Chapter 10. Coaching older adults towards a healthier lifestyle: psychological and technological methods

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Abstract This chapter discusses the theoretical behaviour change framework and its integration and implementation of behaviour change techniques that form the conceptual psychological basis for innovative but efficient coaching approach. We review the current state of e-coaching solutions for older adults that can be found in the literature and identify gaps. Finally, we review and discuss the technological implementation of behaviour change techniques applied in NESTORE to support healthy older adults to adopt a healthy lifestyle in all NESTORE well-being domains as reference case study.

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10.1 Introduction

This Chapter presents the insights collected during the NESTORE project for the definition of a multi-domain behaviour change model and its integration in a virtual coach for supporting the user's behaviour change.
From a theoretical point, selecting a specific health-behaviour change model (BCM) as underlying theoretical approach was important as many such models have been proposed in the literature. From the behaviour change techniques (BCTs) perspective, one needs to integrate the variables from the theoretical model with the more general (and digital) intervention strategies and BCTs and apply these to the intervention domains.
As an overarching theoretical framework to the NESTORE project, the lifespan theoretical model of selection with optimization and compensation (SOC) has been proposed. It is a lifespan theoretical model on developmental regulation, i.e., how individuals actively shape their own developmental trajectories in the context of all resources available to them and the changes in these resources with increasing age (i.e., gains and losses). Central tenets of the SOC model are that optimal lifespan development and successful aging are best represented by a positive balance between developmental gains and developmental losses through three strategies (Baltes & Baltes, 1990; Freund, 2008): selection of goals and preferences, optimization in terms of acquiring and improving means for goal attainment, and compensation as counteracting for losses in and blockage of goal-relevant means. The flexible implementation of the three proposed strategies is suggested to lead to the maintenance of one's functional capacity and well-being, and a wide range of empirical evidence supports the central tenets of the SOC model (e.g., Freund, 2008; Freund & Baltes, 2002; Freund & Baltes, 1998).
An important feature of NESTORE is that this coaching platform has been co-designed in participatory fashion, as a friend and companion that helps in assessing the current health status in key domains for aging and health, individuals' personal goals and aims to facilitate the monitoring and person-specific recommendations for health-related behaviour change. As such, it is important that NESTORE focuses on positive coaching strategies (e.g., educational information, highlighting benefits, planning for coping) rather than on negative ones (e.g., punishing, threats).
This chapter is structured as follows: after the introduction, we summarize in Section 2 theoretical BCMs from health psychology and outline why the NESTORE project primarily focuses on the Health Action Process Approach (HAPA) model. In Section 3, we provide an overview over commonly used BCTs and intervention strategies in the health (and aging) domains, including the specific strategies and techniques as they are applied to each of the NESTORE domains. Section 4 mainly summarizes the results of a literature on e-coaching conducted in the health domain, with a particular focus on whether and which health BCMs and BCTs are used across the NESTORE domains. In the fifth section, we describe how the NESTORE system can be implemented in terms of applying the conceptual HAPA framework in the planned e-coaching environment of NESTORE and illustrating the planned

user journey of choosing well-being and health pathways and first illustrations of the planned interfaces. We close this chapter with a brief conclusion.

10.2 Theoretical Behaviour Change Models in Health Psychology

Given the wide range of changes observed in the general population of older adults, including health-related impairments, it is surprising that there is little research on health-behaviour changes in older adults (Ziegelmann & Knoll, 2015). However, the studies that exist and used theory-guided behaviour change have empirically shown to be effective (e.g., Schwarzer et al., 2011). There are many different social-cognitive behaviour change models that provide a conceptual framework for describing and understanding how individuals can successfully adopt a change in behaviour in general, and some models also explicitly target health-related behaviours. These latter models aim to describe how individuals successfully replace health-compromising behaviours (e.g., sedentary behaviour, social reclusion) with health-enhancing behaviours (e.g., physical activity, social integration) through a process of adoption, initiation and maintenance of health behaviours (Schwarzer, 2008). The main goal of these (health) behaviour change theories is to understand how a set of psychological constructs can jointly explain how individual can be motivated to change an established behavioural pattern in the interest of improved or maintained overall long-term health. Many of these share a set of common variables that are listed in Table 1.

