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Ageing@Work

Smart, Personalized and Adaptive ICT Solutions for Active, Healthy and Productive Ageing with enhanced Workability

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The Ageing@Work smart virtual coach

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Disclaimer

Executive Summary

The purpose of this deliverable is to present the design and development of the Ageing@Work ambient virtual coach (AVC). The cognitive functionality along with the persuasive framework which are used to implement the behavior of the AVC are described by including the scenarios that trigger the coach to provide recommendations to the workers. Based on literature review and studies implemented during the execution of the project, rules have been formulated to create a proactive and discreet behavior of the coach both for working and personal life. These rules provide the basis for the cognitive functionalities of the coach which aim at establishing the overall interaction with the worker. Alongside, further to the AVC's cognitive behavior, the adaptations of the coach's visual and auditory modules are enhancing support provided to workers by boosting the persuasive framework.

Regarding the cognitive functions, the AVC is able to offer recommendations for five distinct but correlated dimensions concerning worker's personal and working life. These are: 1) level of stress, 2) symptoms of depression, 3) sedentary activity, 4) job scheduling and 5) levels of socialization. Based on both self-reporting and trained machine learning models the AVC is able to offer supportive recommendations behavior. The questionnaires used for self-reporting are valid for each one of the dimensions measured like PHQ9 for depression and the trained machine learning models are able to predict sedentary activity for the next day thus, the AVC can be proactive and intervene if necessary.

In terms of the persuasive techniques used for implementing a framework with multimodal interfaces, the deliverable presents the conceptual design and architecture of the AVC. In order to engage the worker with the coach's recommendations, the similarity principle effect is investigated which is expressed through age, gender and extroversion level in behavior. Age and gender are taken by the demographics of each worker and the extroversion level is calculated by the Big Five Model questionnaire. Extroversion is chosen based on the experiment that was conducted in D5.1 for the design of the avatar that embodies the virtual coach. Age and gender are implemented in terms of visual cues while differences in extroversion level are implemented through visual and auditory cues.

A preliminary evaluation of the persuasion framework revealed that trust and likeability are affected by both a user's extroversion level and their perception of the extroversion level of the avatar that embodies the coach. Further results will be gathered through the pilot studies regarding the effects of the AVC's behavior and persuasiveness.

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List of Terms and definitions

Abbreviation	Definition
AT	Autogenic Training
AVC	Ambient Virtual Coach
cCBT	Computerized Cognitive Behavioural Therapy
DB	Diaphragmatic Breathing
DSM IV	Diagnostic and Statistical Manual of Mental Disorders IV
EFT	Emotional Freedom Technique
GAMA	Gamma-AMinobutyric Acid
HAI	Human Agent Interaction
ICT	Information and Communications Technology
IOT	Internet of Things
FFM	Five Factor Model
LKM	Love Kindness Meditation
MB	Mindful Breathing
OSH	Occupation Safety and Health
PHQ	Patient Health Questionnaire
POI	Point Of Interest
PMR	Progressive Muscle Relaxation
TM	Transcendental Mediation
VUM	Virtual User Model
WP	Work Package
wVUM	Worker Virtual User Model

Table 1. Definitions

1. Introduction

1.1 Scope of the deliverable

The aim of this deliverable is to present the cognitive functions of the Ageing@Work ambient virtual coach which offers an overall supportive behavior. The system is responsible for realizing as self-monitor module, some essential functionality of the worker for both workplace and personal life and present recommendations through a user friendly ambient virtual coach (AVC) which is embodied at the worker's smartphone or further personal ICT device. Functionality of the AVC is described based on the multi-modal system for worker interaction which is orchestrated by the cognitive functions. In this deliverable, we present the proactive and discreet behavior of the virtual coach as a result of both visual and auditory modules that consist of the persuasive framework.

Regarding the cognitive functions, there is an extended description of how the AVC is triggered at work in order to perform measurements that can enhance productivity. Furthermore, we describe how it provides reminders and suggestions based on the worker's behavior analysis and detection of adverse signs which may need to be counteracted for. There are sections that present how we have achieved this target by explaining the system design and model which has taken place and which follows OSH, behavioral and ergonomics factors. Besides, based on behavior analysis, sensor-based monitoring and self-reports, the deliverable showcases the AVC's interaction with the worker. Involved cases are illustrated in detailed and the reaction of the coach is presented based on the adaptations that take place for integrating persuasive techniques.

