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Implementing behaviour change theory and techniques to increase physical activity and prevent functional decline among adults aged 61–70: The PreventIT project

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ABSTRACT

The health and wellbeing benefits of engaging in physical activity (PA), and of improving strength and balance, are well documented. The World Health Organization's recommendations of 150 min per week of moderate intensity physical activity have been adopted across the world in policy and practice recommendations. However, the number of older adults engaging in this level of PA remains low. The European Project, PreventIT, has adapted the Lifestyle-integrated Functional Exercise (LiFE) programme, which reduced falls in people 75 years and over, for a younger cohort (aLiFE). aLiFE incorporates challenging strength and balance/agility tasks, as well as specific recommendations for increasing physical activity and reducing sedentary behaviour in young-older adults, aged 60–70 years. Personalised advice is given on how to integrate strength, balance and physical activities into daily life. aLiFE has been further developed to be delivered using smartphones and smartwatches (eLiFE), providing the opportunity to send timely motivational messages and real-time feedback to the user. Both aLiFE and eLiFE are behaviour change interventions, supporting older adults to form long-term physical activity habits. PreventIT has taken the original LiFE concept and further developed the behaviour change elements, explicitly mapping them to Social Cognitive Theory, Habit Formation Theory and 30 Behaviour Change Techniques (BCTs). Goal setting, planning, prompts and real-time feedback are used to deliver a person-centred experience. Over 1300 motivational messages have been written, mapped to psychological theory, BCTs and evidence regarding the importance of strength, balance and PA. A motivational assessment tool has been developed to enable us to investigate stated motivational drivers with actual performed behaviour within the feasibility Randomised Controlled Trial. The PreventIT mHealth intervention focusses on behaviour change from initiation to long-term maintenance, addressing the different phases of adopting a healthier lifestyle. As such, it makes a strong contribution to the developing field of evidence-based mobile health (mHealth).

Contents

Abbreviations and acronyms: aLiFE, adapted Lifestyle-integrated Functional Exercise;; App, Application; BCTs, Behaviour Change Techniques; eLiFE, enhanced Lifestyle-integrated Functional Exercise; HAPA, Health Action Process Approach; HFT, Habit Formation Theory; LiFE, Lifestyle-integrated Functional Exercise; PA, Physical Activity; RCT, Randomised Controlled Trial; SCT, Social Cognitive Theory.

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Introduction

The global population is ageing. It is projected that from 2000 until 2050, the world's population aged 60 and over will more than triple from 600 million to two billion.[1] The health and wellbeing benefits of engaging in physical activity (PA) are well known.[2–5] The World Health Organization's recommendations of 150 min per week of moderate intensity physical activity, with the addition of strength training for those aged 18–64 and additional balance exercises for those aged 65 and over, have been adopted across the world in policy and as practice guidelines.[6–8] However, the number of older adults engaging in PA remains low.[6,9] Inactivity increases with age and less than a third of older adults report any regular exercise.[10] Even when older adults initiate exercise they often discontinue involvement within six months.[11] Adherence rates to formal exercise programmes and interventions are poor over time.[12,13] For many people reaching their seventh decade, engagement in formal exercise or sport is not appealing.[14,15] To maximise the number of healthy years that people experience as they transition into their later life, we need to find new ways of encouraging older adults to adopt a more physically active lifestyle. In this paper, we present how refining and developing a strong conceptual understanding of behavioural change can also assist to delineate useful techniques for implementing a functionally-integrated balance, strength and physical activity programme.

Integrating physical activity into daily routines is emerging as a promising alternative to structured exercise programmes in older populations.[16] The PreventIT project is a Horizon 2020 European Commission funded project led by a consortium of universities, university hospitals and companies with combined skills in technology development, medical science, behavioural science, communication solutions, healthcare innovation, and product development. Through this collaboration, the consortium aimed to achieve early identification of risk factors for functional decline in younger older adults, and empower them to self-manage their own health and function by adopting a healthy, active lifestyle (www.preventit.eu). The project aimed to develop two personalised behaviour change interventions, with exercise integrated into daily life, for adults aged 61–70 years. The approach adopted builds on the Lifestyle-integrated Functional Exercise (LiFE) programme, which focuses on integrating strength, balance and physical activities into everyday life and was originally developed as a fall prevention intervention for adults 75 years and over.[17,18] Participants are taught to find opportunities in daily routines to challenge their balance and load their muscles. For example, challenging balance through standing on one leg whilst cleaning teeth, or loading muscles by performing a partial-squat whilst emptying a dishwasher. By adopting this approach, many opportunities can be found throughout the day and week to work on strength, balance and increase PA, without having to make extra time for a formal exercise programme. Within the population of community dwelling persons aged 75 years and over, the LiFE programme was found to significantly reduce falls, improve physical function, decrease disability and improve adherence, compared to a traditional exercise programme and a sham intervention.[17] Taking this programme as its starting point, the EC Horizon 2020 PreventIT project has adapted the activities and guidance to focus on a younger population (61–70 years).[19] Adaptations include further physical and neuro-motor challenges, such as hopping and jumping to improve agility; the addition of a physical activity module; and greater emphasis on breaking up sedentary time, in order to prevent age-related functional decline.[19]

The PreventIT project includes the development and feasibility study of (i) a younger age (61–70 years) adapted intervention (aLiFE) and (ii) an Information and Communication Technology (ICT)-enabled version of aLiFE, named eLiFE, and testing a three-site, three-armed feasibility randomised controlled trial (RCT). For eLiFE, all elements of the aLiFE intervention have been adapted to be delivered through smartphone and smartwatch applications (Apps), with progress monitoring and real-time feedback prompting participants to remain engaged in the programme. The two intervention arms run alongside a control arm, with controls being given information about the World Health Organization's recommendations for physical activity.[9] The feasibility RCT is described in detail in the PreventIT feasibility RCT protocol paper.[20] It includes a six-month active intervention phase, with regular contact from project staff, followed by a six-month independent phase, when participants continue with the programme unsupported. At baseline, six months and 12 months, participants undertake a series of assessments to evaluate the feasibility of the intervention, together with physical measures of strength, balance and physical activity to obtain estimates of change.

