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Definition of Intervention Techniques

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Short Abstract

This document represents the first deliverable D5.1 (Definition of Intervention Techniques) of WP5 (NESTORE Virtual Coach) and contains the main results of discussions and activities performed during Task 5.1 (Definition of Intervention Techniques and Coaching Strategies).

In Chapter 2 of this document we summarize seven behaviour change models (BCM) that are frequently used as general theoretical frameworks in health psychology: (1) Theory of Reasoned Action, (2) Theory of Planned Behaviour, (3) Health Belief Model, (4) Protection Motivation Theory, (5) Social Cognitive Theory, (6) Transthoretical Model or Stages of Change Model, and (7) **Health Action Process Approach (HAPA)**. Within the review of these BCMs, we provide an overview of these common theoretical models of how changes in individuals' (health) behaviours can be predicted and outline that we have selected the HAPA as a theoretical framework for the NESTORE coach because it is one of the only BCMs that specifically addresses the intention-behaviour gap.

A wide range of **behaviour change techniques (BCTs)** has been described in the literature, and recent work has focused on how these can be implemented using digital and technological approaches. In Chapter 3 we first describe intervention strategies (i.e. BCTs and general coaching strategies for health and well-being) and how specific intervention strategies can be implemented in the different NESTORE domains.

In Chapter 4 we first provide an overview on how **e-coaching interventions** have been implemented in the past to change health-related behaviour of older adults. Then, we provide an extensive and **systematic review on e-coaching interventions** targeting or containing aspects of physical activity, nutrition, social relations, cognitive activity, and, to some extent, emotional well-being. A total of 27 articles were included in the quantitative analysis and the architecture and design of the e-coaching as well as the results of these studies (where reported) are discussed with regards to the type of coaching and companionship, the theoretical frameworks (BCMs) which underlie the e-coaching strategies, the type of BCTs or coaching activities in general that were used for targeting the specific NESTORE domains, as well as the e-coaching system architecture.

In Chapter 5 we give an overview on **how the NESTORE coaching system will be implemented**. In the first section, we describe how the HAPA model components can be mapped onto common and empirically shown to be effective BCT, although there has been a lack of integration of theoretical models in describing BCT and a lack of clear identification of BCT in individual theories of behaviour change in the past. We further describe the architecture, monitoring, data processing, delivery interface and coaching activity strategy of the NESTORE e-coaching based on the e-coaching strategies described in Chapter 4. This is followed by an example of a coaching journey (i.e., improving well-being as pathway choice) in NESTORE as well as the definition of the process of co-designing coaching activities, that is, how both participants and domain experts co-design the pathway choice process in an integrative manner. Finally, Chapter 5 closes with **recommendations** for WP5 and the integration with other WPs.

Chapter 6 provides a short conclusion based on our discussion and synthesis of behaviour change models, techniques and previous eHealth and eCoaching approaches and the suggested implementation in NESTORE.

Key Words

Behaviour change models, behaviour change techniques, e-coaching, health, older adults, health intervention, HAPA model, embodied eCoach, conversational agent, companion.

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1. Introduction

In this document on the "Definition of Intervention Techniques", we summarize the results of outputs from Task 5.1 within Work Package 5 that deal with general approaches in the health-behaviour change and coaching intervention domain. We summarize both theoretical models as well as commonly used practical intervention approaches found in the literature and map these onto the specifics of the NESTORE coaching platform and environment.

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 NESTORE domains. In close collaboration with WP2, in which the particular coaching paths are defined and outlined for the NESTORE domains from the experts in the physiology/physical activity, nutrition and aging psychology standpoints, one additional task in this deliverable is to map out the personalized coaching pathways across NESTORE domains.

As an overarching theoretical framework to the NESTORE project, the lifespan theoretical model of selection with optimization and compensation (SOC) has been proposed and described in detail in D2.1. 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 (see D2.1 for details). 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 will be designed, including co-designed in participatory fashion (see WP7), 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 deliverable 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) domain, 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 deliverable with a brief final summary and conclusion.

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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.

Existing theoretical health-behaviour change models can be distinguished broadly into two types of models: 1) continuum models and 2) stage models. *Continuum models* 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*, 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. In the following sections, we will briefly present the most common continuum models (i.e., Theory of Reasoned Action, Theory of Planned Behaviour, Social-Cognitive Theory, Health Belief Model, Protection Motivation Theory) and the most common continuum model (i.e., Transtheoretical Model). As will be discussed in Section 2.7, 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.

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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).

2.1 Theory of Reasoned Action

The Theory of Reasoned Action (TRA) by Fishbein and Ajzen (1975), is one of the earliest social-cognitive behaviour change models. As the Theory of Planned Behaviour (TPB) model described in the next section, it centres around "Expectancy Value Theory", according to which the key role of expectations and beliefs about a behaviour and the value one attaches to these characteristics shape a person's attitude towards any given behaviour. In the TRA, a person's beliefs about the outcomes of behaviour and the evaluation of these outcomes influence that person's attitude to that behaviour. Between these evaluative beliefs and behaviour are behavioural intentions which according to this model directly lead to behaviour. Normative beliefs about how others' perceptions of the behaviour in question and one's own motivation to match these perceptions

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and expectations are also thought to influence subjective norms that interact with one's own attitudes and ultimately impact one's intentions. We will further down discuss models which introduce additional variables to bridge the intention-behaviour gap. See Figure 1 for an overview.

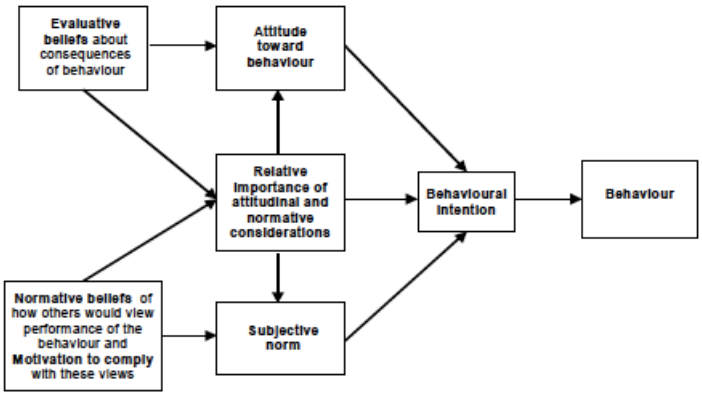

Figure 1: Theory of Reasoned Action (from Darnton, 2008).

2.2 Theory of Planned Behaviour

According to the more widely used TPB (Ajzen, 1991), an extension of the original TRA presented above, a person's intention to actually perform a given behaviour is the key variable underlying any behaviour in the first place (and no longer one's attitude towards the behaviour). This intention is influenced, however, by this person's attitude towards that particular behaviour (such as values and beliefs about the outcome), subjective norms (perceived social pressure or beliefs about other people's thoughts about what the appropriate behaviour would be), and by a variable previously not included in the TRA, namely the perceived behavioural control of a person (i.e., the perception about one's ability or self-efficacy concerning the performance of the behaviour in question). As will be outlined below, many of these variables also play an important role in the HAPA, which extended the TPB and more explicitly differentiates between different phases in the decision-to-act and the actual behavioural process. See Figure 2 for an overview.

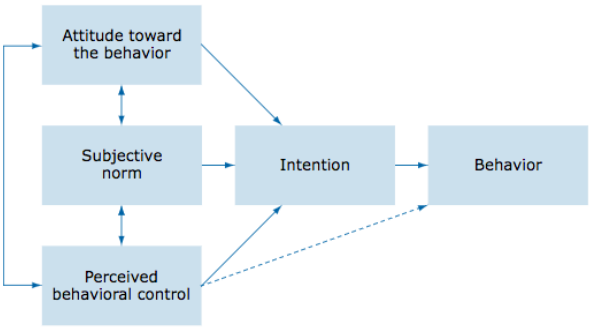

Figure 2: The Theory of Planned Behaviour (adapted from World Bank (2010).

2.3 Social Cognitive Theory

The Social Cognitive Theory (SCT) from Bandura (1997) proposes external factors as the driving factors of individuals' behaviours. Termed reciprocal determinism, this theory views functioning to be the result of a

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triadic interplay between personal factors, the environment and behaviour itself. In this model, environmental factors can be features of a given situation and the overall environmental context in which a behaviour occurs. Personal factors, on the other hand, can include a person's traits, motivational factors, instincts and drives. Key variables in this model include self-efficacy, outcome expectations (what are the likely consequences of a given behaviour?), self-control, and reinforcements (that increase or decrease the likelihood of a given behaviour), emotional coping (the ability to cope with emotional stimuli), and observational learning (learning from observing others' behaviours and outcomes of their actions). See Figure 3 for an overview.

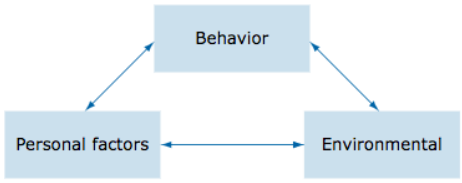

Figure 3: The Social Cognitive Theory (adapted from World Bank, 2010).

2.4 Health Belief Model

The Health Belief Model by Rosenstock (1974) is also based on expectancy value theory. Its main variables driving preventive health behaviors are perceptions of vulnerability and severity that influence perceptions of benefits and barriers and both of these are related to action cues. Benefits/barriers perceptions, vulnerability/severity perceptions and action cues influence health behaviors. See Figure 4 for an overview.

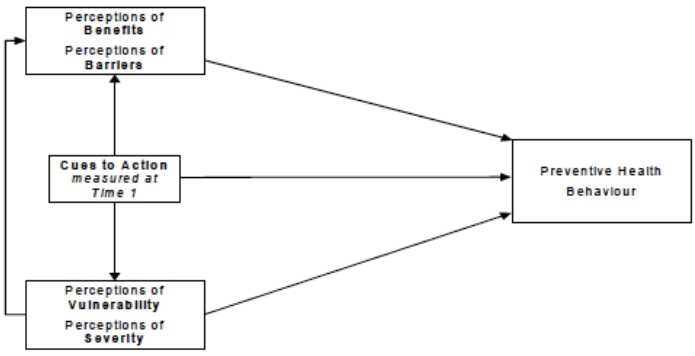

Figure 4: Health Belief Model (from Darnton, 2008).

2.5 Protection Motivation Theory

The Protection Motivation Theory (PMT; Maddux & Rogers, 1983) was developed as an extension of the HBM. In this model, self-efficacy plays a central role in response to fear appeals. In its original conceptualization, four components were proposed to determine health-related behaviours: Self-efficacy, response effectiveness, severity and vulnerability. Whereas severity, vulnerability and fear are considered to reflect threat appraisal (how detrimental is a given behaviour and current behavioural pattern if not changed), response effectiveness and self-efficacy are proposed to reflect coping appraisal. All of these components are thought to be influenced by two sources of information, namely those from the environment and those from intrapersonal exchanges. Where the previously discussed models include intention as the mediating variable between attitudes and

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beliefs about a behaviour and the actual behaviour change, in this model protection motivation takes on the mediating role. See Figure 5 for an overview.

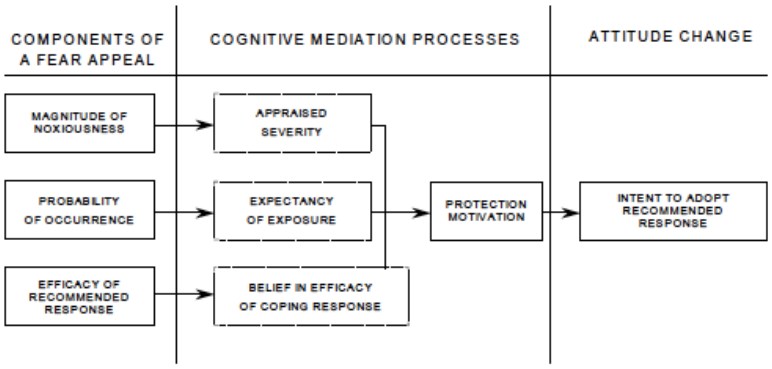

Figure 5: Protection Motivation Theory (from Darnton, 2008).

2.6 The Transtheoretical Model or Stages of Change Model

In the Transtheoretical Model of Behaviour Change (TTM; Prochaska, Johnson, & Lee, 1998), behaviour change is proposed as a process consisting of six stages that range from pre-intentional precontemplation, during which individuals have not yet formed an intention for immediate action, and termination, during which individuals are completely certain and efficacious and will maintain the given behaviour.

The stages in between are contemplation (the phase during which individuals form an intention that refers to the coming six months and are aware of both pros and cons of the particular behaviour change), preparation (during which individuals develop a plan of action for the immediate future), action (during which the behaviour change occurs), and maintenance (during which individuals try hard to avoid relapse). This last to final state of maintenance is the most common that individuals achieve, as the termination phase is very difficult to get to. See Figure 6 for an overview.

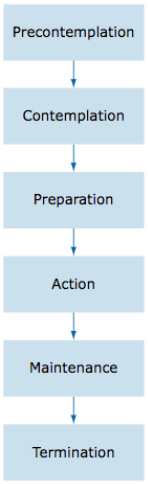

Figure 6: The Transtheoretical Model / Stages of Change Model (adapted from World Bank, 2010).

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2.7 The Health Action Process Approach

The HAPA (Schwarzer, 2008) is one of the more recent models in the health-behaviour change literature (for more details, also see D2.1). 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 7 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)

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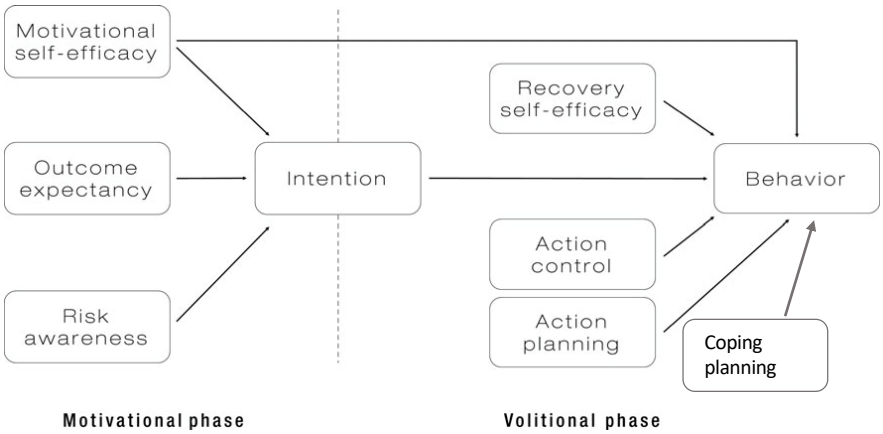

Figure 7: The Health Action Process Approach (adapted from Bierbauer et al., 2017).

In line with the stage-like characteristics of the model, interventions can be matched to each stage and subgroup of individuals. We will briefly outline the implications of this for how the HAPA framework can shape the NESTORE coaching implementations in Section 5.1. 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.

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3. Intervention Strategies in NESTORE Domains

3.1 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). In this deliverable, we will provide the results of a systematic review on e-coaching approaches and what can be learned with regard to the techniques and theoretical frameworks guiding these approaches for the NESTORE project (see Sections 4.2. to 4.5).

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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)

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3.2 Specific Coaching Strategies for NESTORE Domains

Most BCTs target physiological status, physical activity and nutrition, with additional age-specific interventions otherwise targeting the social domain. As described in D2.1, many of these interventions also indirectly target subjective well-being as people tend to feel better once they have managed a personally important goal. As D2.2 describes empirically verified intervention types and target behaviours in each NESTORE domain in much detail, we here only briefly review again the main intervention approaches in each of the NESTORE domains. It is noteworthy that particularly in the cognitive and social domains, but also in many other health-related interventions, the specific BCTs are not explicitly outlined (although often implemented, e.g., feedback), or there is a lack of theoretical underpinnings in one or more of the health-behaviour change models reviewed above. The following Section 4 then summarizes a systematic review with the explicit focus on digital coaching interventions and what can be learned from those on health-behaviour change interventions in older adults in the NESTORE domains.

3.2.1 Common interventions targeting physiological status, physical activity, and nutrition

In their meta-analysis, Michie, Abraham, Whittington, McAteer, and Gupta (2009) have investigated the effect of the above-mentioned behaviour change techniques in physical activity and healthy eating. All of the 26 BCTs have been used in previous studies (*N* = 122) and across all included studies there was a pooled effect size of 0.31. The technique "self-monitoring" was the most effective strategy. Further, studies that used self-monitoring with at least one other technique were more effective than other interventions (effect size of 0.42 vs. 0.26). On average, six techniques were used per intervention (*SD* = 3.1). Two techniques were used in less than four studies (i.e., "provide information about others' approval", "prompt identification as role model"). The duration of the intervention ranged from a single session to 2.5 years (*M* = 25 weeks, *SD* = 29 weeks), with 59 % of interventions using multiple sessions. A moderator analysis revealed that "prompt self-monitoring of behaviour" accounted for most variance in outcome measures. Most studies used "prompted intention formation", "providing feedback on performance", "prompted self-monitoring of behaviour", "prompted specific goal setting", and "prompted review of behavioural goals". Much of the commercially available mobile technology for health focuses on physical activity (i.e., fitness trackers), and many of these explicitly include different BCTs such as goal setting and self-tracking information (e.g., Sullivan & Lachman, 2017).