Persuasive techniques and strategies are based on theories like first impression effect and similarity effect which explain trust and likeability amongst people. Trust and likeability affect persuasion, thus we investigated and presented in this deliverable firstly, the adjustment of these theories from human to human interaction into human to agent interaction and secondly their effects to users. Moreover, personalized messages were integrated to the system regarding salutations and recommendations' targets.

A preliminary evaluation has taken place during T5.1 which was extended in T5.4 and revealed that feelings of trust and likeability which affect persuasion are affected by a user's personality and their perception of the avatar.

1.2 Relation to other activities and deliverables

In order to achieve the development of the novel, joint productivity and personal life support ambient virtual coach (AVC), the actions and results of this deliverable are related to the ageing worker and workplace models described in deliverable 3.2. Dynamic Virtual Worker and Workplace Models, along with the user activity and behavior tracking methods described in deliverable 4.2.Worker behavior & Affective

Traits monitoring methods & infrastructure. Thus, the system design has been based on a careful modelling of ergonomics, behavioral and automatic user monitoring and behavior analysis with the support of both ICT technology and life scheduling decisions taken by the workers. Moreover, the empathic and "mirroring" avatar that embodies that AVC is related with the deliverable 5.1. Ageing@Work mirroring avatar and ageing worker dashboard which describes the subtle adaptations of the appearance of the AVC based on its cognition and on the self-understanding metrics of the dashboard.

1.3 Structure of the deliverable

The structure of the deliverable is as follows: In Section 2 an extensive literature review is presented regarding persuasive framework that use techniques to implement affective technology and psychological theories that have engaging effects in human-agent interaction. Section 3 continues with the description of the cognitive functionality integrated into the AVC's system. Subsections of section 3 regard sedentary activity detection, job scheduling adaptations, stress detection, socializing behavior and depression detection. For all these aforementioned cognitive functions the recommendations provided are presented as well. In Section 4 we present the persuasive framework, therefore, its concept and design along with some preliminary evaluation results and scenarios of the coach in action. More specifically, we present how the theories of persuasive models are combined with the rules for cognitive functions and the AVC's behavior both visually and acoustically is created. The deliverable concludes with section 5, which presents an overview of the activities taken so far.

2. Background and Rationale

2.1 Affective computing for persuasive technology

Virtual agents are becoming increasingly more present in our everyday lives as they are being used in many applications in a number of diverse fields like commerce (Gong 2007; Van Doorn et al. 2017), health (Bickmore and Picard 2005; Song et al. 2013), therapy (Gaggioli et al. 2013; Song et al. 2013), learning (Burleson and Picard 2007; Subhash and Cudney 2018) military systems (Gratch and Marsella 2004; Moening et al. 2016) and videogames (Lin and Wang 2014). The way humans perceive and interact with these virtual agents is essential for the success of the applications (Breazeal 2009; Tinwell et al. 2011). Despite the progress in the area, several considerable issues in the interaction between humans and the virtual agents remain unsolved (e.g. Tinwell et al. 2011).

To facilitate the interaction between virtual agents and users, researchers are trying to create virtual agents capable of having natural and effective communication with the users (Beale and Creed 2009; Tinwell et al. 2011). This has led them to explore ways to enhance virtual agents with the ability to express human emotions (Tinwell et al. 2011; Torre, Goslin and White 2019). The increased focus on the expression of emotions is motivated by relevant literature findings appointing the importance of emotion in peoples' everyday lives. Expression of emotions is considered to be essential for social interaction (Russell et al., 2003), as extant literature agrees that one of its essential functions is social, e.g. to provide people with information about changes in the environment and predict behavior of the one expressing the emotion (Ekman 1999).