The original LiFE programme is underpinned by the behavioural change concepts of habit formation, self-efficacy, skills training and outcomes gained.[21] The PreventIT project has extended the behavioural change framework supporting the interventions. Recent studies and reviews have shown that theory-based interventions can significantly increase PA and have the potential to improve population health at low cost.[22,23] Behaviour change theories identify how an intervention should work and guide intervention development.[24] We are then able to test our ideas, attempting to explain and predict behaviour change,[24] generalise findings from previous work into novel areas,[25,26] and to further refine and develop the theories themselves.[24] In the absence of explicit theory, ineffective interventions are repeated, such as focusing on the risks of not being physically active (e.g. chronic diseases, falls), which we know are not effective.[27] However, research tells us that the application of theories within interventions is often not clearly specified, limiting our ability to understand exactly what works and why.[23] Thus there is a need for clear and systematic applications of theory in the development of interventions, as described in the U.K. Medical Research Council's guidance for evaluating complex interventions.[28] Describing them clearly makes the intervention easier to replicate and enables us to more easily identify successful components, which is particularly important in clinical trials. This paper presents the development of the PreventIT behavioural change strategy, which has been developed through three stages: (1) developing the conceptual model and identifying theory; (2) implementing the model; (3) measuring motivation and behavioural change.

Stage one: developing the conceptual model and identifying theory

In order to develop the conceptual model for the aLiFE and eLiFE interventions, we mapped out how the Lifestyle-integrated Functional Exercise programme, with its inclusion of habit formation, self-efficacy, skills training and functional gains,[21] could achieve the outcomes of the PreventIT project (improved balance; increased strength; increased physical activity; reduced sedentary time), identifying the mechanisms

