of life, but the TCM group had better gains in the mental component score. Physical activity increased across all groups, but the ordinary app group reported the highest levels, showing that while the TCM app improved specific health indicators, the ordinary app was equally effective at enhancing physical activity.

2.3.2 Interventions targeting physical activity

This section summarizes seven studies focusing on physical activity, which employed various BCTs. The number of BCTs used ranged from five to 10, with common techniques including goal setting (beaviour), action planning, self-monitoring of beaviour, information about health consequences, and problem solving. **Goal setting (beaviour)** was employed in all seven studies (7/7, 100%), highlighting its central role in helping participants establish clear, actionable objectives for increasing physical activity. **Action planning**, used in 6/7 studies (85.7%), encouraged participants to outline specific steps to achieve their goals, ensuring a practical approach to beaviour change. Similarly, **self-monitoring of beaviour**, also present in 6/7 interventions (85.7%), enabled participants to track their progress and reflect on their achievements. **Information about health consequences**, included in 5/7 studies (71.4%), provided participants with a better understanding of the physical and mental benefits of regular activity, fostering motivation. Lastly, **problem solving**, utilized in 4/7 studies (57.1%), addressed barriers to physical activity, equipping participants with strategies to overcome challenges and sustain their efforts. Most interventions used self-reported measures as the primary outcome, though some also included objective assessments. The interventions were diverse, incorporating methods such as text message-based, web-based, and in-person sessions. The duration of interventions varied, from 10-20 minutes to 12 months, depending on the study. Effectiveness across these interventions was mixed. While some studies found no significant changes in physical activity levels, others showed trends toward positive outcomes. However, the overall effectiveness remained unclear, suggesting that the combination of BCTs may have a variable impact depending on the intervention type. The studies suggest that more structured approaches, incorporating multiple BCTs, might have a higher likelihood of producing positive changes in physical activity. Yet, the inconsistency of results across different interventions indicates that further research is needed to identify the most effective strategies for promoting sustained physical activity.

In the study by Harada (2022), a randomized controlled crossover trial was conducted to evaluate the effectiveness of a self-regulation intervention aimed at increasing exercise behaviour among older adults. The intervention, which lasted for seven weeks, provided print-based materials to participants, focusing on self-regulation techniques for exercise. The BCTs used in this intervention included **self-monitoring of behaviour**, where participants tracked their exercise activities; **goal**

setting (behaviour), which encouraged participants to set specific exercise goals; and **action planning**, helping participants plan when, where, and how they would engage in exercise. Additionally, **problem solving** was incorporated to identify potential barriers and develop strategies to overcome them, while **review beaviour goals** encouraged participants to reflect on their progress and adjust their plans as needed. To further support the intervention, **social support** was provided in multiple forms: unspecified, practical, and emotional, ensuring participants felt motivated and supported throughout the program. The intervention also included **information about health consequences**, which emphasized the benefits of regular physical activity; **pros and cons**, helping participants weigh the benefits of exercising against potential barriers; and **focus on past success**, encouraging reflection on previous achievements to boost confidence. The results indicated that the self-regulation intervention successfully increased the exercise behaviour of older adults, regardless of their health literacy level or habit strength.

In the study by Landais et al. (2022), a randomized, web-based, four-arm experiment was conducted to promote physical activity among inactive adults (i.e., physically active for at least 30 min on less than 5 days a week and engaged in less than 150 min of physical activity in total throughout an average week). The primary goal of this very brief intervention (i.e., lasting 10-20 minutes) was to investigate whether promoting an active choice (i.e., a conscious, informed, autonomous decision-making process) could increase physical activity intentions and behaviours. Participants were assigned to one of four groups: i) the control group, which only received physical activity guidelines; ii) the guideline and information group; iii) the guideline and active choice group; and iv) the guideline, active choice, and action planning group. The last two groups were encouraged to make an active choice by weighing the pros and cons of physical activity, reflecting on personal values, and identifying barriers. The guideline, active choice, and action planning group additionally engaged in action and coping planning exercises to address potential obstacles. The guideline and information group, like the guideline and active choice group, was encouraged to consider advantages and disadvantages but did not receive the same level of personalized decision-making support. Key BCTs used in the intervention included:

- **Goal setting (behaviour)**, where participants were prompted to define physical activity goals.
- **Action planning**, which involved planning when, where, and how to perform physical activity, helping participants create concrete steps for behaviour change.
- **Coping Planning**, which helped participants anticipate and plan for barriers to physical activity.

Results showed that promoting an active choice did not significantly improve physical activity behaviour. However, participants in the guideline, active choice, and action planning group reported **higher commitment to physical activity** and a greater perceived increase in activity (i.e., "Have you changed your physical activity behaviour in the past two weeks?") at follow-up, compared to the control group. The guideline and information group showed higher intention strength, autonomy, and commitment compared to the control group, suggesting that providing information could enhance motivation and commitment. While the interventions that promoted active choice did not produce significant changes in physical activity behaviour, the use of active choice, action planning, and coping planning did improve some psychological outcomes, particularly in terms of commitment and autonomy. This suggests that while active choice interventions may not lead directly to behaviour change, they may foster psychological commitment, which could have long-term effects on behaviour when combined with other strategies and follow-up support.

In the study by Lithopoulos et al. (2020), a RCT was conducted to compare the effects of three types of messaging interventions on sedentary behaviour in the workplace. Participants were assigned to one of four groups: affective messaging, instrumental messaging, self-regulation messaging, or a control group that received nutrition information. Each group received three in-person Microsoft PowerPoint presentations in total delivered by a researcher. The interventions aimed to reduce sedentary behaviour by promoting active breaks during the workday. The key BCTs used in this study included **information about emotional consequences** (affective group), which emphasized the mood and mental health benefits of reducing sitting, and **information about health consequences (**instrumental group), which focused on the cardiovascular risks of prolonged sitting. The self-regulation group utilized BCTs such as **self-monitoring of behaviour**, **goal setting (behaviour)**, **action planning**, and **problem solving**. These techniques were aimed at helping participants track their sitting time, set specific goals for reducing sedentary behaviour, and plan how to overcome barriers to sitting less. The results indicated that, in the short term (at weeks 4 and 8), the affective group showed the greatest reduction in sitting time compared to the other groups. However, by week 12, there were no significant differences between the groups, suggesting that while affective messaging was effective in the short term, it did not result in lasting changes. The self-regulation group, which utilized a combination of goal setting and planning strategies, did not show significant reductions in sitting time compared to the other groups. This study highlights that affective messaging, which targets emotional responses and immediate outcomes, can lead to short-term reductions in sedentary behaviour. However, it also suggests that longer-term behaviour change may require additional strategies, such as self-regulation techniques, to maintain reductions in sedentary time. The findings imply that interventions focusing on emotional and immediate benefits could be more effective initially, but sustained behaviour change might require more comprehensive approaches, including self-regulation strategies.

In the study by Patel et al. (2022), a cluster RCT was conducted to evaluate the impact of an education-based workplace intervention (Move in Office with Education, MOWE) on sedentary behaviour, maximal oxygen consumption (VO_2max), and workplace well-being in desk-based workers. The intervention lasted for four weeks, with participants divided into two groups: the MOWE group, which received education on physical activity, and a control group not receiving intervention. The key BCTs used in the study included **self-monitoring of behaviour**, where participants were encouraged to track their break times and walking activities using a log. **Feedback on behaviour** was provided via weekly SMS messages, reminding participants to take breaks and walks as recommended. **Goal setting (behaviour)** was implemented by encouraging participants to set specific targets for taking breaks and walking 30 minutes daily during the intervention period. **Action planning** was incorporated with weekly prompts to help participants plan their activity for the week. The intervention also included **problem-solving** strategies to help participants overcome barriers to physical activity at work, such as standing during phone calls and walking during lunch breaks. Additionally, **behavioural practice/rehearsal** was encouraged, with reminders to practice taking breaks and walking. Lastly, the intervention **added objects to the environment**, such as providing an education manual with strategies for incorporating more activity, like using stairs or standing during calls. The results of the study indicated that while the MOWE group did not show significant changes in sedentary behaviour or VO2max, there was a notable improvement in workplace well-being, particularly in areas like work satisfaction and perceived employer care.

In the study by Sersli et al. (2019), a longitudinal quasi-experimental design was used to evaluate the effectiveness of an adult bicycle skills training program aimed at increasing bicycling frequency and confidence. The courses, consisting of a single-session lasting from 2 to 4.5 hours long, were

designed to help participants improve their comfort and skills for bicycling on residential and urban streets. The participants were enrolled in the intervention group or a comparison group, with data collected at baseline, 1 month, 3 months, and 12 months after the intervention. The key BCTs used in this intervention included **instruction on how to perform the behaviour**, where participants learned about traffic rules relevant to cyclists and how to plan their routes using cycling maps. **Information about health consequences** was provided, focusing on cycling's benefits for health and safety. **Demonstration of the behaviour** occurred during the course as instructors demonstrated key bicycling skills, such as emergency braking, shoulder-checking, and handling left turns. The participants also had opportunities for **behavioural practice/rehearsal**, practicing cycling skills in traffic-free areas and on streets with low to moderate traffic, progressing to more complex street environments as their skills improved. The BCTs also included **graded tasks**, where participants gradually practiced their skills in increasingly challenging traffic environments. The study found that while the bicycle skills training course did not lead to significant long-term changes in overall bicycling frequency compared to the comparison group, it did have short-term effects. Participants in the intervention group increased their leisure bicycling frequency immediately after the course. However, these changes were not sustained at the 12-month follow-up, suggesting that additional support and interventions may be needed to maintain and extend the impact of the course.

In the study by Suorsa et al. (2021), a RCT was conducted to evaluate the effectiveness of a consumer-based activity tracker intervention in reducing sedentary behaviour among retirees. The intervention used a wrist-worn activity tracker (Polar Loop 2) with an integrated web-based program, delivering a series of BCTs aimed at reducing sedentary time and increasing physical activity over a 12-month period. The key BCTs incorporated in the activity tracker and web-based program included **prompts/cues**, which reminded users to break up long periods of inactivity with vibrating alerts and screen messages; **self-monitoring of behaviour**, where participants tracked their sedentary time and physical activity levels; **feedback on behaviour**, which provided daily updates on the user's progress toward their activity goals and insights into the health benefits of reducing sedentary behaviour; and **information on health consequences**, which educated users on the risks associated with prolonged sedentary time and the benefits of physical activity. Despite these interventions, the results showed that the activity tracker with inactivity alerts did not lead to significant reductions in either daily total sedentary time or prolonged sedentary time over the 12 months. The findings suggest that while the intervention successfully raised awareness of sedentary behaviour and encouraged brief activity breaks, the use of an activity tracker alone may not be sufficient to induce long-term changes in sedentary behaviour among retirees. More comprehensive interventions that combine activity trackers with other BCTs, such as goal setting or social support, might be necessary to achieve more sustained reductions in sedentary time.

In the study by Warner et al. (2016), a RCT was conducted to examine the effectiveness of self-regulatory techniques in promoting physical activity among older adults. The study included four groups: i) an intervention group that received BCTs based on the HAPA model with a views-on-ageing component (i.e., promoting positive perceptions of ageing and focusing on reshaping participants' beliefs and attitudes about ageing, emphasizing the potential for maintaining an active and healthy lifestyle, and reducing stereotypes or negative associations linked to growing older), ii) a planning-based intervention group, iii) an active control group focusing on volunteering, and iv) a passive control group. The key BCTs used in the intervention included **goal setting (behaviour)**, **action planning**, **self-monitoring of behaviour**, and **restructuring the social environment** (encouraging participants to plan for social support). The HAPA-based intervention targeted both the motivational and volitional phases of behaviour change, encouraging participants to develop

coping strategies and action plans. Additionally, the intervention group received a views-on-ageing component, which aimed to enhance positive attitudes toward aging, while the planning-based intervention group had an additional focus on **action planning** without the views-on-ageing component. The results showed that neither the intervention nor the additional planning component led to significant increases in physical activity, whether assessed by accelerometer or self-report. The study indicated that the self-regulatory techniques, such as **goal setting** and **self-monitoring**, might not be as effective for older adults as they are for younger populations. Participants in the planning-based intervention group showed a slight increase in self-reported physical activity at the 14-month follow-up, suggesting that planning alone might have had some effect, but the overall findings were null. The study highlights that older adults might find some of the self-regulatory techniques less acceptable, possibly due to cognitive overload or a mismatch between the intervention content and their needs and preferences. For instance, some participants expressed reluctance to engage in rigid planning and self-monitoring tasks, preferring more flexible approaches.

2.3.3 Interventions targeting diet

This section summarizes six studies that focus on dietary behaviours. These studies employed a variety of BCTs, with the number of BCTs per study ranging from 1 to 23. The most commonly used BCTs in the studies targeting diet were **information about health consequences, self-monitoring of beaviour**, **action planning**, and **credible source,** each appearing in 50% (3/6) of the studies. Providing **information about health consequences** helped participants understand the impact of dietary changes, while **self-monitoring of beaviour** (e.g., tracking dietary intake) enabled individuals to assess their progress. **Action planning** supported the development of concrete steps to achieve dietary goals, and the inclusion of **credible sources** focused on providing evidence-based information and dietary advice.

Among the interventions, most studies utilized self-report as the primary outcome measure, with some combining objective measures. Intervention types included SMS-based messaging, web-based platforms, and unspecified methods. Intervention durations varied, with some lasting only few minutes (i.e., a single-session intervention by Caso et al, 2024), while others extended for 24 weeks.

Effectiveness varied across studies: while one study found no change in behaviour, others reported significant changes, particularly in interventions using self-monitoring and action planning. Notably, the **studies that incorporated a higher number of BCTs tended to show more effective outcomes,** suggesting that a multi-faceted approach may be more successful in influencing dietary behaviours. However, the relationship between the number of BCTs and intervention effectiveness remains unclear for some studies, indicating the **complexity of behaviour change in dietary interventions**.

The study by Carfora et al. (2017a) investigated strategies to reduce red meat consumption using a text message intervention. This study is divided into two parts: a correlational study and a RCT. In the RCT (Study 2), participants were assigned to either a message group or a control group. The message group received daily SMS reminders to self-monitor their red meat consumption using a food diary, while the control group did not receive these reminders. The main BCT used in this intervention was **self-monitoring of behaviour**, where participants were prompted daily to track their red meat intake. In addition to self-monitoring, the study also explored the role of self-identity, particularly healthy-eating identity and meat-eating identity, in mediating the effects of the intervention. The hypothesis was that changes in self-identity would influence participants' intentions and behaviours regarding meat consumption. Results showed that the text messaging intervention,

which lasted one week, was effective in reducing red meat consumption. Participants in the message group reported significantly lower consumption of red meat compared to the control group. Mediation analysis revealed that changes in healthy-eating identity played a crucial role in driving this behaviour change. As participants began to identify more as healthy eaters, they reduced their consumption of red meat. The meat-eating identity also showed a significant relationship with consumption reduction, with a decrease in meat-eating identity correlating with lower red meat consumption. These findings underscore the importance of incorporating self-identity and self-monitoring in interventions aimed at changing dietary behaviours. The study highlights the potential of simple, low-cost strategies like text message reminders to effectively promote healthier eating habits among young adults. However, it should be noted that this was a one-week intervention, and the observed reduction in consumption represents a short-term change rather than sustained behaviour modification.

The study by Carfora et al. (2017b) focused on a text messaging intervention aimed at reducing processed meat consumption among young adults. This RCT included a messaging group and a control group, with participants in the intervention group receiving daily text messages over a one-week period. The intervention utilized two key BCTs: **anticipated regret** and **self-monitoring of behaviour**. Anticipated regret was elicited by framing the messages in a way that participants could visualize the negative feelings associated with exceeding the recommended consumption of processed meat, while self-monitoring was encouraged by asking participants to track their processed meat consumption using a daily food diary. Results indicated that the daily text messaging intervention led to a significant reduction in self-reported processed meat consumption in the intervention group compared to the control group. Mediation analyses suggested that anticipated regret influenced intentions to processed meat consumption processed meat consumption, which in turn mediated the reduction in consumption. These findings support the role of text messaging as a low-cost, effective method for encouraging behaviour change, particularly when it combines emotional motivation (anticipating regret) with a practical tool (self-monitoring). The combination of these BCTs – anticipated regret and self-monitoring – proved to be effective in promoting healthier eating habits in the short term. However, similarly to the previous study, because of the short duration of this intervention, the observed reduction in processed meat consumption might represent a short-term change rather than sustained behaviour modification.

Caso et al. (2024) conducted a RCT to explore the effectiveness of a single-session interventions targeting dietary behaviour, specifically focusing on adherence to the Mediterranean diet. The study involved several BCTs designed to influence participants' dietary habits. The intervention provided **information about health consequences**, where participants were educated on the health benefits of following the Mediterranean diet, such as reduced risks of cardiovascular disease and diabetes. **Salience of consequences** was emphasized, helping participants understand the relevance of these benefits to their own lives. Additionally, **information about others' approval** highlighted recommendations from authoritative institutions like the World Health Organization, fostering external validation of the dietary changes. **Credible sources** ensured that all information provided was trustworthy and evidence-based. Lastly, **valued self-identity** was addressed by encouraging participants to reflect on how following the Mediterranean diet aligned with their personal values and self-perception. Despite the incorporation of these BCTs, the results of the study were mixed.

Domke et al. (2021) conducted a RCT to evaluate the immediate effects of a brief **action planning** intervention lasting 13 days on fruit and vegetable consumption. The study involved a simple intervention in which participants were asked to form a plan for when, where, and what type of fruit and vegetable they would consume on a given day. This intervention aimed to improve fruit and

vegetable intake by leveraging the power of **action planning** and **mental rehearsal of successful performance**. In this study, participants in the planning condition formed an action plan for one additional serving of fruit and vegetable, while participants in the control condition did not receive any intervention. The intervention aimed to create a mental link between situational cues (when and where) and the desired behaviour (eating fruit and vegetable), enhancing participants' self-regulatory abilities. Results showed that the action planning condition led to an **immediate increase in fruit and vegetable consumption on the first day following the intervention**. Participants in this group consumed, on average, 3.99 servings of fruit and vegetable, compared to 3.68 servings in the control group. Additionally, self-efficacy for fruit and vegetable consumption increased in the planning group, further supporting the role of self-regulatory factors in dietary behaviour change. Action control - defined as a self-regulatory factor crucial for behavioural adoption and maintenance, encompassing awareness of behavioural standards, self-monitoring, and self-regulatory effort to align actual behaviour with planned intentions – was also considered as outcome measure. However, it did not show significant improvements, suggesting that while action planning improved fruit and vegetable intake and self-efficacy, it did not enhance participants' overall control over their eating behaviours. These findings underscore the effectiveness of action planning in achieving immediate dietary changes, but also highlight that additional strategies, such as forming multiple plans or incorporating other behavioural support, may be necessary for maintaining these changes over the long term.

The study by Tapper et al. (2014) evaluated the effectiveness of an internet-based program aimed at promoting healthy eating, with a focus on increasing fruit and vegetable consumption. The program was designed around several BCTs, with an emphasis on **motivational, volitional and maintenance strategies**. The study used a RCT design, with participants either receiving the intervention or being assigned to a control group. In terms of the BCTs used, the program incorporated a comprehensive set of strategies across motivational, volitional, and maintenance phases. Motivational strategies included **information about health consequences** to reinforce the health benefits of consuming fruits and vegetables, **anticipated regret** to help participants reflect on the potential negative feelings associated with unhealthy eating, and **imaginary rewards** to encourage visualization of positive outcomes. Volitional strategies emphasized **goal setting (beaviour)**, where participants were encouraged to set specific targets for fruit and vegetable intake, **action planning** to outline the steps needed to achieve these goals, and **review beaviour goals** to track progress and adjust strategies. **Discrepancy between current beaviour and goals** highlighted gaps between participants' current habits and their dietary aspirations, while **feedback on beaviour** provided tailored insights. Other volitional strategies included **social support** to encourage reinforcement from others, **prompts and cues** to remind participants to act, and **mental rehearsal of successful performance** to envision achieving their goals. Maintenance strategies were designed to sustain these changes through **habit formation**, **beaviour substitution** (replacing unhealthy foods with healthier options), and **restructuring the physical environment** to make healthy choices more accessible. **Avoidance/reducing of exposure to cues for the behaviour**, **adding objects to the environment** to facilitate healthy eating, and emphasizing **body changes** as tangible progress also supported long-term adherence. **Social rewards** and **information about emotional consequences** further reinforced sustained behaviour changes. Key findings showed that the intervention group significantly increased their fruit and vegetable consumption compared to the control group. These changes were attributed mainly to the motivational and maintenance components of the intervention, which helped participants reflect on their health-related desires and concerns, leading to sustained behaviour change. This suggests that the intervention was particularly effective in motivating participants to incorporate more fruits and vegetables into their diet. The success of the

intervention in increasing fruit and vegetable consumption underscores the importance of addressing motivational, volitional and maintenance aspects, and providing personalized feedback, which can drive behaviour change in dietary habits.