Table 1. Overview of Key Concepts in Various Behaviour Change Models

KEY ELEMENT	DEFINITION	STRATEGIES FOR BEHAVIOR CHANGE
Threat	Event that is dangerous or harmful	Raise awareness that the threat exists, focusing on severity and susceptibility
Fear	Emotional experience in response to the perception of a personally relevant threat	Fear can powerfully influence behaviour and, if it is channelled in the appropriate way, can motivate people to seek information, but it can also cause people to deny they are at risk
Intentions	A person's conscious decision and plans to pursue a certain goal	Determine if intentions are genuine or proxies for actual behaviour
Self-Efficacy	An individual's perception of or confidence in their ability to perform a recommended response	Raise individuals' confidence that they can perform response and help ensure they can avert the threat
Response Efficacy	Perception that a recommended response will prevent the threat from happening	Provide evidence of examples that the recommended response will avert the threat

Barriers	Something that would prevent an individual from carrying out a recommended response	Be aware of physical or cultural barriers that might exist, attempt to remove barriers
Benefits	Positive consequences of performing recommended response	Communicate the benefits of performing the recommended response
Subjective Norms	What an individual thinks other people think they should do	Understand with whom individuals are likely to comply
Attitudes	An individual's evaluation or beliefs about a recommended response	Measure existing attitudes before attempting to change them
Cues to Action	External or internal factors that help individuals make decisions about a response	Provide communication that might trigger individuals to make decisions
Reactance	When an individual reacts against a recommended response	Ensure individuals do not feel they have been manipulated or are unable to avert the threat

Note. Table adapted from World Bank (2010).

Existing theoretical health-behaviour change models can be distinguished broadly into two types of models: 1) continuum models and 2) stage models. Continuum models (e.g., Theory of Reasoned Action [Fishbein & Ajzen, 1975], Theory of Planned Behaviour [Ajzen, 1991], Social-Cognitive Theory [Bandura, 1997], Health Belief Model [Rosenstock, 1974], Protection Motivation Theory [Maddux & Rogers, 1983]) describe the degree to which individuals are likely to act, and interventions based on such models focus on moving people closer to action. One characteristic of interventions rooted in continuum models is that they mainly target groups of people (instead of subgroups or individuals) and on changing all variables for all individuals, but no tailoring to particular subgroups occurs.
Stage models (e.g., Transtheoretical Model [Prochaska, Johnson, & Lee, 1998]), on the other hand, divide the behaviour change trajectory into qualitative and ordered stages, into which individuals can be classified. Within a stage, individuals are more similar than across stages. Thus, they provide a good framework for stage-matched treatments for subgroups of individuals. In the context of intervention research, stage models provide some advantages over continuum models because they are not overgeneralizing to the entire population. The HAPA, selected as the conceptual framework for the NESTORE coaching platform represents an integration between continuum and stage models of behaviour change (Schwarzer et al., 2011) and additionally addresses the intention-behaviour gap that other models often neglect.

The HAPA (Schwarzer, 2008) is one of the more recent models in the health-behaviour change literature. Its advantage over the earlier models is that it focuses on two distinct phases (i.e. the motivational phase and volitional phase) and on phase-specific psychological factors explaining or underlying behaviour change (or its failure) in each phase (see Figure 1 for an overview). It thus allows a closer examination and understanding of those variables that underlie intention formation and it also addresses the intention-behaviour gap by including variables (mainly from the self-regulation domain) that mediate the relation between intentions and

the target behaviour. It is thus more comprehensive than other models, which often successfully predict intention itself, but then consider intentions to be the proximal predictor of behaviour, thus ignoring the often-found so-called intention-behaviour gap. In contrast, the HAPA model has identified distinct predictive factors for each of two phases, including post-intentional variables. As mentioned above, the HAPA model has both a continuum and a stage layer, addressing shortcoming of either model type. The inclusion of post-intentional variables as predictors of behaviour addresses criticism of traditional continuum models, which often fail to account for the lacking prediction of behaviour by intention alone. The distinction between two main phases, the motivational and the volitional phase, the HAPA also incorporates a stage-like layer.