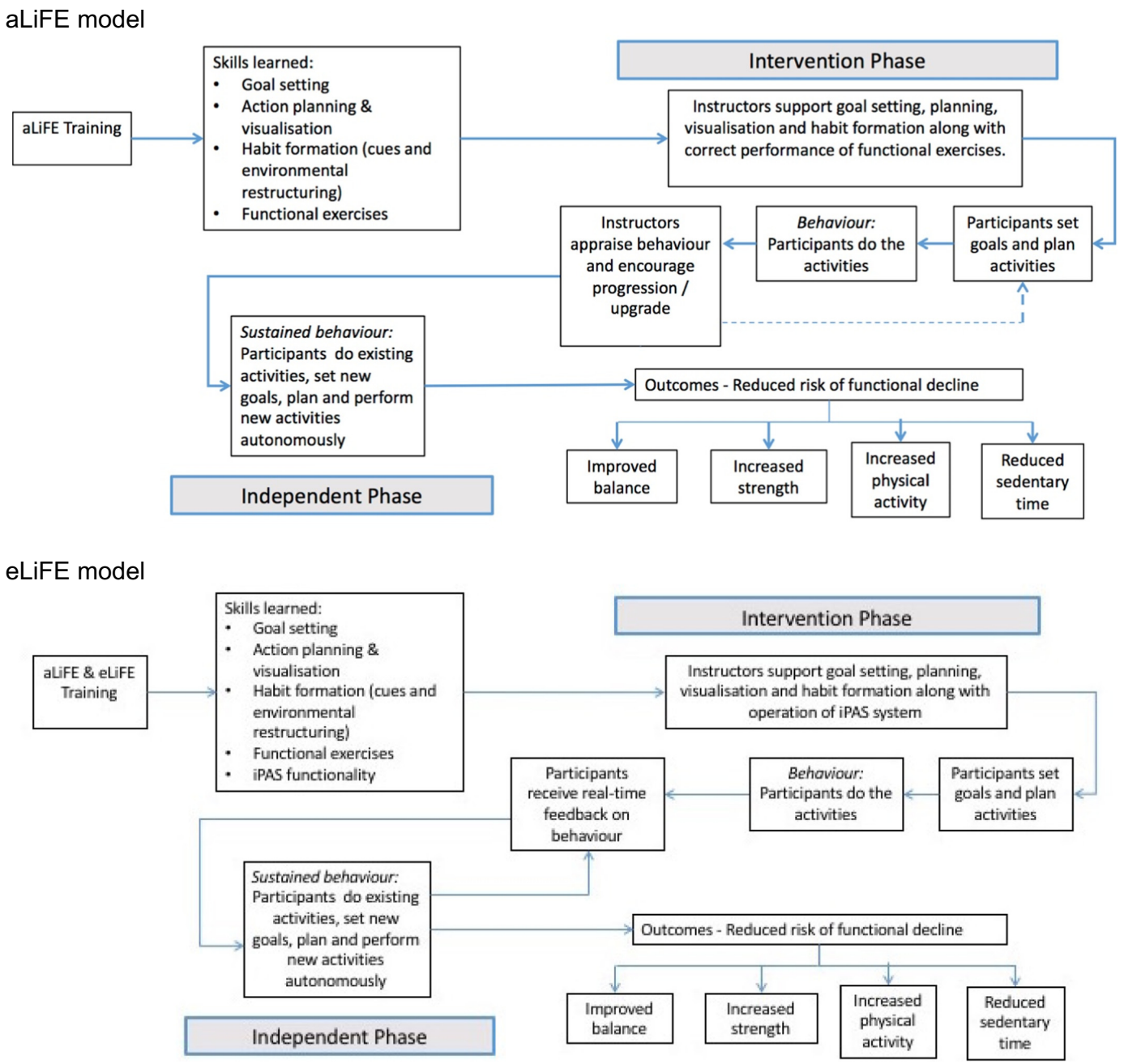

Fig. 1. The aLiFE and eLiFE conceptual models.

at work. Fig. 1 presents the conceptual models for aLiFE (above) and eLiFE (below).

In both interventions, instructors delivering the programme receive training on the evidence and concepts underpinning the LiFE approach. They learn how to set goals related to individuals' lifestyles and desires (to be able to walk in the mountains); to make detailed plans for activities that would help people to achieve those goals (to strengthen legs through squatting when emptying the dishwasher and improve agility through practising stepping patterns); to understand how habits are formed through performance and repetition of activities in unvarying contexts; the correct performance of strength, balance and physical activities; and, in the case of eLiFE, how the smartphone and smartwatch technology operates to support these processes. Following this training, instructors support participants to understand and undertake the programme. With initial support, participants set their own goals and plan activities that will help them to achieve their desired outcomes. Once they have commenced the programme, aLiFE participants receive feedback from instructors through a series of home visits and phone calls during the active intervention phase of the first six months. In eLiFE, feedback is provided through the smartphone App, in real time (described in Stage Two in this paper), and participants are encouraged to remain engaged and receive tailored recommendations to upgrade their activities according to their progress. During the subsequent 6-month independent phase, participants receive no further visits or phone calls. They are encouraged to continue with their existing activities, to upgrade them, to set new goals, and plan activities autonomously. In eLiFE only, feedback continues through the App.

The LiFE approach[21] targets self-efficacy, in that it encourages participants to master or improve a particular skill, (e.g. balancing on one leg whilst doing an everyday task such as waiting for the kettle to boil). Once a participant is able to perform this skill without undue challenge, they are encouraged to upgrade the task, for example, by adding a

cognitive challenge (e.g. talking on the telephone). In addition, the LiFE approach encourages participants to consider their own personal motivations through setting goals and thinking about the outcomes they want to achieve. This focus on self-efficacy and outcome expectancies led us to look at Social Cognitive Theory (SCT)[29] as a theoretical underpinning. Self-efficacy has been defined as "the belief in one's capabilities to organize and execute the courses of action required to produce given attainments"[29] Theoretically, a person with high self-efficacy regarding her/his capacity to be more active is more likely to initiate increases in physical activity, as well as sustain attempts to maintain these increases when faced with barriers. In a recent systematic review, interventions reviewed generally were successful at increasing self-efficacy and physical activity.[30] SCT highlights the importance of self-efficacy, risk perception and outcome expectancies in forming intentions to change behaviour,[29] but stops short of showing how to turn those intentions into action. Given the focus in LiFE on detailed action planning, we looked to the Health Action Process Approach (HAPA) to recognise the different phases of behavioural change, from forming intentions in a motivational phase, to turning them into action in a volitional phase.[31] The HAPA was chosen as it is the only model of health behaviour change to specifically focus on how to bridge the gap between intention and actual performance of a new behaviour.[31] It has also demonstrated good validity across a variety of health behaviours, including physical activity.[32–34]

It appears to have particular reference to eLiFE where the processes underpinning adoption and sustainability of aLiFE activities include the real-time feedback loop to support habit formation. The HAPA model is presented in Fig. 2.

The links between the HAPA constructs and the PreventIT interventions are presented in Table 1. Our use of HAPA recognises that adopting and maintaining a new behaviour is a long-term process, which must be supported by detailed planning and confidence in one's own ability to integrate strength, balance and physical activities into daily life successfully. We have developed our interventions to focus and support each of these elements of behaviour change explicitly.

The original LiFE programme applied Habit Formation Theory (HFT), which states that new behaviours must first be planned and visualised in a specific location and situation. Then, the target behaviour should be performed repeatedly, in the same location and situation, until it has become habitual.[35,36] To increase the likelihood of habit formation, prompts and cues can be used to remind the participant to perform the behaviour. In terms of our overall model of behaviour change, we regard HFT as an extension of the volitional stages of the HAPA. Planning activities, which are then performed repeatedly in stable contexts, will lead to automatic performance of the behaviour. Increased physical activity will become a habitual part of everyday life.

The LiFE programme can only be successful if participants change their behaviour to integrate strength and balance activities into their everyday lives. As such, our starting point with adapting the LiFE programme to younger older adults was to identify the behaviour change techniques (BCTs) that would be used. To address the need to clearly

Table 1
Links between HAPA constructs and PreventIT interventions.