In the study by Watson et al. (2023), a pilot RCT was conducted to investigate a habit-based dietary intervention for older adults who had undergone oral rehabilitation. The goal was to improve healthy eating habits, specifically increasing the consumption of fruits and vegetables, wholegrains, and healthy proteins. The intervention consisted of three sessions over six weeks, spaced three weeks apart, with a focus on habit formation, encouraging participants to repeat healthy behaviours until they became automatic. Automaticity, defined as the extent to which a beaviour is performed with little conscious thought or effort, was measured using the Self-Report Beavioural Automaticity Index, a validated tool that assesses the automatic nature of specific behaviours through participant ratings. The program incorporated a comprehensive set of BCTs, including **goal setting (behaviour and outcome)** to establish dietary objectives, **action planning** to outline specific steps for behaviour adoption, and **reviewing behaviour goals** to review habit goal. Participants engaged in **problem-solving** to address barriers, and **self-monitoring of both behaviour and outcomes** was encouraged through tracking sheets and assessment of anthropometry and other health outcomes at each study visit. Additional strategies included **feedback on behaviour**, **biofeedback**, and providing **instructions on how to perform the behaviour**, such as portion guides and tips on eating on a budget. The intervention also utilized **information about health consequences**, **anticipated regret**, and **information about emotional consequences** to motivate participants by emphasizing the personal and emotional benefits of healthier eating. **Prompts and cues**, such as fridge magnets, acted as environmental reminders, while **habit formation** and **habit reversal** were core strategies for embedding new behaviours and replacing unhealthy habits. Other techniques, such as **behaviour substitution**, **behavioural practice/rehearsal**, and **credible sources,** were also used. The intervention group demonstrated significant improvements in the automaticity of three targeted dietary behaviours: increasing fruit and vegetable intake to three or more portions daily, substituting whole grains for white alternatives, and choosing healthy proteins over red or processed meat. These improvements were sustained at follow-ups at four and eight months, with the strongest gains observed at six weeks. However, while the automaticity of these specific behaviours increased, no significant changes were observed in overall nutritional intake. This indicates that while specific eating habits improved, the intervention did not lead to broader changes in overall diet composition or nutrient consumption.

2.3.4 Interventions targeting smoking

One study focused on smoking behaviour. In the study by Naughton et al. (2023), a RCT was conducted to evaluate the feasibility and effectiveness of the Quit Sense app, an intervention aimed at supporting smoking cessation in smokers willing to make a quit attempt. The app was designed to provide tailored, real-time behavioural support to smokers by learning about their situational smoking cues. Participants were randomized to receive either usual care (text message referral to the NHS SmokeFree website) or the Quit Sense app, which provided contextual, location-based support during a quit attempt. The Quit Sense app incorporated several BCTs, including **self-monitoring of behaviour**, where users reported their smoking episodes and triggers; **feedback on behaviour**, which provided real-time feedback based on the user’s smoking reports; **goal setting (behaviour)**, encouraging users to set and track their quit date; and **prompts/cues**, sending context-specific messages to help prevent lapses when users were in locations associated with previous smoking. The app also featured **social support (unspecified)** through tailored messages and **action planning** to help users plan for situations where they might be tempted to smoke. Other BCTs

included in the intervention were: **instruction on how to perform the beaviour**, **re-attribution**, **information about health consequences**, **anticipated regret**, **associative learning**, **habit reversal**, **restructuring the physical environment**, **avoidance/reducing exposure to cues for the beaviour**, **distraction**, **verbal persuasion about capability**, **mental rehearsal of successful performance**, and **self-talk**. The results of the trial indicated that the Quit Sense app group had a significantly higher rate of sustained abstinence at 6 months (11.5%) compared to the usual care group (2.9%), with an odds ratio of 4.46, suggesting that the app was effective in supporting smoking cessation. The findings demonstrate the feasibility of delivering a context-aware, adaptive intervention via smartphone and its potential to improve smoking cessation outcomes.

2.3.5 Interventions targeting weight management

This section summarizes two studies that focus on weight management. Both studies employed a variety of BCTs, with one intervention using 6 BCTs (Graham et al. 2024), the other one using nine BCTs (Young et al., 2015). The most commonly used BCTs included **goal setting (behaviour)** and **problem solving**, which were used to promote weight loss by helping participants set targets and address obstacles.

In the study by Graham et al. (2023), a RCT was conducted to investigate the feasibility and acceptability of a "small change" approach for weight gain prevention. The intervention aimed to help participants prevent weight gain by encouraging them to make small, manageable changes in their daily behaviours, such as adjusting calorie intake or increasing energy expenditure by 100-200 kcal per day. This 12-week intervention involved remote delivery through animated videos delivered via email and automated text messages. The BCTs included in the text messages were **goal setting (behaviour)**, where participants set specific targets for their dietary and physical activity behaviours; **self-monitoring (behaviour)**, encouraging participants to track their progress; **reviewing behavioural goals**, which helped participants assess their progress and make adjustments; **discrepancy between current behaviour and goal**, which highlighted the gap between desired and actual behaviours to motivate change; **problem solving**, which helped participants address barriers to achieving their goals; and **action planning**, to assist in planning specific actions for behaviour change. The study found that the intervention was feasible and acceptable, with high retention rates (91%) and a positive response to the "small change" approach, with 62% of participants reporting it as helpful for managing weight. However, adherence to the intervention was less than 60% of participants making the recommended seven small changes per week. Despite this, the intervention group gained less weight than the comparison group, with a mean weight difference of 1.1 kg at the end of the intervention.

In the study by Young et al. (2015), a RCT was conducted to evaluate the effectiveness of a gender-tailored, social-cognitive theory (SCT)-based weight loss maintenance program designed for men. The program aimed to help participants maintain weight loss by improving physical activity and dietary behaviours after an initial weight loss phase prior to the study. A total of 92 overweight/obese men (aged 18–65, with an average BMI of 30.7 kg/m²) who had lost at least 4 kg were randomly assigned to either the intervention group or a self-help control group. The intervention incorporated several BCTs based on SCT. These included **goal setting (behaviour and outcome),** where participants set both short-term and long-term goals related to physical activity and dietary behaviours; **graded tasks**, which helped participants achieve their goals in manageable steps; and **self-monitoring of behaviour and outcomes**, encouraging participants to track their physical activity and dietary intake. Additionally, the program emphasized social support - **social support (unspecified)**, **social support (practical)** and **social support (emotional)** - which might

be critical for sustaining long-term behaviour changes. **Material reward (behaviour)** was provided contingent on successful behaviour, reinforcing adherence to the program's objectives. The study found that while the intervention led to improvements in self-efficacy, goal setting, and planning, these **improvements did not translate into significantly greater behaviour changes** when compared to the self-help control group. Notably, physical activity outcomes were slightly improved for those in the intervention group, but the effects were not sustained over time.

The interventions were diverse in terms of delivery, including SMS, videos, text messages, and booklets. Young et al. (2015) used a consumer-based mobile application and focused on the time spent in physical activity, while the other study (i.e., Graham et al., 2024) incorporated a photo diary approach to track weight loss. Both studies utilized self-report as the primary outcome measure, with Young et al. (2015) combining objective measures. The duration of the interventions varied, lasting 6 months in Young et al. (2015) study and the other lasting 12 weeks (Graham et al., 2024). Effectiveness results were mixed: Young et al. (2015) showed no significant changes in weight management outcomes, while Graham et al. (2024) reported a small mean difference in weight from baseline. Overall, these studies suggest that while interventions targeting weight management may employ various BCTs and delivery methods, the effectiveness of these approaches remains unclear, highlighting the complexity of achieving sustained weight management changes.

2.4 Summary

When developing the iBeChange mobile app, it is essential to carefully select and implement BCTs that will effectively drive long-lasting behaviour change. Research has shown that BCTs such as **goal setting (behaviour)**, **self-monitoring of behaviour**, and providing **information about health consequences** are highly effective. However, one limitation of this review is that it exclusively included studies explicitly citing the BCTT (Michie et al., 2013), potentially excluding relevant interventions where BCTs were used but not explicitly categorized or reported according to this taxonomy.

This section provides an overview of the most commonly used and effective BCTs identified for each health pillar, offering actionable insights for applying these results in the implementation of the iBeChange platform.

Physical Activity

The most frequently used BCTs for interventions targeting physical activity included goal setting (behaviour) (used in 7/7 studies, 100%), action planning (6/7, 85.7%), self-monitoring of beaviour (6/7, 85.7%), information about health consequences (5/7, 71.4%), and problem solving (4/7, 57.1%). Studies highlighted the effectiveness of these techniques in helping participants establish specific goals, plan their activities, monitor progress, and address barriers to maintaining physical activity. Interventions using combinations of these BCTs demonstrated improvements in physical activity levels, though results were mixed across studies, indicating the need for further exploration of tailored and sustained approaches (e.g., Harada et al., 2022; Suorsa et al., 2021).

Diet

Interventions focusing on dietary behaviours most commonly utilized information about health consequences, self-monitoring of behaviour, action planning, and credible sources (all used in 3/6 studies, 50%). Providing participants with tailored information about the benefits of dietary changes, tools for tracking food intake, and step-by-step planning strategies were key components

of effective dietary interventions. Notably, self-monitoring and action planning were often associated with improved outcomes, such as increased fruit and vegetable intake, though long-term adherence remained a challenge (e.g., Tapper et al., 2014; Watson et al., 2023).

Smoking

Only one study targeted smoking cessation, utilizing a broad set of BCTs, including goal setting (behaviour), action planning, problem solving, self-monitoring of outcomes, and feedback on behaviour. The Quit Sense app, which leveraged real-time, location-based prompts and contextual feedback, demonstrated a significant increase in smoking abstinence rates compared to usual care (11.5% vs. 2.9%, Naughton et al., 2023).

Weight Management

For weight management, commonly used BCTs included goal setting (behaviour and outcome), self-monitoring of behaviour, and feedback on behaviour. These techniques were integral in interventions promoting weight loss through dietary and physical activity changes. However, the effectiveness of these strategies varied, with some studies reporting modest weight loss outcomes (e.g., Graham et al., 2024).

Alcohol Consumption

No studies included in this review specifically targeted alcohol consumption. This represents a critical gap in the current evidence base and highlights an area for further research and development within the iBeChange platform.

2.4.1 Implications for the iBeChange Platform

The findings underscore the importance of leveraging evidence-based BCTs tailored to each lifestyle pillar. In iBeChange, users will be able to set specific, measurable goals, track their progress in real-time, and gain insights into how their behaviours impact their health. These features will provide the continuous feedback necessary to enhance motivation and self-efficacy**,** two critical factors for sustaining behaviour change.

However, relying on a single technique may not suffice for achieving long-term success. Evidence from the review suggests that the most effective behaviour change interventions employ a multifaceted approach, tailored to each specific behaviour.

For physical activity, techniques such as action planning, problem solving, and self-monitoring of behaviour have shown to be particularly effective across various formats and durations (e.g., Harada et al., 2022; Suorsa et al., 2021).

For diet, self-monitoring, action planning, and providing information about health consequences have demonstrated efficacy in interventions targeting dietary improvements (Tapper et al., 2014; Watson et al., 2023).

For smoking cessation, the Quit Sense app highlighted the effectiveness of combining goal setting, feedback on behaviour, and contextual prompts/cues to deliver real-time support (Naughton et al., 2023).

In iBeChange, this could mean integrating these techniques based on the specific lifestyle targeted. For example, action planning (helping users plan when, where, and how to engage in healthy behaviours), problem solving (providing tools to overcome challenges), and feedback on behaviour (offering personalized insights into progress) are particularly suited for a mobile app, where users can regularly track their behaviours and receive customized guidance to help them stay on course.

Social support, frequently identified as a critical component in effective interventions (e.g., Graham et al., 2024; Watson et al., 2023), can also play a pivotal role in iBeChange. For physical activity, features such as social comparison—allowing users to track and compare their progress against others or within a community—boost accountability and motivation by encouraging friendly competition and peer reinforcement. For dietary changes, unspecified social support, such as the ability to share achievements and challenges with family or peers, has been shown to enhance adherence to healthy eating interventions. By integrating these elements, iBeChange can create a virtual support network tailored to the needs of its users.

One of the major advantages of a mobile app like iBeChange is its ability to deliver constant prompts, cues, feedback and recommendations. The Quit Sense app (Naughton et al., 2023) demonstrated the value of using features such as self-monitoring, prompts/cues, and feedback on outcomes to deliver tailored support at critical moments. Similarly, for physical activity and dietary behaviours, reminders and context-specific feedback were shown to improve adherence and engagement (Harada et al., 2022; Watson et al., 2023). In iBeChange, these features can be delivered through push notifications, in-app messages, or reminders, providing users with the support they need when they are most likely to need it—whether it is tracking physical activity, managing dietary intake, or responding to cravings. These evidence-based approaches can ensure that the app remains engaging and effective in promoting sustainable behaviour change.

In conclusion, iBeChange has the potential to be a powerful tool for supporting behaviour change. By integrating BCTs such as goal setting, self-monitoring, feedback, and social support, it can provide users with personalized support to help them achieve and sustain healthy behaviours. By focusing on user engagement, habit formation, and continuous feedback, iBeChange can ensure that the behaviour changes are not just short-term but sustainable over the long term.

3 Systematic Review of Digital Automated Psychological Interventions for Psychosocial Risk Factors

3.1 Introduction

In the previously conducted umbrella review (T2.2; see also D2.1) we identified psychosocial factors associated with cancer onset, summarised in Figure 2.

Figure 2. Psychosocial factors associated with cancer onset identified in the umbrella review.

Psychological factors	Social factors
Stress-related factors ▪ Stressful life events ▪ Avoidant coping strategies	Socio-economic status ▪ Income ▪ Education ▪ Employment/occupation
Emotional aspects ▪ Depression ▪ Anxiety	Social support
Personality ▪ Irritable personality ▪ Type A behaviour ▪ Always being in sulks ▪ Outgoing personality	Urbanicity (e.g., residence)

These findings served as the foundation for discussions among clinical partners to determine which psychosocial variables to prioritise in the development of the iBeChange platform, informing the selection of Patient Reported Outcome Measures (PROMs; see T2.5) and the design of appropriate interventions (see T2.7).

As outlined in T2.4, we conducted a systematic review, which is presented in this deliverable, to further support the development of T2.7. Specifically, this systematic review aims at **identifying the most effective digital psychological interventions and psychoeducational tools for addressing specific psychosocial risk factors**. Based on the results of the umbrella review and subsequent discussions among clinical partners, we decided to focus on **stress related factors**, **emotional aspects**, and **social support** as core areas of interest.

Regarding psychological variables, **personality** was excluded due to its complexity and the time limitations of the iBeChange prospective studies, which span three months for the pilot study and six months for the randomised controlled trial (RCT). Indeed, personality traits are stable constructs that require long assessment tools to be evaluated. Furthermore, they are not significantly modifiable, particularly within short timeframes. Therefore, including them could unnecessarily burden

participants with lengthy questionnaires and would not provide practical benefits, since those traits would not be targeted through specific interventions.

Concerning stress related factors, we opted to focus more generically on **perceived/self-reported levels of stress** rather than on adverse life events specifically. Indeed, focusing on such events would present ethical and practical challenges, including participants recalling and self-reporting such experiences, along with the lack of immediate professional support for participants following the assessment. Furthermore, it might convey a link between unchangeable past experiences and cancer onset, potentially leading to participant distress. Therefore, concentrating on perceived/self-reported stress without delving into the specific adverse life events that may have caused it is more aligned with our ethical considerations, as well as with the iBeChange objectives. In fact, perceived/self-reported stress is a modifiable variable that can be effectively managed through targeted interventions. Moreover, the iBeChange project does not aim to address potential posttraumatic symptoms but rather to promote healthy and sustainable habits and good practices, making adverse and stressful life events more manageable, and this can be achieved by targeting general stress management. This approach will also ensure that the intervention is applicable on a broader scale.

Regarding **social factors**, while we will collect information on **socioeconomic status** (i.e., income, education, employment/occupation) and **urbanicity** during demographic data collection, these variables cannot be directly changed through psychological or psychoeducational interventions. Therefore, our focus will remain on aspects of **social support** that can be addressed and improved within the scope of the iBeChange platform.

3.2 Aim

This systematic review aims to identify the **most effective digital psychological interventions** and psychoeducational tools for addressing psychosocial risk factors for cancer onset for the development of the iBeChange automated intervention. The risk factors were previously identified in the umbrella review presented in D2.1 and, after discussions among Clinical Partners, the following ones have been selected: stress, depression, anxiety, and social support. We chose to specifically focus on automated interventions to encourage behavioural change and emotional management as independently as possible to minimise the need for direct involvement from professionals. By doing so, we aim to maximise the potential for the iBeChange platform to be accessible and applicable to the general population on a large scale. This approach enhances the scalability and sustainability of the intervention, ensuring that it can be effectively deployed for widespread primary cancer prevention. Additionally, automated interventions align with the goal of providing cost-effective, easily accessible, and self-guided tools that address psychosocial risk factors, making them particularly well-suited for use in resource-limited settings. Therefore, the most effective interventions identified through this systematic review will be used for the automatic intervention of the iBeChange platform.

3.3 Methods

Study design

This systematic review was conducted following the guidelines provided by the **Joanna Briggs Institute** (Page et al., 2020) to address the research question: "What are the most effective digital psychological interventions and psychoeducational tools addressing depression, anxiety, stress, and

social support?”. The results are presented in accordance with the Preferred Reporting Items for **Systematic Reviews and Meta-Analyses** (PRISMA; Page et al., 2021). A narrative synthesis was performed to report the findings.

Data sources and search strategy

PubMed, **Embase**, and **Scopus** were the databases used to identify studies. The search strategy was optimised with the assistance of a research librarian of the IEO, and the final search string consisted of the combination of the following terms: *digital, computerised, psychosocial, psychological, psychoeducational, intervention, support, tool, treatment, RCT, adult*. Specific terms such as anxiety, depression, stress, and social support were excluded from the search string to ensure a broader retrieval of studies, focusing on the overall landscape of digital psychological interventions and psychoeducational tools without prematurely narrowing the scope based on target outcomes. The search string syntax was first developed for PubMed:

((digital OR digitally OR computerised OR computerized OR ehealth OR e-health OR "m-health" OR "mhealth" OR "Mobile Applications"[Mesh] OR "mobile application*" OR "mobile app" OR "mobile apps" OR "mobile phone*" OR "mobile application*" OR "software application*" OR smartphone OR "portable electronic*" OR "portable software" OR telemedicine OR telepsych* OR "tele-psych*") AND ("Psychosocial Support Systems"[Mesh] OR "Psychosocial Intervention"[Mesh] OR psychology OR psychological OR psychoeducational* OR "psycho-educational*" OR psychosocial* OR cognitive OR (beavioural OR behavioural))) AND ("intervention*" OR "support tool*" OR "strateg*" "treatment program*" OR "method*" OR "approach*" OR "technique*" OR training OR "treatment program"[Title/Abstract:~3] OR "treatment programs"[Title/Abstract:~3] OR "treatments program"[Title/Abstract:~3] OR "treatments programs "[Title/Abstract:~3] OR "treatment programme"[Title/Abstract:~3] OR "treatment programmes"[Title/Abstract:~3] OR "treatments programme"[Title/Abstract:~3] OR "treatments programmes "[Title/Abstract:~3]) AND (randomized controlled trial[pt] OR "randomized controlled trials as topic"[MeSH Terms] OR RCT OR RCTS OR controlled clinical trial[pt] OR randomiz*[tiab] OR randomis*[tiab]) AND ("health*" AND (alladult[Filter] OR adult OR adults OR adulthood))

We then adapted this search string specifically for Embase and Scopus. During the database search, specific filters were applied to ensure the selection of relevant studies. For PubMed, the filters included studies published in the last 10 years, randomized controlled trials (RCTs), and availability of full-text articles. For Embase, the filters were studies from the last 10 years, articles, and RCTs. Similarly, for Scopus, studies published in the last 10 years, articles, and RCTs were selected. The final database search was conducted in August 2024.

Eligibility criteria

The criteria for inclusion in this systematic review were the following:

- **Target outcomes:** studies evaluating the efficacy of digital psychological intervention and/or psychoeducational support tools to target as outcome variables psychosocial risk factors for cancer onset (i.e., stress-related factors, emotional factors, social support).
- **Intervention format:** self-managed, automated, and remotely delivered digital psychological interventions.
- **Participants:** adults (aged 18 years and above).
- **Study design:** Randomized Controlled Trials (RCTs).
- **Publication year, source, and language:** articles published (1) in English, (2) in peer-reviewed academic journals, (3) after 2014.
- **Intervention protocol** clearly defined (e.g., theoretical framework, number of sessions, contents, etc.).