3.2.2 Cognitive functioning

Most interventions that specifically target the maintenance or enhancement of cognitive functioning in older age focus on the structured delivery of cognitive training programs. These programs can be categorized into three broad areas (1) strategy-based training interventions focusing on the delivery of standardized strategies to enhance encoding or recall of information, (2) process-based training interventions focusing on the enhancement of basic cognitive functions which are shared with many other higher-order functions (e.g., intelligence), and (3) multi-component training interventions targeting multiple cognitive functions (simultaneously or consecutively) and are thus thought to be more ecologically valid. Most studies, meta-analyses and reviews conducted in this area concluded that cognitive training does lead to improvements in the directly trained tasks (i.e., training gains, see e.g., Guye et al., 2016; Karbach & Verhaeghen, 2014). However, transfer to untrained cognitive abilities and to everyday functioning is still limited, particularly if the experimental group is compared to an active control group instead of a passive control group (e.g., Guye et al., 2016, von Bastian, Guye, & De Simoni, in press). However, two studies have found transfer to measures of everyday life functioning immediately after training (Cantarella, Borella, Carretti, Kliegel, & de Beni, 2017) and even a few years after training (Ball et al., 2010). As mentioned above, these studies barely mention explicitly which BCTs are used in the studies. However, many of those use feedback to provide the users with information on their training progress, interventions are often personalized (i.e., adaptive algorithms to change level of difficulty) and use motivational aspects (e.g., slogans during training intervention) to keep individuals committed.

3.2.3 Social integration, loneliness and social behaviour

Most interventions in the social domain target loneliness reduction, including a focus on strengthening social support and social networks (e.g., Gustafsson, Berglund, Farnobi, Barenfeld & Ottenvall Hammer, 2017;

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Honigh-de Vlamin, Haveman-Nies, van't Veer, & de Groot, 2013; Masi et al., 2011). As with interventions in other psychological domains (e.g., cognition), the interventions rarely state explicitly what kind of BCTs were used and how they map on to the taxonomy of Michie et al. (2008). It is interesting to note that few of them explicitly target older adults (Ertel et al., 2009). Many loneliness interventions intend to increase the quantity and quality of relationships. Interventions to reduce loneliness can either focus on the individual or on so-called structural enablers within the community.

The evidence about the effectiveness of social network interventions is mixed (e.g., Findlay, 2003). There is some support for the positive outcomes of educational and social activity group interventions for particular subgroups of adults as a means of decreasing social isolation and loneliness in later life (Cattan et al., 2005). Coll-Planas, Nyqvist, Umitia, Sola, and Monteserin (2016) recently showed in a systematic review that there is some evidence for partially positive effects of social capital interventions during later life, even though overall, no reliable effects on important late life outcomes such as loneliness, mood and mortality could be found. To date, there is a clear lack of clear evidence relating to later life and including methodologically sound studies with appropriately large samples and control groups. Mobile technology can be particularly helpful for interventions in the social domain to facilitate communication and networking in later life. For more details, see D2.1 and D2.2.

3.2.4 Mental status

BCTs, as the name implies, focus on changing behaviour rather than cognition and feelings, and thus, these approaches typically do not focus on mental status (i.e., rather stable dispositions and traits) or mental states (i.e., fluctuations in how a person feels or perceives the environment).

As reviewed in D2.1, well-being is often regarded an important outcome or correlate of interventions on health even though the interventions do not explicitly target well-being. In addition, many interventions that specifically target well-being involve other age groups than those in later life. These interventions include, for example, expressive writing, gratitude, good actions and counting kindness, to name a few (e.g., Gander et al, 2013; Pennebaker, 1997; Seligman et al, 2005; Smyth, 1998). Most of these types of interventions are effective in the short-run, but long-term benefits remain to be seen and properly investigated in longitudinal studies (e.g., Lyubomirsky et al, 2011). The use of micro-longitudinal approaches that are minimally invasive through the use of sensing technology can be an effective way of monitoring subjective well-being trajectories in daily life and identifying general and person-specific risk factors such as the loss of close confidants and health-related impairments that pose severe constraints to compensatory strategies and thus to the pursuit of important personal goals (Brose & Ebner-Priemer, 2015). The NESTORE coaching platform thus will allow older adult users to monitor their subjective well-being as well as be able to detect changes that may indicate problems or challenges with regard to a persons' goal progress in the NESTORE domains of physical activity, nutrition, cognition and social behaviour.

3.2.5 Specific other target domains for health behaviour change interventions in older adults

Apart from BCTs and interventions focusing on the NESTORE domains, health-related BCTs have focused on several other health behaviours and domains listed below:

- *Medication adherence* (e.g., Easthall, Song, & Bhattacharya, 2014 for meta-analysis),
- *Smoking* (e.g., Michie, Hyder, Walia, & West, 2011),
- *Excessive alcohol use* (e.g., Michie, Whittington, Hamoudi, Zarnani, Tober, & West, 2012), and
- *Condom use* (e.g., Abraham, Good, Warren, Huedo-Medina, & Johnson, 2011).

For smoking alone, 43 BCTs have been investigated, but listing all of those is beyond the scope of this deliverable.

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4. Health-Related E-Coaching and Digital Intervention Strategies

4.1 E-Coaching as Digital Health Behaviour Change Interventions

This section of the deliverable 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 systems, as illustrated in Figure 8.

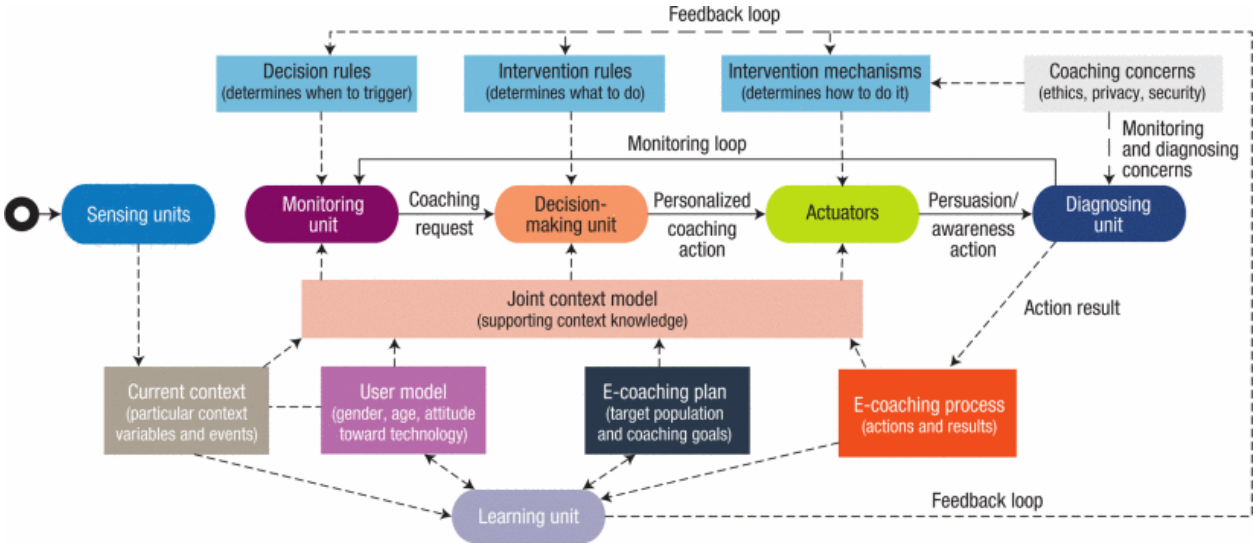

Figure 8: Architecture for E-Coaching Systems (adapted from Ochoa & Gutierrez, 2018).

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

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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

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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 and colleagues) 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).

In order to obtain a clear overview of the existing digital systems that aim at promoting behaviour change and healthy lifestyles in older adults through virtual e-coaching, a systematic literature review has been conducted. The following subsections present the objectives (see Section 4.2), the methodology (see Section 4.3) and the results of the systematic review (see Section 4.4) as well as implications for NESTORE (see Section 4.5).

4.2 E-Coaching for Older Adults: Review Objectives

The aim of our literature review is the analysis of previous virtual coaches and companions for promoting healthy lifestyles in older adults. In our analysis, we did not include coaches for rehabilitation or treatment purposes of particular conditions, since the types of interventions are likely to qualitatively different from those implemented in NESTORE. However, we include all other studies that targeted the different NESTORE domains (i.e., physical activity, nutrition, social, cognitive and mental, cf. NESTORE Deliverable D2.1) and we are particularly interested in analysing previous multi-domain studies targeting older adults.

Objective 1: Definition of "coach" and "companion"

The first objective of our systematic literature review is to understand how previous eHealth interventions defined and used the terms of "coach" and "companion", which are two key elements for the NESTORE project. The results of this analysis will be used to define the NESTORE coach (see Section 5.2).

Objective 2: Identification of applied behaviour change models and behaviour change techniques

The second objective is to identify which BMCs have been adopted in virtual coaches and companions for older adults (if any) and how these models have been translated into digital interventions through specific implementations of the BCTs. Since Abraham and Michie's taxonomy includes 26 BCTs and research papers often lack the required details for identifying all of them, we concentrated our analysis on the eight key components for e-coaching, identified by Lentferink et al. (2017) (see Section 4.1).

Objective 3: Identify tackled NESTORE domains

The third objective of our analysis is to identify the domains tackled by the different coaches including the intervention types, target behaviours and coaching activities proposed in each domain. The categories used for the analysis of intervention types and target behaviours are borrowed from the analysis performed for the NESTORE deliverable D2.2, with the aim of comparing previously identified interventions to e-coaching

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Objective 4: Understanding the systems' implementation

The fourth objective of our analysis is to understand how the systems reviewed were implemented, with a particular focus on the strategies for collecting data (i.e., devices for automatic monitoring or software for self-reporting), for processing the data, determining how interventions are adapted (if any adaptation was present) and for delivering the intervention to the user.

In sum, our analysis aims at reviewing previous scientific results on e-coaching for older adults in order to build on these findings for the development and design of the NESTORE coach. The next section presents the methodology used to conduct the systematic review and to achieve the objectives defined above.

4.3 E-Coaching for Older Adults: Review Methodology

The systematic review presented in this paper aimed at identifying previous work on virtual coaches to enhance well-being in older adults. A systematic literature search was performed in Pubmed, Ebsco and Scopus. Pubmed and Ebsco were chosen because our review should include studies targeting well-being. In contrast, Scopus was selected as literature search databases because it allows to identify articles in the field of engineering and thus performs searches beyond the medical literature.

Phase 1: Literature search

Three sets of keywords have been defined for identifying virtual coaching systems targeting well-being in older adults. Using these keywords, we aim at identifying systems that provide coaching to the user (even if the authors did not specifically call it a coach). We identified the following list:

> *"Embodied conversational agent" OR "virtual companion" OR "socially communicative machine" OR "virtual agent" OR "autonomous robotic agent" OR "virtual carer" OR "virtual assistant" OR "digital avatar" OR "robotic psychological assistance" OR "animated conversational agents" OR "relational agents" OR "virtual coach" OR "conversational agent-based system" OR "conversational agent" OR " coaching system" OR "screen agent" OR "virtual conversational partner" OR "robotic pet" OR "communication robot" OR "virtual personal trainer" OR "virtual mentor" OR "virtual tutor" OR "virtual friend" OR "virtual educator" OR "virtual instructor" OR "virtual advisor" OR "virtual expert" OR "ecoaching" OR "e-coaching" OR "e-coach" OR "ecoach" OR "tutoring system" OR "virtual exercise coach" OR "artificial companionship" OR "virtual therapist" OR "home dialogue system" OR "chatbot"*

For filtering systems that promote well-being and healthy lifestyles, the following keywords were used:

> *"wellbeing" OR "well-being" OR "fitness" OR "health"*

And finally, in order to filter systems used for older adults, the following keywords were used:

> *"Elderly users" OR "older adults" OR "older seniors" OR "eldercare institutions" OR "elderly" OR "retiree" OR "active aging" OR "grownup" OR "senior".*

As a result, the full query for this systematic review was:

> *Query 1= (Embodied conversational agent OR virtual companion OR socially communicative machine OR virtual agent OR autonomous robotic agent OR virtual carer OR virtual assistant OR digital avatar OR robotic psychological assistance OR animated conversational agents OR relational agents OR virtual coach OR conversational agent-based system OR conversational agent OR coaching system OR screen agent OR virtual conversational partner OR robotic pet OR communication robot OR virtual personal trainer OR virtual mentor OR virtual tutor OR virtual friend OR virtual educator OR virtual instructor OR virtual advisor OR virtual expert OR ecoach* OR e-coach* OR tutoring system OR virtual exercise coach OR artificial companionship OR virtual therapist OR home dialogue system OR chatbot) AND(fitness OR wellbeing OR well-being OR health) AND (Elderly users OR older adults OR older seniors OR eldercare institutions OR elderly OR retiree OR active aging OR grownup OR senior)*

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Note that the asterix ("*", e.g., in ecoach*) is used to identify all the words that start with ecoach such as "ecoach", "ecoaching" etc. Also, note that the omission or use of "-" in any keyword leads to different search results. Hence, wellbeing and well-being as well as ecoach and e-coach were used as key words in the query. We ran Query 1 on Pubmed and Ebsco identify all the articles that contain at least one of these keywords in the title or abstract. Next, we ran Query 1 in Scopus to identify all the articles that contain at least one of these keywords in the abstract. The results are shown in Table 3.

Table 3. Overview of Query Libraries, Strategy and Results for Literature Review

DATABASE	SEARCH BY	RESULTS (# OF PAPERS)
Pubmed	Title-Abstract	11
Scopus	Title-Abstract	58
Ebsco	Abstract	67

Performing the query in the three aforementioned databases we obtained a total of 136 papers. These results were retained and saved in the reference management software Mendeley. In addition, a manual search was performed on Google Scholar to identify those articles that we could not find in the aforementioned databases. Twenty additional papers from this search were added to Mendeley to complete the search phase. As a result, we obtain 156 papers. After removing duplicates, we obtained a total of 140 papers.

Phase 2: Screening

The screening phase aimed at eliminating non-relevant papers by screening the title and abstract and was based on objective exclusion criteria. Exclusion criteria were: Press articles (3), book chapters without available full text (1), unavailable full-text (1), articles not in English (1), not relevant to virtual coaching (53). After the screening phase 81 papers were retained.

Phase 3: Eligibility

The eligibility phase aimed at distinguishing relevant full-text papers that comply with the following criteria:

The paper presents a coaching system. The coaching system has a closed loop on the user, which includes a monitoring system (e.g., through sensors or self-monitoring), a processing system (for elaborating the data and deciding the intervention) and a feedback system (through apps, emails, robotic interfaces, etc.) to coach the user. The system might include a human component but should include at least a technological component in one of the sub-systems (monitoring, processing or intervention delivery). The system coaches the user for promoting healthy lifestyles, focused on disease prevention (not for therapy, rehabilitation or medication). Papers that present a system solely for entertaining or leisure (for example social companion), without any coaching in relevant domains, should be discarded. Note that a system that helped stop smoking or improved lifestyle in obese people can still be considered in the prevention category. Finally, the target population of the system should be older than 50 years old.

Two of the authors of this deliverable have evaluated independently the eligibility for each paper. A third author further reviewed articles with disagreeing ratings. At this point, eligibility was assigned according to a majority vote rule. This process has been conducted following a less conservative version of PRISMA review protocol (Moher et al., 2009). The process is summarized in Figure 9. After this phase, 27 papers were declared as eligible.

Phase 4: Analysis

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In the analysis phase, the 27 papers have been by two authors each in order to have more reliable results for the defined outcomes. The analysis allowed us to describe each paper by its aim, the technologies used for the e-Coaching system parts, the intervention medium and frequency, the definition of companion or coaching, as well as the coaching domain(s), coaching type, intervention types, intervention techniques, target behaviour and BCM. In the following parts, we report the specifications for the outcome variables:

The system has three main parts: monitoring, processing and the intervention delivery. Monitoring can be hardware (e.g., any environmental or wearable sensor) or software (mobile apps, web apps used by user for self-monitoring). Processing is divided into two aspects: one to specify the technologies used for activity or behaviour recognition and another to specify adapted suggestions for coaching activities. BMCs were also listed in order to gain an overview on which BCMs are frequently applied in this research field.

The coaching type can be virtual (i.e., no external human intervention) or hybrid (i.e., human takes part in intervention).

Coaching domains and activities were divided into physical, nutrition, social, cognitive and mental/emotional. The intervention type specifies which coaching domain was used in the paper (e.g., yoga training in the physical coaching domain). The target behaviour is to specify the reason the intervention type (e.g., improve strength for the yoga training listed in the intervention type).

For physical activities, the intervention types are pre-specified and listed in this analysis: Aerobic/Endurance Training; Strength/Resistance Training; Flexibility Training; Balance Training. Their target behaviours are consecutively Retain/Improve Cardio-Respiratory Fitness; Retain/Improve Strength-Power; Retain/Improve Flexibility; Retain/Improve Balance.