HAPA construct	Link to PreventIT interventions
Action self-efficacy	Participant believes they can become more active; they can find opportunities in daily life to improve balance, increase strength, move more and sit less.
Outcome expectancies	Participant believes they will gain from changing their behaviour; they will achieve positive outcomes through taking part in the programme.
Risk perception	Participant believes there will be negative consequences if they do not change their behaviour; they will experience functional decline and loss of independence as they age.
Action planning	Participants are supported to identify opportunities to integrate strength, balance and physical activity into their daily routines. Resources are provided to enable participants to record their plans and monitor their progress.
Coping planning	Participants are supported to identify barriers and make plans to address these. For example, if a participant is going away on holiday, they could make plans to pack their walking shoes so that they can maintain their daily walk. Coping plans can also take the form of garnering social support from friends or family.
Coping self-efficacy	Participant believes that they can continue with their new behaviour even when barriers arise.
Recovery self-efficacy	Participant believes that they can return to performing the new behaviour even when there has been a long period of disengagement. For example, if they have been in hospital or unwell for a long period of time.

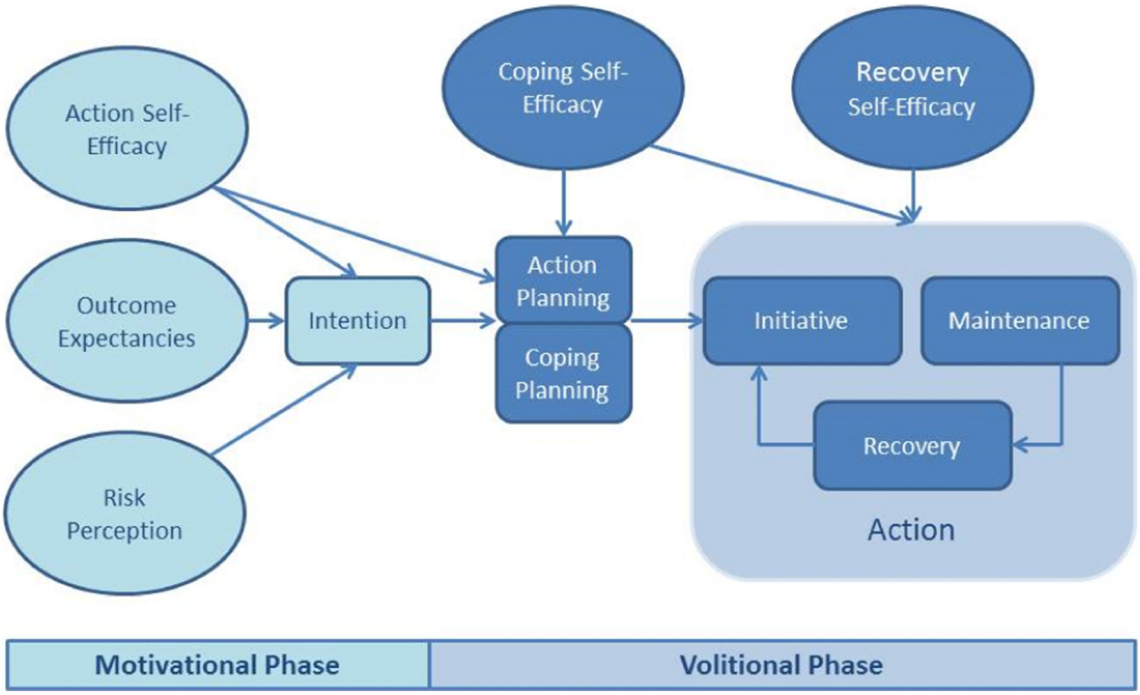

Fig. 2. The Health Action Process Approach (HAPA) model of behavioural change, following Schwarzer.[31]

Table 2
Behaviour change techniques used in PreventIT.