On the other hand, the criteria for exclusionin this systematic review were the following:

- **Target outcomes:**
  - Studies focusing on non-psychosocial variables or psychosocial variables not consistently and clearly correlated with cancer onset (e.g., personality traits, eating disorders, quality of life, self-efficacy, health literacy, etc.) or that cannot be directly changed or targeted through psychological interventions (e.g., socio-economic status, urbanicity).
  - Studies evaluating cost-effectiveness, feasibility, usability, accessibility, acceptability, recruitment and retention rates as outcomes.
- **Intervention type:**
  - Non-psychological interventions (e.g., physical activity programs, medical support).
  - Non-digital or phone-based interventions.
  - Digital interventions requiring professional facilitation (e.g., video calls, virtual reality)
  - Interventions tailored for specific populations, such as couples/groups or specific conditions (e.g., postpartum depression, social anxiety, health anxiety, work stress, or other specific medical conditions).
  - Interventions addressing neurological, neuropsychological, or psychiatric aspects such as cognitive impairments or psychotic symptoms.
  - Only digital psychological interventions as adjunct to other psychological and non-psychological interventions (e.g., pharmacotherapy for psychological conditions or physical activity).
- **Participants:** participants under 18 years of age.
- **Study design:** non-RCTs or pilot studies showing preliminary results
- **Intervention protocol** undefined or poorly defined (not replicable)
- **Publication year, source, and language:** articles (1) in languages other than English, (2) published in non-peer reviewed academic journals, (3) before 2014

Study selection

The preliminary screening of titles, abstracts, and keywords was carried out independently by two researchers (E.T. and P.D.), who were blinded to each other's decisions. It was conducted using

the online **software Rayyan** (Ouzzani et al., 2016). Search results from the databases were imported into Rayyan, where duplicates were identified and removed. Articles deemed potentially relevant for full-text screening were selected based on the inclusion and exclusion criteria. Any disagreements regarding study eligibility were resolved through discussion and consensus. The percentage of agreement between the two reviewers was 94%.

Data extraction

The following data were extracted from the retrieved articles: publication data (i.e., name of the authors, year of publication, title, study origin), aim of the study, study design, sample size, characteristics of the sample, intervention(s) and duration, comparison condition(s), outcome variables, measures, baseline differences, results. In studies with multiple aims and endpoints only the information related to our research question has been extracted. The effect sizes were reported when they were present and statistically significant ($p<0.05$). When multiple estimates were reported, the range of these estimates was provided.

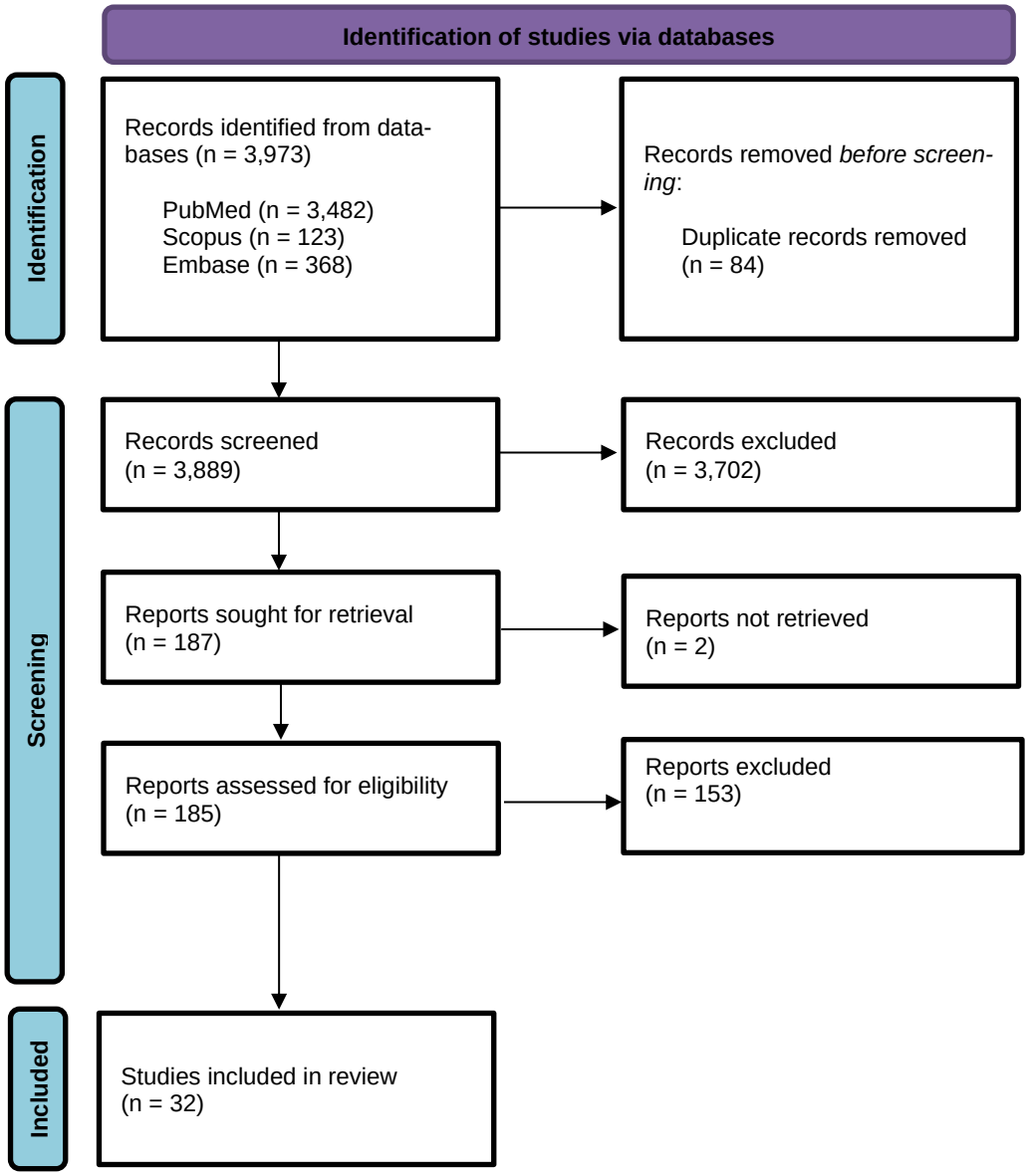
In Table 4 (Section 3.4), the characteristics and results of the studies are detailed.

3.4 Results

3.4.1 Results of the selection process

The search in 3 electronic databases (PubMed, Embase, and Scopus) identified 3,973 references, and 61 papers have been included in the present systematic review. All the details regarding the selection process are shown in the PRISMA 2020 flow diagram (Figure 3).

Figure 3. PRISMA 2020 flow diagram: summary of study selection through the application of the eligibility criteria via databases and registers.



3.4.2 Results from the selected studies

The results of the selected studies are reported in Table 4, along with their characteristics. Below, Table 5 shows a summary of the most effective interventions, whose protocols are described in detail in Section 3.4.3.

Table 4. Characteristics and results of the studies selected to target psychosocial risk factors.

Authors	Year	Title	Study origin	Aim	Study Design	Sample size	Participants characteristics	Intervention	Duration of the intervention	Comparison	Baseline differences	Outcome variables	Measures	Results
Bakker et al.	2021	A randomized controlled trial of three smartphone apps for enhancing public mental health	Australia	To evaluate and compare the efficacy of three publicly available mental health apps (MoodKit, MoodPrism, and MoodMission) against a waitlist control condition for improving mental wellbeing, reducing depression	Randomized Controlled Trial	226	81% female; mean age: 34 years; age range: 18–76 years. Participants had moderate depression and low mental wellbeing.	(1) MoodKit (CBT-based tools for mood improvement) (n=56), (2) MoodPrism (mood tracking with psychoeducation) (n=56); (3) MoodMission (CBT strategy recommendations for coping) (n=50)	30 days	Waitlist control group (n=64)	MoodKit group had higher levels of depression and anxiety than control. The differences were accounted for in the analysis.	Depression, anxiety	Patient Health Questionnaire-9 (PHQ-9), Generalized Anxiety Disorder-7 (GAD-7)	Significant reductions in depression for MoodKit ($p < .05$, $\eta^2 = 0.035$) and MoodMission ($p < .05$, $\eta^2 = 0.038$) but not for MoodPrism. As for anxiety, no significant effects in any group compared to control.
Bendtsen et al.	2020	A Mobile Health Intervention for Mental Health Promotion Among University Students: Randomized Controlled Trial	Sweden	To estimate the effect of a fully automated mobile health (mHealth) intervention on positive mental health, anxiety, and depression symptoms among university students	Randomized Controlled Trial	654 participants randomized; 381 completed the primary outcomes analysis	78% females, median age: 25 years, university students from Sweden with access to a mobile phone, and without high baseline positive mental health or severe depression/anxiety symptoms (exclusion for high MHC-SF	Fully automated mHealth positive psychology program, including themes such as gratitude, positive emotions, social environment, health behaviors, and goal setting (n=348)	10 weeks	Received usual care, defined as text message referrals to student health centers, primary care, or a national health website (n=306)	NS	Depression and anxiety	Hospital Anxiety and Depression Scale (HADS).	Depression decreased gnificantly lower scores in the intervention group (IRR = 0.820, 95% CI = 0.714–0.942). Anxiety dicreased significantly in the intervention group (IRR = 0.899, 95% CI = 0.840–0.962).
Catuara-Solarz et al.	2022	The Efficacy of "Foundations," a Digital Mental Health App to Improve Mental Well-being During COVID-19	UK	To evaluate the efficacy of the Foundations app in improving anxiety, resilience, sleep, and mental well-being during the COVID-19 pandemic.	RCT (Proof-of-Principle)	136 participants analyzed (Intervention: 62, Control: 74)	Adults aged 30-50 years, with mild to severe anxiety (GAD-7 scores 5-18), moderate to high stress (PSS-10 >13),	Foundations App: a digital mental health intervention providing CBT, positive psychology, mindfulness, and relaxation techniques through psychoeducational modules and interactive exercises (n=62)	4 weeks	No-intervention waitlist control (n=74)	No significant differences in baseline characteristics (e.g., stress, anxiety, well-being scores).	Anxiety, stress	Generalized Anxiety Disorder-7 (GAD-7), Perceived Stress Score (PSS-10)	Anxiety: intervention significantly reduced anxiety at 4 weeks (mean change = -2.05 vs. -0.78; d = 0.32). Stress: no significant differences between groups despite within-group reductions.
Dai et al.	2022	Mindfulness-based online intervention on mental health among undergraduate nursing students during coronavirus disease 2019 pandemic in Beijing, China	China	To evaluate the effects of a 6-week online mindfulness intervention on mental health among nursing students during the COVID-19 pandemic.	Randomized Controlled Trial (Open-label)	120 initially randomized (60 intervention, 60 control); 108 completed the study (52 intervention, 56 control)	79.63% females, mean age: 19.16 years (SD = 0.80); all participants were 18 years or older and undergraduate nursing students with no prior mindfulness training within six months	Mindfulness Living With Challenge (MLWC), an online program delivered via WeChat. The course included mindfulness meditation, mindful stretching, and practices such as mindful eating and breathing, based on Mindfulness-Based Stress Reduction (MBSR) and Mindful Awareness Practices (MAP).	6 weeks	Waitlist control	NS	Depression, anxiety, stress, perceived social support	Depression Anxiety Stress Scale (DASS-21), Perceived Social Support Scale (PSSS).	Significant reduction were found in the intervention group compared to the control for anxiety (d = 0.47) and stress (d = 0.42). There were also significant improvement in the intervention group for perceived social support (d = 0.34). No significant differences emerged for depression.
Dainer-Best a et al.	2018	Positive Imagery Training Increases Positive Self-Referent Cognition in Depression	USA	To assess whether a Positive Self-Referent Training (PSRT) delivered online could improve self-referent processing and reduce depressive symptoms.	Randomized Controlled Trial	87 completers	Adults aged 18-45 with CES-D scores >13 (mild-to-moderate depressive symptoms), predominantly female (84%) and white (66%). Average age: 26.4 years.	Positive Self-Reference Training (PSRT): participants visualised themselves in positive, future-oriented scenarios using guided cues (e.g., achievements or celebrations) (n=44)	2 weeks	Neutral Training Condition (NTC) focusing on non-self-referential neutral cues.	NS	Depression	CES-D	No significant differences between groups.
Guo et al.	2020	Effect of a WeChat-Based Intervention (Run4Love) on Depressive Symptoms Among People Living With HIV in China	China	To evaluate the efficacy of a WeChat-based mHealth intervention, Run4Love, in reducing depressive symptoms in people living with HIV (PLWH) and depression (PLWHD).	Randomized Controlled Trial	Total: 300 (Intervention: 150; Control: 150)	92.3% males; adults aged ≥18 years (28.3 years, SD: 5.8), HIV-positive, with CES-D ≥16 (indicating elevated depressive symptoms)	Run4Love Program, a WeChat-based cognitive-behavioral stress management (CBSM) course with 9 sessions and 3 reviews on stress management, muscle relaxation, and mindfulness (n=150)	3 months active intervention; additional 3-month booster content	Usual care and brochure on nutrition for PLWH (n=150)	NS	Depression, stress	CES-D, PHQ-9, Perceived Stress Scale	Significant reduction in the intervention group at 3 months (mean difference = -5.77, Cohen's d = 0.66) sustained through 6 months (mean difference = -6.08) and 9 months (mean difference = -5.30). Stress reductions were significant at 3 months (mean difference = −2.45)
He et al.	2022	Mental Health Chatbot for Young Adults With Depressive Symptoms During the COVID-19 Pandemic	China	To evaluate the clinical effectiveness and nonclinical performance of a cognitive behavioral therapy (CBT)-based mental health chatbot (XiaoE) for young adults with depressive symptoms during the COVID-19 pandemic.	Single-blind, three-arm randomized controlled trial.	Total: 148 (XiaoE: 49; e-book: 49; Xiaoai: 50)	Chinese university students, mean age 18.78 years; 37% female; moderate depressive symptoms (mean baseline PHQ-9 score 10.02).	XiaoE Chatbot: CBT-based chatbot delivered via WeChat, addressing cognitive distortions, self-esteem, relaxation, and loneliness through seven modules and a daily gratitude journal.	1 week	E-book group read depression-related materials; Xiaoai group engaged with a general chatbot without therapeutic design.	No significant baseline differences in depressive symptoms or demographics.	Depression	PHQ-9	Significant reductions in depression for the XiaoE group at 1 week (d = 0.51) and 1 month (d = 0.31) compared to controls.
Imamura et al.	2014	Effects of an Internet-Based CBT Program in Manga Format on Subthreshold Depression Among Workers	Japan	To examine the effectiveness of a six-week internet-based cognitive behavioral therapy (iCBT) program in manga format for improving subthreshold depressive symptoms among workers.	Randomized Controlled Trial	Total: 762 (Intervention: 381; Control: 381)	Japanese workers from private companies, majority male (85.3%), mean age 38 years, no clinical depression or other severe mental health diagnoses	Manga-based iCBT: web-based CBT lessons featuring Japanese manga-style stories. Focused on self-monitoring, cognitive restructuring, assertiveness, problem-solving, and relaxation skills, with optional homework and staff feedback (n=361)	6 weeks, with assessments at 3 and 6 months	Control group received monthly emails with general stress management tips and access to existing employee assistance programs (n=361)	NS	Depressive symptoms, psychological distress	Beck Depression Inventory-II (BDI-II), Kessler Psychological Distress Scale (K6),	Small but significant reductions at 3 months (d = -0.14) and 6 months (d = -0.16) in the intervention group for depression. No significant differences in psychological distress.
Kranenburg et al.	2022	The Effectiveness of a Nonguided Mindfulness App on Perceived Stress in a Nonclinical Dutch Population	Netherlands	To assess the efficacy of a nonguided mindfulness mobile app for reducing perceived stress and burnout in a nonclinical population.	Randomized Controlled Trial	Total: 587 (Intervention: 224; Control: 363)	Predominantly female (74.6%), mean age 46.05 years, predominantly highly educated (64.5%), employed (74.7%), with no clinical diagnosis.	Minddistrict Mindfulness App: Eight-week structured, unguided mindfulness-based stress reduction program based on psychoeducation, mindfulness exercises (e.g., breathing, body scan, sitting meditation), and daily practice prompts.	8 weeks	Waitlist control receiving general stress management information.	NA	Perceived stress	Perceived Stress Scale (PSS)	No significant effect
Larrazabal et al.	2024	Online Cognitive Bias Modification for Interpretation to Reduce Anxious Thinking During the COVID-19 Pandemic	USA	To test the efficacy of Cognitive Bias Modification for Interpretation (CBM-I) in reducing anxiety and changing interpretation bias during the COVID-19 pandemic	RCT	608	Community adults with moderate-to-severe anxiety symptoms, predominantly female (77.14%); mean age: 41.93 years (range: 18–81 years).	Cositive CBM-I, each consisting of 40 scenarios designed to reduce negative interpretation bias and promote positive cognitive bias	5 weeks	Psychoeducation including (1) an introduction to anxiety; (2) anxiety symptoms and disorders; (3) prevalence, causes, and maintenance of anxiety; (4) the impact of anxiety; and (5) anxiety management	NS	Anxiety	OASIS, DASS-21	CBM-I outperformed psychoeducation in reducing anxiety (OASIS: d = -0.31).

Table 3. Characteristics and results of the studies selected to target psychosocial risk factors. (*Continued*)

Authors	Year	Title	Study origin	Aim	Study Design	Sample size	Participants characteristics	Intervention	Duration of the intervention	Comparison	Baseline differences	Outcome variables	Measures	Results
Larrazabal et al.	2024	Online Cognitive Bias Modification for Interpretation to Reduce Anxious Thinking During the COVID-19 Pandemic	USA	To test the efficacy of Cognitive Bias Modification for Interpretation (CBM-I) in reducing anxiety and changing interpretation bias during the COVID-19 pandemic	RCT	608	Community adults with moderate-to-severe anxiety symptoms, predominantly female (77.14%); mean age: 41.93 years (range: 18–81 years).	Positive CBM-I, each consisting of 40 scenarios designed to reduce negative interpretation bias and promote positive cognitive bias	5 weeks	Psychoeducation including (1) an introduction to anxiety; (2) anxiety symptoms and disorders; (3) prevalence, causes, and maintenance of anxiety; (4) the impact of anxiety; and (5) anxiety management	NS	Anxiety	OASIS, DASS-21	CBM-I outperformed psychoeducation in reducing anxiety (OASIS: d = -0.31).
Levin et al.	2018	Comparing In-The-Moment Skill Coaching Effects from Tailored Versus Non-Tailored Acceptance and Commitment Therapy Mobile Apps in a Non-Clinical Sample	USA	To evaluate the immediate, in-the-moment effects of tailored versus non-tailored Acceptance and Commitment Therapy (ACT) mobile apps on psychological functioning in a non-clinical sample	Randomized controlled trial (RCT) with intensive longitudinal data analysis	39	60% females aged 18 or older; mean age: 21.85 years (SD: 5.18)	Tailored ACT app with skill coaching based on immediate pathological processes identified through assessments (n=17)	4 weeks	Non-tailored ACT app delivering random skill coaching (n=22)	NS	Depression, anxiety	Visual Analog Scales	Anxiety and depression improved in both groups. For anxiety, the tailored app group showed a mean reduction from 21.95 (SD = 22.10) to 15.01 (SD = 16.93), while the random app group improved from 19.03 (SD = 21.10) to 15.59 (SD = 20.10). The overall effect size was 0.17 SD units, with significantly greater improvements in the tailored app group compared to the random app group. For depression, the tailored app group improved from 17.80 (SD = 21.62) to 13.41 (SD = 16.74), and the random app group improved from 16.09 (SD = 21.48) to 13.31 (SD = 18.69). The overall effect size was 0.27 SD units, with improvements comparable between the two groups (interaction effect non-significant).
Lindsay et al.	2018	Acceptance lowers stress reactivity: Dismantling mindfulness training in a randomized controlled trial	USA	To examine whether acceptance is a critical emotion regulation mechanism within mindfulness training for reducing biological stress reactivity and to dismantle mindfulness training components into monitoring and acceptance to test their individual and combined effects.	Three-arm randomized controlled dismantling trial	144 (out of 153 recruited)	67.32% females; mean age: 32 (SD: 14); English-speaking smartphone owners who scored >5 on the four-item Perceived Stress Scale	(1) Monitor+Accept (MA): 58 participants received a 15-lesson smartphone-based mindfulness training focusing on both monitoring of present experiences and acceptance; (2) Monitor Only (MO): 58 participants received a 15-lesson smartphone-based mindfulness training focusing only on monitoring present experiences.	14-day intervention with daily 20-minute lessons, plus a booster session.	Active Control (Coping control): 37 participants received a 15-lesson smartphone-based program that focused on reappraisal and problem-solving without mindfulness components.	NS	Cortisol reactivity, systolic and diastolic blood pressure, subjective stress reactivity	Salivary samples, oscillometric blood pressure monitor, Visual Analog Scale	The MA group exhibited significantly reduced cortisol reactivity, with lower area-under-the-curve increases (d = 0.40–0.47) compared to both the MO and Coping control groups. Systolic blood pressure reactivity was also significantly lower in the MA group during the stress task (d = 0.72) compared to the control group.
Lindsay et al.	2019	Mindfulness training reduces loneliness and increases social contact in a randomized controlled trial	USA	To test the efficacy of a remote, individually delivered mindfulness intervention for improving social-relationships; to test the prediction that MA mindfulness training would decrease loneliness and increase social interactions in daily life compared with MO and control training programs	Three-arm randomized controlled dismantling trial	153	67.32% females; mean age: 32 (SD: 14); English-speaking smartphone owners who scored >5 on the four-item Perceived Stress Scale	(1) Monitor+Accept (MA): 58 participants received a 14-lesson smartphone-based mindfulness training focusing on both monitoring of present experiences and acceptance (57 completed); (2) Monitor Only (MO): 58 participants received a 14-lesson smartphone-based mindfulness training focusing only on monitoring present experiences (56 completed).	14 days, with participants completing one 20-minute lesson per day and brief daily practice (3–10 minutes).	Active Control (Coping control): 37 participants received a 14-lesson smartphone-based program that focused on reappraisal and problem-solving without mindfulness components (all completed).	NS	Loneliness, social contact, social support, reactions to social interactions	(1) Loneliness: UCLA Loneliness Scale (global loneliness) and daily diary ratings; (2) social contact: Ecological Momentary Assessments (EMA) and diary reports on social interactions and interaction partners, (3) social support: Assessed using the Interpersonal Support Evaluation List (ISEL), (4) reactions to social interactions: follow-up EMA questions on connectedness, meaningfulness, and feelings of rejection during interactions; (5) Social network diversity and size: Social Network Index (SNI)	MA group showed a significant decrease in loneliness (d = 0.44), a significant increase in social interactions (d = 0.31) increase in interactions measured by EMA (d = 0.47) and diary reports (d = 0.39). More connection and meaningfulness in social interactions were reported both in MA (d = 0.14) and MO (d = 0.30) groups compared to the control group (d = −0.38).
Litvin et al.	2023	The Impact of a Gamified Mobile Mental Health App (eQuoo) on Resilience and Mental Health in a Student Population: Large-Scale Randomized Controlled Trial	UK	To assess the effects of the gamified mental health app eQuoo on anxiety and depression among a student population	Large-scale, three-armed randomized controlled trial	1165	Students from 180 universities aged ≥18 years; 76.5% females; 21.5% males, 1.5% other	eQuoo, a gamified mobile app teaching psychological skills using principles from Cognitive Behavioral Therapy (CBT), systemic psychology, and positive psychology, and combining psychoeducation with gamification, (n=389)	5 weeks	(1) Active control: Sanvello app, i.e., a non-gamified evidence-based mental health app based on CBT (n=384); (2) passive control: waitlist group (n=392)	The eQuoo group showed slightly higher baseline scores for anxiety and depression and a higher proportion of postgraduate students than the other groups. Other differences were detected in the living situation among groups. Baseline differences were controlled to ensure valid comparisons of intervention effects.	Anxiety, depression	GAD-7, PHQ-8	Anxiety levels decreased across all groups, but the eQuoo group exhibited the most substantial reduction, with a medium effect size (Cohen's d = 0.60). Depression scores significantly decreased in all groups, but the eQuoo group achieved the largest effect, with a medium effect size (Cohen's d = 0.58).