For nutrition, the intervention types used are Hypocaloric Diet, High-protein Diet, Hypercaloric Diet, Healthy Dietary Habits and the target behaviours are Retain/Achieve Optimal Body Weight/Body Composition; Maintain/Achieve Healthy Diet and are considered independent from the intervention type in this case.

For cognitive, the intervention types are Cognitive Training Intervention for Executive Functioning, Working memory (Training), General Cognitive Functioning and Everyday Cognition (Transfer), Video Game intervention for Multiple Cognitive Domains (Training and Transfer), Productive Intellectual Engagement for General Cognitive Functioning and Everyday Cognition (Training and Transfer) and its target behaviour are Executive Functioning, Working Memory, General Cognitive Functioning and Everyday Cognition.

Finally for social, the intervention types are Computer / Internet Use for Social Skills, Befriending for Improving the Opportunities for Social Contact, Elderly Support Home Visits, Animal-Assisted Therapy (pets or robots), Educational Classes and Psychosocial Counselling for Social Support, Reminiscence Therapy Sharing Memories, Awareness of Feelings, Counselling Sessions to Reframe Perception of Loneliness or Self-control, Cognitive Behavioural Therapy Including Development of Positive Interpersonal Relationships, Communication skills, Intervention Groups to Educate Participants about Brain/Memory, Activities Designed to Facilitate Social Interactions for Social Cognition and its target behaviour are Social Skills, Improving the Opportunities for Social Contact, Social Support, Social Cognition.

Finally, intervention techniques were also listed such as eduction (setting short term goals to reach long term goals), personalization of goals, personalization of content, praise, reminders, validity-tested devices, self-tracking and e-coaching.

General information was also listed as well such as target population, their mean age, the type of study and the results of each paper.

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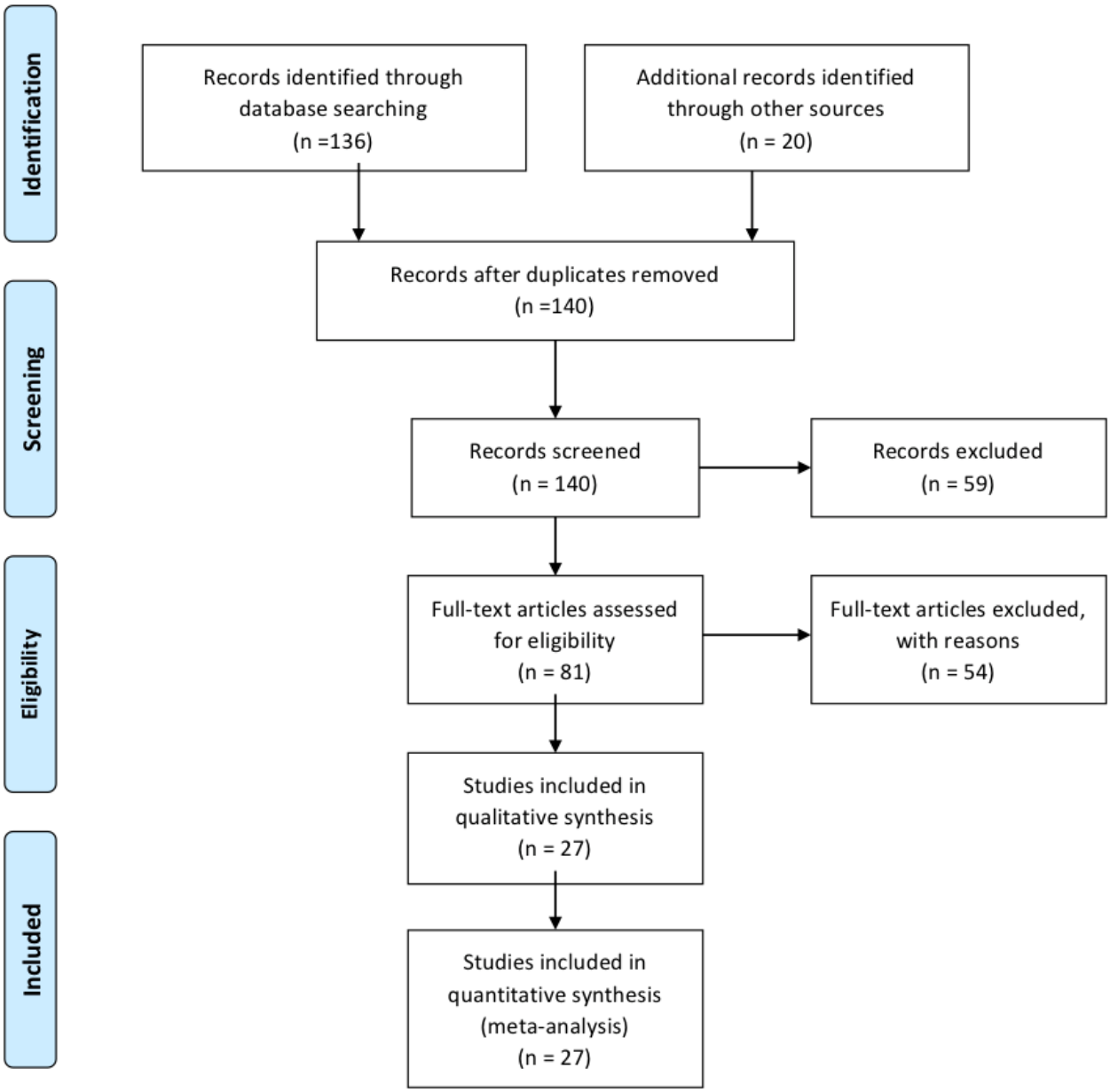

Figure 9: PRSIMA Flow Diagram.

4.4 Review Results

This subsection presents the result of our literature review analysis. Table 4 gives an overview of the types of studies found and the assignment of all identified papers to each type. Please see Section 7 (References) for a list of the 27 included papers.

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Table 4. Overview of Types of Study and Paper Classifications

TYPE OF STUDY	PAPERS
Randomized trial	[4, 5, 31]
Pilot study	[34, 37, 42, 64, 80]
Preliminary studies for assessing usability or co-design choices	[1, 7, 22, 43, 50, 61, 67, 77, 81]
System proposal (no user study)	[10, 44, 46, 57, 65, 79]
Study protocol	[6, 11, 15]
Field study	[30]

Since there is still limited understanding of how to design and implement e-coaching interventions for older adults and as well as limited evidence regarding their effectiveness in promoting positive health-related outcomes, we refrained from excluding further papers and kept all 27 for our analysis in order to gain a broad insight into recent developments in this area. Among the 27 papers selected as eligible for the analysis, three of them reported results of randomized trials [4, 5, 31], three of them reported protocols for future randomized trials [6, 11, 15], five of them presented results of pilot studies [34, 37, 42, 64, 80], nine of them presented the results of preliminary assessment of the system, in terms of usability or co-design choice, one of them presented a field study for deriving the requirements of a coaching system and five of them presented only a proposal of a coaching system or an architectural implementation, without any user study. It is also worth noting that one study [65], although potentially also targeted older adults, presented the result of a study conducted with younger adults. Moreover, papers [1, 67] and papers [34, 42] were related to the same project; presenting different versions of the same system. Also, in papers [4, 5, 31, 64] different versions of the same embodied conversational agent were used as intervention media.

Because of the heterogeneity of the papers included in the analysis and the limited number of RCT studies found, we did not perform statistical analysis on the collected data but provide a qualitative and descriptive review of the past work in the field of virtual coaching systems targeted to older adults. In the remaining sections, we present the results of the review according to the objectives described in Section 4.2.

4.4.1 Definition of virtual coaching and companionship

The following Table 5 summarizes the definitions and the relevant aspects for understanding the components of a virtual coach and a virtual companion. Some of these definitions have been summarized by the reviewers.

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Table 5. Overview of Coaching and Companion Definition Used Across Papers

PAPER	DEFINITION OF COACHING	DEFINITION OF COMPANION
[1] Flowie: A persuasive virtual coach to motivate elderly individuals to walk	the developed system is referred to as a persuasive virtual coach to motivate older adults	
[7] Older Adults Co-Creating Meaningful Individualized Social Activities Online for Healthy Ageing.	A digital coaching system that gives older adults personalized support for increasing participation in meaningful social activities.	They use the term remote companion, but this is a human allowing the subject to enjoy activities remotely
[10] A Virtual Coach for Active Ageing Based on Sentient Computing and M-Health	conversational coaches to encourage healthy habits, monitoring the user's health during the exercises, planning appropriate exercise routines, and supporting users to achieve their goals.	
[30] Embodying care in Matilda - An affective communication robot for the elderly in Australia	support in emotional well-being, by helping older adults in "being useful and productive", resilience and coping, provide sensory enrichment, satisfy basic needs/comfort, and social connections	none, but assistive robots should meet both companion and service-type requirements
[34] Multi-disciplinary design and in-home evaluation of Kinect-based exercise coaching system for elderly	unobtrusive sensing of participants' behaviours in combination with artificial intelligence tools that aid the coach to send individualized messages to the participants	
[42] Design and Evaluation of an Interactive Exercise Coaching System for Older Adults: Lessons Learned	the coaching system guides users through a series of video exercises, tracks and measures their movements, provides real-time feedback and records their performance over time	
[44] Interaction design of encouraging daily healthcare habit with communication robots		User to use it for long term: user friendly (adapting to characteristics of elderly for acceptability and usability, reduction of cognitive load), enjoyable (by conversational interactions, elements of surprised, impressive presence)

Note. The coloured words highlight the different dimensions of the definition of a virtual coach and companion, as discussed later

(Table 5 continues)

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Table 5 (continued)

PAPER	COACHING DEFINITION	COMPANION DEFINITION
[46] The Roberta IRONSIDE project a cognitive and physical robot coach for dependent persons	1) cognitive coaching through speech and dialogue 2) although declared as physical coaching, the robot merely supports the person while walking and measures level of activity, more an assistant rather than a coach	companion for conversing
[50] Comparing Two Coaching Systems for Improving Physical Activity of Older Adults	1) text-based coaching (desktop view with tools, like calendar, video exercise, internet browser; tips and suggestions as pop-ups) 2) animated virtual coach on a screen with vocal functionality, who suggests and guides exercises.	
[57] Intelligent virtual companion system for independent living		This service not only provides help in performing daily tasks and connecting with the outside world, it also provides therapeutic diversions in simulated casual conversations.
[61] Developing a virtual coach for chronic patients: A user study on the impact of similarity, familiarity and realism	Self-management support, goes beyond diagnosis, reminders, and direct feedback. Deploys different behaviour change techniques and uses those to persuade users to change attitudes and behaviours.	

(Table 5 continues)

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Table 5 (continued)

PAPER	COACHING DEFINITION	COMPANION DEFINITION
[64] Addressing Loneliness and Isolation in Older Adults	1) Agents could directly provide companionship and the perception of social support by providing a wide range of social activities that it could conduct with the older adult, such as game play 2) agents can address isolation by helping elders to stay connected with friends and relatives via electronic communication, visit and chat coordination, and proactive social behaviour change interventions to establish and maintain friendships 3) conversational agents can directly intervene at times of loneliness, depression, and other mood disorders, through conversational therapy, ranging from simple active listening skills, to full-blown cognitive behavioural therapy.	The agent assesses the older adult's affective state at the beginning of every conversation via dialogue ("How are you?") and provides appropriate empathetic feedback. The agent engages with older adult in brief chat for social support and talks about local sports to try and build a sense of companionship.
[67] Designing Acceptable Assisted Living Services for Elderly Users	Motivational system that appeals to the older adults user group and the naturally fits into their existing living patterns. In terms of motivation, the resulting system would have to link to short-term gains rather than long-term goals	

(Table 5 continues)

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Table 5 (continued)

PAPER	COACHING DEFINITION	COMPANION DEFINITION
[77] Using Socially Assistive Human–Robot Interaction to Motivate Physical Exercise for Older Adults	Social agents that aim to assist individuals in health-related tasks such as physical exercise have been developed in both the human–computer interaction (HCI) and human–robot interaction (HRI) communities. These systems are similar to our SAR exercise system in the manner in which they provide feedback (from a social agent), and with the exception of French's work, in the activity being monitored (physical exercise). However, our system differs from all in that the agent, a robot in our case, not only provides active guidance, feedback, and task monitoring, but is also directly responsible for instructing and steering the task. Hence, our agent is both an administrator and active participant in the health-related activity, resulting in a unique characteristic for the system: the social interaction between the robot and the user is not only useful for maintaining user engagement and influencing intrinsic motivation, but is also an instrumental necessity in achieving the physical exercise task.	The companionship of the robot was measured based on participant responses to nine ten-point semantic differential scales concerning the following robot descriptions: bad/good; not loving/loving; not friendly/ friendly; not cuddly/cuddly; cold/warm; unpleasant/pleasant; cruel/kind; bitter/sweet; and distant/close (Cronbach's alpha = 0.86). These questions were derived from the Companion Animal Bonding Scale of Poresky et al. [53]. The companionship of the robot was measured to assess potential user acceptance of the robot as an in-home companion, thereby demonstrating the capability of the system toward uses in independent living/aging-in-place.
[79] eHealth Services for the Elderly at Home and on the Move	Coaching is defined as providing an educational/motivational application that dynamically adapts to evolving risk assessment of the person and is personalized according to the motivational model that is most suited for the person.	

(Table 5 continues)

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Table 5 (continued)

PAPER	COACHING DEFINITION	COMPANION DEFINITION
[80] Behavioural Informatics and Computational Modeling in Support of Proactive Health Management and Care	No particular definition of coaching. Here a health coach platform is used to collect data from patients, analyse their behaviour and provide tailored information to human coaches that deliver the intervention (either face-to-face or digitally through the system).	
[81] Socially Assistive Robotics: Robot Exercise Trainer for Older Adults	A Socially Assistive Robot (SAR) that coaches and motivates older adults while providing performance assessment on physical activity exercises.	A Socially Assistive Robot (SAR) that engages older adults in the needed physical activity. Enlarging the scope of the interaction could be of great benefit to older adult users, providing them with a socially assistive robot that acted like a mentor, coach and companion.

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In all the papers analysed in this systematic review, none reports a definition of e-Coach. However, 17 out of 28 articles mention some of the characteristics that an e-coach should present. One characteristic reported in these articles (7 out of 28) concerns companionship and the social role that the e-coach should play. In the paper entitled "Using Socially Assistive Human–Robot Interaction to Motivate Physical Exercise for Older Adults", it is referred to the Companion Animal Bonding Scale items and that should present the following qualities: good, loving, friendly, cuddly, warm, pleasant, kind, sweet, and close. The main activity considered to be part of the e-coach intervention is linked to supporting the user to reach her goal (8 papers). Only a few refer to target behaviours and behaviour change techniques. Another fundamental characteristic for an e-coach is the ability of motivating the user with 5 papers explicitly referring to this requirement. Another important feature that the e-coach should provide is the personalization (sometimes referred to it as tailoring) of the intervention. The elements identified here as well as those identified in the introduction of this section will be used to obtain a definition for the NESTORE coach, which is provided in Section 4.5.

4.4.2 Behaviour change models and intervention techniques

Three out of the 26 papers included in the review used or explicitly discussed a behaviour change model to support the functioning of the e-coaching system. For the majority of papers, no such model was referenced. Rather, more general psychological theories relating to motivation and well-being, such as self-determination theory (Deci & Ryan, 1985), were mentioned, or the general provision of feedback to participants and the tracking of emotional states as one way of tailoring the intervention under study. All three of the papers [15, 30, 80] referencing a BCM used the Transtheoretical Model of Behaviour Change. For instance, in a larger project intended to increase exercise and healthy nutrition intake (i.e., fruit and vegetable consumption) in healthy older adults, Clark et al. (2002 [15]) provided participants person-specific intervention materials that also mapped each different stage outlined in the TTM (see also Section 2.6), a feature of the TTM that led to their decision of using this model as the conceptual framework. A similar approach was used in Pavel et al. (2015 [80]), in which an adapted version of the TTM was used for the mathematical modelling of states of behaviour and behaviour change derived from a multitude of sensor input in a multi-domain intervention targeting physical activity, nutrition, sleep, socialization and cognition. It is interesting to note, that a recent review of eHealth interventions targeting physical activity in older adults identified a conceptual framework as a guiding principle for the intervention design in the majority of studies, spanning a wide range of behaviour change models also summarized in Section 2. These also included the application of the HAPA model and found evidence for a greater effectivity of theory-based rather than non-theory-based interventions (see Muellmann et al., 2018; see also Van Dyck et al., 2016).

Table 6 shows the key components of the intervention techniques (Lentferink et al., 2017) implemented in each study. Each paper used different factors for improving the effectiveness and usability of its study.

None of the papers used all the intervention techniques cited in this analysis. However, from the table above, we can conclude that the personalization of content was the most considered factor in the majority of studies. Some systems in a few research papers had a memory of previous interaction of the user [1 ,31, 57, 61,79], negotiated barriers and checked in on the user [5], interacted remotely with the user [4, 6, 7], allowed the user to choose modalities for the interaction [10, 34], provided local news [44], presented advice for behavioural change based on the user [80] or other [30, 46]. It is worth knowing that article [77] had a minimized personalization of content (system using only user's name in its sentences) that was considered in the analysis but noted as a low content personalization. Plus, most devices in most papers were also validated.