According to the HAPA model, the motivational (pre-intentional) phase describes a number of variables thought to predict that individuals form the intention to improve their own health, often through a change in their usual behaviour in a particular domain. During this initial stage, individuals are considered as pre-intenders. Individuals who have made the decision to act and thus have formed an intention but have not yet started to act, are considered intenders in the model. The volitional (post-intentional) phase describes those variables that predict the success of setting the implementation into action. A person's perceived self-efficacy is emphasized in each phase as one of the key variables within the HAPA model (Scholz, Sniehotta, & Schwarzer, 2005). Another important self-regulatory variable during the volitional phase is planning the when, where and how of behaviour, both in general and in the face of obstacles. Individuals in the action phase of the model are considered actors. The model has been applied to a wide range of samples/patient groups and targeting a variety of health behaviours (Schwarzer, Schüz, Ziegelmann, Lippke, Luszczynska, & Scholz, 2007).

Motivational phase: Three key variables to predict the intention to act (Schwarzer, Lippke, & Luszczynska, 2011)

- Risk awareness is thought to prepare the stage for a process of contemplation
- Positive outcome expectancies and self-efficacy jointly operate to form the intention

Volitional phase: Three key variables predict the actual behaviour implementation

- Self-efficacy during the volitional phase is considered an important variable to overcome the intention-behaviour gap and a key asset of the HAPA model (Schwarzer, 2008); degree of confidence a person has about being able to get back on track after a relapse (Scholz, Sniehotta, & Schwarzer, 2005)
- Action planning (when, where and how the target behaviour will be performed): involves the prospective linkage of specific cues from the situational environment with concrete behaviours so that the intention is being put in place (Scholz et al., 2008). An additional self-regulatory strategy in the planning domain is coping planning, which describes

how individuals will deal with problems or difficulties that arise in executing their plans (Schwarzer et al., 2011).

- Action control: comprises sub-facets of general self-regulation (Carver & Scheier, 1998), such as self-monitoring, awareness of standards, and self-regulatory effort, and has also been shown to be a reliable precursor of subsequent behaviour (Sniehotta, Scholz, & Scharzer, 2005)

Much research on the basis of the HAPA considers interindividual differences, that is differences between individuals in a number of health domains (for overview, see Schwarzer, 2008; see also D2.1). There is some initial evidence about the validity of HAPA assumptions on the within-person level (e.g., Bierbauer et al., 2017).

One challenge within the NESTORE project is that NESTORE focuses on a multidimensional approach to health and aims to offer healthy older adults a variety of life domains to choose from and create one's own more holistic coaching intervention. The HAPA variables will have to be applied and assessed for the separate well-being and health domains in NESTORE in a way that allows a complete but yet economic and least burdensome data collection pipeline. There is some evidence in younger and middle-aged groups that multiple health behaviour change interventions (MHBC) versus single health behaviour change interventions (SHBC) can be effective and more efficient in terms of time and costs, but little is known about how these MHBC compare to the SHBC in older adults. Given that older adults often experience multiple health conditions and that even in relatively healthy older adults, changes in resources occur in several domains (e.g., physical, social, cognitive), it would be very useful to examine MHBC also in this age group (e.g., James et al., 2016; Nigg, & Long, 2012). One of the advantages of a focus on more than one domain that has been proposed is that mastery in one domain may foster self-efficacy for changing one's habits in a different domain. On the other hand, a drawback could be that individuals feel overwhelmed. A recent systematic review of six randomized trials that examined the comparative efficacy of two kinds of MHBC interventions suggests that both a sequential and a simultaneous approach can be equally effective, and that further research is needed to pinpoint whether one is indeed advantageous over the other and in which domain and for which population (James et al., 2016). It is also noteworthy that much of this work targets classical health behaviours only (e.g., nutrition, physical activity, smoking), and even less is known through the lens of behaviour change models and interventions for domains such as cognitive and social well-being and health.