Table 3. Characteristics and results of the studies selected to target psychosocial risk factors. (*Continued*)

Authors	Year	Title	Study origin	Aim	Study Design	Sample size	Participants characteristics	Intervention	Duration of the intervention	Comparison	Baseline differences	Outcome variables	Measures	Results
Liu et al.	2022	Using AI chatbots to provide self-help depression interventions for university students: A randomized trial of effectiveness.	China	To evaluate the effectiveness of chatbot-delivered self-help depression interventions compared to bibliotherapy	Unblinded randomized controlled trial	83	55.42% females; university students and native Chinese speakers aged 19–28 years (mean: 23.08, SD: 1.76) with PHQ-9 score ≥9	Chatbot named XiaoNan, delivering cognitive behavioral therapy (CBT) principles through WeChat (n=41)	16 weeks	Bibliotherapy using the book "Change Your Thinking" by Edelman, focusing on CBT principles for depression (n=42)	NS	Depression, anxiety	PHQ-9, GAD-7	Significant reduction in PHQ-9 scores in the chatbot group compared to the bibliotherapy group was found (F = 22.89; Cohen's d = 0.83), as well as a slight reduction in GAD-7 scores (F = 5.37; Cohen's d = 0.30). However, follow-up analysis of completers suggested that the reduction of anxiety was significant only in the first 4 weeks.
Lyzwinski et al.	2019	The Mindfulness App Trial for Weight, Weight-Related Behaviors, and Stress in University Students: Randomized Controlled Trial	Australia	To test the effectiveness of a student-tailored mindfulness app for stress	RCT	90	67% females; mean age: 20.19 years (age range: 18-24)	A mindfulness app incorporating Mindfulness-Based Stress Reduction (MBSR) and Mindful Eating (ME) techniques (n=45)	11 weeks	Behavioural self-monitoring electronic diary (e-diary) for diet and exercise (n=45)	Intervention group showed slightly higher stress levels and differences were controlled.	Stress	Perceived Stress Scale	The mindfulness app group demonstrated significantly lower stress levels compared to the control group, with a mean difference of 3.291 points on the Perceived Stress Scale (PSS) (F = 5.943, 95% CI: 0.591–5.992, R^2 = 0.326, partial eta² = 0.090). However, low adherence to the app (14% of participants used it regularly) likely limited the overall effect of the intervention.
Millán-Calenti	2015	Efficacy of a computerized cognitive training application on cognition and depressive symptomatology in a group of healthy older adults: A randomized controlled trial	Spain	To evaluate the efficacy of a multimedia and interactive cognitive program on cognition and depressive symptomatology in healthy older adults	RCT	160	Gender: 74.6% female, 25.4% male. All participants were aged 65 or older (mean age: 74.34 years, SD: 6.40).	Cognitive training via the "Telecognitio" computerized application (n=80)	12 weeks, with bi-weekly sessions of approximately 20 minutes each	No intervention. Number of participants: 80 (initially), with 62 completing the study due to attrition.	NS	Depressive symtpomatology	Short Form of the Geriatric Depression Scale (GDS-SF)	Marginal improvement in GDS-SF scores in the experimental group, but not statistically significant
Min et al.	2023	The Effectiveness of a Neurofeedback-Assisted Mindfulness Training Program Using a Mobile App on Stress Reduction in Employees: Randomized Controlled Trial		To evaluate whether neurofeedback-assisted mindfulness via a mobile app improves stress reduction compared to mindfulness-only and paper-based interventions	RCT	92	Full-time employees, 18 years or older; mean ages in the groups ranged between 37.66-39.72.	Mindfulness training with neurofeedback via a mobile app (29 participants)	4 weeks	(1) Mindfulness training via a mobile app without neurofeedback (32 participants); (2) stress-management paper materials (31 participants).	NS	Perceived stress, insomnia, depression	Perceived Stress Scale, Patient Health Questionnaire (PHQ-9), Insomnia Severity Index (ISI)	Both the neurofeedback-assisted mindfulness group (d=0.85) and the mindfulness-only group (d=0.47) demonstrated reductions in stress levels, with the effect being more pronounced in the neurofeedback-assisted group. Insomnia severity showed significant reductions in the neurofeedback-assisted mindfulness group (d=0.63) compared to the mindfulness-only and control groups. For depression, the neurofeedback-assisted mindfulness group achieved significant symptom improvements (d=0.58), underscoring the added benefits of integrating neurofeedback with mindfulness training.
Pratap et al.	2018	Using Mobile Apps to Assess and Treat Depression in Hispanic and Latino Populations: Fully Remote Randomized Clinical Trial	USA	To compare recruitment and engagement in a fully remote trial of individuals with depression who self-identify as Hispanic/Latino or not and to assess treatment outcomes using three self-guided mobile apps	RCT	274	Participants aged 18 and older with mild to moderate depression (PHQ-9 ≥ 5 or related functional impairment); 77.1% females, mean age approximately 34.9 years; including Hispanic/Latino and 637 non-Hispanic/Latino	(1) iPST (internet-based problem-solving therapy, evidence-based) (n=98), (2) Project Evolution (EVO, cognitive training app) (n=96)	12 weeks	Daily health tips (HTips) for overcoming depressed mood such as self-care (e.g., taking a shower) or physical activity (e.g., taking a walk) (n=80)	NS	Depression	PHQ-9	Depressive symptoms improved (β = −2.66, P = .006) over the study in all groups.
Sasaki et al.	2024	Effectiveness of an online text-based stress management program for employees who work in micro- and small-sized enterprises: A randomized controlled trial	Japan	To examine the effectiveness of a fully automated text-based stress management program, "WellBe-LINE," in improving mental health and job-related outcomes for employees in workplaces with fewer than 50 employees	RCT	1021	18 years or older (mean age: 49.3 years for the intervention group, 49.7 years for the control group), full-time employees at enterprises with fewer than 50 employees, users of the LINE app; 67.8%	A fully automated text-based 8-week stress management program, "WellBe-LINE" (n=510)	8 weeks	Waitlist: participants in the control group received the program after the six-month follow-up (n=511)	NS	Psychological distress	Kessler 6 (K6)	No significant effects.
Schillings et al.	2024	Effects of a Chatbot-Based Intervention on Stress and Health-Related Parameters in a Stressed Sample: Randomized Controlled Trial	Germany	To investigate the effects of a 3-week chatbot-based intervention using ELME on reducing stress in individuals with medium to high stress levels	Multicenter, two-armed randomized controlled trial (RCT)	118	72% female in the intervention group, 81% female in the control group. Participants were aged 18 or older (mean age: approximately 33 years in both groups) and reporting medium-to-high perceived stress (PSS-10 score ≥ 14)	Guided by the chatbot ELME, participants underwent 3 weeks of training focusing on stress, mindfulness, and interoception. Two daily interactive sessions (10-20 minutes each) were delivered via smartphones. (n=59)	3 weeks	Treatment-as-usual with no specific intervention (n=59)	NS	Perceived stress	PSS-4	No significant effects.
Short & Schmidt	2020	Developing and Testing a Novel, Computerized Insomnia and Anxiety Intervention to Reduce Safety Aids Among an at-Risk Student Sample: A Randomized	USA	To evaluate the acceptability and efficacy of a brief, computerized intervention targeting safety aids to address anxiety and insomnia in young adults	RCT	61	All participants were undergraduates; 84% females; mean age 19.43 (SD: 2.04).	A 45-minute computerized cognitive-behavioral therapy session called FAST (FSET Anxiety and Sleep Treatment). FAST contained four modules: motivation, psychoeducation, behavioral tools, and	Single session lasting 45 minutes, with a 1-month follow-up.	Physical Health Education Treatment (PHET), a 45-minute computerized session focusing on general health without	NS	Anxiety, insomnia severity	Beck Anxiety Inventory (BAI), Insomnia Severity Index (ISI)	No significant improvements in insomnia and anxiety symptoms.
Suen et al.	2022	Effect of brief, personalized feedback derived from momentary data on the mental health of women with risk of common mental disorders in Hong Kong: A randomized clinical trial.	Hong Kong, China	To evaluate the efficacy of digitalized personalized feedback derived from experience sampling method (ESM) data in improving mental health and exploring its potential as a preventive intervention for common mental disorders (CMDs) in women	A three-arm, randomized controlled trial with individually randomized, parallel groups	124	Gender: Female. Mean age: 43.4 years (range: 18–64 years). Women with mild to moderate depressive and anxiety symptoms with smartphone access	(1) Experience sampling method (ESM) with feedback (ESM-f; n=40); (2) ESM without feedback (n=43) groups underwent the ESM procedure.	6 weeks, with assessments extending to 32 weeks	No additional intervention (n=41).	Significant differences in age and education levels between groups, with older age and middle education levels higher in the ESM-f group compared to controls. Controlled for age and education level in statistical analysis.	Mental well-being (global score inclusing depression, anxiety symptoms and stress), depressive, anxiety symptoms and stress levels	DASS-21	Significant reduction in depressive symptoms (β = -0.12, 95% CI: -0.22, -0.02). ESM-f group experienced significantly lower stress levels. Significant reduction in overall DASS-21 scores (β = -0.12, 95% CI: -0.22, -0.02). The ESM-f group maintained significant symptom improvements throughout the 32-week follow-up, with a sustained reduction in DASS-21 total scores (β = -0.12, 95% CI: -0.22, -0.02), while the control group remained stable, and the proportion of severe depressive or anxiety symptoms was lowest in the ESM-f group (10%) compared to ESM (14%) and control (17.1%).

Table 3. Characteristics and results of the studies selected to target psychosocial risk factors. (*Continued*)

Authors	Year	Title	Study origin	Aim	Study Design	Sample size	Participants characteristics	Intervention	Duration of the intervention	Comparison	Baseline differences	Outcome variables	Measures	Results
Sylvia et al.	2022	Web-Based Mindfulness-Based Interventions for Well-being: Randomized Comparative Effectiveness Trial	USA	To compare the effectiveness of an 8-session web-based mindfulness-based cognitive therapy (MBCT) program with a 3-session brief mindfulness intervention in improving well-being. Secondary aims included examining whether treatment effects varied by participant baseline characteristics.	Randomized Comparative Effectiveness Trial	4411	Mean age: 54.78 years (standard deviation: 14.90). Gender: 80.41% female. Ethnicity: Predominantly White (87.80%). All participants were aged 18 or older.	8-session web-based MBCT program, with focus on structured mindfulness practices such as breath awareness, mindfulness of thoughts, and nonjudging (n=2220).	8 weeks	3-session brief mindfulness program focusing on single breath-awareness meditation (n=2191).	Generally ns, controlled in the analysis	Anxiety, depression, perceived stress	PROMIS scales	During the intervention period (baseline to 8 weeks), both groups demonstrated significant improvements in anxiety, depression, and perceived stress. For anxiety, the MBCT group reported a reduction of slope = -0.95 (95% CI: -1.14 to -0.76), while the brief mindfulness group showed a reduction of -1.07 (95% CI: -1.27 to -0.87), with both results being statistically significant. For depression, the MBCT group achieved a reduction of -1.52 (95% CI: -1.86 to -1.17), slightly higher than the reduction of -1.32 (95% CI: -1.68 to -0.96) observed in the brief mindfulness group, both statistically significant. Regarding perceived stress, the MBCT group showed a reduction of -1.00 (95% CI: -1.25 to -0.75), compared to -1.18 (95% CI: -1.45 to -0.91) in the brief mindfulness group, with both findings being significant. Over the total study period (baseline to 20 weeks), improvements remained evident. For anxiety, the MBCT group reported a reduction of -0.07 (95% CI: -0.08 to -0.05), while the brief mindfulness group recorded a reduction of -0.05 (95% CI: -0.06 to -0.04), both statistically significant. For depression, the MBCT group showed a reduction of -0.11 (95% CI: -0.13 to -0.09), compared to a reduction of -0.06 (95% CI: -0.08 to -0.04) in the brief mindfulness group. Perceived stress decreased by -0.08 (95% CI: -0.09 to -0.06) in the MBCT group and by -0.07 (95% CI: -0.08 to -0.05) in the brief mindfulness group, all statistically significant.
Taleban et al.	2016	Applications of Text Messaging, and Bibliotherapy for Treatment of Patients Affected by Depressive Symptoms	Iran	To assess the effectiveness of bibliotherapy and text messaging in reducing depressive symptoms and enhancing treatment compliance among patients.	RCT	210 participants initially, with 198 completing the study	Participants were over 18 years old, mean ages were approximately 41.36 (booklet group), 39.46 (text messaging group), and 39.68 (control group). Gender distribution included a majority of females (e.g., 98.5% in the control group).	(1) Booklet group: booklet with educational content (n=66); (2) Booklet and text messaging group: same booklet along with daily motivational and educational text messages (n=67)	30 days, with assessments before, immediately after, and 3 months post-intervention	Control group: no intervention	Gender distribution showed significant difference and was controlled for in the analysis.	Depression	Beck Depression Inventory-II (BDI-II)	Both intervention groups demonstrated a significant reduction in depressive symptoms compared to the control group (Booklet Group vs. Control Group = Mean difference (MD) between groups: -5.42 ± 1.83; p = 0.01) and (Booklet + Text Messaging Group vs. Control Group = Mean difference (MD): -5.30 ± 1.82). The reduction in depressive symptom intensity persisted significantly for the Booklet Group at 3 months post-intervention (MD: -12.61 ± 10.14 for pre-intervention vs. 3 months follow-up) compared to the Booklet + Text Messaging Group, where the effect diminished (MD: -11.80 ± 10.20 for pre-intervention vs. 3 months follow-up, but non-significant for post-intervention vs. 3 months follow-up, MD: 1.26 ± 12.50). These findings suggest a more sustained improvement with bibliotherapy alone compared to the combined intervention.
Twomey et al.	2014	A randomized controlled trial of the computerized CBT programme, MoodGYM, for public mental health service users waiting for interventions	Ireland	To evaluate the effectiveness of the computerized CBT (cCBT) program, MoodGYM, in reducing symptoms of general psychological distress (primary outcome), depression, anxiety, stress, and impaired daily functioning among public mental health service users.	RCT	149 participants at baseline (80 in the MoodGYM group, 69 in the control group)	Gender: 73.8% female Age: Range 18–61 years, Mean = 35.3 years (SD = 10.3) All participants aged 18 or older.	MoodGYM program, i.e., computerized CBT delivered online (initially n=80; n=28 completed the study)	32 days	Waiting list control group with no active intervention during the study (initially n=69; n=38 completed the study)	MoodGYM participants had higher stress symptoms and impaired daily functioning symptoms compared to control participants. Differences were controlled for.	General psychological distress (measured via DASS-21 Total Score), depression, anxiety, stress	DASS-21	MoodGYM was significantly more effective than the waiting list control group in reducing general psychological distress ($F(1, 64) = 4.45$, $p < .05$, $\eta^2 = 0.065$) and stress ($F(1, 64) = 5.35$, $p < .05$, $\eta^2 = 0.077$).
Versluis et al.	2018	Effectiveness of a smartphone-based worry-reduction training for stress reduction: A randomized-controlled trial	Netherlands	To evaluate the effectiveness of a smartphone-based worry-reduction training, incorporating mindfulness exercises, for improving heart rate variability (HRV) and reducing unconscious stress among individuals with high levels of work stress.	Randomized-controlled trial with a three-arm parallel group design	136 participants initially, 118 participants completed the study	Gender: 71% female Mean Age: 43.23 years (SD = 11.39) Adults (18+ years) experiencing work stress.	Worry-reduction training and mindfulness exercises delivered via a smartphone app (MovisensXS). Mindfulness exercises varied in length (1 to 37 minutes), with an average duration of 7.33 minutes.	4 weeks, with training sessions offered 5 times daily	(1) Control Condition (CC): Recorded emotions without receiving worry-reduction training. (2) Waitlist Group (WL): No intervention, only assessments.	Significant differences were observed in implicit positive and negative affect. The EC showed higher levels of both implicit negative and positive affect compared to the other groups. These differences were not controlled for analysis.	HRV, anxiety, depression	GAD-7, PHQ-9	No significant effects.

Table 3. Characteristics and results of the studies selected to target psychosocial risk factors. (*Continued*)

Authors	Year	Title	Study origin	Aim	Study Design	Sample size	Participants characteristics	Intervention	Duration of the intervention	Comparison	Baseline differences	Outcome variables	Measures	Results
Watson-Singleton & Pennefather	2024	Using a Randomized Clinical Trial to Test the Efficacy of a Culturally Responsive Mobile Health Application in African Americans	USA	To evaluate the efficacy of a culturally responsive mindfulness mHealth application (BlackFULLness) in improving stress-related outcomes and promoting positive behaviors among African Americans.	RCT	170	Gender: 77 males, 92 females, 1 gender non-conforming Mean Age: 36.06 years (SD: 12.29; age range: 18–75 years)	Access to BlackFULLness app, which includes mindfulness practices and psychoeducational content tailored to African American cultural values (84 participants)	12 weeks	Wait-list control group comprising 86 participants	Significant differences noted in age and pretest resilience, mindfulness, and mindfulness behavior usage for those who completed versus those who did not complete the study. These differences were not reported to be controlled in the analysis.	Stress, depression, anxiety	DASS-21	No significant differences were observed for stress, depressive symptoms, anxiety.
Yang et al.	2018	Happier Healers: Randomized Controlled Trial of Mobile Mindfulness for Stress Management	USA	To assess whether 10–20 minutes of daily mindfulness meditation over 30 days using a mobile app could reduce perceived stress and improve well-being among medical students	Prospective, randomized controlled trial	88	All participants were medical students aged 18 or older; 56 females (64%); mean age: 25.11 years (range 21–47)	Mobile app "Headspace" for daily mindfulness meditation (10–20 minutes over 30 days) (n=45)	30 days	Waitlist control (n=43)	NS	Perceived stress	Perceived Stress Scale (PSS)	Significant reduction in perceived stress from baseline to follow-up in the intervention group ($F[2,142] = 3.98$).
Zarski et al.	2024	Efficacy of an Internet- and Mobile-Based Intervention for Subclinical Anxiety and Depression (ICare Prevent) with Two Guidance Formats: Results from a Three-Armed Randomized Controlled Trial	Germany, Switzerland	To evaluate the efficacy of a transdiagnostic and self-tailored internet and mobile-based intervention (IMI) in reducing subclinical anxiety and depression severity with two guidance formats compared to a waitlist control group	RCT	566	Gender: predominantly female (72.44%). Mean age: Approximately 40 years. Age range: 18–81 years. Participants with subclinical anxiety (GAD-7 ≥ 5) and/or depressive symptoms (CES-D ≥ 16)	Cognitive-behavioral 7-session internet-and-mobile-based interventions IMI plus a booster session with either individualized guidance (IG-IMI; n=186) or automated guidance (AG-IMI; n=189)	8 weeks post-randomization, plus a booster session	Waitlist control (WLC) with care-as-usual access (n=191)	NS	Observer-rated and self-reported anxiety and depression	HAM-A, QIDS-C, GAD-7, CES-D	Individually guided (IG-IMI) and automatically guided (AG-IMI) interventions were effective in reducing subclinical anxiety and depression compared to a waitlist control group (WLC), with effect sizes for anxiety ranging from d = 0.28 to d = 0.45, while for depression from d = 0.25 to d = 0.44. The differences between IG-IMI and AG-IMI were minimal and not statistically significant. While significant reductions in both anxiety and depression were observed at the 6-month follow-up across both IG-IMI (anxiety: d = 0.34–0.41; depression: d = 0.18–0.44) and AG-IMI (anxiety: d = 0.28–0.35; depression: d = 0.15–0.44), the effects dimished and were no longer statistically significant for most outcomes at the 12-month follow-up.