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Table 6. Overview of Intervention Techniques and Paper Classification

INTERVENTION TECHNIQUES	PAPERS
Reduction	[4, 10, 77, 79, 80]
Personalization of goals	[1, 4, 5, 7, 10, 11, 15, 31, 43, 50, 65, 77, 79, 80]
Personalization of content	[4, 5, 6, 7, 10, 30, 31, 34, 44, 46, 57, 61, 67, 77, 79, 80]
Praise	[1, 4, 5, 6, 10, 30, 34, 43, 44, 61, 65, 77, 81]
Reminders	[6, 22, 30, 44, 57, 61, 67, 79]
Validity-tested devices	[1, 5, 6, 7, 10, 31, 34, 42, 43, 46, 50, 61, 64, 65, 80]
Self-tracking + e-coaching	[1, 4, 5, 6, 10, 11, 31, 34, 50, 61, 67, 77, 79]
Face-to-face instructions	[11, 15, 30, 31, 34, 42, 50, 64, 80]

To sum up, 5 out of 26 articles provided short-term goals in order to achieve long-term goals [4, 10, 77, 79,80]. Papers who provided only short-term goals without stating a solution to meet long -term goals were not accepted and not treated as a reduction intervention technique.

Eight out of 26 papers had reminders in their system [6, 22, 30, 44, 57, 61, 67, 79]. It is worth noting that many systems had personalized goals, praise messages or provided self-tracking and e-Coaching. Finally, face-to-face instructions were found in 9 papers out of 26 papers. Note that systems that used a robot and not an actual human being for instructions were not considered in this analysis. As a result, article [42] that used a video session by a human coach were accepted.

4.4.3 Coaching domains, intervention types and coaching activities

Table 7 shows how the reviewed studies explored the different coaching domains. 10 of the 27 studies proposed a multi-domain approach. Among these studies only [30] addressed all the domains, [22, 37, 64] and address 3 domains and all the other multi-domain coaches dealt only with two domains, often nutrition and physical activity. It is worth noting that [67] presented two different use cases addressing physical and social coaching but not integrated multi-domain coaching. Also, systems that do offer multi-domain coaching, such as Matilda [30], a robot for elderly care in residential facilities, provide different coaching activities for each domain, without relying on a multi-domain coaching model. As discussed in Section 2 health behaviour change models provide little support to multi-domain coaching and need to be adapted for the NESTORE project.

The next subsections will focus the analysis on the different coaching domains and in particular to the intervention types, target behaviours and coaching activities adopted for each domain. As anticipated, intervention types and target behaviours are analysed according to the categories defined in the deliverable D2.2. Since the mental domain has not been retained for intervention in NESTORE, no analysis of intervention types, target behaviours and coaching activities in this domain will be presented here.

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Table 7. Overview of Coaching Domains and Classification of Papers

DOMAIN	PAPERS
Physical	[1, 4, 5, 6, 10, 15, 22, 30, 31, 34, 42, 43, 46, 50, 61, 64, 65, 67, 77, 79, 81]
Nutrition	[6, 15, 30, 57, 79]
Social	[7, 30, 37, 57, 61, 64, 65, 67, 80]
Cognitive	[11, 22, 30, 37, 46, 77]
Mental/emotional	[22, 30, 37, 44, 64]
Multi-domain	[6, 15 ,22, 30, 37, 46, 57, 61, 64, 65, 79]

Physical Activity

Physical activity was included as coaching domain for most of the studies found in the review (21 out of 27). One reason for this may be that physical activity can be reliably measured with little obtrusiveness using sensor technology and many guidelines exist on the recommended and optimal physical activity behaviour in daily life in different age groups (see also D2.2). Table 8 shows interventions and target behaviours that addressed the domain of physical activity.

Table 8. Overview of Intervention Types, Target Behaviours and Paper Classification

INTERVENTION TYPES	TARGET BEHAVIOURS	PAPERS
Aerobic/Endurance Training;	Retain/Improve Cardio-Respiratory Fitness	[1, 4, 5, 10, 15, 30, 31, 44, 46, 64, 65, 67]
Strength/Resistance Training;	Retain/Improve Strength-Power	[10, 34, 42, 43, 77, 81]
Flexibility Training;	Retain/Improve Flexibility	[10, 34, 42, 77, 81]
Balance Training	Retain/Improve Balance	[34, 42, 81]
Not specified	Not specified	[6, 50, 61, 79]

Most interventions were oriented to aerobic/endurance training (11 out of 21), although strength/resistance training and flexibility training were also implemented respectively in six and five studies. Balance training was implemented only in three studies.

Target behaviours defined in D2.2, i.e., Retain/Improve Cardio-Respiratory Fitness; Retain/Improve Strength-Power; Retain/Improve Flexibility; Retain/Improve Balance; they are mapped directly to the respective intervention types so the same distribution among studies can be found. Studies analysed did not distinguish

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between “retain” and “improve” target behaviours; indeed, such distinction depends generally on the fit level of the user.

In four papers, i.e., system or architecture proposals, intervention types and target behaviours were not specified. Table 9 shows the coaching activities proposed to the user in the different studies.

Table 9. Overview of Coaching Activities by Intervention Types and Paper Classification

INTERVENTION TYPES	COACHING ACTIVITY	PAPERS
Aerobic/Endurance Training;	Walking	[1, 4, 5, 10, 30, 31, 44, 46, 64, 65, 67]
	Running	[10, 65]
	Aerobic exercises	[10]
Strength/Resistance Training;	Playing petanque	[10]
	Strength exercises	[34, 42, 77, 81]
	Stepping	[43]
Flexibility Training;	Playing petanque	[10]
	Joint strengthening	[10]
	Flexibility exercises	[34, 42, 77, 81]
Balance Training	Balance exercises	[34, 42, 81]

Walking was the typical activity for training in the aerobic/endurance interventions. This was generally supported through step counting. Only one study [31], suggested brisk walking as a coaching activity. Running was proposed in [10, 65]. Aerobic exercises were mentioned in [10], although no specific description was provided.

For strength, flexibility and balance, a specific set of exercises was generally implemented in order to train the user in the respective domains. In particular, [34, 42, 77, 81] implemented exercises for strength and flexibility, while [34, 42, 81] implemented exercises for balance. It is worth mentioning that a variety of exercises were described in these papers: those exercises are generally tracked with the help of a 3D camera in order to support the user during execution and give feedback about correct performance.

In [42], 12 exercises were implemented and categorized as full-body, upper-body with core and lower-body. In [34], the authors extended this set to 40 exercises. In [81], the authors implemented a set of exercises recommended by the English National Health Services in the coaching system, which include 23 different exercises for flexibility, strength and balance. The authors stated that most of the proposed exercises were

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successfully implemented and tested by users, although 8 exercises could not be tracked by the system since they involved the side of the body.

Nutrition

Five articles included nutrition for coaching activities, however only 2 of them mentioned the type of intervention they used in this analysis and the target for a better behaviour. In other words, 2 out of 27 papers [15, 30] had a system that provided healthy diet habits related to the consumption of fruit and vegetables in order to maintain or achieve healthy diet.

Social relations

Social activity was included in the coaching domain in 10 of the 27 studies found in this review [7, 30, 37, 53, 57, 61, 64, 65, 67, 80].

The main *coaching activities* include remote participation in activities (i.e., through a remote companion) or real participation in activities enhancing social contact [e.g., 7, 80], positive engagement and conversations with a companion or real person [e.g., 30, 46, 53, 57, 61, 64, 65], multi-user games [e.g., 30, 80] and encouraging the use of social interactions via phone, email, skype or visits [e.g., 37, 67, 80].

The main *target* of these studies was to enhance social skills [e.g., 7, 80], to improve opportunities for (remote) social contact [e.g., 7, 30, 37, 65, 67, 80], to enhance social support [e.g., 30, 64], and to reduce feelings of loneliness [e.g., 37, 46].

The main *intervention types* were specifically designed social activities to facilitate (remote) social interactions and befriending [e.g., 7, 30, 37, 65, 67] or to generally engage the user in a conversation [e.g., 64].

Cognitive activity

Cognitive activity and functioning were included in the coaching domain in 6 of the 27 studies found in this review [11, 22, 30, 37, 46, and 77].

The main *coaching activities* include virtual tasks that mimic daily tasks [e.g., 11], tasks performed at the computer [e.g., 22], quizzes [e.g., 30], reminders of daily activities [e.g., 30], story-telling and conversations to enhance speech and memory ability [e.g., 46], and memory games [e.g., 77].

The main *target* of these studies was general cognitive functioning (e.g., memory, prospective memory, executive functioning) and everyday cognition [e.g., 11, 22, 30, 46] or speech abilities [e.g., 46].

The main *intervention types* include video game training targeting multiple cognitive domains simultaneously [e.g., 11] or productive intellectual engagement [e.g., 46].

Emotional well-being

Although it is not planned to develop interventions in the emotional activity domain, it is planned to assess the subjective well-being of participants of NESTORE at baseline and post-test and throughout the intervention phase. We therefore think it is worthwhile to briefly summarise the papers that did target emotional well-being or emotional activity in general.

The emotional activity was included in the coaching domain in 5 of the 27 studies found in this review [22, 30, 37, 44 and 64].

The main *coaching activities* include the promotion of regular breaks during work and exercises to reduce stress [e.g., 22], responding to emotions which are registered through facial or speech recognition [e.g., 30], mood mapping [e.g., 37], and the recognition of affective states and providing feedback and recommendations based on a person's mood [e.g., 64].

4.4.4 E-coaching system architectures

As discussed in Section 4.1, three main components can be identified in the architecture of e-coaching systems presented by Ochoa and Gutierrez (2018): (i) one for **data collection**, necessary for monitoring the user's behaviour, (ii) a second for **processing the data**, aimed at recognizing a particular user's activities and to

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develop tailored coaching interventions, and (iii) a third and final part for the **delivery of such interventions** to the user. We analyse here how the system identified in the systematic review implemented each component of the system. Before such analysis, we discuss briefly the human role in these e-coaching systems. Indeed, e-coaching systems are opening up new perspectives for reducing health intervention costs, since they can reach a large population with or without minimally dedicated personnel. Still, human support is often fundamental in digital interventions. For example, Lentferink et al. (2017) showed that face-to-face instructions can positively affect both the effectiveness of the intervention and the usability of the e-coaching system. However, in some cases e-coaching systems might also include a human component in one or more parts of the system, for example for delivering the coaching intervention to the user based on system analysis and recommendation. We define here a system as **"hybrid e-coaching"** when actual persons still have a fundamental role for gathering data, elaborating the coaching plan, or delivering the intervention and as **"virtual e-coaching"** systems when no human support is needed for its functioning.

In 6 of the 27 papers, there was an essential human role in the e-coaching system. In [1], a professional was employed for setting an adapted goal for the user. In the system presented in [15] adaptation was provided by a human coach. In [6] the intervention delivery included a phone call from a nurse, who adapted the intervention based on data collected by the system. In [80] the described platform for behavioural informatics allowed a human coach to modify and adapt coaching messages generated by the system through a web interface. Such messages would then be delivered to the user through the digital platform. In [7], the social support intervention consisted of a remote participation in events or outdoor walking activities performed by a remote "companion", a human who helped the older adult to participate in the activity through video-conferencing software. Finally, in [79] the user had the opportunity to talk with doctors and caregivers as part of the e-coaching system.

E-coaching monitoring

In this section, we analyse the different sensors used to gather data in the 27 reviewed papers. Table 10 summarizes the types of monitoring systems implemented in previous e-coaching systems. Reflecting on the coaching activities discussed in Section 4.4.3, pedometers and accelerometers where often adopted in order to provide step counting and to support walking activities [1, 4, 5, 10, 31, 44, 50, 65, 67]. While most systems used a pedometer [1, 4, 5, 10, 31, 44], an actigraph [50] or accelerometer integrated in the smartphone [65] were used to support activity recognition. In [10], such information was complemented with GPS data, in order to provide more accurate activity recognition. In [65] smartphone usage was also exploited to infer users' sleep patterns. Weight monitoring was also supported in [6, 50] through smart scales.

In some physical activity interventions, physiological signals such as heart rate [6, 10], blood pressure [6, 50] and skin conductivity [10, 22] were acquired. Activity of the user was often detected through statistics of phone [37, 80], email [80] and video-communication software [80] usage. Social activity was also inferred from smartphone microphone data [65]. In [10, 30, 46], audio collected from the microphone was further used for user affect recognition.

Cameras are often needed for coaching for strength, flexibility and balance. Indeed, in [34, 42, 43, 77, 81] a Kinect camera is used to track the user's body movements. Cameras are also used in robots to assess the affective state of the user [46, 30]. In [22], a Kinect is used for assessing the psychophysiological state of the user while using a computer, combining it with information from mouse-use and from an eye-tracking system.

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Table 10. Overview of Monitoring Systems Used Across Papers

MONITORING SYSTEM	PAPERS
Pedometer	[1, 4, 5, 10, 31, 44, 50 (actigraph), 65 (smartphone accelerometer, activity recognition), 67]
Weight scale	[6, 50]
Heart rate/ pulsometer	[6, 10]
Skin conductivity	[10, 22]
Blood pressure	[6, 50]
Microphone	[10 (smartphone, for affect), 30, 46 (robot, for affect), 65 (smartphone, for social)]
GPS	[10 (smartphone, for activity detection)]
Mouse,	[22 (cognitive overload and psychophysiological state)]
Eye-tracking	[22 (cognitive overload and psychophysiological state)]
2D/3D Camera	[22 (Kinect, cognitive overload and psychophysiological state), 30 (robot, for affect), 34, 42, 43, 77, 81 (Kinect, for tracking movements of exercises), 46 (stereoscopic camera in robot, for affect recognition)]
Phone activity and other sensor platforms	[37, 80 (for social activity), 65 (for sleep)]
Email/skype usage	[80 (for social)]

E-coaching processing

In order to find out how the data were processed in each study or project, if present, we examined two characteristics: The first characteristic concerned the **type of activity and behaviour recognition** used in each paper and the second characteristic focused on possible **adaptations in the suggested coaching activities** in each project. In papers [1, 4, 5, 31, 50], a step counter was used. However, the adapted suggestions of coaching activities differed across these papers. In [1], for example, walking goals were set based on three consecutive days of activity. Another system had feedback personalization based on the walking steps provided by the user and negotiating new goals [4]. In [5], the step counter was based on a daily 5 minutes conversation between the user and the conversational agent, whereas in [31], the system's coaching suggestion was more elaborated and was geared towards adjusting the goals with personalized feedback and educational information based on current user progress and user performance. Finally, in [50] an accelerometer was used to detect the number of steps and activity levels; the history of activities was shown through calendars but no goals or personal goals were defined, although there were a set of activities to select from.

Other studies focused on recognizing behaviour based on weight measurement and blood pressure with weekly telephone calls by a nurse for the first month after discharge and then monthly telephone calls by nurses over the next 5 months. In order to obtain coaching, an alarm is generated and the nurse calls the patient to ensure the device's measurements do not exceed threshold values [6].

Activity detection, speech, gesture and emotion recognition are useful methods for processing data. Indeed, the system in [10] used this kind of recognition approach. Moreover, the system adapts activities and feedback according to the individual user's profile and emotions based on a model developed by experts. In [30], speech recognition and facial expression analysis was used. Dialogue is personalized according to the user's emotional state and illness status (e.g., dementia, etc.), and diet suggestions are described as tailored to each user (diabetic, obese, etc.). [34] recognized the motion and posture by a movement capture system. Then, difficulty levels, exercise preference, and a skip and change video were the features used in the adapted coaching

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system. In another project [46], facial emotion recognition and non-verbal interaction, speech analysis and the use of semantic representation for human-robot interactions were included in the behaviour recognition algorithm. In another system, a gesture movement and posture recognition algorithm was employed for the processing of data [77]. This system also maintained the appropriate level of difficulty according to user performance plus sustained intrinsic motivation and suggestions to correct posture for physical exercise. One project mentioned that data elaboration, conceptual activity recognition and data analysis were all conducted via designated units within the project (i.e., Health Data Collection Unit and Health Interpretation Unit; only the conceptual description is available). Moreover, there is a unit dedicated to determine the urgency of system messages based on "an innovative health monitoring ontology" and the health coach is meant to provide short- and medium-term recommendations, which are adapted to the users' needs and also provide advice related to each user's health status.

Some papers did not mention what technology they used for recognizing activities [7, 11, 15, 56, 67], in addition to some papers that did not mention any type of suggestions for personalizing or adapting the coaching activities [7, 42, 44, 46, 57, 64, 67, 81]. One study used a human coach to adapt coaching activities [15], whereas in [11] only the set of different levels based on users' performance were mentioned. In order to detect hesitation, drowsiness, vigilance, fatigue, cognitive overload, stress, anxiety, and frustration, [22] used hardware data and contextual data taken from a PC. Plus, advice and tips are offered based on the analysis of this data. Social interaction was measured by sensors and processed in a way that the older user is depicted as a sun in the centre of the display, surrounded by planetary representations of friends and other social network partners [37]. Some systems focused on motion tracking [42] (Pose Measurements Primitives, Complex Pose Measurements, Function of Primitives) whereas others used a Kinect system [43] and the adapted coaching suggestions were that game difficulty depended on the users' physical abilities and was estimated by subjective degree of fatigue (input using a tablet) and objective degree of fatigue (Kinect).