Behaviour change techniques	aLiFE content	eLiFE content
1. Goals and planning		
1.1 Goal setting (behavioural – which activities and how often?).	Daily routine chart, activity planner.	App content (planning screens), instructor.
1.2 Problem solving.	Manual, instructor,	App content, instructor.
1.3 Goal setting (outcome – long term).	Paper form, instructor.	App content (planning screens), instructor.
1.4 Action planning.	Activity planner, instructor.	App content (planning screens), instructor.
1.5 Review behavioural goals.	Activity planner, activity counter.	App content (daily reporting).
1.6 Discrepancy between current behaviour and goal.	Paper form, activity planner.	App content (motivational messaging, activity reporting).
1.7 Review outcome goals.	Paper form, activity planner, activity counter, instructor.	App content (motivational messaging, activity reporting).
2. Feedback and monitoring		
2.2 Feedback on behaviour.	Instructor.	App content (real-time feedback).
2.3 Self-monitoring of behaviour.	Activity planner, activity counter.	App content (activity reporting).
2.4 Self-monitoring of outcomes of behaviour.	Activity planner, activity counter.	App content (motivational messaging).
2.6 Biofeedback	Not included.	System components (accelerometer) and app content (feedback screens).
2.7 Feedback on outcomes of behaviour.	Instructor.	App content (real-time feedback).
3. Social support		
3.1 Social support	Instructor.	App content (motivational messaging).
4. Shaping knowledge		
4.1 Instruction on how to perform the behaviour.	Manual, instructor.	App content (text, pictures, videos).
5.Natural consequences		
5.1 Information about health consequences.	Manual.	App content (motivational messaging).
5.3 Information about social and environmental consequences.	Manual.	App content (motivational messaging).
6. Comparison of behaviour		
6.1 Demonstrate the behaviour.	Manual (text, pictures), instructor.	App content (text, pictures, videos).
6.2 Social comparison.	Not included.	App content (motivational messaging).
6.3 Information about others' approval.	Not included.	App content (motivational messaging).
7. Associations		
7.1 Prompts/cues.	Manual, instructor.	App content (planning screens).
8. Repetition and substitution		
8.1 Behavioural practice/rehearsal.	Manual, instructor	App content (planning screens, real-time feedback, motivational messaging).
8.3 Habit formation.	Manual, instructor, activity planner, activity counter.	App content (planning screens, real-time feedback, motivational messaging).
8.6 Generalisation of a target behaviour.	Manual, instructor, daily routine chart, activity planner.	App content (motivational messaging).
8.7 Graded tasks.	Manual, instructor.	App content (planning screens, real-time feedback, motivational messaging).
10. Reward and threat		
10.10 Reward (outcome).	Instructor.	App content (real-time feedback, motivational messaging).
10.3 Non-specific reward.	Instructor.	App content (real-time feedback, motivational messaging).
12. Antecedents		
12.1 Restructuring the physical environment.	Manual, instructor.	App content (planning screens, motivational messaging).
12.2 Restructuring the social environment.	Manual, instructor.	App content (planning screens, motivational messaging).
15. Self-belief		
15.1 Verbal persuasion about capability	Not included.	App content (motivational messaging).
15.3 Focus on past success	Not included.	App content (motivational messaging).

specify the components of an intervention, with clear terminology, Michie et al (2013) developed the Behaviour Change Techniques Taxonomy (BCTTv1.0)[37] describing 93 different techniques that can be used in behaviour change interventions. We reviewed the PreventIT interventions against the taxonomy with the aim of mapping all elements of aLiFE and eLiFE to clearly defined BCTs.

Stage two: implementing the model

Mapping to theoretical constructs and behaviour change techniques

Having identified the HAPA as the core model, we strengthened the emphasis on goal setting for outcomes in the aLiFE intervention. We drew upon research on promoting physical activity with older adults in the target group of 61–70 year olds, spoke to people delivering exercise to older adults and compiled a list of 43 goals for participants to select from. Goals were then organised under the headings: 'activity related' (walk further; go hiking with friends); 'daily life related' (maintain independence; carry heavy bags); 'health related' (lose weight; become stronger); 'wellbeing related' (improve quality of life; relieve stress). Participants can also add their own goals, if these are not included in the list provided.

Detailed action planning for when, where and in which situations to carry out strength, balance and physical activities was already part of the original LiFE programme (Daily Routine Chart; Activity Planner), together with procedures and tools for monitoring progress (Activity Planner; Activity Counter), so we used the BCT taxonomy to map and classify these processes. In so doing, we identified that PreventIT could employ 30 of the 93 different behaviour change techniques in Michie et al.'s taxonomy,[37] as shown in Table 2. The BCTs are implemented in different ways, depending on the intervention delivery.

In aLiFE, the BCTs related to information and support are provided to the participant through a series of home visits and phone calls from an

instructor, written materials (aLiFE manual) and monitoring forms. In eLiFE, whilst the instructor carries out some initial home visits and phonecalls, this is largely to explain the concept of lifestyle- integrated activities and to explain the content and functionality of the smartphone App and the smartwatch. In place of the aLiFE manual, eLiFE participants can read text, listen to audio and watch video instructions about the programme and activities within the PreventIT App. (See http://www.preventit.eu/index.php/about-preventit/videos-preventit/ to view the App video instructions in action.) Examples of the planning tools for aLiFE and eLiFE are shown in Fig. 3.

An important difference between aLiFE and eLiFE is that the latter affords the opportunity to introduce regular prompts and real-time feedback to participants on their performance of planned activities. Participants are asked to self-report on their performance of strength and balance activities and they receive feedback regarding their achievements. Physical activity is recorded objectively by the sensors embedded in the Android smartphones and smartwatches. Graphical feedback is given to participants based on their personal goals (activities performed, time spent sedentary, minutes spent walking).

Providing feedback to individuals as they adopt a new behaviour is a powerful method of motivating them to continue.[38,39] Our eLiFE messages include i) prompts and reminders to participants to carry out the activities that they have planned; ii) references to the goals that they have set at the beginning, to show how engaging in eLiFE would help them to achieve their goals; iii) encouragement and congratulations when participants are doing well; and, iv) encouragement and suggestions when participants are not doing as much activity as they planned. The reporting options and examples of responses are presented in Table 3. Feedback is linked to self-reporting of achievements for strength, balance and some planned physical activities, and to actual activity data, recorded by embedded sensors in the smartphone and smartwatch, for physical activity and sedentary behaviour. When participants self-report on their planned activities, they receive an immediate feedback message, examples of which are provided in Table 3. To reduce the risk of feedback messages becoming repetitive, 57 different feedback responses have been included. In addition, when the sensors in the smartwatch and smartphone detect a (pre-specified) period of 30 or 60 min of sedentary time, an alert is sent to remind the participant to stand up and move around. Data on time spent sedentary and in active minutes is presented to the participant as graphical feedback on screens showing daily, weekly and longer-term achievements.