Figure 10 shows the HAPA phases and variables that each predict the intention first and the behaviour second. It also provides the general overview of system and general study components. Table 11 in addition indicates which BCT can be mapped onto the variables of the motivational and those of the intention formation and volitional phases. So far, the HAPA model has been used for single health domains and behaviours. Given the multi-domain approach within NESTORE, this strategy would need to be extended to include more than one domain. In order to allow for a clear evaluation of the predictive utility of the conceptual HAPA variables in each phase, in relation to the individually tailored interventions across domains, HAPA variables would need to be assessed for each NESTORE domain.

Table 11 lists exemplar items for the physical activity domain, and these single items can both easily be implemented in the daily life monitoring and coaching phase and be assessed for all those domains a NESTORE user has chosen as part of her individual well-being pathway. BCT can then also be mapped onto the different motivational and volitional variables shown in Table 11 to personalize interventions not only with regard to a given target coaching domain and pathway but also with respect to the conceptual underpinnings of the HAPA framework.

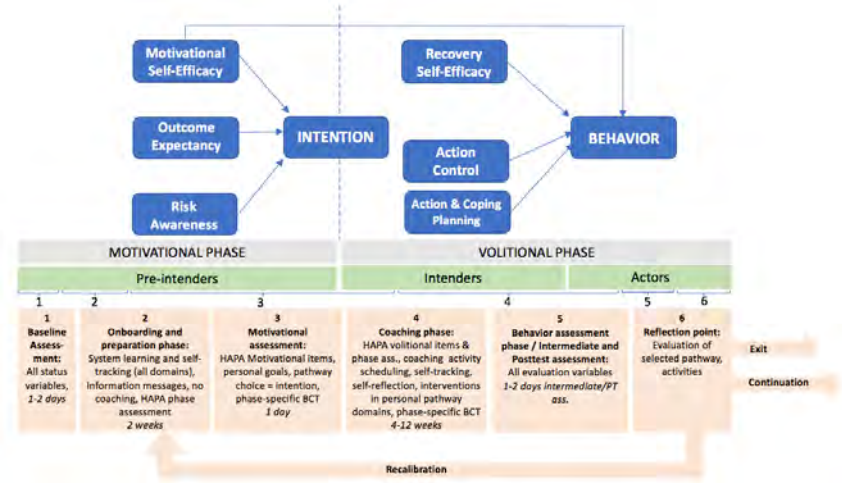

Fig. The Health Action Process Approach Model: Mapping of Study and System Phases

In this context, the stage properties of the HAPA model are useful in following users along their health behaviour change process. As described in Schwarzer et al. (2011), depending on a person's stage position (or mindset) as either pre-intender, intender or actor, different predictor variables are important for the intervention to be successful. For example, in the pre-intentional phase, prompting outcome expectancies and an appropriate level of risk information may be the intervention of choice, as well as highlighting the positive outcomes the new behaviour would have. In other subgroups, such as the actors, are thought to particularly benefit from supporting them in high-risk situations in which relapses are likely.

Table 11. Key Variables from HAPA Model Distinguished by Phase and Including Exemplary Items and Corresponding BCT

Variables proposed to predict the intention / the behaviour	Exemplary item for assessment (in daily life)	Corresponding behaviour change techniques (BCT)
Phase I: Motivational Phase		
Risk awareness	If I am not regularly physically active, the probability is high that I	Educational messages/provide information about health consequences, self-