In [61] the processing was manually done by entering measurements and responding to survey questions. Users can connect to members of a telehealth team through video-chat. The coaching techniques used were mostly reminders, diagnosis, and direct feedback of behaviour. Another study used a tablet interface for recognizing the emotional state through pre-defined text [64]. In [65], data collected from accelerometer, microphone and phone usage are elaborated to derive the score for three different dimensions (physical activity, sleep, social activity). The score in each dimension is adapted according to the community the user belongs to (e.g., children, older adults).

The technology in [80] for processing the activity's behaviour was to use algorithms and inferring user's behaviour using metrics such as time and contacts on email, time and contacts on the phone, time and contacts on Skype, and inferred time out of the home. A key point for the authors in that project is to provide timely and adapted coaching interventions based on digitalized behaviour change models. Furthermore, a system analysed the body's movement recorded via camera to assess the exercise execution [81]. In addition, the system recognized how well the user is performing the exercise in order to provide feedback.

E-coaching intervention delivery modalities

This section presents an analysis of intervention media, i.e., **interfaces used for the delivery of the intervention**, across the reviewed papers. A more detailed analysis will be presented in the Deliverable D5.2. The keywords used in the queries were aimed at individuating intervention media beyond typical web-based and smartphone interfaces. For this reason, we included in the keywords "conversational agents" and "robots", which are common examples in the literature of interfaces used for providing social support to older adults. Indeed, it is worth noting that conversational agents, in the past often developed to provide social support for older adults in digital health behaviour change approaches, are now growing in popularity also for younger generations, under the term of "chatbots", which are typically text-based conversational agents that can be used in most messaging applications. Robots are also a typical, yet controversial, interface used as tools for social support for older adults.

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We want to highlight that in this literature review we are not interested in such interfaces and systems as means for providing social support and virtual companionship, but more generally as a means for delivering e-coaching interventions in the different domains investigated. Indeed, companion systems that did not coach the users in one or more of the different domains were discarded according to the eligibility criteria.

Conversational agents were used in 6 of the 27 papers. In particular, [4, 5, 31, 61, 64] described a similar embodied conversational agent, where an animated computer character simulates face-to-face conversations using a synthesised voice which is synchronized with other non-verbal behaviours such as hand and head gestures, gaze cues, posture shifts and facial expressions. The user can reply to the agent by selecting an answer from a predefined list. In [10], the authors describe a conversational agent integrated in the smartphone, which besides visual animations and speech can also provide haptic feedback through vibrations. Conversational agents are often embodied in robots, as shown in [30, 46, 77]. In particular, in [77], an anthropomorphic robotic torso acted as an avatar for supporting the execution of physical exercises. An avatar robot was proposed also in [43], to support the execution of physical exercises while playing against another robot. In [81], instead, a social assistive robot, realized through a touchscreen standing tablet mounted on robotic wheels, provided audio and visual instructions for the execution of flexibility, strength and balance exercises. A conversational robot for encouraging daily healthcare has been proposed also in [44].

Screen-based interventions can be found in [1, 11, 22, 34, 37, 42, 44, 61, 65, 67]. In particular, [1, 67] used a touch-based digital photo frame for the delivery of their coaching intervention. It is worth noting that the authors chose to represent in the digital frame the virtual coach as a flower, in order to give an intuitive overview of the physical activity level and to support empathy. In [11], a PC-based virtual board game was used for cognitive training while a computer-based personal assistant supported older adults at work in [22] by providing tips and suggestions. In [34, 42], a display was used also to provide information to support the execution of physical exercises (which were tracked by a 3D camera). In [50], two different intervention media on a desktop PC (a traditional application supported by calendar scheduling and an avatar-based virtual coach) for supporting the execution of physical exercises are compared, discussing advantages and drawbacks of each solution. Touchscreen solutions are considered in [37] (a mobile touch phone for monitoring and feedback), in [61] (a tablet for telehealth application), and in [65] (a smartphone). In particular, in [65], the authors propose to represent the progress of the user in the different domains (physical activity, sleep and social activity) through a naturalistic representation, to be used as ambient display: using the sea as a scenario for the ambient display, two different fishes changing in amount and size represented the physical activity and the social activity while the colour of the sea represented the quality and quantity of one's sleep. As a particular screen-based intervention media, video-communication software has been used in [7] to allow older adults to attend events remotely from their home through the support of a person acting as a remote companion. A tablet was also used in [43] as information support screen for a robot-based game.

Other traditional intervention media found in the reviewed papers were **emails** [15], **phone calls** [6, 15] and **printed material** such as booklets [6] and manuals [15].

4.4.5 Previous findings

In this section, we summarize the findings of the 27 studies reviewed. As mentioned at the beginning of Section 4.4, only 3 studies [4, 5, 31] presented the results of a randomized trial, providing therefore little evidence on the effectiveness of all the other different interventions described here. Nevertheless, for completeness we also report the results of the pilot studies and of the preliminary usability investigations conducted so far.

In [4], it is shown that the group that used the conversational agent significantly increased the number of steps per day after the 2 months of intervention. In contrast, no effect emerged for the effectiveness of the agent to increase user satisfaction with life and reduce loneliness. The acceptance and usability of the conversational agent was overall positive. The results after a 12-months follow-up, presented in [5], show that there were no significant long-term effects, however. The authors also showed that the intervention was more effective in individuals with higher health literacy.

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In [31], similar results could be shown: there was a significant increase in walking activity for the intervention group at the end of the 4-month test, but in the 20-week follow-up, there was a gradual drop-off of system use by participants. This was true even though, as in the previously reported case, the system was generally well accepted and considered easy to use.

Analysing papers that conducted pilot studies with users, the Kinect-based exercise system presented in [34, 42] received a good appreciation from the 7 users who tested it. Three of the users completed the 18-week program.

In [37] an 8-month pilot study for a system to promote older adults' social interactions, showed that it was able to a slight increase in social engagement. The authors reported also that the feedback display showing the network of social contacts of the user as a heliocentric representation facilitated motivation to use the system.

In [64], a one-week pilot study with 14 older adults involving a conversational agent for reducing loneliness showed that the system was accepted by the user group and successfully intervened on loneliness. Indeed, participants felt a sense of companionship. Exercise promotion and anecdotal stories reduced perceived loneliness. Social support by the agent was considered personified by 8 of 12 users in the sense of a 1:1 relationship in which the agent acted as a friend, an exercise buddy, a presence akin to a pet, or a helpful reliever of solitude and inactive time. Two participants introduced the agent into their social network by remarking about the agent's personality or situation to friends or family. The proactive approach (where the system prompts the user for interaction) was more successful in reducing loneliness than the passive approach (where the users needed to initiate the conversation with the agent). In [80], a 9-week intervention for promoting socialization showed that all participants improved their level of socialization and continued to see a benefit in the maintenance phase of coaching (after the nine weeks) from using Skype to communicate with remote family members and friends. It is noteworthy that not all studies involved appropriate control groups to fully evaluate the specific effectiveness of the proposed coaching system.

The other studies [1, 7, 22, 43, 50, 61, 67, 77, 81] were generally shorter or involved less participants and can thus be considered as providing preliminary results only. For example, the digital photo frame with the flower as virtual coach presented in [1] was accepted by the users and considered as easy to use and trustworthy. The flower metaphor was appreciated and motivating although there was no evidence for physical activity improvement. Also, in [7] the video-communication system for remote social engagement was considered as easy to use and useful. In general, the authors noted that the levels of usability and simplicity, in combination with the quality of basic functions of the communication software, had an essential impact on the quality of personal interaction during the activity, thus affecting the meaningfulness of the activity. The virtual assistant system, CogniWin, for helping older adults at work [22] also showed a good appreciation during a preliminary evaluation of the system. The preliminary evaluation of the avatar robot for playing games and promoting physical exercises was also appreciated by the 49 subjects who tested the system: the system was enjoyable and easy (more than 77 % of positive evaluation); 58 % judged it secure; 85.7 % felt a familiarity with robots. The majority of users (41 %) reported wanting to use this system several times a week; but only 6.5 % would like to use it every day. The two systems presented in [50] for promoting physical activity were also both appreciated, although each one showed advantages and disadvantages. The visualization of data was better in the traditional desktop interface, while the agent interface was perceived as more versatile and the speech functionality was well received. Nevertheless, having no control over scheduling events in the agent interface was perceived as frustrating. In general, participants had different needs from the exercise videos (too hard, too easy, not enough variation, annoying instructions). Moreover, tips were not found to be relevant, while self-monitoring was perceived as easy and interesting. Counting steps in particular was appreciated. The test effectuated in [61] for the embodied conversational agent showed that users preferred the realistic looking ECA over the more stylized one, with a slight preference to the unfamiliar ECA than the familiar one and of younger looking ECA over the older looking. In general, there was a positive attitude towards the coach. In [77], the robot providing motivational and praise messages was more enjoyable and was preferred to the one without this kind of input. The first robot provided more companionship. The authors also tested whether the

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user preferred to choose the exercises to be performed or not, showing that there were mixed preferences among users. Therefore, it is recommended to provide a customization of a selection option. Finally, for the robotic system for promoting physical exercise presented in [81], the authors reported good user appreciation, although the system was tested only for 10 minutes. In general, the users reported that such system would help them stick to the exercise plans.

4.5 Findings and Perspectives for NESTORE

From the analysis of the 27 papers we can conclude that little work has been done so far in the area of multi-domain coaching for (healthy) older adults. Although a number of e-health interventions have already been conducted, virtual coaching differs substantially from previous interventions. Analysing the e-health interventions for older adults reviewed recently by Muellmann et al. (2018), only 4 systems can be considered as e-coaches, meeting our eligibility criteria. Summarizing the definitions of virtual coach and companion that we presented in sections 4.1 and 4.4.1, we provide the following **definition of an e-coach to be adopted in NESTORE**:

> *"An e-coach is a system able to collect and process a user's data in order to provide a personalized intervention able to support and motivate the user to reach her goal. The e-coach is able to do so through a set of behaviour change techniques that guide the user to develop internal and external structures that help to achieve success and to increase her potential by expanding the personal sense of what is possible. An e-coach is further able to build a sense of companionship for the user. The e-coach is a good, cuddly and loving entity, providing a warm and pleasant sense of companionship and able to dialogue in a kind and sweet way, while at the same time supporting the user to stay on track of her personal goals, in order to act like a close friend."*

The results of this literature review show that few thorough evaluations of e-coaching systems have been conducted, especially considering multi-domain coaching approaches that go beyond interventions in a single health domain and that include appropriate control groups for evaluation of the specificity of the observed effects. While the effectiveness of behaviour change techniques and digital interventions have been validated for e-coaching systems, there are few studies in the e-coaching or digital health behaviour change field specifically on older adults or considering age-differential effects and thus few recommendations can be drawn from previous results in this area. This stands in marked contrast with the large literature in some of the NESTORE domains, such as cognition (i.e., cognitive training), that involve highly validated and well-described benefits and limitations of a wide range of intervention approaches in general (i.e., not framed as e-coaching approaches; see also D2.1 and D2.2). In general, we have seen that conversational agents and robots are often appreciated by older adults, but this may vary consistently depending on the target users and on how the system is implemented. Other work has indicated that older adults also value the interaction with health-care professionals and thus "real" human interaction, at least at distinct phases in the intervention / coaching trajectory (e.g., when selecting health-related goals or developing the plans for intention implementation; e.g., Arnautovska et al., 2017; Scholz et al., 2007). There is also little evidence on the long-term benefits of such systems and digital e-coaching interventions. The analysis of the literature review presented here will be extended and published as a future NESTORE publication.

Implications of these previous findings for the NESTORE system will be discussed in more depth in the next section, which shows how the NESTORE system will be implemented and how it will address the criteria discussed so far with regard to previous systems.

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5. Implementing the NESTORE Coaching System

5.1 Integration of HAPA with General Coaching Strategies

As outlined above, the HAPA model provides a useful conceptual framework as it has been used in many health behaviour change studies also with older adults and provides good predictive capacity with regard to changes in the target behaviour as it involves a number of important self-regulation variables that can help bridge the intention-behaviour gap most other conceptual models do not address. Its differentiation into two broader stages along the intention-behaviour trajectory and provides the general timeline for mapping our NESTORE user assessment, monitoring and intervention modules. 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.

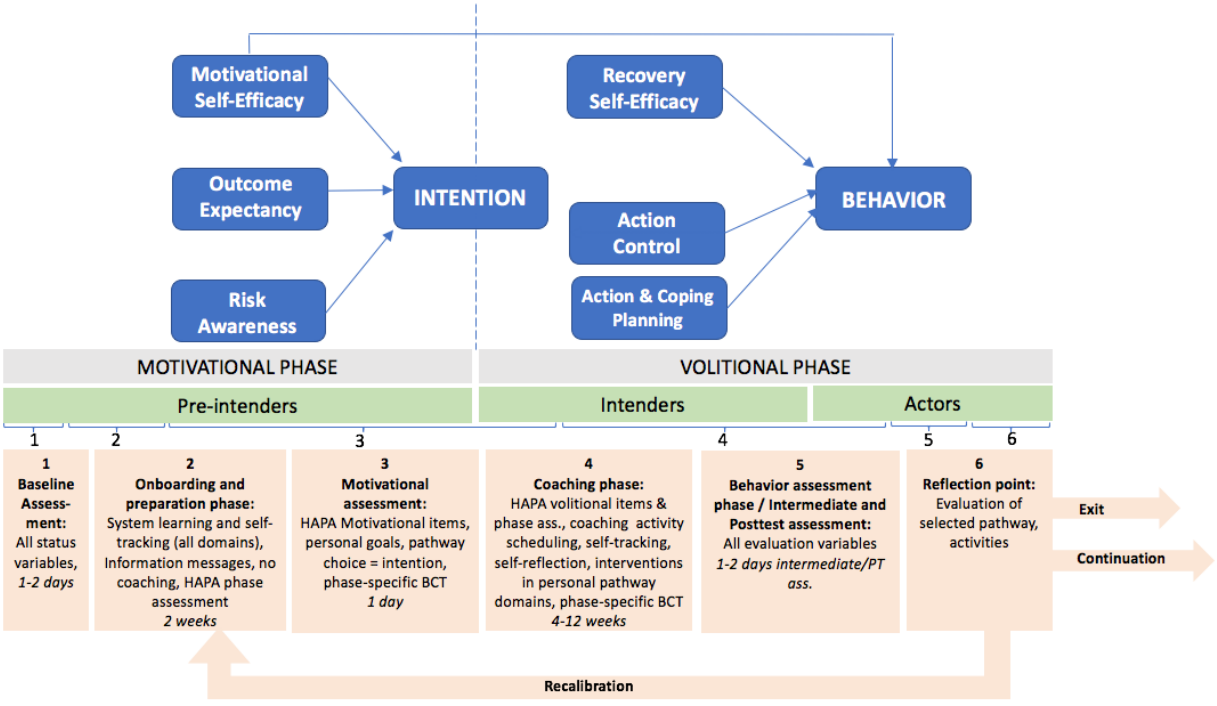

Figure 10: The Health Action Process Approach Model: Mapping of Study and System Phases.

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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. Figure 11 provides a summary of the stage-mapping of the HAPA variables that complements Figure 10 above.

Table 2
Intervention Matrix for HAPA-Based Stage-Specific Treatments

	Stage group		
	Preintender	Intender	Actor
Motivational constructs			
Self-efficacy (motivational)	x		
Risk perception	x		
Outcome expectancies	x		
Goal setting	x		
Volitional constructs			
Action planning		x	x
Coping planning		x	x
Social support		x	x
Self-efficacy (maintenance)		x	
Self-efficacy (recovery)			x
Action control			x

Figure 11: Mapping HAPA Variables to HAPA Stage (Mindset) Groups (from Schwarzer et al., 2011).

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 an item such as the one shown in Figure 12. This example is from a rehabilitation study and could be adapted to the NESTORE context, for example, by asking individuals to consider the 4 weeks prior to getting started with NESTORE and to determine whether they engaged in physical activity (OR cognitive activities such as cognitive training, learning a complex new task OR new social activities OR activities intended to promote healthy eating) over an appropriate time period and frequency that is considered "training" or "intervention-like" in each domain.

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

PHASE	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 will have serious health problems.	Educational messages/provide information about health consequences, self-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: (1) Awareness of standards (2) Self-monitoring (3) Self-regulatory effort	(1) During the last 4 weeks, I was always aware of my intended training program. (2) During the last 4 weeks, I constantly monitored whether I was as physically active as I had planned. (3) During the last 4 weeks, I always tried to be as physically active as I had intended.	(1) Prompt review of behavioural goals, educational messages, self-tracking, model/demonstrate behaviour, instruction (2) Self-monitoring, provide feedback (3) Provide general encouragement, self-monitoring / review of performed activities, prompts/reminders (of plans to overcome problems and of goals)

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Table 1
Stage Assessment

"Please think about the month before the rehabilitation started. Did you engage in physical activity at least 3 days per week for 40 min or more? Please choose the statement that describes you best."