As demonstrated by the HAPA model, adopting a new behaviour, or changing behaviour, is a process of progressing through different stages. As such, our messages are related to those stages. In total, 1322 motivational messages have been written, mapped to the constructs of the HAPA (Fig. 2) and to the four outcome areas of PreventIT: strength, balance, physical activity and sedentary behaviour. The message types include general prompts and specific feedback related to selected long term goals. Examples of messages for each construct are presented in Table 4 and the numbers of messages written for each construct and domain are provided in Table 5. The large number of messages related to the strength domain reflect the fact that there are several elements to building lower limb muscle strength. These include strengthening the muscles supporting the ankles, the knees and the hips. Our messages have been broken down into each of these elements of muscle strengthening.

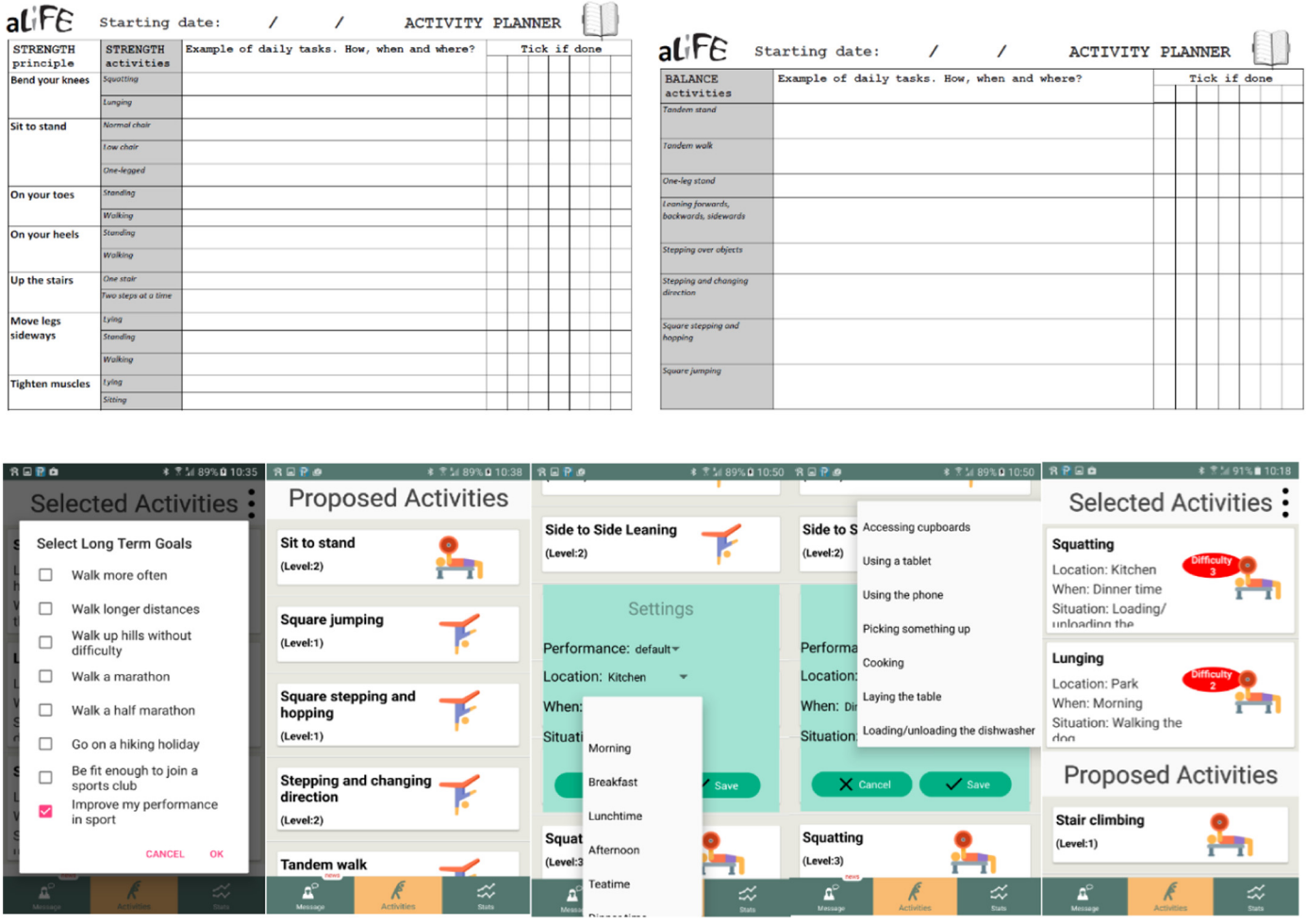

Fig. 3. Examples of planning tools in aLiFE (above) and eLiFE (below).

Table 3
Reporting response options and example feedback.

Responses to reporting questions	Feedback 1	Feedback 2	Feedback 3
Yes - I did more than I planned	That's terrific!	Great work!	Super!
Yes - I did them all	Well done! You are making progress towards your goal! We will check this activity again tomorrow.	Well done! You've done this activity every day for a week. Is it time to make it harder?! Do you want to add a new activity?	Good work!
Yes - but not as much as I intended	Can you fit in some more activities today?	Don't worry, you're still doing well.	Stay positive. You're on the right track.
No - I didn't feel well	Sad face emoji + Sorry you don't feel well. Do you want to try again tomorrow?	Sad face emoji + Try again when you are well.	Sad face emoji + Hopefully you will feel better tomorrow.
No - I forgot	Don't worry, sometimes things don't go to plan. Try again tomorrow and let's see how you do.	Don't worry, you're still using the app so you're on the right path!	It's ok, tomorrow could be better.
No - I didn't have time	Don't worry, perhaps you will have more time tomorrow.	It's ok. You can try again tomorrow.	Can you find more time tomorrow?
No - I don't like this activity	Don't worry if this activity isn't for you. Let's plan a different one.	Ok. You could select a different activity to achieve your goals.	Perhaps you can try a different activity?