	will have serious health problems.	monitoring/provide feedback, (social comparison?)
Positive outcome expectancy	There are more advantages than disadvantages in being physically active on a regular basis.	Educational messages/provide information about health consequences, provide general encouragement, self-monitoring/provide feedback, praise
Motivational self-efficacy	I am confident that I will engage in regular physical activity in the next four weeks, even if it is difficult.	Educational messages/provide information about health consequences, provide general encouragement, self-monitoring/radar according to recommendations?
Intention formation		
Behavioural Intention	In the next four weeks, I intend to be regularly physically active.	Behavioural contract
Phase II: Volitional Phase		
Recovery self-efficacy	I am confident that I can be as physically active as I have planned during the next four weeks even as barriers arise.	Provide general encouragement, prompt review of behavioural goals (plans for overcoming barriers and also regarding the personal goals), stress management
Action planning	I have made detailed plans for when and how I will be regularly physically active in the next four weeks.	Calendar scheduling, set graded tasks, social support/social comparison for planning (ideas), time management
Coping planning	I have made a detailed plan regarding what to do if something interferes with my plans	Prompt barrier identification, problem solving
Action control: Awareness of standards Self-monitoring Self-regulatory effort	During the last 4 weeks, I was always aware of my intended training program.	Prompt review of behavioural goals, educational messages, self-tracking, model/demonstrate behaviour, instruction
	During the last 4 weeks, I constantly monitored whether I was as physically active as I had planned.	Self-monitoring, provide feedback Provide general encouragement, self-monitoring / review of performed activities, prompts/reminders (of plans to overcome problems and of goals)
	During the last 4 weeks, I always tried to be as physically active as I had intended.	

During the user journey of selecting a NESTORE well-being and health pathway, it is thus crucial to determine the mindset of a user both with regard to the person's overall willingness and plans to engage in (new) health behaviours, and also concerning the particular subdomains. One easy way of classifying individuals in terms of this mindset (in addition to determining the need for intervention based on the set of baseline status assessments and sensor inputs), one can ask users to self-classify their mindset using Likert Scale questionnaires.

10.3 Behaviour Change Techniques and General Coaching Strategies for Health and Well-Being

There is a large variety of intervention types that can be found in the behaviour change and coaching intervention literature: In a review of prominent health behaviour change researchers (Abraham & Michie, 2008), 26 different general BCTs were identified (see left column of Table 2).

New intervention approaches specifically focus on a range of digital BCTs (see also Abraham & Michie, 2008; Roberts, Fisher, Smith, Heinrich, & Potts, 2017). Several different types or delivery modes of digital interventions can be differentiated:

- Online workshop
- Emails
- Access to e-counsellor
- Website / mobile-enabled website
- Online portal
- Text messaging
- Mobile app
- Wearable and ambient sensors (e.g., Fitbit)
- Telephone counselling
- Social media (Facebook support group)
- Video conferencing (e.g., Skype)

Recently, a focus in the health-behaviour change literature has been on so-called digital BCTs (Roberts et al., 2017), many of which are identical or can at least easily be mapped onto the more traditional (non-digital) BCTs (see right column of Table 2).

Table 2. Overview of General and Equivalent Digital Behaviour Change Techniques

GENERAL BEHAVIOUR CHANGE TECHNIQUES (a)	DIGITAL BEHAVIOUR CHANGE TECHNIQUES (b)
Provide general information	Pros and cons
Provide information on consequences	Provide information about health consequences
Provide information about others' approval	Social reward
Prompt intention formation	
Prompt barrier identification	Problem solving, behaviour substitution
Provide general encouragement	Verbal persuasion about capability
Set graded tasks	Graded tasks
Provide instruction	Instruction of how to perform a behaviour
Model or demonstrate behavior	Demonstration of the behaviour
Prompt specific goal setting	Goal setting (behaviour or goal)
Prompt review of behavioral goals	Review behavioural goals
Prompt self-monitoring of behavior	Self-monitoring of behaviour or goals or outcomes
Provide feedback on performance	Feedback on behaviour
Provide contingent rewards	
Teach to use prompts / cues	Prompts / cues
Agree on behavioral contract	
Prompt practice	
Use follow-up prompts	Prompts / cues
Provide opportunities for social comparison	
Plan social support / social change	Social support
Prompt model identification as role model	
Prompt self-talk	
Relapse prevention	
Stress management	Reduce negative emotions
Motivational interviewing	
Time management	
	Credible source
	Offering deals for healthy goods/ services for completing self-monitoring (independent of behaviour reported)
	Framing / reframing
	Adding objects to the environment