"No, and I do not intend to start"	"No, but I am considering it"	"No, but I seriously intend to start"	"Yes, but only for a brief period of time"	"Yes, and for a long period of time"
☐	☐	☐	☐	☐

Note. This stage assessment can be adapted to any other goal behavior.

Figure 12: Exemplary Item to Classify User Mindset for Health Behaviour Change (from Schwarzer et al., 2011).

Whereas the HAPA model is used in NESTORE as the main underpinning theoretical model for behaviour change, we consider the SOC model on a higher-order level. SOC provides the meta-theoretical framework of how individuals deal with changes in their (cognitive, physical, social etc.) resources and how their selection of goals and ways of achieving those goals shapes their individual developmental trajectories. As such, SOC variables would have to be part of the baseline assessment to identify personal goals and preferences and make goal hierarchy (selection), identify what can still be achieved and what not and how life domains and goals or the means of achieving them can be replaced if no longer available or possible to reach (compensation), and define steps to be taken for improvement in a particular domain (optimization). These aspects can be assessed with regard on a general level to identify differences between individuals in their tendency to engage in the three regulatory strategies regarding their life and health in general. They also relate well to some key aspects of BCT found to be most effective, such as goal setting in general, personalization (in the face of a particular person's resources, life context and motivation), as well as planning with regard to action implementation but also for how to overcome barriers (e.g., coping planning; Scholz et al., 2007).

5.2 E-coaching in NESTORE

5.2.1 E-coaching architecture

In this section we depict how the NESTORE system will implement the e-coaching architecture according to the models presented in Section 4.1 and 4.4.4 and the e-coaching strategies described in Section 4.1. Figure 13 depicts an abstraction of the e-coaching architecture for NESTORE. A detailed system architecture will be provided in D6.3.

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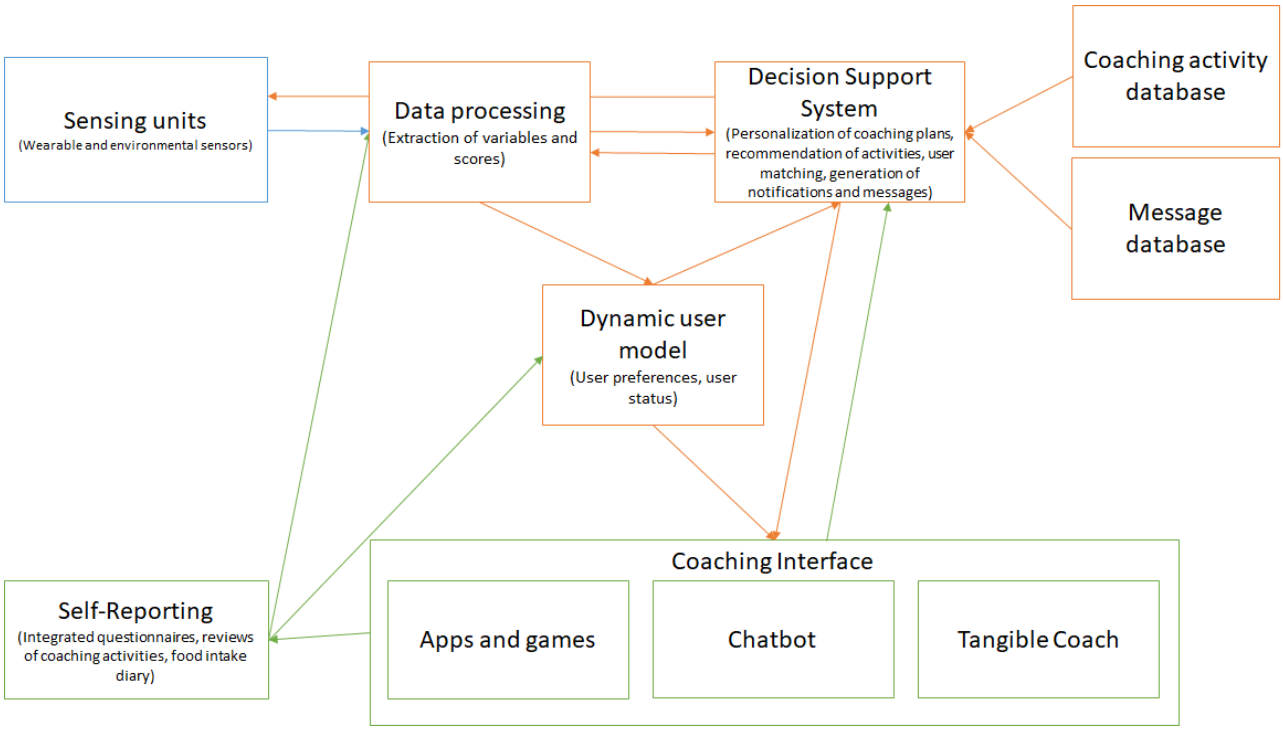

Figure 13: NESTORE e-Coaching Architecture.

5.2.2 Monitoring

Both types of automated and self-reported monitoring are supported. Wearable and environmental sensors will be used to collect data on user behaviour and activities (wearable sensors will be described in D3.1, and D3.4; environmental sensors in D3.2). The user will also input data into the system through different interfaces for self-reporting, e.g., integrated questionnaires in the chatbots, dedicated apps, etc. In particular, self-reporting of food intake via the chatbot will be supported by automatic-food recognition from photos of dishes, which will be described in D3.3. A first prototype of the chatbot integrating food recognition from photos has already been realized within WP5 at the time of writing of this deliverable.

5.2.3 Data processing

All data collected by the sensors and by self-reporting interfaces are processed in a cloud server in order to extract the relevant variables, which will be selected from the list described in deliverable D2.1. The current status of the user is assessed and stored in the dynamic user model. The dynamic model includes not only the status of the user with respect to the different NESTORE coaching domains, as tracked by the system, but also the user's motivational status with regard to the HAPA model, as reported through integrated questionnaires, and user preferences, also reported by the user through the different NESTORE interfaces. Moreover, user behaviour is inferred from the analysis of data collected. This includes the recognition of activities, suggested by the system or autonomously carried out by the user. All the data analysis carried out by the system will be described in deliverables D4.1, D4.2, and D4.3.

The dynamic user model created by the system will be used by the Decision Support System (DSS) that will dynamically adapt the coaching plan according to user preferences and user states and will provide timely and tailored coaching activity suggestions and information messages. In particular, the DSS will ensure that messages will be dispatched according to the different phases of the HAPA model and the current state of the user. The coaching plan adaptation strategy is described in more detail in Section 5.2.5. The description of the DSS will be released in the deliverable D4.4.

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5.2.4 E-coaching intervention delivery interface

In order to adapt to the different needs and desires of the NESTORE users, different interfaces will be provided. In particular, the e-coaching intervention can be delivered through:

1) Mobile apps and games
2) Chatbot
3) Tangible coach

Users will be able to choose among the different interfaces, according to their preferences. Each interface has different advantages and disadvantages, providing a different user experience but the same e-coaching content. Indeed, the coaching plans suggested by the Decision Support System will be dispatched to one or more interfaces, according to user preferences and context information (e.g., if the user is outdoor, the e-coaching intervention will be delivered to the chatbot or the mobile app; if she is indoor, close to the tangible coach, this latter interface will be used). Moreover, a consistent experience will be ensured for the e-coaching: through a co-design process, a virtual coach embodiment will be identified and coherently distributed in the different interfaces. The purpose of such embodiment is to make the user identify the embodied virtual coach sender of any e-coach message as this embodied virtual coach. Such embodiment (e.g., a pet plant) can be physically implemented for the tangible coach, and linked visually in the chatbot (e.g., in the chatbot avatar) as well as in the tips and messages provided by the apps and games. Such embodiment for the virtual coach is intended to increase the user's empathy and the user's trust in the system.

The mobile apps and games are integrated in the personal device of the user, therefore available ubiquitously, provided that an internet connection is available when using the personal mobile device. In order to maximize the compatibility with existing personal user devices, a cross-platform development framework should be used, ensuring compatibility with most Android and iOS devices. The mobile app could support, among others, the following features:

- Pathway choice and intention making
- Calendar scheduling of the coaching activities (if possible, integrated with a user's own calendar)
- Review of activities
- Self-monitoring in the different domains, through graphs of the user's progress
- Control of coaching preferences and data privacy settings

A detailed description of user pathways and coaching strategies is provided in Section 5.2.5.

The chatbot is a text-based conversational agent where the user can chat with the user through text or media content (e.g., images, emoticons, etc.). The chatbot interface can be integrated in the NESTORE mobile app (a first prototype of such interface is shown in Figure 15) or in an existing compatible messaging application (e.g., Facebook Messenger). The chatbot could support, among others, the following features:

- On-boarding, including coach and system presentation, first preference settings
- Intuitive food intake self-monitoring, through text and/or image entries (i.e., dish photos).
- Mood state assessment, through semantic analysis of user-inputted text
- Motivational assessment, through standardized questionnaire based on HAPA model

The tangible coach is a physical device that will be installed in the user's environment and that will physically embody the virtual coach. The main role of such interface is building empathy with the user and providing tailored feedback and coaching through an ambient tangible interface. This latter, could provide unobtrusive feedback in the user environment through data physicalisation (Thudt et al., 2018; e.g., a new flower in the pet plant for an achieved goal). The interface could also support voice conversation with the users through the

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same conversational agent infrastructure available in the chatbot, using text-to-speech and speech-to-text APIs. The tangible coach could support, among others, the following features:

- Physical embodiment of the virtual coach
- Tangible display and physicalisation of user progress in the goal
- Empathic vocal interaction with the coach through the chatbot infrastructure
- Facial expressions of the coach for empathy building

The mobile app, the chatbot, and the tangible coach will be described in detail in deliverables D5.2, D5.3 and D5.6.

Additional feedback could be delivered through the wearable sensors, especially for supporting coaching activities outdoor. Such opportunity is currently investigated by experts and will be further investigated through a co-design process.

As a complementary platform for delivering the coaching activities, games will be also developed. A coherent user experience can be ensured in the game, with the same embodied virtual coach acting as a guide also in the game. The NESTORE game(s) will be detailed in the deliverable D5.5. This deliverable will also provide information about gamification techniques throughout the NESTORE platform. Preliminary investigations of the user appreciation of such features showed mixed feelings: some users where enthusiastic about rewards, while others strongly disliked such features. If gamification will be implemented in NESTORE, it would be important to provide users with the choice to enable or disable certain features.

5.2.5 E-coaching domains and coaching activity strategy

NESTORE will coach the user in the following domains (cf. deliverable D2.2):

- Physical activity and physiology
- Nutrition
- Social activity
- Cognitive functioning

It is worth noting that although the mental/emotional domain has not been retained for coaching, the affective state of each user will be measured in order to provide a better user experience in the system and to track how things are going in general across domains. As discussed in Section 4.4.3, the majority of previous systems provided coaching for only one domain. Even systems that coached the user in different domains did not provide a truly integrated multi-domain approach. This is often true for many of the individual coaching domains, such as in cognitive training (see, e.g., Binder et al., 2015). Therefore, a major challenge of the NESTORE system is defining a multi-domain implementation of the HAPA model and the associated BCTs. While Section 5.1 depicted the different BCT components according to the HAPA model, we detail here those supporting the multi-domain coaching. Starting from the user perspective that even in older age time for additional activities is often limited and therefore the user cannot or does not want to train all the domains available in NESTORE, at least not one by one in consecutive fashion, it is necessary to support, first, the possibility to coach only in the domains of interest and second, the possibility to train in multiple domains of interest in a simultaneous and integrated fashion that may be achieved, for instance, through engaging in particular everyday activities. To ensure that the user can maintain or improve their wellbeing and health in the different domains, three levels of coaching are defined:

1) Pathway
2) Coaching activities
3) Training activities

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A **pathway** is the process of pursuing a high-level goal to which the user will commit at the end of the motivational phase. A pathway could be directly linked to a domain (e.g., I want to improve my healthy eating habits) or span across more domains (e.g., I want to maintain my physical health level, involving physical activity and nutrition). Technical and scientific names would be avoided in order to ensure an easy understanding of the pathway goal to every user. Additionally, educational messages will provide the required information to the user to understand the importance of each pathway and to choose the one that fits their interests best.

Once the user chooses a pathway, a set of **coaching activities** related to the pathway (thus often particular training in the selected domains) is proposed. A coaching activity is a time-bound activity that can be scheduled in the personal calendar (thus helping her in planning the activity and sticking to the plan). The activity can be composed by a set of specific exercises (e.g., flexibility exercises), or can be proposed as an everyday activity (e.g., gardening with a friend, or buying vegetables in an unknown supermarket). In both cases, instructions for carrying out the activities and maximizing the impact in the involved domains are provided. In particular, a coaching activity can be composed by different training activities in different domains.

Training activities are the atomic building blocks of coaching activities and are defined by the experts in each of the NESTORE coaching domains. They can be defined as structured activities (i.e., specific exercises carried out to train the user in a specific domain) or non-structured activities (i.e., everyday activities that can be conducted as part of the daily routines but that can still contribute to the improvement of well-being in one or more domains).

While coaching activities will be defined in the system as a list of training activities in one or more domain, such list can be customized by the system according to user preferences in terms of duration and level to be attained. The user can also choose to carry out only a part of the proposed activity. After the completion of the activity, the user can review her personal trajectory in the system. Eventually the system might have recognized a part or all the training activities performed. The user can still modify what was recognized by the system. A score system assigned to each training activity will allow to keep track of user progress and personal goal attainment. Such scores can be shown to the user or not, according to her preferences.

The following structure presents the possible elements that can be used to describe a coaching activity plan in the system:

Coaching Activity 1:

- Possible weekdays
- Duration
- Context requirements
    - Weather requirement: Sunny, Snow, etc.
    - Battery requirement: >50%
- Social context: Alone, Couple, Group, etc.
- Location Type : Gym, Park, Garden, etc.
- Total Score
    - Physical
    - Nutrition
    - Cognitive
    - Social
- Training activity list

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- Training activity 1
  - Type: Structured/non-structured
  - Repetitions, minimum duration, maximum duration, score for subdomain 1
- Training activity 2
  - Type: Structured/non-structured
  - Repetitions, score for subdomain 2
- …

This generic coaching activity plan can then be customized for the user and transformed into a coaching activity to be scheduled into the user calendar. Based on context information and on the user calendar, the decision support system will provide a list of suitable coaching activities from which the user can choose one activity or more and schedule them in the calendar. In order to help the user stick to her plan, the system can also suggest a location where the activity could be performed (e.g., a nearby park), and suggest people with similar interests that can perform the activity with the user. This latter function could be supported by the social platform, which will be detailed in deliverable D5.4.

When the user accepts to perform one of the suggested activities, the following coaching activity scheduling will be generated:

Coaching activity name

- Date
- Time
- Context requirement
  - Weather requirement: Sunny
  - Battery requirement: >50%
- To be performed with User 1 (invitation pending)
- Location: Park Name and link to Google Maps
- Total Expected Scores (Adapted to the user)
  - Physical
  - Nutrition
  - Cognitive
  - Social
- Training activity list
  - Training activity 1
    - Repetitions, duration, score for subdomain 1
  - Training activity 2 (adapted to the user)
    - Repetitions, score for subdomain 1

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At the end of the activity, the user will review the obtained results, adjust the results tracked by the system (e.g., adding an interaction partner not tracked by the system, annotating a food image not well-recognized by the system, etc.) and provide a rating for the activity. The results of the recorded activity could contain the following elements:

Coaching activity name

- Date
- Time
- Context information
    - Weather: Sunny
    - Battery: 80%
- Performed with User 1
- Location: Park Name and GPS data
- User rating
    - Overall
    - Social engagement
    - Perceived improvement
    - Fun
    - Fatigue
- Total Obtained Scores
    - Physical
    - Nutrition
    - Cognitive
    - Social
- Training activity list
    - Training activity 1
        - Repetitions, duration, score for subdomain 1
    - Training activity 2
        - Repetitions, score for subdomain 1

The rating provided by the user can then be used for improving the pertinence of the coaching activity suggestions provided by the system as well as to adapt the difficulty level to the user preferences and performance. It is worth noting that the coaching plan elements and in particular context information may vary significantly according to the selected coaching and training activities. The selection process of the coaching activities is still ongoing, since important requirements for the definition of coaching activities were defined in deliverable D2.2. The coaching activity definition process is described in more detail in Section 5.4 and is carried out as a cross-workpackage activity. The result of this activity will be described in the deliverable D5.6.

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5.2.6 Summary of e-coaching BCT components and features 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*: as shown in Section 5.2.5, 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
- *Personalization of goals*: as shown in Section 5.2.5, 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.
- *Praise messages:* praise messages will be an integral part of the system and will be ensured in all interfaces (mobile apps and games, chatbot, tangible coach). Particular rewards could be provided by the tangible ambient display integrated in the tangible coach or through gamification techniques.
- *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 will 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:* sensor choice is currently ongoing. Wearable sensors will be developed according to user needs, while environmental sensors will mostly use off-the shelves products. Each sensor will be thoroughly tested.
- *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, emotional experience and personal goal attainment) but also for reviewing activities that are tracked by the system. At the same time the system will leverage on the HAPA model to provide effective coaching according to the user motivation and mindset.
- 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 will be considered at the beginning of each pilot test. In order to ensure the sustainability of face-to-face instructions, one consideration can be to design coaching activities in which an expert user can show and explain the system to a novice user.
- *Provision of personalized content*: all content will be personalized by the different pilot sites, leveraging on co-design to conceive conversations and coaching activities that respect local traditions and facilities. Moreover, the system will be tailored to individual levels according to user preferences: the user will be able to choose among three different interfaces to access the coaching intervention, deciding what to share with other users and the frequency and timing of coaching messages.