Iterative development of the PreventIT application

In order to operationalise the behavioural change strategy for eLiFE, the behaviour change and computer scientists within the PreventIT consortium developed a series of consecutive screens within a smartphone application, replicating the planning and reporting processes within aLiFE. A flow diagram representing these processes is presented in Fig. 4.

A first semi-functional App, with limited functions (pre-alpha version), was developed at the beginning of the project to elicit requirements and to foster debate among the partners. A second fully functional App was developed and tested in Dutch, German and Norwegian in the eLiFE pilot study, which took place between October and December 2016, in Amsterdam, Stuttgart and Trondheim. The study received ethical approval from all three sites and was registered at www.isrctn.com. Fourteen older adults aged 60–70 years used the prototype application for 4 weeks and provided feedback to consortium partners through completion of structured questionnaires, semi-structured interviews and focus groups. Initial feedback from users informed the development of a third semi-functional App, with limited functions but with a complete user interface. This was presented to the users during a usability focus group, to determine which interface they preferred. The App was finalised for the feasibility RCT on the basis of the feedback from the pilot study, the usability focus group, and the interactions among consortium partners and the project's Advisory Board.

Stage 3: Measuring motivation and behavioural change

We have developed a motivational assessment tool, which maps to the constructs of the HAPA,[31] to enable us to look at individual participants' stated motivations at baseline, six months and 12 months. We will be able to explore participants' adherence to the interventions, their self-reported and objectively measured behaviour, alongside the motivational assessments that they will complete. As such, we will be able to explore the relationships between motivation and engagement and contribute to the evidence regarding tailoring interventions on the basis of motivational assessment.

We have administered the Self-Report Behavioural Automaticity Index (SRBAI) questionnaire, which has been found to have good reliability and sensitivity in measuring the relationship between habit and automatic behaviour.[40] We will be able to explore whether aLiFE and eLiFE are feasible interventions for developing and maintaining changes in habit.

In addition, we have developed a specific questionnaire to ask participants about the motivational elements of both aLiFE and eLiFE, to help us to refine and develop the interventions in future iterations. Finally, we will measure usability of the eLiFE smartphone application through the System Usability Scale questionnaire[41] and the Technology Satisfaction Questionnaire for Wearable Technology.[42]The results of these questionnaires will be presented in subsequent papers.

Discussion

There is growing literature on the importance of identifying behaviour change theory and techniques in interventions, whether they are making use of mHealth technologies or not.[23–26] Both the aLiFE and eLiFE interventions have been mapped explicitly to behaviour change theory and behaviour change techniques, as described above. These links between established theories and the way the programme works are essential if we wish to promote this intervention as an evidence-based, effective way to promote healthy ageing.[24] This detailed mapping will enable us to understand how our interventions work in the feasibility RCT, identify necessary changes before a definitive trial, and hopefully make an important contribution to the field of evidence-based mHealth. Results will be published by the PreventIT consortium in subsequent papers.

Table 4
Examples of messages for each HAPA construct.

HAPA construct	Outcome area (message type)	Motivational message
Outcome expectancies	Strength (goal related)	Stair climbing will give your legs the strength to power up hills.
Action self-efficacy	Physical activity (prompt)	Remember to take more steps today. Could you walk to the shops?
Action planning	Strength (prompt)	Remember to do your strength activities today. How many times can you fit them in today?
Coping self-efficacy	Balance (prompt)	You can make plans to do your activities when you're away from home.
Coping planning	Sedentary behaviour (prompt)	If you are going to visit family, remember to break up your sitting then too. Tell them what you're doing so they can do it too!
Recovery self-efficacy	Physical activity (prompt)	It's normal to have times when you are not so active, you can get back to where you were before!
Recovery planning	Sedentary behaviour (prompt)	Could you get a family member to remind you to break up your sitting?

Table 5
Numbers of messages by domain, message type and HAPA construct.

		HAPA construct									
		Action self-efficacy	Action planning	Coping self-efficacy	Coping planning	Recovery self-efficacy	Recovery planning	Outcome expectancies	Social support	Social comparison	Totals
PreventIT outcome domain	Strength prompts	8	7	11	9	9	10	15	16	15	100
	Strength goals	0	0	0	0	0	0	688	0	0	688
	Balance prompts	8	7	11	9	9	10	15	10	10	89
	Balance goals	0	3	0	0	0	0	59	10	10	82
	Physical activity prompts	9	8	10	12	9	10	15	14	12	99
	Physical activity goals	0	3	0	0	0	0	74	8	6	91
	Sedentary prompts	6	9	9	9	9	8	9	10	10	79
	Sedentary goals	8	8	8	8	0	0	42	10	10	94
	Totals	39	45	49	47	36	38	917	78	73	1322