Researchers working on the topic of human-machine interaction indicate that virtual agents need to be able to recognize and express emotions to facilitate the communication between humans and the agents (Breazeal, 2009). However, it remains unclear how these emotional displays from the virtual agent's side will affect people's behavior in the interaction, and more specifically some prime facets of the interaction such as trust. Trust is a vital ingredient for social relationships; it has proved to be important in stimulating the initiation and maintenance of social interactions (Mcknight, Cummings, & Chervany, 1998). The absence of trust may initiate the collapse of the bonds between the two sides of an interaction (Lewicki & Bunker, 1996). Trust is also an important element for the use of a technology (Braun 2013; Kim and Peterson 2017). Therefore, trusting a virtual agent can greatly affect the intention to use the app.

During the last decades, artificial intelligence or machine intelligence has been welcome in the daily life of many people in order to facilitate tasks that include reasoning, knowledge extraction and representation, learning, natural language processing and perception. The general idea of artificial intelligence though is that it can simulate the nature of the mind so that artificial beings can be endowed with human-like behavior. This behavior has been evolved on systems that integrated the way a person is thinking before taking any decision by changing the weights of various parameters that matter. Lately, in the group of

these parameters, emotional and personality parameters have been added that describe a dimension which adds empathy to the system.

Emotion is "a state of physiological arousal and cognition appropriate to this state of arousal" (Schachter & Singer, 1962). Thus, when emotion is depicted in a person's face, a non-verbal communication has been achieved that is universally understandable. This type of communication influences the behavior of people around the subject by creating various reactions based on it. In similar way, if emotion can be depicted in technology systems, users will react as if these systems are real persons expressing emotional states. Emotional states are affective states that last for a short period of time and have several dimensions, most commonly used the valence and arousal.

Personality is the psychological concept for individual differences on how people reflect emotional, interpersonal, experiential, attitudinal and motivational styles. It is a personal characteristic that is stable for long periods of time and it is widely described by the Five Factor Model (FFM). Based on personality, real-life preferences are related, such as music (Chamorro-Premuzic & Furnham, 2007), implying that it appears to be a good feature set for modelling long term user preferences. Thus, personality along with emotions have to be combined in order to create a complete process of human-decision making that can be integrated into technology.

It has been studied and verified that personality and emotions are correlated in a way that personality traits predispose individuals to certain moods which influence later emotional states (Rusting, 1998). So, a lot of attempts have been done to model human personality and emotional status in order to enhance affective technology with studies that had a mixed method evaluation that involved unobtrusive detection [Subramanian et al., 2016] for both of them.

In human computer interaction, there are many researches that support the importance of adapting systems in order to create a more personalized experience. This personalization is based in adapting the content, interface or services provided to each user separately. Thus, it is important to identify the bricks that are needed to build such systems which are the recognition of basic emotions and personality of users. Such systems use unobtrusive and robust methods for detecting the appropriate information by analyzing and checking traffic in social media, mobile devices and sensors.

Emotions and personality along with sentiments can be described with psychological theories translated into computational models for use in personalization systems. Up to today's evolution, technology has integrated techniques for implicit and explicit acquisition of personality, emotions, sentiments and signals from either social media or mobile phones or sensors generally.

This emerged technology has offered the ability to create user models which take into consideration a more user centric information like emotions and personality which earlier was difficult to acquire. Personalized systems have started to develop an emotion and personality-aware engine which takes advantage of the knowledge that is offered about users through their traces.

2.2 Related Theories for Persuasive Models

2.2.1 The first impression effects

The success of the first impression effects regards the factors that influence the users' reactions according to the context. Essential role plays the correct choice of features that formulate a first impression of an embodied virtual agent which demands study of the goal that is going to be served. In case of professional looking agents, trustworthiness and credibility should be inspired during the first seconds, thus appearance is one factor to take into consideration. An agent dressed in white coat and wearing a stethoscope is positively rated on these characteristics, the relationship formed with the user and the intention to use it (Parmar et al., 2018). First impressions are long-lasting, it has been shown that they last for months (Gunaydin et al., 2017) and influence judgements even when contradictory evidence about an individual exists (Rydell & McConell, 2006). It is possible that first impressions affect the implicit impressions, which are resistant to change (Mann & Ferguson, 2015), thus, making it essential to design a virtual agent with the desirable first impression result for better Human-Agent Interaction.