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

- *Social ability*: as discussed in Section 5.2.3, a conversational agent will be an integral part of the e-coaching system supporting text based and voice-based conversations. Moreover, to increase the user experience of such conversations, user's affect will be assessed in order to adapt the conversation and build empathy with the user.

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- *Credibility*: since the system is built according to the recommendation of experts in the different coaching domains it should have the needed credibility. In the onboarding phase, such scientific underpinning will be highlighted. Moreover, informational messages could be 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 will be 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. As described in Section 5.2.5, coaching activities could be selected and adapted not only according to the user state and preferences but also according to context information, such us weather condition, or 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 (cf. Section 5.2.5) can be used to continuously improve user recommendations. Possibly, the system's ability to recognize user activities while food can be improved through the coaching activity review and through dedicated user feedback during food self-monitoring.
- *Data gathering*: the system will gather information from wearable and environmental sensors as well as from user self-reporting in the different interfaces.
- *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 described in Section 5.1, the HAPA model is integrated in the system in order to deliver the different interventions in a time-appropriate manner.
- *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 as well as the volitional phase with appropriate planning.

5.3 Example of Coaching Journey in NESTORE

In this section we present an example of how a person will use the NESTORE system to improve her well-being in a pathway of her choice. It is worth highlighting that this example is only meant to show the different intervention techniques discussed before and that the design choices of the coach might change during the project, according to the work that will be done in Tasks 5.2, 5.3, and 5.6.

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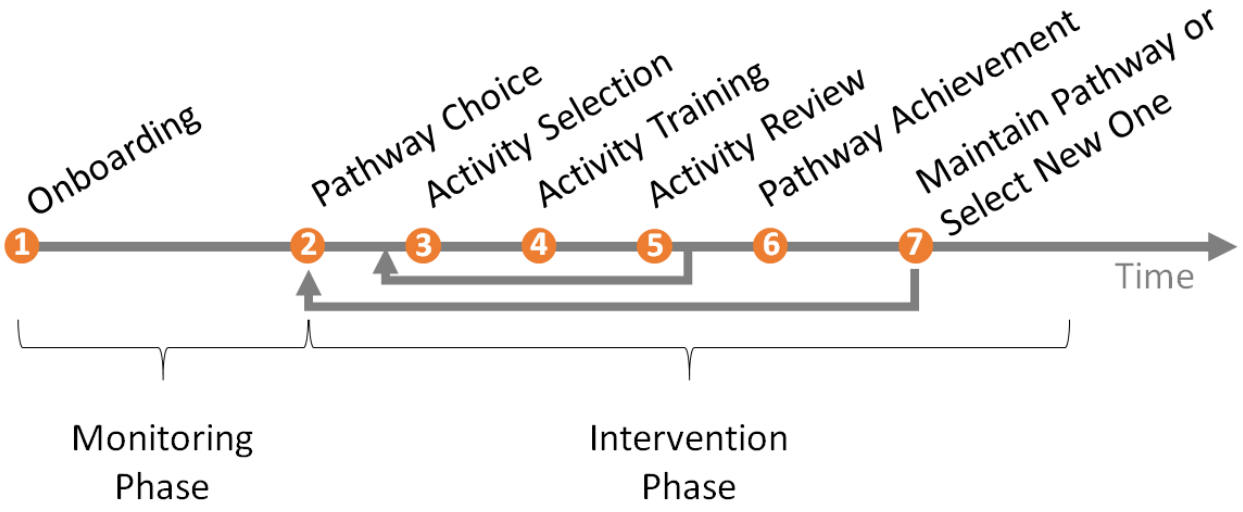

Figure 14: Representation of the User Journey with the Milestones Representing the Major Events Throughout the Intervention.

After downloading the application from the store and the registration, the first event in the NESTORE experience is onboarding, step number 1 in Figure 14 (see also Figure 10). The system needs information concerning the user in order to personalise interventions after the monitoring phase. The system will then ask for this information in a conversational manner. The chatbot can perform this task as shown in Figure 15. During this phase, the user can become acquainted with the system, which will provide messages about risk awareness, outcome expectancy and motivational self-efficacy. Please note that additional (in-person) assessments involving health and psychological experts will be necessary to characterize user status in each NESTORE domain as described in the variable lists in D2.1. At the end of the monitoring phase, the application allows the user to choose her pathway (point 2 in Figure 14). This choice will be experienced as making an oath, declaring the commitment to improve her health similarly to the "implementation intentions" technique (Gollwitzer, 1999). The interface imagined for this process is depicted in Figure 16, where the user will compose a sentence prompted by some suggestions visualized in the orange buttons. Tapping on each part of the sentence, the user will progressively compose the entire statement representing the commitment to a specific pathway. This has been structured as the pathway created in the design process as shown in Figure 19. Once the statement will be completed, it will be shown full screen as the personal motivational motto and at the same time the system will register the user's choices in order to understand a person's preferences and needs.

Once the pathway has been selected, the user enters the intervention phase and she can select specific activities proposed by the system, which are related to the chosen pathway (point 3 in Figure 16). As shown in Figure 17, the application proposes a list of activities that the user can choose with a proposed schedule. If the user accepts this scheduling, the application will synchronise the intervention plan with the user's calendar in order to provide recurring reminders. The application will also send personalised messages in order to apply all the possible interventions implemented in the system and link to the particular pathway. The application allows the user to follow the plan on a weekly basis. After the user will have conducted the planned activities and performed her training (point 4 of Figure 14), it will be possible for her to access a specific interface (see Figure 18) for the review and self-tracking of these activities (point 5 of Figure 14). This review will enable self-reflection and analysing the quantified outcomes will enable the user to improve or maintain her lifestyle. These milestones are all part of the intervention phase, which will be longer than the monitoring one. If the system records that the user improves in a given domain and achieves the personal goals she chose during step 2, the system will inform her that the pathway has successfully been achieved (point 6 of Figure 14). The system will automatically prompt the user to choose if she wants to choose a new pathway or keep working on

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this particular one to maintain (or further improve) a given domain. This closes the decision loop and brings the user from point 7 back to point 2 as depicted in Figure 14.

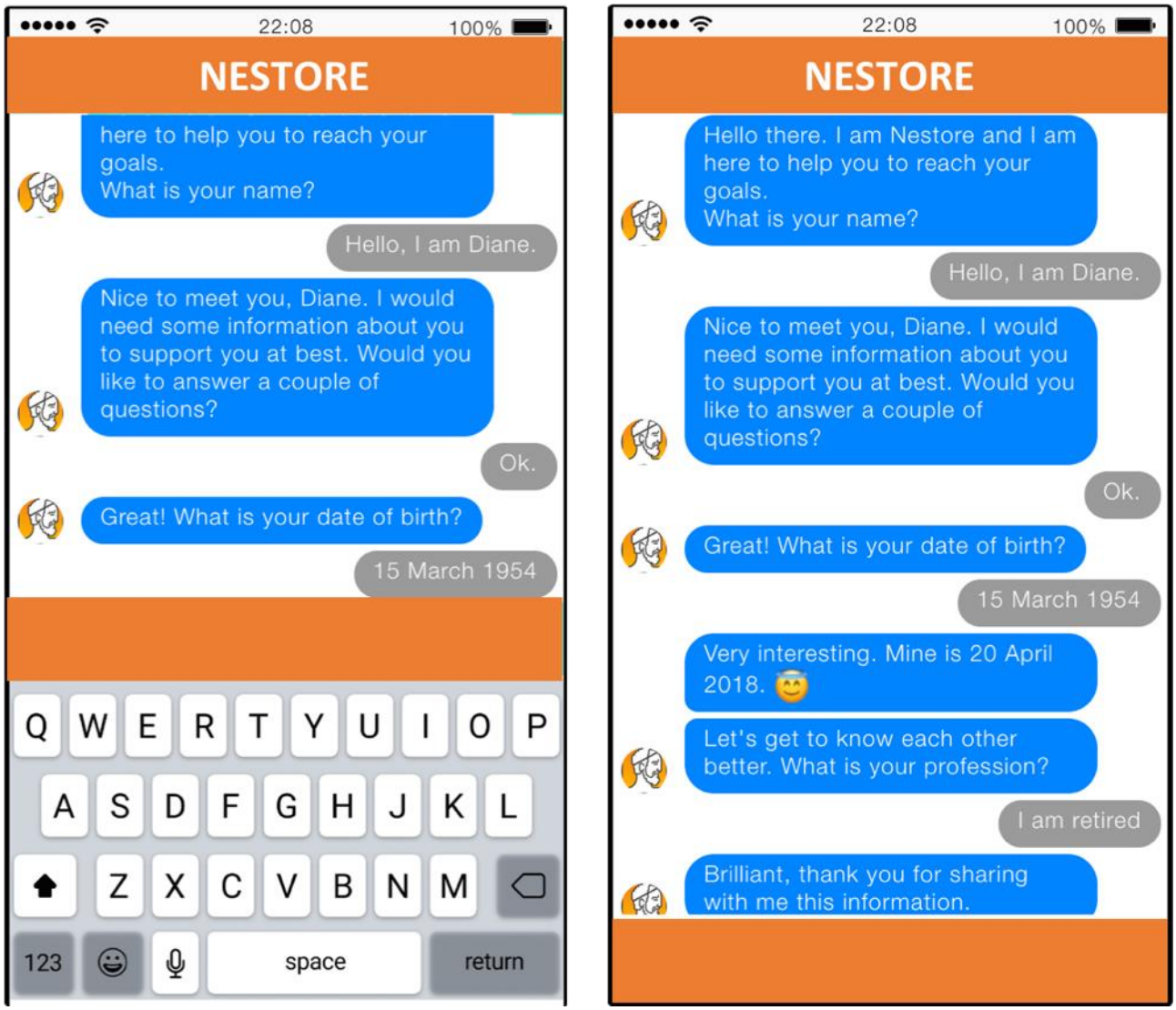

Figure 15: Mock-up of the Interface for the Onboarding of the User. The Chatbot Will Ask the User Some Questions in Order to Collect Relevant Data for the Tailoring of the Intervention.

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Figure 16: Mock-up of the Interface for the Pathway Choice.

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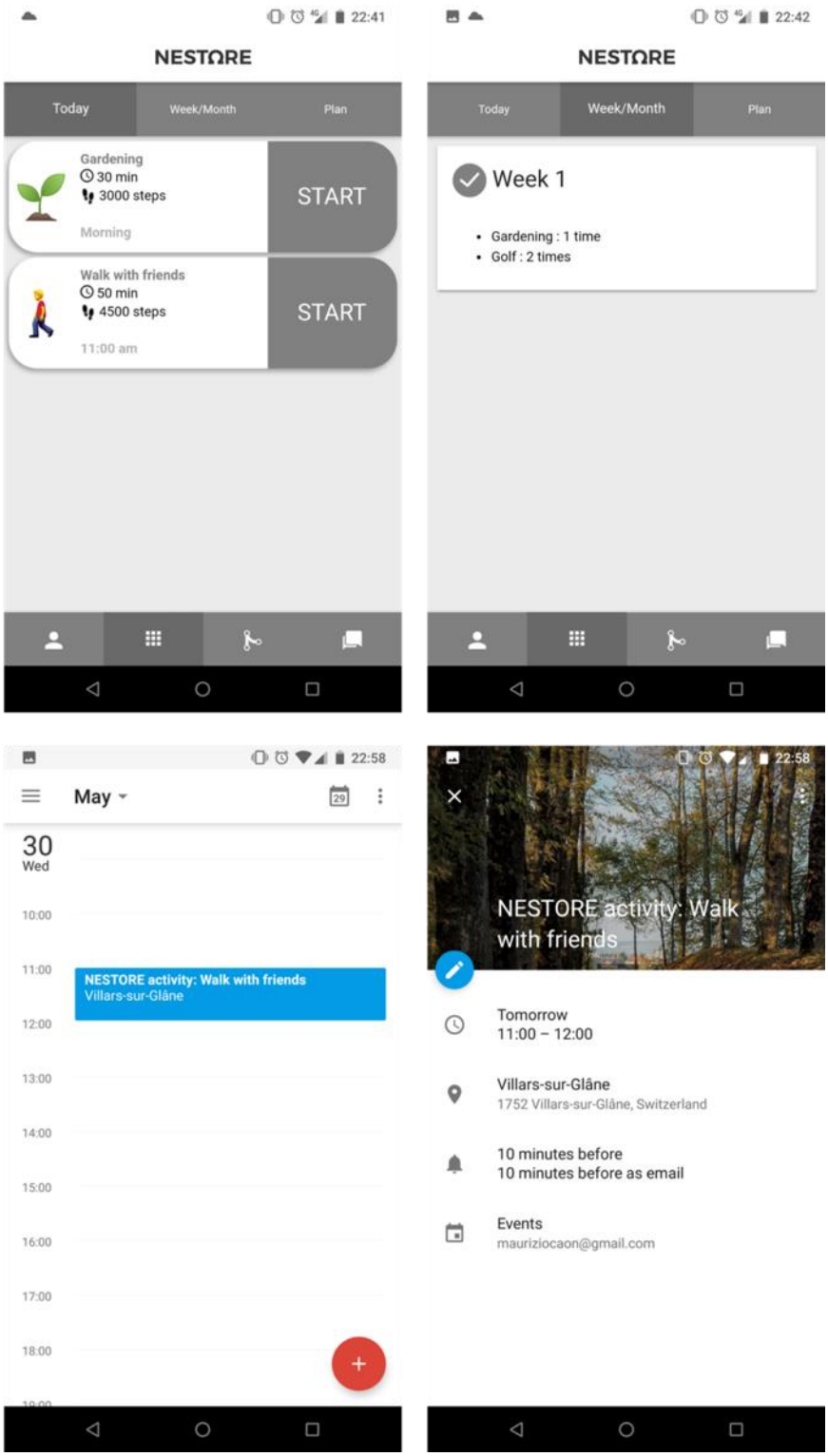

Figure 17: Prototype of the NESTORE Mobile Application Interface for the Activity Selection. The NESTORE Application Creates an Event in the User's Calendar.

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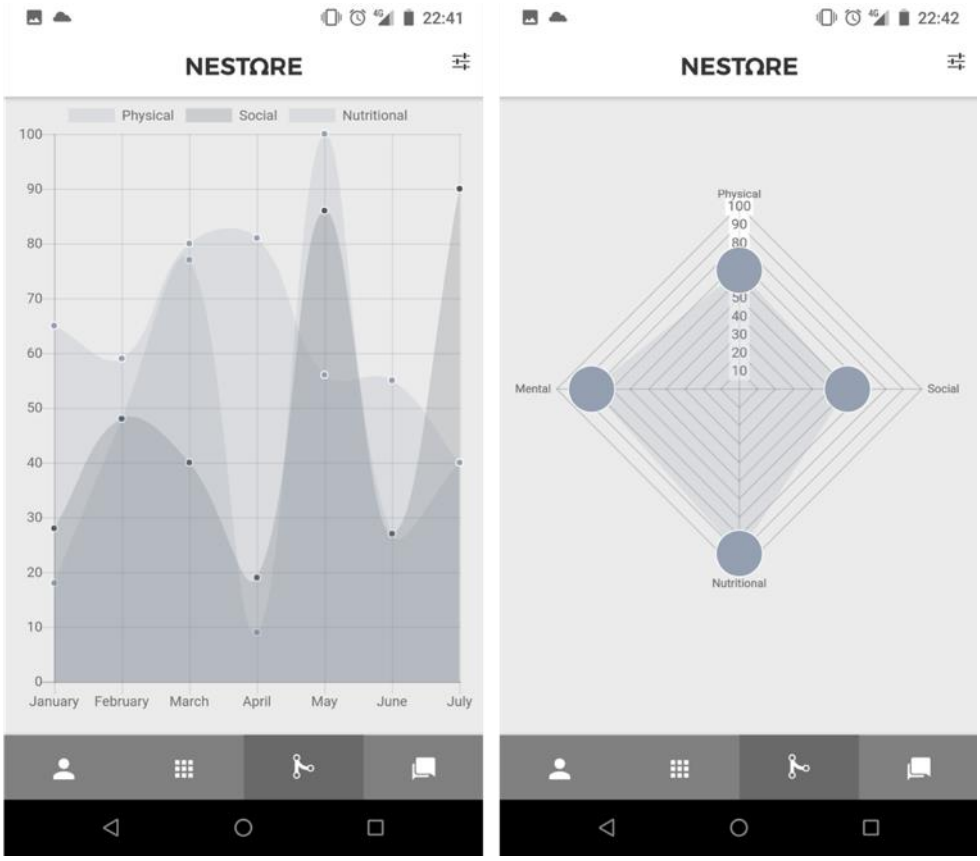

Figure 18: Prototype of the Interface for the Review of the Activities Performed by the User.