Notes. RCT = Randomised Controlled Trial; NS = non-significant.

Tab. 4. Summary table of the effective interventions identified.

Study	Intervention	Target factors
Bakker et al. (2021)	Cognitive Beavioural Therapy (CBT)	Depression, anxiety
Bendsten et al. (2020)	Positive psychology	Depression, anxiety
Catuara-Solarz et al. (2022)	CBT, positive psychology, mindfulness, and relaxation techniques	Anxiety
Guo et al. (2020)	Psychoeducation, relaxation techniques, meditation	Depression, stress
He et al. (2022)	Cognitive Beavioural Therapy (CBT)	Depression
Imamura et al. (2014)	Cognitive Beavioural Therapy (CBT)	Depression
Larrazabal et al. (2024)	Cognitive Bias Modification for Interpretation (CBM-I)	Anxiety
Levin et al. (2018)	ACT	Anxiety and depression
Li et al. (2024)	Behavioural Activation	Anxiety, depression
Lindsay et al. (2018; 2019)	Monitoring and Acceptance, mindfulness	Stress reactivity, social support
Litvin et al. (2023)	CBT, Systemic Psychology, and Positive Psychology for Anxiety	Anxiety, depression
Liut et al. (2022)	CBT	Anxiety, depression
Lyzwinski et al. (2019)	Mindfulness	Stress
Min et al. (2023)	Mindfulness and neurofeedback	Stress
Pratap et al. (2018)	Problem solving, cognitive, cognitive training, psychoeducation	Depression
Suen et al. (2022)	Experience Sampling Method (ESM) with feedback	Depression, anxiety, stress
Twomey et al. (2014)	CBT	Depression, anxiety, stress
Sylvia et al. (2022)	MBCT and Mindfulness	Depression, anxiety, stress
Taleban et al. (2016)	Psychoeducation and text messages	Depression
Yang et al. (2018)	Mindfulness	Stress
Viskovich & Pakenham (2020)	ACT	Depression, anxiety, stress
Vázquez et al., (2023)	CBT	Depression
Zarski et al. (2024)	Cognitive-Behavioural interventions	Anxiety and depression

3.4.3 Most effective digital psychological automated interventions for psychosocial risk factors

In this section, we provide a detailed description of the interventions that have proven effective in addressing depression, anxiety, stress, and social support (as summarised in Table 4). This detailed overview aims to offer insights into how each intervention was implemented, providing a foundation for potential adaptation and application on the iBeChange automated intervention. The tables and figures presented below are extracted from the main articles of the studies and their supplementary materials.

StepByStep (SbS) Program to Manage Anxiety and Depression (Li et al., 2024)

The program consists of **five text- and picture-based sessions**, each designed to teach users about **Behavioural Activation (BA)** and incorporate interactive therapeutic practices. These practices include:

- Audio-guided relaxation exercises
- Planning skills for activities
- Strengthening social support
- Relapse prevention strategies

The sessions follow a narrative structure, featuring a leading character who serves as the therapist and a student character dealing with mental health issues. Through their story, these characters guide participants through the program in a supportive and culturally appropriate manner. The characters encourage users to engage in the therapeutic practices within the app and to incorporate these practices into their daily lives.

Each session lasts **approximately 20-30 minutes**, and the entire program is designed to be completed over **five weeks**. The program teaches specific techniques, including:

- Stress management
- Planning physical and social activities
- Reducing avoidance coping
- Improving self-acceptance
- Preventing relapse

The program is structured as follows:

- Week 1: Completion of pre-treatment demographic information.
- Week 2: Introduction session.
- Week 3-7: Completion of five online sessions.
- Week 8: Final week for relapse prevention practice and post-treatment assessment.

Participants are instructed to engage with the program in a quiet environment and to complete one session per week (5 weeks in total). The last session focuses on relapse prevention, and participants are given additional time (one week) to practice the skills learned during the program before undergoing a post-treatment assessment at the end of Week 8. Therefore, while the online sessions take five weeks to complete, the overall intervention lasts eight weeks.

Monitoring and Acceptance for Stress Reactivity and Social Support (Linsday et al., 2018; Linsday et al., 2019)

	Monitor + Accept	**Monitor Only**
Lesson 1	*Introduction*: Intro to the course and three core skills: • **Concentration**: ability to maintain focus on present-moment experiences • **Clarity (*Monitoring*)**: ability to pinpoint exactly what you're experiencing in each moment • **Equanimity *(Acceptance)***: openness to experience	*Introduction*: Intro to the course and two core skills: • **Concentration**: ability to maintain focus on present-moment experiences • **Clarity (*Monitoring*)**: ability to pinpoint exactly what you're experiencing in each moment
Lesson 2	*Concentration I*: developing a deeper understanding of concentration	*Concentration I*: developing a deeper understanding of concentration
Lesson 3	*Concentration II*: concentrating continuously on body experience	*Concentration II*: concentrating continuously on body experience
Lesson 4	*Concentration III*: maintaining focus on body experience while listening to someone speak (with topic options)	*Concentration III*: maintaining focus on body experience while listening to someone speak (with topic options)
Lesson 5	*Concentration IV*: labeling body experiences to maintain focus	*Concentration IV*: labeling body experiences to maintain focus
Lesson 6	*Concentration V*: labeling different types of body experiences	*Concentration V*: labeling different types of body experiences
Lesson 7	*Equanimity I*: maintaining global body relaxation to promote equanimity	*Clarity I*: discriminating different types and patterns of body sensations
Lesson 8	*Equanimity II*: promoting equanimity by intentionally using a matter-of-fact tone of voice when labeling	*Clarity II*: detecting subtle or faint body sensations, and increasing sensual fulfillment by detecting subtle pleasure
Lesson 9	*Clarity I*: discriminating different types and patterns of body sensations	*Clarity III*: introduction to six types of sensory discrimination with respect to body experience: quality, quantity, spatiality, instant of onset, what triggers what, types of change
Lesson 10	*Clarity II*: detecting subtle or faint body sensations, and increasing sensual fulfillment by detecting subtle pleasure	*Clarity IV*: recognizing physical and emotional themes of body experience
Lesson 11	*Equanimity III*: developing equanimity by applying a welcoming attitude toward all experiences	*Clarity V*: recognizing "energy flow" (changes) in body experience
Lesson 12	*Clarity III*: recognizing four basic categories of body experience (physical, emotional, restful, "energy flow")	*Clarity VI*: exploring three basic categories of body experience (physical, emotional, "energy flow")
Lesson 13	*Equanimity IV*: integrating the three equanimity strategies: body relaxation, tone of voice, welcoming attitude	*Clarity VII*: choosing to focus on one or all three themes of body experience
Lesson 14	*Course Review*: guided practice through the major strategies learned in the preceding 13 lessons	*Course Review*: guided practice through the major strategies learned in the preceding 13 lessons
Lesson 15 (Booster Training)	• Applying clarity and equanimity techniques to a challenging situation • Applying three equanimity strategies to body focus	• Applying clarity techniques to a challenging situation • Monitoring physical, emotional, and "energy flow" themes in the body

Retrieved from Lindsay et al. (2018). Caveat: Lesson 15 was not included for social support.

eQuoo Emotional Fitness App for Anxiety and Depression (Litvin et al., 2023)

The players assume the role of a **Lodestar**, a character who travels through time and space to fight against **The Quavering**, a negative force symbolising greed and negativity. The game features a narrative that motivates players to engage with the content and learn psychological skills, encouraging players to grow their "inner light" to fight The Quavering. *Example:* "*For centuries, the Lodestars have watched over this world, and they would love for YOU to join them. Get ready for the ultimate adventure... You'll help to counter a massive threat called The Quavering...*"
The game includes multiple books of various genres (e.g., **fantasy**, **historical drama**, and **teen drama**). Each book has **8-10 chapters**, in which players can learn and re-practice **up to 4 psychological skills** per chapter.
Main features:

- **Skill tutorials**: before each new chapter, players undergo a **gamified skill tutorial** led by **Joy**, a guide who is a former player of the game. Players must successfully learn the psychological skills before progressing.
- Players undergo an in-app baseline assessment through a chatbot conversation with Joy.
- **Skills taught**: topics include **emotional bids**, **generalisation**, **catastrophisation**, **beliefs**, and **psychological skills** used in treating **anxiety** and **depression**.
- **Interactive adventure**: after the tutorial, players engage in interactive adventures where they practice the learned skills in a **low-risk environment**, meaning failure has minimal consequences (e.g., replaying a level).
- **Gamification elements**, including
    - Levels
    - Points (gem shards)
    - Rewards (unlocking levels and gems)
    - Personalization (story choices and avatars)
    - Mini-games and quests
    - Badges (personality types)
    - Unlockable content
    - Artificial assistance
- **Weekly engagement**: players could only play **one level per week**, encouraging gradual learning and practice.
- **Biweekly nudges**: the game uses in-app nudges and weekly emails to encourage players to return and continue their progress.
- **Surveys**: players filled out surveys only after completing the levels, ensuring engagement and progress tracking.

After each lesson, players are tested on their mastery of the skills via multiple-choice scenarios, that can be (1) beneficial (the player chose a healthy response), (2) neutral (the skill is ignored), (3) unbeneficial (the player chose an unhealthy response).
Players must wait **7 days** between chapters to allow real-life practice of the skills, which enhances therapeutic outcomes and prevents addictive patterns.

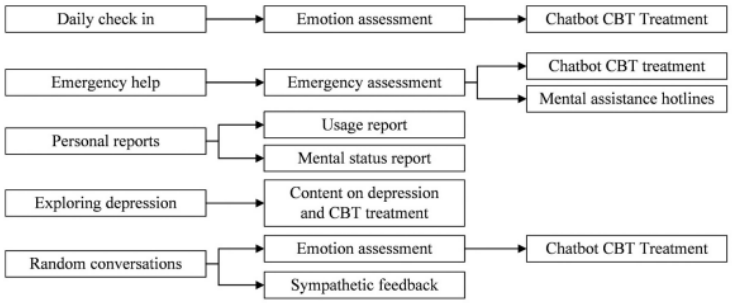
XiaoNan Therapy Chatbot: A Conversational AI for CBT-Based Mental Health Support for Anxiety and Depression (Liu et al., 2022)

XiaoNan offers a **conversational AI-based therapy chatbot** that integrates **CBT principles** to help users manage depression and emotional well-being. The chatbot is accessible through **WeChat**, and provides an interactive experience where users can track emotions, engage in therapeutic conversations, and practice cognitive restructuring techniques.

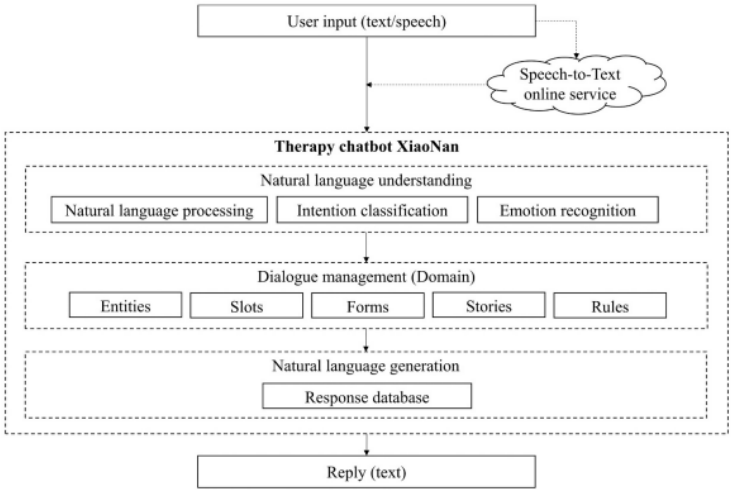
The chatbot helps users **separate their emotions, thoughts, reactions, and beaviours** and establish healthier **automatic thoughts**, similar to what would occur in a traditional CBT session. It can help users with depression, anxiety, and emotional regulation by encouraging **self-reflection** and guiding them through **CBT-based exercises** designed to modify negative thought patterns and beaviours. Additionally, users can use XiaoNan to track their **daily emotions** or engage in **random conversations**. XiaoNan is specifically designed to help users manage **depression** by estimating the severity of the user's emotional state, by using pre-written CBT templates to guide users through CBT techniques. The combination of **natural language processing**, **intention classification**, and **emotion recognition** ensures that the chatbot responds appropriately to users' needs.

See also figures from Liu et al. (2022) below for workflow, chatbot structure, and examples.

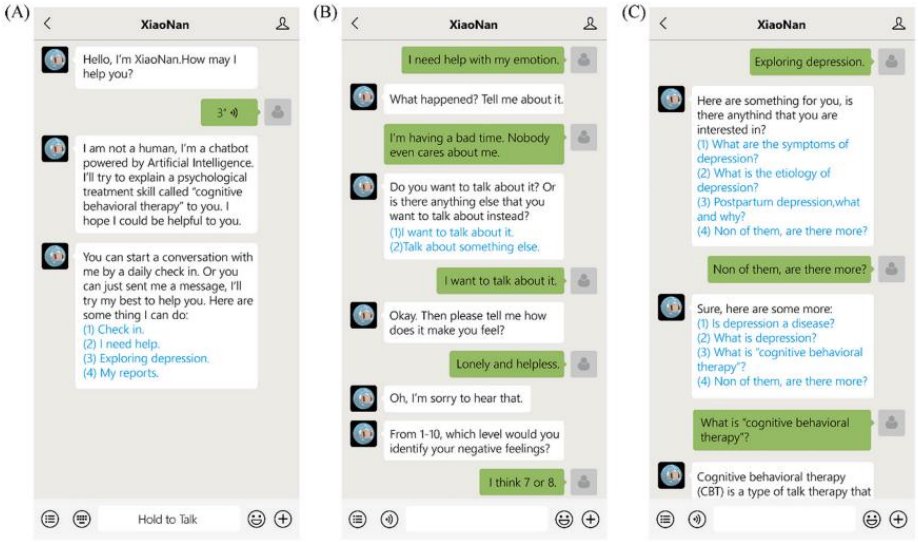
Workflow (Liu et al., 2022)



Structure of the chatbot (Liu et al., 2022)



Examples of using the chatbot (Liu et al., 2022)



Minfulness App to Target Stress (Lyzwinski et al., 2019)

Retrieved from Lyzwinski et al. (2019)

	Written lectures	Audios	Videos	Journal	Games
#1	Lecture 1. Introduction. University student stress and lifestyle challenges. Covers key challenges that are common for students	Audio1. Observing the breath	Video 1. Intro on stress, lifestyle, and weight in university students	Entry 1. Formal and informal practice	Game 1. User enters their stress and presses the bubble to watch it pop and disappear Game 2. Common issues students face with cloud solutions on how to mindfully address them
#2	Lecture 2. The relationship between stress, lifestyle, and weight in students. Discusses research	Audio 2. Diaphragmatic breathing	Video 2. What is mindfulness?	Daily formal and informal practice	Repeat of game options
#3	Lecture 3: Healthy lifestyle guidelines	Audio 3. Loving kindness meditation	Video 3. Mindfulness qualities	Daily formal and informal practice	Repeat of game options
#4	Lecture 4. Mindfulness intro: What is mindfulness?	Audio 4. Body scan	Video 4. Mindfulness of breath	Daily formal and informal practice	Repeat of game options
#5	Lecture 5. Relevance of mindfulness to students: In context	Audio 5. Mindful eating coconut meditation	Video 5. Common barriers to formal mindfulness	Daily formal and informal	Repeat of game options
#6	Lecture 6. Qualities to avoid: Mindfulness barriers	Audio 6. Binger trigger meditation	Video 6. Mindful eating	Daily formal and informal practice	
#7	Lecture 7. Mindfulness qualities to foster	Audio 7. Hunger meditation	Video 7. Mindful fun eating	Daily formal and informal practice	
#8	Lecture 8. What do these qualities mean to me as a student?	Audio 8. Satiety meditation	Video 8. WHO dietary guidelines		
#9	Lecture 9. Case study of a mindful versus not mindful student	Audio 9. Sitting meditation (concentrative): Cave meditation	Video 9. WHO physical activity guidelines	Daily formal and informal practice	
#10	Lecture 10. Mindfulness formal technique modules	Audio 10. Sitting meditation (concentrative) lighthouse meditation	Video 10. Mindful exercise	Daily formal and informal practice	
#11	Lecture 11. Observing the breath : 10 breaths	Audio 11. Sitting Meditation (concentrative) sky meditation	Video 11. Mindful swimming	Daily formal and informal practice	
#12	Lecture 12. Diaphragmatic breathing: 15 minutes	Audio 12. Sitting meditation (concentration) Audio 12. Forest fire meditation	Video 12. Mindful tennis	Daily formal and informal practice	
#13	Lecture 13. Student centered	Audio 13. Choiceless	Video 13. Adopting a	Daily formal	

	tips/campus tips for mindful breathing	awareness mindfulness meditation	mindful lifestyle (barriers to a mindful lifestyle)	and informal practice	
#14	Lecture 14. Body scan: 45 minutes	Review Audios	Video 14. Tips for being mindful on and off campus	Daily formal and informal practice	
#15	Lecture 15. Sitting meditation: loving kindness		Video 15. Environmental cues	Daily formal and informal practice	
#16	Lecture 16. Concentrative meditation (sitting): Different exercises	Video 16. Loving kindness		Daily formal and informal practice	
#17	Lecture 17. Mindfulness awareness meditation: 5-45 minutes can increase by 5 min each week	Review audios	Review videos	Daily formal and informal practice	
#18	Lecture 18. Tips when practicing formal choiceless awareness mindfulness meditation			Daily formal and informal practice	
#19	Lecture 19. Walking meditation			Daily formal and informal practice	
#20	Lecture 20. Mindful eating what is it			Daily formal and informal practice	
#21	Lecture 21. Mindful eating case study			Daily formal and informal practice	
#22	Lecture 22. Mindful eating tips			Daily formal and informal practice	
#23	Lecture 23. Making mindful eating fun/playing with one’s senses mindfully			Daily formal and informal practice	
#24	Lecture 24. Mindful eating meditation			Daily formal and informal practice	
#25	Lecture 25. Binge trigger meditation			Daily formal and informal practice	
#26	Lecture 26. Hunger meditation			Daily formal and informal practice	
#27	Lecture 27. Satiety meditation			Daily formal and informal practice	
#28	Lecture 28. Mindful exercise			Daily formal	

Retrieved from Lyzwinski et al. (2019)

Mindfulness and Neurofeedback for Stress (Min et al., 2023)

The following table, published by Min et al. (2023), represents the **4-week mindfulness training program**.

Programs	Frequency	Duration (days)
First week		
Breathing with self-exercise	Twice a day	3
Awareness with self-exercise	Twice a day	2
Body scan with self-exercise	Twice a day	2
Second week		
Breathing with self-exercise then awareness with self-exercise	Both, twice a day	7
Third week		
Breathing with self-exercise then body scan with self-exercise	Both, twice a day	7
Fourth week		
Self-exercise	Twice a day	7

Neurofeedback

The **neurofeedback function** was implemented in this study through the **OMNIFIT Brain** system during **self-exercise sessions**. The neurofeedback training was based on an **alpha protocol**, specifically designed to enhance the power of **alpha frequency** compared to other frequency bands. Indeed, **alpha waves** (8-12 Hz) are commonly associated with a state of relaxation.

Feedback system:

- **Positive feedback**: participants were informed that they would receive a **positive auditory feedback** (a **1-second ringing bell**) when they achieved a focused and relaxed state.
- **Negative feedback**: In contrast, participants would hear a **negative auditory feedback** (a **1-second chirping sound of a cricket**) when they were in a distracted or unrelaxed state.

Neurofeedback process:

- **During** each **self-exercise session**, the system calculated the ratio of **alpha power (8-12 Hz)** to **high beta power (20-30 Hz)** at **2-second intervals**.
- **Auditory Feedback**: If the ratio of **alpha power** to **high beta power** reached or exceeded a specific level (**2.775**), participants received the **positive auditory feedback** sound through their earphones.