Note. (a) Abraham & Michie (2008); (b) Roberts et al. (2017)

10.4 Health-Related E-Coaching and Digital Intervention Strategies

This section of the chapter focuses on digital interventions (i.e., e-coaching) for a healthy lifestyle in older adults. With respect to traditional eHealth interventions, here we particularly focus on systems that monitor user behaviour and provide personalized suggestions to improve health-related goals through a virtual coach. Such a coach can be simply embedded in smartphone devices (e.g., app), but can also have a more anthropomorphic and physical embodiment, for example in form of an Embodied Conversational Agents (ECA) or a robot. As defined by Banos and Nugent (2018) in the introduction to a recent IEEE Computer special issue on E-coaching for Health, coaching a user means to "frequently, but not continuously, observe, listen to, question, understand, reason with, teach, and/or advise the users in order to change their behaviour and to improve their health". To this purpose, they continue, "intelligent systems are used to encourage progress toward specific health-related goals by providing tailored training and guidance". Warner (2012, p.22) provides another definition of coaching. He says that "coaching is the ability for someone—or something— to ask thought-provoking questions that inspire the coachees to maximize their personal and professional potential by utilizing the tools, skills, and views the coachee already possesses." In this same paper, the goal of coaching is defined as "to help individuals develop internal and external structures that help them achieve success and to increase their potential by expanding their sense of what is possible." Although these two definitions differ to some extent, the core part remains the same namely the support activity of the coach to guide the user to exploit her full potential in order to achieve a target behaviour. As part of the above-mentioned special issue, Ochoa and Gutierrez (2018) propose a loosely-coupled architecture for e-coaching system.

The key elements of the proposed architecture can be categorized in (1) data gathering, (2) data processing (which include sensor data analysis and decision making for adapting the intervention to the context) and (3) actuation of the intervention through the delivery of the coaching action to the user. Data analysis includes both the understanding of user variables (i.e., monitoring unit) and user actions (i.e., diagnosing unit). In particular, the intelligence of the system (i.e., learning unit) should be able to adapt the intervention according to different contexts: the state of users' variable, the user model (including users' preferences), the coaching plan and the progress throughout the coaching plan.

Kamphorst (2017) propose a minimal set of features that each e-coaching system should implement. These can be considered as functional requirements that are complementary to the architectural requirement:

- **Social ability**: The coach should be able to engage in a conversation with the user.
- **Credibility**: The system has to be perceived as having expertise and being trustworthy.

- **Context-awareness**: The system needs to be aware of user context to propose ideas and actions that are relevant for the user.
- **Learning abilities**: The system needs the ability to ask questions, give feedback, and offer advice that is tailored to the individual user, building up and maintaining a personalized user model.
- **Data gathering**: The system will need to interface with different types of data streams (e.g., direct user input, but potentially also measurements of physical activities, mood self-reports, sleeping patterns), to provide individually tailored coaching.
- **Proactivity**: The system should initiate interactions with the aim of stimulating action.
- **Reflection**: The system should initiate interactions in a proactive manner, depending on user's sensed or predicted behaviour.
- **BCM integration**: The system needs to know how a behaviour change trajectory looks like in order to provide successful coaching.
- **Planning support**: In order to support users in setting themselves up for behaviour change success, the system should guide the user through the intention formation with appropriate planning strategies.