5.4 Definition of the Process of Co-Designing the Coaching Activities

Defining coaching activities that are adapted to users' needs and values is fundamental for determining the success of a coaching intervention. A key challenge in this process is identifying the values of users that are intrinsically heterogeneous (as older adults have a variety of personal needs as well as different occupational, social and psychophysical status) and that also span across four countries that are fundamentally different in terms of culture and habits (the NESTORE system will be co-designed and piloted in Italy, Spain and The Netherlands and co-designed in the UK).

The literature review evidenced different strategies for adapting coaching activities to users' needs and values. For example, for physical activity, walking and exercises for flexibility, strength and balance were often adopted. However, few other activities were proposed that matched everyday user activities, besides walking (for example, playing petanque). In NESTORE, we aim at proposing coaching activities that should help the user train in multiple domains, aggregating structured and non-structured training activities into an integrated overall coaching activity suite. For example, a coaching activity "taking a walk with a friend" will contribute to the physical and social domains, engaging in a new complex physical activity either alone or in groups has the potential to support improvements in the cognitive, physical and social domains.

Co-design is a typical approach for identifying activities that can be embedded in daily routines. At the same time, it is also important to identify daily activities that could be encouraged and supported to achieve the required daily training.

In NESTORE, the coaching activity definition will be the result of an ongoing iterative co-design process that will involve older adults as "expert users" participating in co-design workshops in the different countries and interdisciplinary "domain experts" for each of the different coaching domains.

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On the co-design side, users will define their preferred pathways through a co-design process based on physical cards and illustrated in Figure 19 (more details on this process will be provided in WP7 activities).

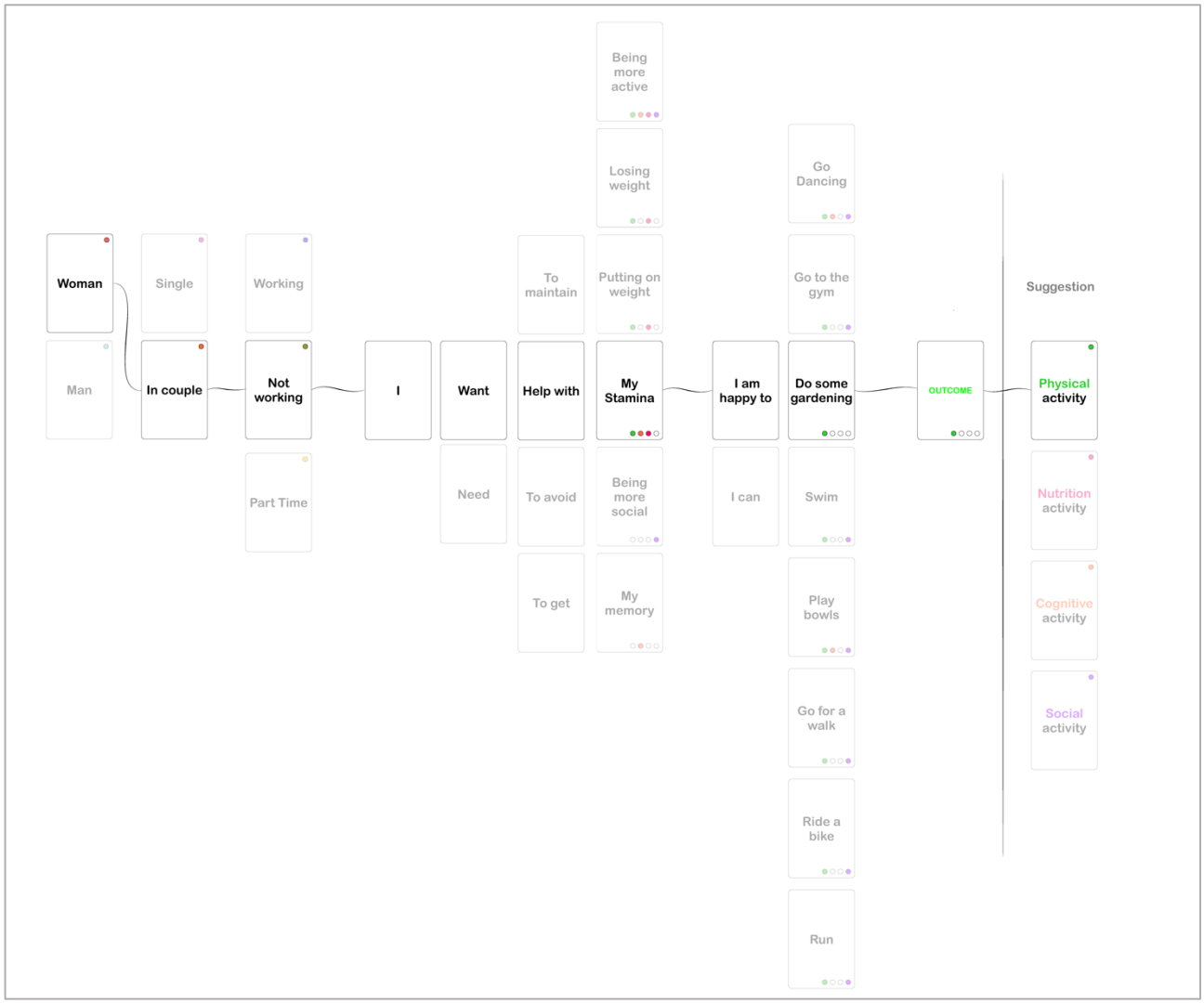

Figure 19: Illustration of User Pathway Choice Process.

The participant in this co-design process identifies herself and her well-being needs (i.e., a particular pathway, e.g., social-cognitive or cognitive-nutritional) with respect to the selection of NESTORE interventions. She then defines the type of activities she would be eager to or be ready to do in order to fulfil her needs and reach the selected personal goals.

On the other side, "domain experts" will define a list of activities and interventions, structured and non-structured, that are suitable for improving or maintaining the user's well-being and health in the different domains, based on guidelines identified in deliverable D2.2. Table 12 presents a preliminary list of training activities identified by a NESTORE expert for the aerobic/endurance domain for illustrative purposes.

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Table 12. Overview of Activities for Aerobic/Endurance Intervention in Cardiorespiratory Subdomain

TYPE OF ACTIVITY	THEORETICAL INTENSITY	CARDIORESPIRATORY SCORE
Structured Activities		
Any activity with measured HR 25-49% HR max	light	1
Any activity with measured HR 50-69% HR max	moderate	2
Any activity with measured HR 70-89% HR max	vigorous	4
Any activity with measured HR >90% HR max	severe	8
Non-Structured Activities		
Running slow speed	light	1
Running medium speed	moderate	2
Running high speed	vigorous	4
Walking with the dog	light	1
Slow Walking	light	1
Brisk Walking or nordic walking	moderate	2
Dancing	moderate	2
Cycling in the city/in the park	light	1
Cycling outside the city (main roads)	moderate	2
Climbing stairs (less than or equal to 4 floors)	moderate	2
Climbing stairs (more than 4 floors)	vigorous	4
Shovelling	moderate	2
Swimming in the sea	light	1
Swimming in the swimming pool	moderate	2
Sweeping	moderate	2
Lawn mower	light	1
Skiing	light	1
Nordic skiing	moderate	2
Gym courses (step, zumba, aerobic dance)	moderate	2

Note. Depending on the initial status of a user, some activities that can be regarded as light or moderately intense can differ in perceived and actual intensity between persons. The same will be true in other domains, such as cognition, where some activities can be cognitively challenging for some individuals and more or less automatized for others.

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It is worth noting that the domain expert identified a score for each activity, considered as an activity block of 10 minutes. The sum of the activity scores performed will help the system determine whether a user met the experts' recommendations, as described in deliverable D2.2. Therefore, the score is important for the system in order to assess the user progress in each domain, once the training activity is completed.

The final list of training activities will be defined at the intersections of the two processes, retaining activities that the "domain experts" judge as valid for training, that the technical "system experts" judge as easy to integrate in the system and that "expert users" judge as interesting for improving or retaining their well-being level.

Training activities will then be combined into meaningful coaching activities that the system can personalize according to user preferences and needs. Coaching activities will be mapped to one or multiple pathways. In this manner, when the user selects a pathway only the coaching activities that are beneficial for the associated goal will be proposed to the user. In order to validate the selected coaching activities, they need to be iteratively implemented and tested with users. Such process will be based on an incremental approach starting with coaching dimensions that are easier to treat in the system (e.g., physical activity and nutrition) and then implementing strategies for dimensions that require additional development, such as those that rely on the user's subjectivity for evaluation and that need to be based on user-defined goals (e.g., social).

Feedback on the different prototypes will be used to adjust the coaching activities as well the modalities of intervention delivery. In the last iteration, the different dimensions will be combined in order to provide multi-domain coaching activities. See Figure 20 for an overview.

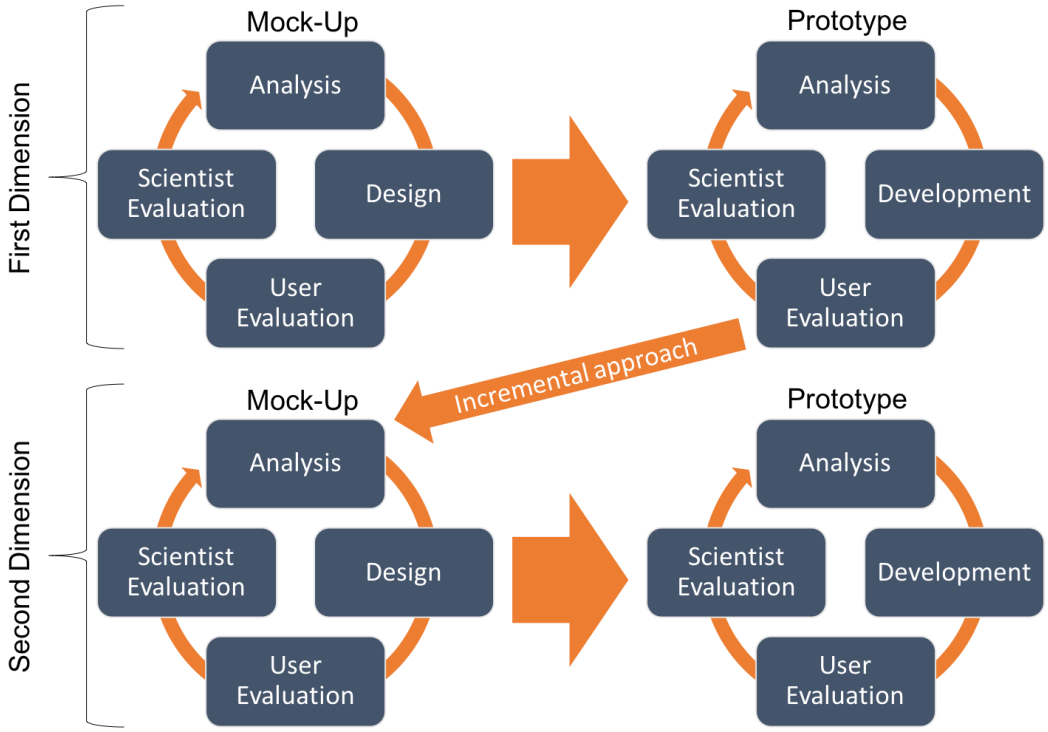

Figure 20: Example of iterative process for the design and implementation of coaching activities. The process would then continue with the integration of the different dimensions and the definition of multi-domain activities.

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5.5 Recommendations for WP5 and Integration with Other WPs

The definition of the e-coaching model proposed in this section defines important requirements for the implementation of the different coaching interfaces. The recommendations described in Section 5.2.4 for the intervention delivery will be implemented in Tasks 5.2, 5.3, 5.5 and 5.6.

In order to propose to the user appropriate suggestions for the coaching activities, the Decision Support System should learn from the user's previous choices and from the rating of the previous activities that she completed and reviewed. In particular, the coaching activities should be personalized according to the user state and preferences and should take into account the context information for an optimal execution of the activity. Moreover, in order to make the user stick to the plan, the Decision Support System should help the user to schedule the activity in her calendar, fitting the activity in the available time slots. The social platform defined in Task 5.4 might additionally help schedule the activity in order to perform it with a friend working on the same pathway or with similar interests.

As described in Section 5.2, the co-design process is one key element of the NESTORE development. The wide range of leisure activities named in D7.1 indicates the importance of personalizing the NESTORE coaching (or at least to plan the coaching strategies with the option to personalize to some extent). This also well reflects one of the BCTs found to be most effective for behaviour change ("personalization"). In the initial user-workshops, barriers named fit well with the planned health-behaviour-change approach to be used as the underpinning conceptual framework within the NESTORE approach, the HAPA model, which includes an explicit intention formation, clarification of risks perceived, assessment of a person's self-efficacy and then explicit planning of how to go about changing a particular behaviour and dealing with challenges. At the same time, others have also found that planning needs to allow sufficient flexibility to not feel overly intrusive and detrimental to the personal sense of autonomy (Arnautovska, O'Callaghan, & Hamilton, 2017) but ensures a person to feel the goals selected and plans made are one's own and fit one's own daily life routines (e.g., van Dyck et al., 2016). The barriers named by user representatives also reiterate the need / benefit of providing NESTORE users with continuous feedback (e.g., visualization of the physical activity/mood/social interaction/cognition/nutrition trajectory from day-to-day) regarding the planned behaviour change. Again, providing self-monitoring access and information has been shown to be among the more effective BCTs as described in the sections above. Intervention and coaching suggestions seem to be easier to follow if they are motivating in the sense of involving social interactions (i.e., which includes social reinforcement of one's goals) as well as a personally comfortable degree of being challenged. Comments made regarding "creative activities" could be well considered with regard to the serious games, targeting both the cognitive and the well-being domains in particular.

Another important aspect to be considered in planning the pilot studies is the selection of an appropriate control group or of appropriate control groups. In the cognitive training literature, the issue of control groups and their appropriateness has long been discussed. The most conservative and thus credible evaluation of intervention effects that are specific to the intervention itself (and not simply due to general engagement of participants in any kind of new activity) are so-called "active" control groups who engage in structurally similar activities as the intervention group(s) but without those ingredients considered to be the active features driving the intervention effect (for review, see Guye et al., 2017). In the behaviour change intervention literature, particularly the one using digital or e-coaching approaches, another type of control group has been one that receive similar intervention input but not via technological platforms (e.g., Czaja et al., 2018).

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6. Conclusions

In this deliverable, we present a rich summary and discussion of several different and to date only loosely (if at all) integrated literatures from the health behaviour domain in general and in aging in particular. These include theories of health behaviour change, behaviour change techniques (both traditional and digital), as well as e-coaching approaches and systems.

Often times, theories of behaviour change are implemented with little specification of the concrete behaviour change techniques employed. Vice versa, behaviour change technique taxonomies often lack theoretical underpinnings. Thus, theory-driven approaches and behaviour change techniques that fit the target population and the coaching domain are highly important to ensure user-oriented implementation and efficient change of health behaviour (Schwarzer et al., 2011; Sullivan & Lachman, 2017).

From the wide range of theoretical health-behaviour change models we have selected the Health Action Process Approach (HAPA) as the guiding conceptual framework for NESTORE for its continuous and stage-like properties and post-intentional predictions of behaviour that can help to close the intention-behaviour gap evident in other models. Within the HAPA framework, we will implement a selection of behaviour change techniques that have been shown to be effective in various health domains, mapped onto the appropriate (motivational or volitional) phase during the overall user journey of interacting and using NESTORE.

We conducted a systematic review of the e-coaching literature to determine an appropriate definition of a coaching companion and to be able to build upon previous approaches and system propositions in the area of digital health interventions using a coaching approach. The review results indicate some consistencies with the behaviour change technique literature in general. Given the focus on **e-**coaching approaches, the review needs to be viewed as complementary to the findings and guidelines reported in D2.2, particularly regarding the cognitive domain. Existing approaches in the "coaching" literature that we identified in the review reflect BCT approaches reasonably well. Personalization and the opportunity for self-tracking, support in setting personal goals, including a number of self-regulatory and motivational variables and ensuring autonomy support are some of the key features that emerge from this literature as key to be considered in NESTORE.

However, for the particular content of the domain-specific interventions, the respective training and intervention literatures are not well captured (e.g., cognitive training literature and state-of-the-art not captured in cognitive "coaching" papers). NESTORE has the advantage of drawing from well-established standards for training and evaluation in each of the NESTORE domains (outlined in D2.2) while at the same time using digital behaviour-change approaches including embodied e-coaching and conversational agents to health interventions grounded in theoretical health behaviour change frameworks that have been put forth recently. NESTORE will put a strong emphasis in going beyond traditional eHealth interventions by developing an e-coaching platform on the basis of both expert knowledge and a user-involved co-design approach that facilitates proper interactions with the coach in support of the various intervention domains and features. This work will be conducted, based in part on this deliverable, in the other tasks within WP5.

Whereas most previous approaches both in the traditional intervention literature, in the e**H**ealth and the e-coaching domains are mainly single-domain approaches. NESTORE aims to go the multi-domain route through a combination of both structured and non-structured coaching activities implementable in daily life for each coaching domain and at an even higher level, each well-being and health pathway.

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