Experience Sampling Method (ESM) – with and without feedback – to manage, depression, anxiety and stress (Suen et al., 2022)

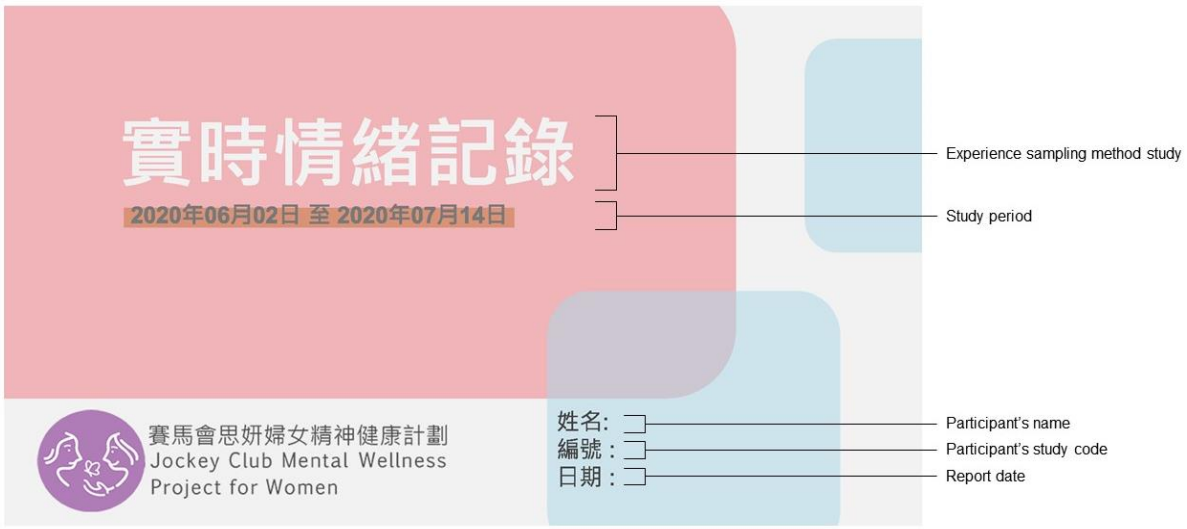
The **ESM procedure** involved participants receiving **beep questionnaires** multiple times daily to assess their emotional states, activities, and context. The feedback system for the **ESM-f group** provided personalized, **biweekly reports** based on their data, helping participants track their affective states and activities over time. The intervention aimed to explore the relationship between mood and activities, with additional incentives to encourage high compliance. Participants' smartphones were programmed to receive random beep notifications 10 times per day, with intervals of more than 60 minutes between 9 am and 10 pm over five days (totaling 50 beep questionnaires per participant). The six-week intervention period involved participants completing 10 beep questionnaires per day, distributed across three different days per week, which added up to a total of 180 beep questionnaires for each participant. One of these three days was specifically set to be a weekend to capture different mood states and activities. Participants were reminded that responses submitted more than 15 minutes after the beep notification would be considered invalid. Participants who achieved an overall compliance rate greater than 70% received monetary compensation equivalent to 64.32 USD for their time. In addition, three participants with compliance rates above 70% were entered into a monthly lottery for monetary prizes

- **ESM-f Group**: participants received **biweekly standardized and personalized feedback** based on their **ESM data**. The feedback was provided in **digital written form**.
    - Feedback was generated by inputting raw data into a **Microsoft Excel spreadsheet**, which was programmed with **macro scripts** to produce graphical charts.
    - The feedback covered **current affective states**, the relationship with various **daily contexts**, and their overall mood ratings.
    - **Feedback Modules**: The feedback system was structured into **three modules**, with each module gradually added as a new element:
        - **First module**: A graph showing the levels of **positive and negative affect** over the previous two weeks.
        - **Second module**: Included the first graph and added information about the **activities** the participant was engaged in during the event.
        - **Third module**: Provided feedback on the **activities** participants were expected to perform in the next two hours, alongside their **positive and negative affect ratings**.

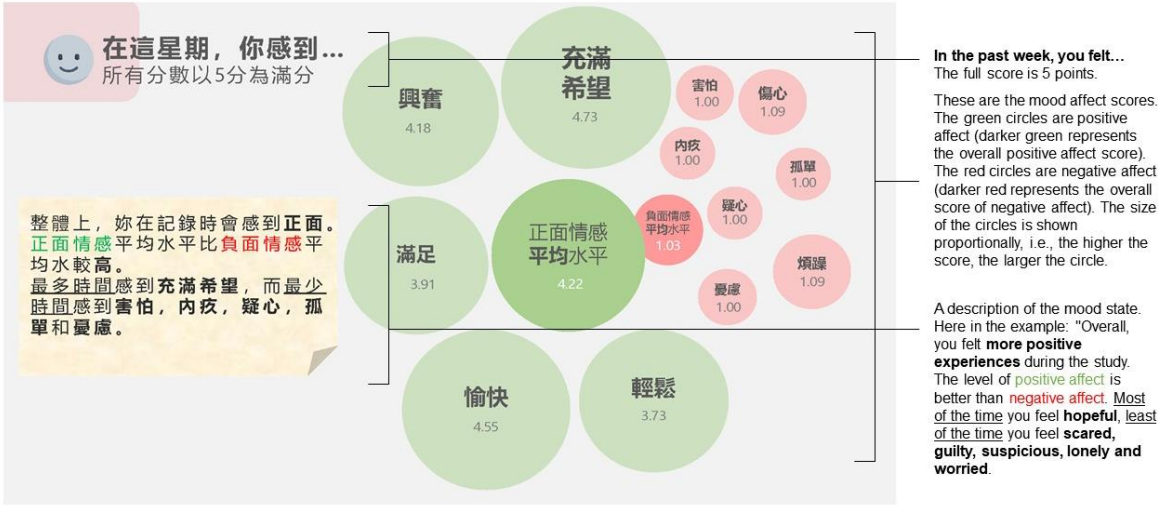
- **ESM Group**: participants did not receive personalised feedback during the intervention period, and only completed the beep questionnaires without additional interventions. See examples in the following pictures (reported in the main article and supplementary materials; Min et al., 2023)

Example of personalised feedback (Min et al., 2023)

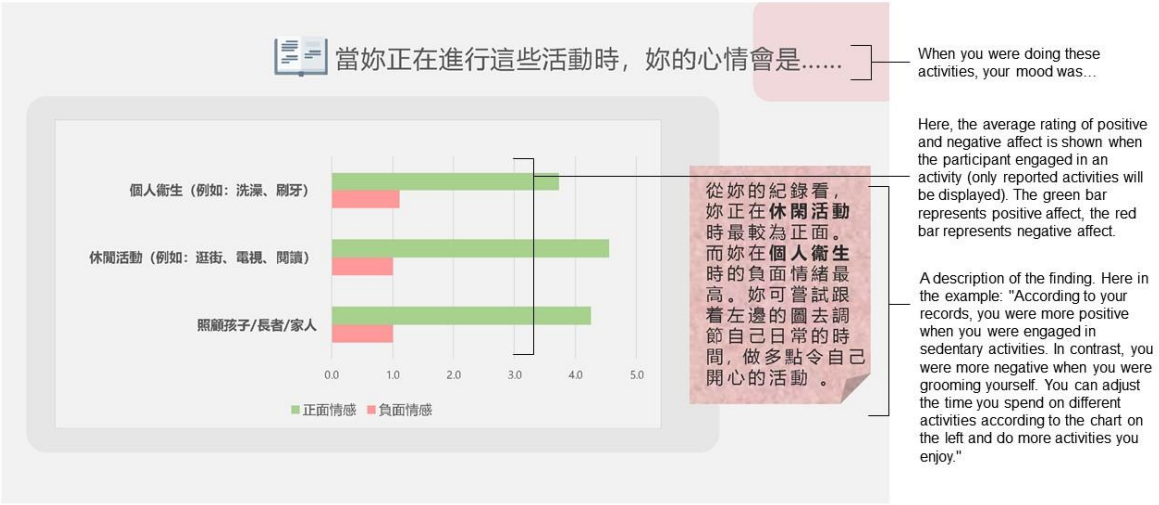
Cover page (Min et al., 2023)



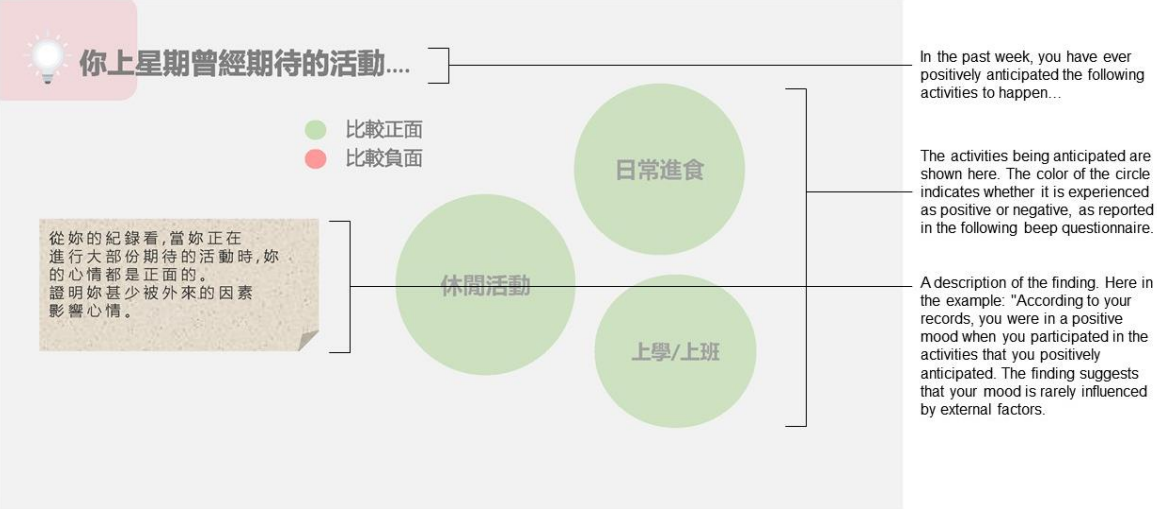
Actual levels of positive and negative affects (Min et al., 2023)



Participant’s mood in different activities (Min et al., 2023)



Activities that participants positively anticipated in upcoming two hours (Min et al., 2023)



MoodGYM for Depression, anxiety, stress (Twomey et al., 2014)

MoodGYM is an online program designed to provide **Cognitive Beavioural Therapy (CBT)** with a focus on **mental well-being**. The program consists of an introductory session and five additional sessions, each lasting between **20 to 40 minutes**, completed sequentially in a **personalized online workbook**.

The program was structured as follow:

- **Introductory Session**: The program begins with a **brief introductory session** to familiarize participants with the concepts and objectives of MoodGYM.
- **Five CBT Sessions**: Following the introductory session, participants progress through **five sessions** that focus on different aspects of **CBT**:
  - **Content**: Each session includes a combination of:
    - Written information
    - Animations
    - Interactive exercises
    - Quizzes

Participants complete the sessions within a **personalised online workbook**, which helps them track their progress and tailor the content to their individual needs. To combat **high dropout rates**, **MoodGYM** participants receive **weekly automated reminder emails**. These emails are personalized with the participant's **name** and encourage continued progress through the five sessions.

MBCT and Mindfulness for Depression, Anxiety, Stress (Sylvia et al., 2022)

Standard MBCT Intervention: the 8-session standard **Mindfulness-Based Cognitive Therapy (MBCT)** program was based on the manual developed by **Segal**. Participants followed a structured curriculum of guided meditation exercises, completing **one session per week** over the course of **8 weeks**. The exercises included:

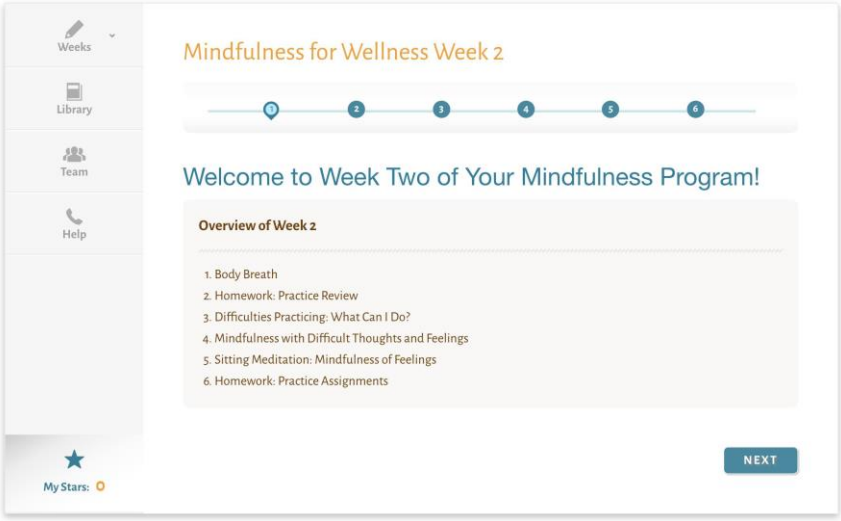
- Mindfulness of the breath
- Mindfulness of the breath and body
- Mindfulness of thoughts and feelings
- Open or choiceless awareness

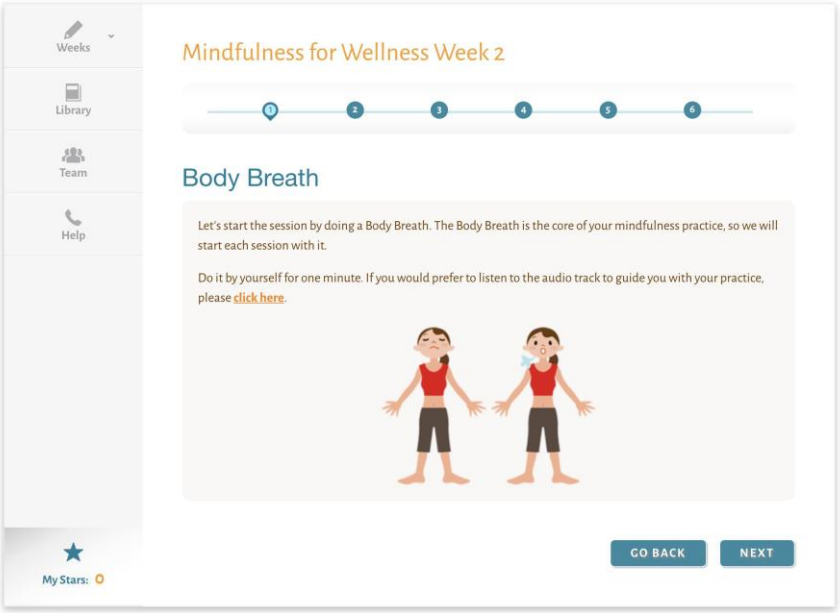
Throughout these exercises, participants learned to adopt an **observing, accepting stance** (mindfulness) towards difficult thoughts, feelings, and bodily sensations. They also practiced applying mindfulness to everyday situations, learning how to recognize and disengage from **negative, ruminative thoughts**.

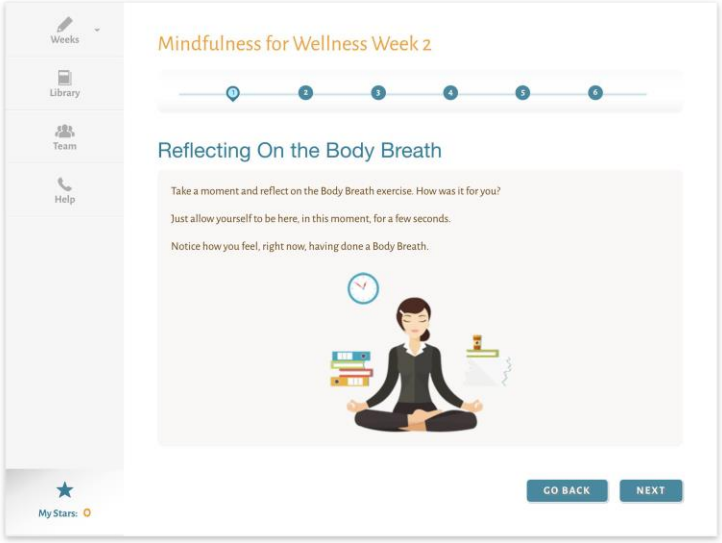
- Brief Mindfulness Intervention: the 3-session **Brief Mindfulness** program was based on the work of **Zeidan** and adapted for a **web-based platform** for this study. This brief mindfulness intervention has been shown to be more effective than sham meditation in reducing **negative mood**, **depression**, and **fatigue**. Participants completed **one session per week** for **3 weeks**, with each session focusing on a single **breath-awareness meditation** exercise. During these exercises, participants learned to **focus on the flow of their breath** while **letting go of thoughts** by returning their attention to the sensations of the breath. They were also guided on how to apply this skill in

daily life and during **stressful situations**. In both groups, participants were limited to completing **one session per week**, but they could access material from previous weeks at any time.

See the examples below retrieved from Supplementary Material (Sylvia et al., 2022).







Sylvia et al. (2022)

Booklet and Text Messages to Target Depression (Taleban et al., 2016)

The content of the booklet was based on educational points documented by the World Health Organization (WHO). The booklet followed the story of a man experiencing depressive symptoms who sought psychotherapy.

- **Chapter 1:** described the signs and symptoms of depression. The patient decided to seek psychotherapy to address his depressive symptoms, and a psychologist explained the benefits of psychotherapy and pharmaceutical treatments.
- **Chapter 2:** in this chapter, the psychologist addressed the patient’s negative thoughts (such as anger, contempt, disgust, and guilt). The therapist also provided effective coping strategies for dealing with insomnia.
- **Chapter 3:** is focused on solutions for overcoming negative thoughts. The patient was also instructed on sleep hygiene techniques.
- **Chapter 4:** encouraged the patient to find and engage in hobbies. It also promoted strategies to overcome insomnia.
- **Chapters 5 and 6:** these final chapters aimed to enhance the patient’s ability to manage problems and improve their coping skills.

The booklet was illustrated with pictures to motivate depressed individuals, making it not just fictional but engaging and relatable.

YOLO Program for Depression, Anxiety, Stress *(Viskovich & Pakenham, 2020)*

Module	Content
Module 1: Values and committed action	Definition of values introductory video, values video, values exercises (e.g., contemplating what is important in your life, 80-year old birthday speech, values drop), committed action exercise (e.g., SMART goal training), troubleshooting video, and experiential avoidance video *Content reflection prompt (at completion of Exercise 2)* – Choose a value you identified in this exercise that you wish to start expressing in your life, identify the “why” behind this value and find one small action to express it
Module 2: Cognitive Defusion	Thought evolution introductory video, defusion exercise (e.g., leaves on a stream), defusion task (e.g., what thoughts hook you), defusing from thoughts video, defusion video, and defusion exercise (e.g., hands as thoughts) *Content reflection prompt (at completion of Exercise 3)* – Reminder to listen to what your mind is saying, create distance and use the “I notice I’m having the thought” strategy
Module 3: Acceptance	Definition of acceptance, willingness video, metaphor (e.g., passengers on the bus) and related task, acceptance exercise (e.g., struggle switch), metaphors (e.g., unwanted party guest), and acceptance exercise (e.g., costs of avoidance and SPACE) *Content reflection prompt (at completion of Exercise 1)* – Quicksand metaphor
Module 4: Mindfulness and the observer self	Mindfulness definition, formal and informal mindfulness task, video on presence, tasks (e.g., practicing mindfulness), metaphor (e.g., classroom metaphor), observing self-video, and observer self exercise (e.g., relaxation observation exercise) *Content reflection prompt (at completion of Exercise 1)* – Do one activity mindfully today

This table has been retrieved from Viskovich & Pakenham (2020).

Cognitive-Behavioural Intervention for Depression (Vázquez et al., 2023)

Contents of the cognitive behavioural app intervention (CBIA), retrieved from Vázquez et al (2023)

Module	Contents
Module 1	Introduction of group members Aim of the program Information on depression and active coping Mood scoring Diaphragmatic breathing training Self-reinforcement Intersession tasks: mood rating, practicing breathing techniques, and self-reinforcement
Module 2	Explanation of the relationship between activities and mood Guidelines and strategies for increasing pleasurable activities Planning of enjoyable activities Behavior contract Intersession tasks: mood rating, practicing breathing techniques, self-reinforcement, and doing planned pleasurable activities
Module 3	Explanation of the relationship between thoughts and mood Thought management techniques (direct approach, priming, and distraction) Planning of enjoyable activities Behavior contract Intersession tasks: mood rating, practicing breathing techniques, self-reinforcement, doing planned pleasurable activities, and practicing thought management techniques
Module 4	Explanation of the relationship between social contact and mood Strategies to increase and improve social relationships Planning enjoyable and social activities Intersession tasks: mood rating, practicing breathing techniques, self-reinforcement, doing planned pleasurable activities, practicing thought management techniques, and making social contact
Module 5	Review of what has been learned. Maintain progress Relapse prevention Good-bye and wrap-up

ICare Prevent for Anxiety and Depression (Zarski et al., 2024)

The **7-session Internet-based Mental Intervention** (IMI) focusing on anxiety and depression included the following components:

- Need orientation
- Beavioural activation
- Psychoeducation
- Cognitive restructuring
- Problem-solving
- Exposure and relapse prevention

An additional booster session occurred 4 weeks after the seventh session. Elective modules covered topics like **rumination, relaxation, self-worth, sleep**, and more. Tailored content within **each session allowed participants to select topics** (e.g., **problem-solving, exposure**) and receive **motivational messages**. The content was interactive, including **text, audio, video, and quizzes**. Participants could also use a **diary** via smartphone.