Using mobile technologies (smartphones, smart watches and activity trackers) to promote increased physical activity is a rapidly growing field. There are thousands of applications available for consumers to download, which are marketed as encouraging and motivating them to be more active.[43] Data from 2017 reveal that the number of health and fitness Apps in the major App stores was 318,000.[44] By 2020, it is predicted that there will be 5.8 billion smartphones worldwide.[45] However, the failure to ground interventions in theory means that App developers miss an important opportunity to make their Apps more effective.[24]

Intervention developers are, however, recognising the importance of user-centred design, involving potential end-users in the development of mHealth interventions.[46–49] The importance of a person-centred and iterative approach, which is refined to meet end-user requirements, has been recommended by an international expert workshop for developing digital behaviour change interventions.[50] The feedback received from end users, consortium members and the Advisory Board in our pilot studies enabled us to make important adjustments to the motivational elements of our interventions. To promote engagement, we needed to improve the 'look and feel' of the smartphone interface, improving navigation and visualisations. Similar feedback was received during the iterative development of mHealth applications for older adults to manage heart failure.[48,49] Our application is not alone in requiring improvements to responsiveness and other technical issues. For example, older adults with mild cognitive impairment reported frustrations with the application in the study by Scase et al.[49] Importantly, the current feasibility RCT[21] will enable feedback from older adults engaging with our interventions over a 12 month period thus providing valuable information about the feasibility and acceptability of our approach.

Our scoping review of mHealth messages, carried out at the beginning of the project, found no studies that focused exclusively on older adults. Current mobile technologies are not designed with older users in mind.[51,52] However, key findings from studies with adults have been incorporated into the PreventIT behavioural change strategy. They include the importance of coherent, underpinning psychological theory and explicit use of behaviour change techniques[39,53]; the importance of plain language and short messages[54]; 'gain-framing' messages to focus on positive outcomes[55,56]; tailoring feedback to personalise messages[57]; developing a plan for message delivery (time, frequency, length)[39]; ensuring there are sufficient messages to avoid excessive repetition[57]; testing the messages with the target group[57]; and visual representations of progress and achievements.[58]

Conclusions

The identification and application of behaviour change theory and techniques within the PreventIT project has provided a rational and coherent basis for understanding how the aLiFE and eLiFE interventions work. Developing the theory and mapping the interventions to specific BCTs enabled us to develop, test, improve and implement technologies to operationalise the behaviour change strategy within eLiFE. The framework and tools that we have developed will enable us to understand and

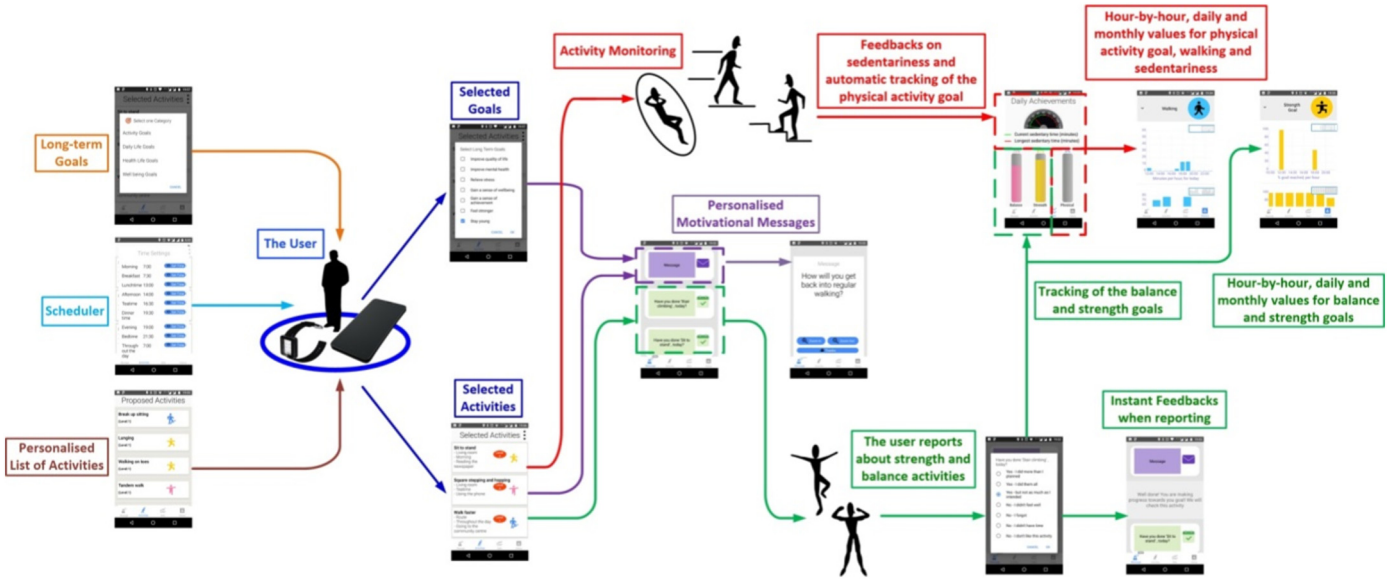

Fig. 4. Flow diagram of planning process and feedback in the application.

evaluate the key concepts underpinning the interventions in the feasibility RCT, providing an exciting opportunity to examine this mHealth approach in detail. This approach is an important one which should be considered by both app developers and researchers when developing and describing technologies and interventions used in studies, including RCTs.

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Conflict of interest

None of the authors have any conflicts of interests with regard to this publication.

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