While Kamphorst (2017) suggested important features that a e-coach system should have, Lentferink et al. (2017) reviewed the key components that can significantly affect a variety of health outcomes, the adherence and the usability of an e-coaching intervention (based on 27 studies involving different age groups and coaching domains / health behaviours). **The following BCTs were found to positively affect both health outcomes and usability in the studies reviewed:**

- Setting short-term goals to eventually reach long-term goals
- Personalization of goals
- Praise messages
- Reminders to input self-tracking data into the technology
- Use of validity-tested devices
- Integration of self-tracking and persuasive e-Coaching
- Provision of face-to-face instructions during implementation, as key components for influencing both health outcomes and usability in a positive way

Moreover, the following BCT was beneficial for both adherence and on usability:

- Provision of personalized content

It is important to note that in addition to the missing link between conceptual health BCMs and the literature on BCTs, as will be discussed in the following sections, few studies consider more than one behaviour/health domain and few include older adults in their samples or consider age-related differences and changes in the degree of effectiveness of select BCTs. So far, there is evidence for both age-related

similarities and differences in some elements of behaviour change predicting variables (e.g., action and coping planning, Scholz et al., 2007).

In addition, those reviews and meta-analyses that focus on older adults that can be found add an interesting perspective to the BCTs listed above. In a recent survey, 66 adults aged 65 and older rated several taxonomies of BCTs (including the one by Michie et al., 2011) according to (1) how much they favoured each BCT in the context of a physical activity enhancing intervention. Further, one important aspect of (digital or traditional) interventions named by participants was *autonomy support*, meaning the importance of any BCT to help maintain rather than conflict with a person's own sense of autonomy and independence. As such, receiving professional support at the time of selecting the appropriate intervention based on credible information was regarded as highly desirable and useful. Planning activities such as diaries were, however, only helpful if they are not overly obtrusive into the flexibility of people to freely structure their daily life activities and adapting any intervention regime to the current (and possibly changing) day-to-day needs (Arnautovska et al., 2017). Another recent review on the effectiveness of both digital and non-digital interventions to enhance physical activity particularly in older adults also indicated that most interventions were tailored to the specific person and that self-tracking as a means of providing feedback to participants and as the basis for person- and time-specific interventions was related to reliable improvements in physical activity behaviour (Muellmann et al., 2018).

El Kamali et al. (2020), recently reviewed the e-coaches for improving older adult well-being, highlighting that only few adopted a fully multi-domain approach and that there is a general lack of evidence on their effectiveness, as few controlled studies were carried out to assess e-coaches for older adults

10.5 E-coaching in NESTORE

In this section, we summarize the main intervention techniques and features implemented in NESTORE. In particular, in the following list we analyse the key components that could affect health outcomes, usability and adherence to the program (Lentferink et al., 2017):

- *Reduction of activity options by setting short-term goals to eventually reach long-term goals*: goal setting is reduced from the high-level long-term intention making (pathway), to specific short-term multi-domain coaching activities, which in turn are composed of elementary training activities (Angelini et al., 2019)
- *Personalization of goals*: users can not only choose pathways and coaching activities according to a predefined list provided by the system, but this list and the intermediate goal thresholds are adapted by the system according to user preferences and states. (Subías-Beltran et al., 2019; see also Chapter 7)

- *Praise messages:* praise messages are an integral part of the system and are provided on differnet interfaces (mobile apps and games, chatbot, tangible coach). In particular, motivational messages are always frased in a positive way.
- *Reminders to input self-tracking data into the technology:* as for praise messages, reminders are provided in different forms in each interface, e.g., through app notifications and through chatbot conversations. Both mechanisms allow bringing the user to the respective interfaces for inputting data in the system with an intuitive and immediate interaction.
- *Use of validity-tested devices:* Wearable sensors and beacons were developed according to user needs, while the other environmental sensors (smart scale and sleep monitor) used off-the shelves products. Each sensor was throuroughly tested (see also Chapter 4 and 6).
- *Integration of self-tracking and persuasive e-Coaching*: self-tracking is supported not only for those domains that need user input to enter data (e.g., nutrition (see Chapter 5), emotional experience (see Chapter 11) and personal goal attainment), but also for reviewing activities that are tracked by the system. At the same time the system leverages on the HAPA model to provide effective coaching according to the user motivation and mindset. A number of charts were integrated in the app to support self-tracking as well, contextual coaching was provided also in the charts to push users' to align to the coach recommendations.
- *Provision of face-to-face instructions* during implementation, as key components for influencing both health outcomes and usability in a positive way: although the NESTORE objective is to develop an intuitive system, leveraging on co-design and providing a gradual learning phase (e.g., through appropriate on-boarding via the chatbot), face-to-face instructions were provided at the beginning of each pilot test. Such instructions were complemented by step-by-step tutorials implemented inside the app.
- *Provision of personalized content*: all content was personalized by the different pilot sites, leveraging on co-design to conceive conversations and coaching activities that respect local traditions and facilities. A web interface was developed to facilitate the translation and adaption of the e-coach content (El Kamali et al., 2020). Moreover, the system was tailored to individual levels according to user preferences: the user is able to choose among three different interfaces to access the coaching intervention frequency and timing of coaching activities (see Chapter 7).