Acceptance and Commitment Therapy and Skill Coaching for Anxiety and Depression (Levin et al., 2018)

The **ACT Daily mobile app** was delivered as a non-native app **via Qualtrics**, accessible exclusively online through a mobile browser.

Participants received text **message notifications twice daily** throughout the **four-week app period**, prompting them to complete an app check-in. Each app session began with a check-in assessment, consisting of seven items designed to measure psychological functioning and specific pathological processes relevant to ACT skill practice.

After completing the check-in, participants in both the random and tailored app conditions could choose from three options:

- No skill training
- A brief, text-based skill for immediate practice, with the option to view additional quick skills or end the session.
- A longer ACT skill training session, selected from a list of available interactive or audio-guided exercises.

Each skill coaching session was organised by ACT components: acceptance, cognitive defusion, present moment awareness, and values. The app included a library of 28 quick skills and 6 depth skills for each ACT component.

Examples of skill types include:

- Brief version: brief prompts or metaphors to reflect on personal values, along with actionable suggestions for aligning beaviour with those values in the moment.
- Long version: audio-guided exercises like the "sweet spot" reflection or interactive activities like a values card sort to identify and clarify top personal values.

To ensure a basic understanding of the app’s check-in assessments and ACT component skills, participants in both the tailored and random conditions completed a 15-minute online training immediately after being assigned to their intervention.
Skill assignment was either random or tailored:

- **Random condition**: after completing the check-in, participants were randomly assigned to one of the four ACT components (acceptance, cognitive defusion, present moment awareness, or values) regardless of their check-in responses.
- **Tailored condition**: skill assignment was determined by participants’ check-in responses, specifically by identifying the most prominent pathological process they reported at that time. For instance:
  - If "fighting your feelings" was rated highest, participants were directed to acceptance skills.
  - If "stuck in thoughts" scored highest, cognitive defusion skills were selected.
  - "Running on autopilot" triggered present moment awareness skills.
  - "Disconnected from values" prompted values-focused skills.

Apart from the method of skill assignment, both versions of the ACT Daily app were identical in functionality and content.

Cognitive Bias Modification for Interpretation to Reduce Anxiety (Larrazabal et al., 2024)

Participants assigned to the CBM-I conditions completed up to five sessions of positive CBM-I training. Each session included scenarios with **90% positive (benign or non-threatening) resolutions** and **10% negative (anxiety-relevant) resolutions**. The scenarios depicted everyday ambiguous situations that could provoke anxiety.
A subset of the positive scenarios (3 out of 40 per session) was specifically designed to illustrate **resilience**. These scenarios initially presented a negative interpretation of the ambiguity but were then reframed positively to demonstrate resilience-building. Participants were instructed to vividly imagine themselves in each scenario to enhance engagement and encourage episodic simulation (i.e., imagining the scene and reinterpreting it in a new way). Each scenario was paired with an image to further promote user relatability and enjoyment. An example scenario included: *“As you are walking down a crowded street, you see your neighbor on the other side. You call out, but they do not answer you. Standing there in the street, you think this must be because they were distracted”* (positive resolution). After reading each scenario, participants completed a **missing letter task** to finalise the positive resolution. For example, they might select the letter “t” to complete the word “distracted.” The complexity of the task increased across sessions:

- **Sessions 1–2**: scenarios featured 1 missing letter
- **Sessions 3–4**: scenarios featured 2 missing letters
- **Session 5**: half of the scenarios featured 2 missing letters, and the other half required participants to fill in an entire missing word

Participants also answered comprehension questions to reinforce the intended interpretation of each scenario. These questions varied in format, including:

- Binary options like “Yes” or “No”
- Positive or negative interpretations of the scenario

For example, after reading the scenario above, participants might be asked: *"Did your neighbor purposely ignore your call to them in the street?"*. Feedback and repeated attempts ensured participants internalised the positive interpretations, emphasizing the training’s focus on reshaping thought patterns.

Mindfulness training program for stress management (Yang et al., 2018)

The program was composed as follow:

Session duration:
- Days 1–10: 10 minutes per session
- Days 11–25: 15 minutes per session
- Days 26 onward: 20 minutes per session

Session content:
- Audio-guided prompts delivered in a calm manner with intermittent breaks.
- Instructions include:
  - Noticing the body at rest
  - Breathing intentionally and normally
  - Observing sounds
  - Sensing emotions
  - Acknowledging thoughts without judgment

Mobile Apps to Assess and Treat Depression (Pratap et al., 2018)

The apps used in this study involved psychotherapy principles, therapeutic games, mindfulness and behavioural exercises, providing daily tips for improving well-being:

- **Project Evolution** was inspired by **video game mechanics** and aimed to **modulate cognitive control abilities**, which are often compromised in individuals with depression.
- **Internet-Based Problem-Solving Therapy (iPST)** was based on **problem-solving therapy**, a well-established and evidence-based treatment for depression. This app guided users through structured exercises designed to help them tackle life’s challenges and manage depressive symptoms.
- **HTips** offered **daily health tips** designed to help overcome depressed mood. These tips focused on simple **self-care activities**, such as taking a shower or engaging in **physical activity** like going for a walk. While this app didn’t include therapeutic interventions per se, it provided daily behavioural suggestions to help improve mood and encourage healthy habits.

To ensure participants remained engaged, each app included **built-in reminders** that prompted users to engage with the app on a **daily basis**. These reminders were sent once a day to encourage consistent use of the app, helping to establish a routine and maximize the potential benefits of the intervention.

Two Smartphone Apps Targeting Depression (Bakker et al., 2021)

MoodMission is an evidence-based app designed to help overcome feelings of depression and anxiety through:

- **Personalised missions**: after indicating how one feels, the app suggests five simple, quick, and effective missions based on scientific research to improve mood.
- **Education**: each mission includes explanations about how and why it can be helpful, increasing understanding of coping strategies.
- **Reward system**: completing missions earns users rewards within the app, motivating them to take steps toward greater health and happiness.

MoodKit is based on Cognitive Beavioural Therapy (CBT) and offers four main tools:

- **Mood improvement activities**, with over 200 activities categorised into areas such as Productivity, Social, Pleasure, Physical, and Healthy Habits, aimed at promoting well-being
- **Thought checker**, helping users identify and restructure negative or distorted thoughts, fostering a more balanced perspective.
- **Mood tracking**, allowing users to record and monitor their mood over time, facilitating the identification of emotional patterns.
- **Journal**, offering customisable templates to reflect on events, thoughts, and personal progress.

Run4Love Program for Depression and Stress (Guo et al., 2020)

The **Run4Love program** was delivered through the enhanced **WeChat platform**, which was customized to provide additional features that supported participants throughout the program:

- **Automated information:** sending regular updates and resources were automatically sent to participants.
- **Progress tracking**: participants’ progress in completing the course and engaging in physical activity was monitored.
- **Weekly personalized feedback**: each week, participants received feedback tailored to their progress, reinforcing their efforts and encouraging continued participation.

Session	Content	Week
Session 1	Introduction to the program and stressors and stress responses	1
	Audio Progressive muscle relaxation for 16 muscle groups	
Session 2	Stress and awareness	2
	Audio Progressive muscle relaxation for 8 muscle groups	
Session 3	Negative thinking and cognitive distortions	3
	Audio Breathing, imagery, passive progressive muscle relaxation for 4 muscle groups	
Review 1	Review and course evaluation of session 1, 2, and 3	4
Session 4	Anxiety and depression	5
	Audio Breathing, imagery, passive progressive muscle relaxation	
Session 5	Rational thought replacement	6
	Audio Autogenic training for heaviness and warmth	
Session 6	Productive coping and executing effective coping responses	7
	Audio Autogenic training for heartbeat, breathing, abdomen, and forehead	
Review 2	Review and course evaluation of session 4, 5, and 6	8
Session 7	Introduction of meditation	9
	Audio Autogenic training with imagery and self-suggestions	
Session 8	Anger management	10
	Audio Mantra meditation	
Session 9	Social support and review of the program	11
	Audio Imagery and meditation	
Review 3	Review and course evaluation of all sessions	12

Table retrieved from the study protocol, i.e., Guo et al. (2018)

XiaoE Intervention: A CBT-Based Chatbot with Personalised Customization for Depression (He et al., 2022)

The intervention delivered by **XiaoE** is grounded in the principles of **Cognitive Beavioural Therapy (CBT)**, incorporating **multiturn dialogue** and **personalised customisation** as the main intervention forms.
The intervention consists of **seven modules**, each focused on a key psychological concept. These modules are designed to address different aspects of mental health and personal development, and they include:

- **Cognition Challenge** – Focuses on addressing **cognitive distortions**.
- **Improve Self-esteem** – Aimed at enhancing **self-esteem**.
- **Learn to Relax** – Introduces **mindfulness meditation** techniques.
- **Energy List** – Designed to boost **mental energy**.
- **Wonderful World** – Encourages **natural connection** and appreciation of life.
- **Are You OK** – A self-assessment module for checking in on one's mental state.
    - **Escape from Loneliness** – Focuses on overcoming **loneliness**.

Each of these modules corresponds to a fundamental psychological concept, helping users work through cognitive distortions, improve their mood, and enhance their overall mental well-being.
Participants in the trial were asked to complete **one module per day** for a **1-week intervention period**, following a structured sequence. In addition to the modules, participants were encouraged to complete a **"Gratitude Journal"** every day, where they could record positive events and their mood, helping to reinforce positive thinking patterns.
XiaoE was designed to guide participants through the intervention with **complete process guidance** and **daily task reminders**. The chatbot provided participants with clear instructions and prompts, ensuring they stayed on track with their daily tasks. Throughout the trial, participants were only required to follow the chatbot's guidance each day.

Internet CBT Program for Depression (Imamura et al., 2014)

This web-based program was designed to provide participants with **stress management skills** and was delivered over a **six-week** period. Each week, participants worked through one lesson, and the total time required for each lesson, including homework, was approximately **30 minutes**.
The **iCBT program** was structured into **six lessons**, each designed to teach participants a different skill aimed at reducing stress and improving mental health, providing both theoretical knowledge and practical exercises.
A unique and engaging feature of this program was the integration of a **Manga story** (i.e., a Japanese comic) featuring a psychologist and a client worker. The use of this **comic story** served as a teaching tool to help participants better understand the concepts presented in the program.
The program was grounded in **Cognitive Beavioural Therapy (CBT)** and covered several key therapeutic techniques:

- **Self-monitoring skills**
- **Cognitive restructuring**

- **Assertiveness**
- **Problem-solving skills**
- **Relaxation techniques**

A Mobile Health Intervention for Depression and Anxiety (Bendtsen et al., 2020)

The protocol of the intervention is described in the following table.

Week	Theme	Number of text messages	Examples of content
1	Gratitude	7	• Reflect on things you are grateful for in life. • Reflect on positive events. • Information on gratitude.
2	Savouring	12	• Mindfulness exercise that prompted users to use your five senses to savour the moment. • Reminiscing on positive events • Information on savouring and living in the moment.
3	Thought patterns	11	• Strategies to break negative thought patterns • Activities to break negative thought patterns • Information on how our thoughts influence our well-being
4	Personal strengths	6	• Identify personal strengths • Develop/expand personal strengths • Information on personal strengths
5	Kindness	9	• Prompt to do acts of kindness • Reflect on how kindness affect our well-being • Information on kindness
6	Empathy and meaningful relations	7	• Tips on how to strengthen relationships • Tips on communication styles • Information on how our social environment influence our well-being
7	Health behaviours	13	• Meditation exercise • Information on the role of physical activity, eating habits, moderate alcohol consumption and smoking on our well-being.
8	Optimism and thoughts about the future	9	• My best possible self exercise • Strategies of how to handle setbacks • Information on the role of optimism on our well-being
9	Goal setting	9	• Define personal goals • Reflect on personal goals and their meaning
10	Plan for the future	9	• Identify favourite exercise in the program • Lessons learnt • Action planning

Retrieved from Bendtsen et al. (2020)

Foundations: a Digital Mental Health App for Anxiety (Catuara-Solarz et al. 2022)

The protocol of the intervention is described in the following table.

Table 1. Activity formats and descriptions of the content delivered in Foundations.

Activity	Number of activities	Type of content	Description
Slides	12	Psychoeducation	Comprises individual screens of 1-2 sentences that the user swipes through. Usually 10-20 screens
Article/blog	13	Psychoeducation and tips	User scrolls through to read. Typically 0.25-1 of A4 page in length
Add record	10	Journaling/reflection	User can add free text (eg, thought records or gratitude journaling)
Label record	5	Journaling/reflection	User selects a record created by the “add record” feature and can choose a theme label
Question record	5	Journaling/reflection	User selects a previous record and is asked a series of questions about the record. There is a free-text box for the user to write in
Record review	4	Journaling/reflection	Log of record entries
Audios	17	Mindfulness/meditations	Mindful meditations (5-8 min), sleep meditations (30 min), relaxation techniques
Ambient sounds	8	Ambient sounds	30-min relaxation sounds and soundscapes (eg, waves, rain)
Quiz	6	Interactive psychoeducation	Reinforces psychoeducation with two-choice answers
Game	1	Spatial working memory game	The user has to recall spatial sequences

Table 2. Description of programs and the number of activities within each program.

Program name	Number of activities	Description
Become a breathing master	3	Teaches the skill of diaphragmatic breathing
Relax your body and mind	2	Teaches the skill of progressive muscle relaxation
Working with thoughts	5	CBT[a]-based journaling and reflection. Includes psychoeducation on cognitive distortions and questions to balance unhelpful thoughts
Positive thinking	5	Gratitude journaling on achievements, reasons to be thankful, and people
Healthy sleep habits	9	CBT psychoeducation on healthy sleep habits and sleep hygiene
Break your bad sleep habits	4	CBT interactive psychoeducation on breaking bad habits
Take control of your sleep	9	CBT sleep scheduling
Constructive worry for sleep	4	Introduces constructive worry to put worries aside before bed
3 days to improve your self-esteem	10	CBT-based journaling and psychoeducation on automatic thoughts and balancing thoughts about oneself
Boost your confidence	3	Identify strengths

Retrieved from Catuara-Solarz et al. (2022).

Mindfulness-based online intervention for stress and social support (Dai et al., 2022)

The protocol of the intervention is described in the following table.

Week	Practice	Content	Homework
1 	Mindful eating practice, mindful breathing meditation	Introduction to mindfulness and its importance. Summaries on how to incorporate mindfulness into daily life, previous application and scientific findings of mindfulness-based interventions.	Daily life mindfulness practices and mindful breathing meditation for 5–10 min daily for 7 days a week.
2 	Mindful body scan practice, 3-min breathing space practice	Introduction to brain's mode of action and being. Instructing participants to talk to their bodies	Mindful body scan practice, 3-min breathing space practice, and filling in pleasant/unpleasant experiences calendar for 10–15 min daily for 7 days a week, respectively.
3 	Sitting meditation (mountain meditation and mindful sleep meditation)	Introduction to the scientific understanding of sleep, sleep hygiene education, and seven attitudes of practicing mindfulness	Sitting meditation and mindfulness clock for 15 min daily for 7 days a week, respectively
4 	Mindful walking meditation, sitting meditation (lake meditation)	Introduction to mindful living with thoughts, using the “STOP” and “RAIN” principle to deal with a storm of thoughts and emotions	Mindfulness listening practice, mindfulness movement, and STOP/ RAIN practice for 15–20 min daily for 7 days a week, respectively
5 	Mindful yoga practice	Introduction to mindful movement for relaxing body and mind. Explanation of identification of avoidance response, allowing and letting it go	Sitting meditation for 15 min daily for 7 days a week and practice mindful yoga three times a day as appropriate
6 	Sounding meditation; loving and kindness meditation	Introduce to tired funnel and how to balance daily life, mindful living with a challenge, and how to live a mindful life, live in the present	listing nourishing/consuming activities and weaving mindfulness parachute

Retrieved from Dai et al. (2022)

3.5 Conclusions

From the results of this systematic review, a range of effective interventions addressing **mental health challenges** such as depression, anxiety, stress, and social support have been identified. **Cognitive Beavioural Therapy** (CBT) was the most frequently employed and effective method, showing significant benefits in reducing symptoms of depression and anxiety across multiple studies (e.g., Bakker et al., 2021; Vázquez et al., 2023). **Mindfulness techniques**, as well as relaxation and meditation, were also highlighted for their efficacy in managing anxiety, stress, and depression (e.g., Catuara-Solarz et al., 2022; Lyzwinski et al., 2019; Yang et al., 2018). **Acceptance and Commitment Therapy** (ACT) and **Beavioural Activation** were shown to be particularly effective in addressing anxiety, depression and perceived stress (e.g., Levin et al., 2018; Viskovich & Pakenham, 2019; Li et al., 2024). To note, improvements in ACT intervention were sustained during follow-up assessments (Viskovich & Pakenham, 2019). While Positive Psychology was explored in only one study (Bendsten et al., 2020), it demonstrated significant potential, especially considering that additional studies showed the effectiveness of combining CBT-based techniques, Mindfulness, and Positive Psychology, with each other but also with other techniques (e.g., neurofeedback, relaxation techniques). Indeed, other notable interventions included **Psychoeducation**, **Cognitive Training**, and **Cognitive Bias Modification for Interpretation** (CBM-I), which targeted specific psychological processes to alleviate symptoms (e.g., Guo et al., 2020; Larrazabal et al., 2024). Additionally, **Integrative approaches** combining multiple techniques, such as CBT with mindfulness or systemic psychology, demonstrated robust outcomes (e.g., Litvin et al., 2023). Only one study investigated social support (Lindsay et al., 2019) and find mindfulness to be effective in enhancing it.

Given these findings, our first proposal for iBeChange is to consider CBT-based techniques and mindfulness as core interventions, including elements of ACT and Positive Psychology along with psychoeducational contents. Indeed, these interventions effectively addressed the key psychological variables of interest (anxiety, depression, and stress), and mindfulness was effective for increasing social support.

The **outcomes presented** in this deliverable will play a crucial role in supporting the development of **Task 2.7**, which focuses on the design of the interventions. Particularly, they will support the design of the interventions for **psychosocial health pillar**.
Furthermore, **UNIPA** and **IEO** are organising a **seminar** (*December 10, 2024*) where evidence-based strategies and best practices will be shared to support sustainable lifestyle choices and mental well-being. This specific seminar will permit to increase and to share knowledge with technical partners about how the **iBeChange Platform** should be developed according to **beavioural change theory and techniques**.

Following this, we will host a **workshop** (*December 16, 2024*) that will allow partners to explore digital solutions, modules, and functions in light of the findings we have obtained. The digital psychological interventions identified through this systematic review will be thoroughly discussed among all clinical partners to ensure a comprehensive evaluation of their suitability for the iBeChange automated intervention. Moreover, technical partners will have the chance to assess their feasibility for implementation. Through a collaborative process, we will carefully identify the

interventions most appropriate for inclusion in the iBeChange automated intervention. Additionally, we will examine how best to integrate these interventions into the user journey and develop detailed plans for their delivery.

Finally, both this **systematic review** (**Task 2.4**) and the preceding **umbrella review** (**Task 2.2**, see D2.1) will be prepared for publication in open access journals in the coming months to ensure the dissemination of the insights gained within the scientific community on psychosocial factors related to cancer onset and digital psychological interventions to address them.

4 Conclusions

The findings from **Deliverable D2.2**, particularly from Tasks 2.3 (“Behavioural change interventions and techniques inventory”) and 2.4 (“Psychosocial support and interventions inventory”), represent a significant advancement in our understanding of the behavioural and psychosocial factors that impact cancer prevention. **Task 2.3’s** systematic review identified a range of effective Behaviour Change Techniques (BCTs) tailored to address key risk factors such as physical activity, diet, smoking, alcohol consumption, and weight management. These insights form the foundation for the development of Behaviour Change (BC) support tools within the iBeChange platform, ensuring that the interventions are based on the best available evidence.

Similarly, **Task 2.4** provided a comprehensive evaluation of digital psychosocial interventions, identifying effective strategies to address emotional distress, anxiety, and depression - factors that significantly affect individuals’ ability to maintain healthy behaviours. These psychosocial interventions will be integral to the platform’s Emotional Wellbeing (EW) tools, enhancing the system’s capability to not only promote behaviour change but also support users in managing emotional and psychological barriers to achieving sustained health improvements.

These findings align closely with other tasks and activities within the iBeChange project. For example, the insights gathered in Tasks 2.3 and 2.4 will contribute directly to the design and functionality of the recommendation systems (Task 4.3), which will provide users with personalised, evidence-based suggestions for behavioural and emotional support.

The findings from **Deliverable D2.2**, particularly from Tasks 2.3 (“Behavioural change interventions and techniques inventory”) and 2.4 (“Psychosocial support and interventions inventory”), can significantly contribute to the advancement of the iBeChange project’s goals of integrating behavioural change techniques and psychosocial interventions into its platform. The systematic reviews conducted in these tasks identified effective BCTs for addressing key behavioural risk factors like physical activity, nutrition, smoking, alcohol consumption, and weight management. Moreover, the review of digital psychosocial interventions in Task 2.4 has highlighted strategies for managing stress, anxiety, and depression, which are crucial in addressing the psychosocial risks that influence cancer prevention behaviours. These interventions are set to be integrated into the platform to promote user engagement and adherence to the recommended changes.

Additionally, the collaboration between clinical, psychological, and technical partners will facilitate the continuous refinement of these interventions. These efforts will ensure that the platform’s tools are aligned with user needs and clinical best practices, offering a comprehensive and adaptable approach to cancer prevention.

Moving forward, the integration of these findings into the co-design process (Task 2.7) will ensure that the iBeChange platform remains dynamic and user-centred, continuously evolving to meet the needs of its users. By leveraging both behavioural science and cutting-edge technology, the iBeChange project is can make a meaningful impact on primary cancer prevention across the European Union, supporting individuals in achieving and maintaining healthier lifestyles in the long term.

In conclusion, the outcomes of Tasks 2.3 and 2.4 lay the groundwork for the next stages of development, ensuring that the iBeChange platform remains a robust, scientifically grounded tool for primary cancer prevention.

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Annex 1

BCT Taxonomy Overview (from Michie et al., 2013, supplemental material)

No.	Label	Definition	Examples
1. Goals and planning			
1.1	***Goal setting (behaviour)***	Set or agree on a goal defined in terms of the behaviour to be achieved	Agree on a daily walking goal (e.g. 3 miles) with the person and reach agreement about the goal Set the goal of eating 5 pieces of fruit per day as specified in public health guidelines
1.2	***Problem solving***	Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators	Identify specific triggers (e.g. being in a pub, feeling anxious) that generate the urge/want/need to drink and develop strategies for avoiding environmental triggers or for managing negative emotions, such as anxiety, that motivate drinking Prompt the patient to identify barriers preventing them from starting a new exercise regime e.g., lack of motivation, and discuss ways in which they could help overcome them e.g., going to the gym with a buddy
1.3	*Goal setting (outcome)*	Set or agree on a goal defined in terms of a positive outcome of wanted behaviour	Set a weight loss goal (e.g. 0.5 kilogram over one week) as an outcome of changed eating patterns
1.4	***Action planning***	Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive)	Encourage a plan to carry condoms when going out socially at weekends Prompt planning the performance of a particular physical activity (e.g. running) at a particular time (e.g. before work) on certain days of the week
1.5	*Review behaviour goal(s)*	Review behaviour goal(s) jointly with the person and consider modifying goal(s) or behaviour change strategy in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of (or in addition to) the first, or no change	Examine how well a person’s performance corresponds to agreed goals e.g. whether they consumed less than one unit of alcohol per day, and consider modifying future behavioural goals accordingly e.g. by increasing or decreasing alcohol target or changing type of alcohol consumed
1.6	*Discrepancy between current behaviour and goal*	Draw attention to discrepancies between a person’s current behaviour (in terms of the *form, frequency, duration, or intensity* of that behaviour) and the person’s previously set outcome goals, behavioural goals or action plans (goes beyond self-monitoring of behaviour)	Point out that the recorded exercise fell short of the goal set

No.	Label	Definition	Examples
1.7	*Review outcome goal(s)*	Review outcome goal(s) jointly with the person and consider modifying goal(s) in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of, or in addition to the first	Examine how much weight has been lost and consider modifying outcome goal(s) accordingly e.g., by increasing or decreasing subsequent weight loss targets
1.8	*Behavioural contract*	Create a written specification of the behaviour to be performed, agreed on by the person, and witnessed by another	Sign a contract with the person e.g. specifying that they will not drink alcohol for one week
1.9	*Commitment*	Ask the person to affirm or reaffirm statements indicating commitment to change the behaviour	Ask the person to use an “I will” statement to affirm or reaffirm a strong commitment (i.e. using the words “strongly”, “committed” or “high priority”) to start, continue or restart the attempt to take medication as prescribed
2. Feedback and monitoring			
2.1	*Monitoring of behaviour by others without feedback*	Observe or record behaviour with the person’s knowledge as part of a behaviour change strategy	Watch hand washing behaviours among health care staff and make notes on context, frequency and technique used
2.2	*Feedback on behaviour*	Monitor and provide informative or evaluative feedback on performance of the behaviour *(e.g. form, frequency, duration, intensity)*	Inform the person of how many steps they walked each day (as recorded on a pedometer) or how many calories they ate each day (based on a food consumption questionnaire).
2.3	*Self-monitoring of behaviour*	Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy	Ask the person to record daily, in a diary, whether they have brushed their teeth for at least two minutes before going to bed Give patient a pedometer and a form for recording daily total number of steps
2.4	*Self-monitoring of outcome(s) of behaviour*	Establish a method for the person to monitor and record the outcome(s) of their behaviour as part of a behaviour change strategy	Ask the person to weigh themselves at the end of each day, over a two week period, and record their daily weight on a graph to increase exercise behaviours
2.5	*Monitoring outcome(s) of behaviour by others without feedback*	Observe or record outcomes of behaviour with the person’s knowledge as part of a behaviour change strategy	Record blood pressure, blood glucose, weight loss, or physical fitness
2.6	*Biofeedback*	Provide feedback about the body *(e.g. physiological or biochemical state)* using an external monitoring device as part of a behaviour change strategy	Inform the person of their blood pressure reading to improve adoption of health behaviours
2.7	*Feedback on outcome(s) of behaviour*	Monitor and provide feedback on the outcome of performance of the behaviour	Inform the person of how much weight they have lost following the implementation of a new exercise regime
3. Social support			

No.	Label	Definition	Examples
3.1	*Social support (unspecified)*	Advise on, arrange or provide social support *(e.g. from friends, relatives, colleagues,' buddies' or staff)* or non-contingent praise or reward for performance of the behaviour. It includes encouragement and counselling, but only when it is directed at the behaviour	Advise the person to call a 'buddy' when they experience an urge to smoke Arrange for a housemate to encourage continuation with the behaviour change programme Give information about a self-help group that offers support for the behaviour
3.2	*Social support (practical)*	Advise on, arrange, or provide practical help *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behaviour	Ask the partner of the patient to put their tablet on the breakfast tray so that the patient remembers to take it
3.3	*Social support (emotional)*	Advise on, arrange, or provide emotional social support *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behaviour	Ask the patient to take a partner or friend with them to their colonoscopy appointment
4. Shaping knowledge			
4.1	*Instruction on how to perform a behaviour*	Advise or agree on how to perform the behaviour	Advise the person how to put a condom on a model of a penis correctly
4.2	*Information about antecedents*	Provide information about antecedents (*e.g. social and environmental situations and events, emotions, cognitions)* that reliably predict performance of the behaviour	Advise to keep a record of snacking and of situations or events occurring prior to snacking
4.3	*Re-attribution*	Elicit perceived causes of behaviour and suggest alternative explanations *(e.g. external or internal and stable or unstable)*	If the person attributes their over-eating to the frequent presence of delicious food, suggest that the 'real' cause may be the person's inattention to bodily signals of hunger and satiety
4.4	*Behavioural experiments*	Advise on how to identify and test hypotheses about the behaviour, its causes and consequences, by collecting and interpreting data	Ask a family physician to give evidence-based advice rather than prescribe antibiotics and to note whether the patients are grateful or annoyed
5. Natural consequences			
5.1	*Information about health consequences*	Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour	Explain that not finishing a course of antibiotics can increase susceptibility to future infection Present the likelihood of contracting a sexually transmitted infection following unprotected sexual behaviour
5.2	*Salience of consequences*	Use methods specifically designed to emphasise the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences)	Produce cigarette packets showing pictures of health consequences e.g. diseased lungs, to highlight the dangers of continuing to smoke

No.	Label	Definition	Examples
5.3	*Information about social and environmental consequences*	Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behaviour	Tell family physician about financial remuneration for conducting health screening Inform a smoker that the majority of people disapprove of smoking in public places
5.4	*Monitoring of emotional consequences*	Prompt assessment of feelings after attempts at performing the behaviour	Agree that the person will record how they feel after taking their daily walk
5.5	*Anticipated regret*	Induce or raise awareness of expectations of future regret about performance of the unwanted behaviour	Ask the person to assess the degree of regret they will feel if they do not quit smoking
5.6	*Information about emotional consequences*	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behaviour	Explain that quitting smoking increases happiness and life satisfaction
6. Comparison of behaviour			
6.1	*Demonstration of the behaviour*	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate	Demonstrate to nurses how to raise the issue of excessive drinking with patients via a role-play exercise
6.2	*Social comparison*	Draw attention to others' performance to allow comparison with the person's own performance	Show the doctor the proportion of patients who were prescribed antibiotics for a common cold by other doctors and compare with their own data
6.3	*Information about others' approval*	Provide information about what other people think about the behaviour. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do	Tell the staff at the hospital ward that staff at all other wards approve of washing their hands according to the guidelines
7. Associations			
7.1	*Prompts/cues*	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour. The prompt or cue would normally occur at the time or place of performance	Put a sticker on the bathroom mirror to remind people to brush their teeth
7.2	*Cue signalling reward*	Identify an environmental stimulus that reliably predicts that reward will follow the behaviour	Advise that a fee will be paid to dentists for a particular dental treatment of 6–8-year-old, but not older, children to encourage delivery of that treatment (the 6–8-year-old children are the environmental stimulus)
7.3	*Reduce prompts/cues*	Withdraw gradually prompts to perform the behaviour	Reduce gradually the number of reminders used to take medication
7.4	*Remove access to the reward*	Advise or arrange for the person to be separated from situations in which unwanted behaviour can be rewarded in order to reduce the behaviour	Arrange for cupboard containing high calorie snacks to be locked for a specified period to reduce the consumption of sugary foods in between meals
7.5	*Remove aversive stimulus*	Advise or arrange for the removal of an aversive stimulus to facilitate behaviour change	Arrange for a gym-buddy to stop nagging the person to do more exercise in order to increase the desired exercise behaviour

No.	Label	Definition	Examples
7.6	*Satiation*	Advise or arrange repeated exposure to a stimulus that reduces or extinguishes a drive for the unwanted behaviour	Arrange for the person to eat large quantities of chocolate, in order to reduce the person's appetite for sweet foods
7.7	*Exposure*	Provide systematic confrontation with a feared stimulus to reduce the response to a later encounter	Agree a schedule by which the person who is frightened of surgery will visit the hospital where they are scheduled to have surgery
7.8	*Associative learning*	Present a neutral stimulus jointly with a stimulus that already elicits the behaviour repeatedly until the neutral stimulus elicits that behaviour	Present repeatedly fatty foods with a disliked sauce to discourage the consumption of fatty foods
8. Repetition and substitution			
8.1	*Behavioural practice/ rehearsal*	Prompt practice or rehearsal of the performance of the behaviour one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill	Prompt asthma patients to practice measuring their peak flow in the nurse's consulting room
8.2	*Behaviour substitution*	Prompt substitution of the unwanted behaviour with a wanted or neutral behaviour	Suggest that the person goes for a walk rather than watches television
8.3	*Habit formation*	Prompt rehearsal and repetition of the behaviour in the same context repeatedly so that the context elicits the behaviour	Prompt patients to take their statin tablet before brushing their teeth every evening
8.4	*Habit reversal*	Prompt rehearsal and repetition of an alternative behaviour to replace an unwanted habitual behaviour	Ask the person to walk upstairs at work where they previously always took the lift
8.5	*Overcorrection*	Ask to repeat the wanted behaviour in an exaggerated way following an unwanted behaviour	Ask to eat only fruit and vegetables the day after a poor diet
8.6	*Generalisation of a target behaviour*	Advise to perform the wanted behaviour which is already performed in a particular situation, in another situation	Advise to repeat toning exercises learned in the gym when at home
8.7	*Graded tasks*	Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behaviour isperformed	Ask the person to walk for 100 yards a day for the first week, then half a mile a day after they have successfully achieved 100 yards, then two miles a day after they have successfully achieved one mile
9. Comparison of outcomes			
9.1	*Credible source*	Present verbal or visual communication from a credible source in favour of or against the behaviour	Present a speech given by a high status professional to emphasise the importance of not exposing patients to unnecessary radiation by ordering x-rays for back pain
9.2	*Pros and cons*	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behaviour	Advise the person to list and compare the advantages and disadvantages of prescribing antibiotics for upper respiratory tract infections
9.3	*Comparative imagining of future outcomes*	Prompt or advise the imagining and comparing of future outcomes of changed versus unchanged behaviour	Prompt the person to imagine and compare likely or possible outcomes following attending versus not attending a screening appointment
10. Reward and threat			

No.	Label	Definition	Examples
10.1	*Material incentive (behaviour)*	Inform that money, vouchers or other valued objects *will be* delivered if and only if there has been effort and/or progress in performing the behaviour	Inform that a financial payment will be made each month in pregnancy that the woman has not smoked
10.2	*Material reward (behaviour)*	Arrange for the delivery of money, vouchers or other valued objects if and only if there *has been* effort and/or progress in performing the behaviour	Arrange for the person to receive money that would have been spent on cigarettes if and only if the smoker has not smoked for one month
10.3	*Non-specific reward*	Arrange delivery of a reward if and only if there *has been* effort and/or progress in performing the behaviour	Identify something (e.g. an activity such as a visit to the cinema) that the person values and arrange for this to be delivered if and only if they attend for health screening
10.4	*Social reward*	Arrange verbal or non-verbal reward if and only if there *has been* effort and/or progress in performing the behaviour	Congratulate the person for each day they eat a reduced fat diet
10.5	*Social incentive*	Inform that a verbal or non-verbal reward *will be* delivered if and only if there has been effort and/or progress in performing the behaviour	Inform that they will be congratulated for each day they eat a reduced fat diet
10.6	*Non-specific incentive*	Inform that a reward *will be* delivered if and only if there has been effort and/or progress in performing the behaviour	Identify an activity that the person values and inform them that this will happen if and only if they attend for health screening
10.7	*Self-incentive*	Plan to reward self in future if and only if there has been effort and/or progress in performing the behaviour	Encourage to provide self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet
10.8	*Incentive (outcome)*	Inform that a reward *will be* delivered if and only if there has been effort and/or progress in achieving the behavioural outcome	Inform the person that they will receive money if and only if a certain amount of weight is lost
10.9	*Self-reward*	Prompt self-praise or self-reward if and only if there *has been* effort and/or progress in performing the behaviour	Encourage to reward self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet
10.10	*Reward (outcome)*	Arrange for the delivery of a reward if and only if there *has been* effort and/or progress in achieving the behavioural outcome	Arrange for the person to receive money if and only if a certain amount of weight is lost
10.11	*Future punishment*	Inform that future punishment or removal of reward will be a consequence of performance of an unwanted behaviour	Inform that continuing to consume 30 units of alcohol per day is likely to result in loss of employment if the person continues
11. Regulation			
11.1	*Pharmacological support*	Provide, or encourage the use of or adherence to, drugs to facilitate behaviour change	Suggest the patient asks the family physician for nicotine replacement therapy to facilitate smoking cessation
11.2	*Reduce negative emotions* [b]	Advise on ways of reducing negative emotions to facilitate performance of the behaviour	Advise on the use of stress management skills, e.g. to reduce anxiety about joining Alcoholics Anonymous
11.3	*Conserving mental resources*	Advise on ways of minimising demands on mental resources to facilitate behaviour change	Advise to carry food calorie content information to reduce the burden on memory in making food choices

No.	Label	Definition	Examples
11.4	*Paradoxical instructions*	Advise to engage in some form of the unwanted behaviour with the aim of reducing motivation to engage in that behaviour	Advise a smoker to smoke twice as many cigarettes a day as they usually do Tell the person to stay awake as long as possible in order to reduce insomnia
12. Antecedents			
12.1	*Restructuring the physical environment*	Change, or advise to change the physical environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments)	Advise to keep biscuits and snacks in a cupboard that is inconvenient to get to Arrange to move vending machine out of the school
12.2	*Restructuring the social environment*	Change, or advise to change the social environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments)	Advise to minimise time spent with friends who drink heavily to reduce alcohol consumption
12.3	*Avoidance/reducing exposure to cues for the behaviour*	Advise on how to avoid exposure to specific social and contextual/physical cues for the behaviour, including changing daily or weekly routines	Suggest to a person who wants to quit smoking that their social life focus on activities other than pubs and bars which have been associated with smoking
12.4	*Distraction*	Advise or arrange to use an alternative focus for attention to avoid triggers for unwanted behaviour	Suggest to a person who is trying to avoid between-meal snacking to focus on a topic they enjoy (e.g. holiday plans) instead of focusing on food
12.5	*Adding objects to the environment*	Add objects to the environment in order to facilitate performance of the behaviour	Provide free condoms to facilitate safe sex Provide attractive toothbrush to improve tooth brushing technique
12.6	*Body changes*	Alter body structure, functioning or support directly to facilitate behaviour change	Prompt strength training, relaxation training or provide assistive aids (e.g. a hearing aid)
13. Identity			
13.1	*Identification of self as role model*	Inform that one's own behaviour may be an example to others	Inform the person that if they eat healthily, that may be a good example for their children
13.2	*Framing/reframing*	Suggest the deliberate adoption of a perspective or new perspective on behaviour (e.g. its purpose) in order to change cognitions or emotions about performing the behaviour	Suggest that the person might think of the tasks as reducing sedentary behaviour (rather than increasing activity)
13.3	*Incompatible beliefs*	Draw attention to discrepancies between current or past behaviour and self-image, in order to create discomfort	Draw attention to a doctor's liberal use of blood transfusion and their self-identification as a proponent of evidence-based medical practice
13.4	*Valued self-identity*	Advise the person to write or complete rating scales about a cherished value or personal	Advise the person to write about their personal strengths before they receive

No.	Label	Definition	Examples
		strength as a means of affirming the person's identity as part of a behaviour change strategy	a message advocating the behaviour change
13.5	*Identity associated with changed behaviour*	Advise the person to construct a new self-identity as someone who 'used to engage with the unwanted behaviour'	Ask the person to articulate their new identity as an 'ex-smoker'
14. Scheduled consequences			
14.1	*Behaviour cost*	Arrange for withdrawal of something valued if and only if an unwanted behaviour is performed	Subtract money from a prepaid refundable deposit when a cigarette is smoked
14.2	*Punishment*	Arrange for aversive consequence contingent on the performance of the unwanted behaviour	Arrange for the person to wear unattractive clothes following consumption of fatty foods
14.3	*Remove reward*	Arrange for discontinuation of contingent reward following performance of the unwanted behaviour	Arrange for the other people in the household to ignore the person every time they eat chocolate (rather than attending to them by criticising or persuading)
14.4	*Reward approximation*	Arrange for reward following any approximation to the target behaviour, gradually rewarding only performance closer to the wanted behaviour	Arrange reward for any reduction in daily calories, gradually requiring the daily calorie count to become closer to the planned calorie intake
14.5	*Rewarding completion*	Build up behaviour by arranging reward following final component of the behaviour; gradually add the components of the behaviour that occur earlier in the behavioural sequence	Reward eating a supplied low-calorie meal; then make reward contingent on cooking and eating the meal; then make reward contingent on purchasing, cooking and eating the meal
14.6	*Situation-specific reward*	Arrange for reward following the behaviour in one situation but not in another	Arrange reward for eating at mealtimes but not between meals
14.7	*Reward incompatible behaviour*	Arrange reward for responding in a manner that is incompatible with a previous response to that situation	Arrange reward for ordering a soft drink at the bar rather than an alcoholic beverage
14.8	*Reward alternative behaviour*	Arrange reward for performance of an alternative to the unwanted behaviour	Reward for consumption of low-fat foods but not consumption of high-fat foods
14.9	*Reduce reward frequency*	Arrange for rewards to be made contingent on increasing duration or frequency of the behaviour	Arrange reward for each day without smoking, then each week, then each month, then every 2 months and so on
14.10	*Remove punishment*	Arrange for removal of an unpleasant consequence contingent on performance of the wanted behaviour	Arrange for someone else to do housecleaning only if the person has adhered to the medication regimen for a week
15. Self-belief			
15.1	*Verbal persuasion about capability*	Tell the person that they can successfully perform the wanted behaviour, arguing against self-doubts and asserting that they can and will succeed	Tell the person that they can successfully increase their physical activity, despite their recent heart attack.
15.2	*Mental rehearsal of successful performance*	Advise to practise imagining performing the behaviour successfully in relevant contexts	Advise to imagine eating and enjoying a salad in a work canteen

No.	Label	Definition	Examples
15.3	*Focus on past success*	Advise to think about or list previous successes in performing the behaviour (or parts of it)	Advise to describe or list the occasions on which the person had ordered a non-alcoholic drink in a bar
15.4	*Self-talk*	Prompt positive self-talk (aloud or silently) before and during the behaviour	Prompt the person to tell themselves that a walk will be energising
16. Covert learning			
16.1	*Imaginary punishment*	Advise to imagine performing the unwanted behaviour in a real-life situation followed by imagining an unpleasant consequence	Advise to imagine overeating and then vomiting
16.2	*Imaginary reward*	Advise to imagine performing the wanted behaviour in a real-life situation followed by imagining a pleasant consequence	Advise the health professional to imagine giving dietary advice followed by the patient losing weight and no longer being diabetic
16.3	*Vicarious consequences*	Prompt observation of the consequences (including rewards and punishments) for others when they perform the behaviour	Draw attention to the positive comments other staff get when they disinfect their hands regularly

Version history

Version	Description	Date completed
v1.0	First upload	27/12/2024