The following list discusses how the NESTORE system implements the e-coaching system features described by Kamphorst (2017):

- *Social ability*: a conversational agent is an integral part of the e-coaching system supporting text based and voice-based conversations (El Kamali et al, 2020b). Moreover, to increase the user experience of such

conversations, user's affect is assessed in order to adapt the conversation and build empathy with the user (see Chapter 11).

- *Credibility*: since the system is built according to the recommendation of experts in the different coaching domains it should have the needed credibility (see Chapter 2). In the onboarding phase, such scientific underpinning is highlighted by the chatbot. Moreover, informational messages are supported by scientific facts for people interested in the additional science behind the project. In general, information material on the scientific background of the project is provided in the NESTORE web site as additional source of reference for the users.
- *Context-awareness*: adapting and suggesting appropriated coaching activities is one of the main goals of the decision support system. Coaching activities are selected and adapted not only according to the user state and preferences but also according to context information such as proximity to local facilities.
- *Learning abilities*: a user dynamic model is built, storing users' system preferences but also preferences related to coaching activities. In particular, the selection of coaching activities among the provided list as well as the user rating at the end of the activity can be used by the the Decision Support System to continuously improve user recommendations (see Chapter 7).
- *Data gathering*: the system will gather information from wearable and environmental sensors as well as from user self-reporting in the different interfaces (Palumbo et al. 2020, see also Chapter 4).
- *Proactivity*: the system initiates interactions by means of reminders and notifications, based on HAPA model integration in order to stimulate and motivate the user to commit with the chosen pathway. However, frequency of system prompts can be configured by the user in order to adapt to personal needs and time availability.
- *Reflection*: the user is stimulated to reflect on the impact of lifestyle choice thanks to educational messages. Self-reflection is also stimulated through self-monitoring and in particular through tangible ambient displays that reflect users' progress in the pathway.
- *Behaviour change model integration*: as the HAPA model is integrated in the system in order to deliver the different interventions in a time-appropriate manner (see Section 2 of this Chapter).
- *Planning support*: In order to support users in setting themselves up for behaviour change success, the system guides the user through the intention formation as well as the volitional phase with appropriate planning (Angelini et al., 2019).

10.6 Conclusion

Supporting individuals in their journey to maintained or better health requires a focus on changing unhealhy lifestyle habits or helping to contiue adhering to healthy lifestyle choices and behavior. Several theoretical accounts about important antecedants and correlates of such health behavior change exist, as well as detailed inventories of (health) behavior change techniques (BCT). Leveraging novel technologies to support a healthy lifestyle is increasingly popular, but much of the work in aging falls short in adopting a clear integrative approach that is theory-based and combines evidence-based BCT employed through mobile technology and computing and capitalizes on an e-coaching format. In NESTORE, we have designed an e-coaching platform that addresses these short-comings by adopting a theoretically informed definition of an e-coach and implementation thereof for the special use case of older adults who are community-dwelling and overall high functioning. This chapter outlines our approach and the results of a systematic review on ecoaching for health in late life, highlighting the need to collect methodologically sound information on the feasibility and impact of such approaches to maintain and improve late life well-being and health.

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