First impressions are used in everyday life in order to determine who one should approach and interact and who not to. They are a deciding factor in trustworthiness and they are responsible for forming impressions about one's context. These impressions are stored in memory as responses to verbal, visual, emotional and self-referential processing in order to create distinct varieties of episodic memories (Macrae, C. N. et al., 2004).

2.2.2 Similarity principle of attraction

In social sciences, first impressions have social and intellectual dimensions which affect interpersonal likeability by fulfilling the similarity principle of attraction (Lydon E. J., 2011). The principle of similarity states that two entities which share visual, acoustic and behavioral cues are perceived as more similar than others. This principle has been applied in agents regarding similarity in values and has been proved to be a successful driver for cooperation (Cruciani C., 2017). Likewise, regarding visual similarity, studies have shown that agents with similar appearance with the user, when performing in a helpful way, help the improvement of the user more than when it was dissimilar. However, and especially in males, when the agent was similar but not helpful, the users expressed negative feelings (Vugt H.C.V, 2008). Thus, apart from the similarity dimension, it was essential to examine the effect of this dimension in terms of both the gender of the agents and the result which mediates likeability according to positive or negative status.

An essential dimension regarding similarity principle is based on the personality of the user and the perception of the agent. In the study conducted for deliverable 5.1 Mirroring Avatar and Dashboard, it was shown that apart from the distal cues that were used for forming extrovert and introvert characters, the proximal cues received by the observers were affected from their personality. In other words, the facial and body features that were used for creating an introvert or extrovert avatar for mirroring the extroversion level of the worker, were not perceived as it was intended by the study. There was a clear distinction of the two groups of avatars but the distinction was affected by the extroversion level of the worker, thus the AVC is embodied with the avatar that is perceived with extroversion similarity apart from gender and age.

3. Cognitive Functions for Supportive Behavior

The core aspect of implementing some cognitive functionality into the AVC's behavior is to help the worker proactively through subtle notifications about health issues and to unobtrusively reduce the system's interference especially when the worker is not available due to work process. This is achieved through context-dependent rules that trigger notifications based on the appropriateness of both time and location. Moreover, an essential variable for enhancing the proactive and discreet behavior of the AVC is to form a type of empathic and "mirroring" approach when providing notifications. This approach is based on embodying the AVC by taking into consideration the current status of the worker along with demographic, mood and personality parameters which mediate the preferred communication style.

The current status of a worker depends on the automatic user monitoring and behavior analysis which are feeding the AVC with information regarding the stress levels, physical activity and productivity of workers which affect its proactive and discreet behavior. The empathic and mirroring approach is supported by the demographic, mood and personality parameters which adapt the notifications to achieve a more empathically personalized communication style. Thus, in order to develop methods for fulfilling the aforementioned requirements, specific worker's variables, either from their personal life or their workplace life, has been involved into adapting the AVC's form during the worker-system interaction. The AVC is embodied initially within a worker's selected 3D avatar from a variety that includes gender and age choices (male/ female, young/ old) (Ratan et al., 2019).

Therefore, the AVC performs a type of empathic cognition which helps into creating feelings of trust and likeability with the worker. These feelings are essential (Van Pinxteren, 2020) for establishing a strong relationship in Human-Agent-Interaction (HAI) especially in the context of health coaching and leading into a healthier lifestyle. For this purpose, an interdisciplinary research has taken place which included computer science studies and psychology theories (Card et al., 2018).

Recent studies show that virtual coaches can have an influence on user's behavior both online and offline (Fox, Bailenson and Binney 2009; Pena and Kim 2014). When people get in contact with a virtual agent, they can take on the perspective of the agent and attribute characteristics to themselves from the agent (Sah , Ratan and Tsai 2017). In this direction, being able to identify with the virtual coach has been shown to have positive influence in users' behavior such as when trust is put on them (Lee, Xiao, and Wells 2018). Therefore, adaptations in the appearance of the AVC based on its cognition can be of utmost importance to ensure the success of the goals of the digital tool using it. Literature has indicated many features in virtual agents' physical appearance that can be used enhance mirroring behavior, however, two have been identified as highly important (at least when it comes to the function of the AVC that is used in the Ageing@Work platform): gender and age.

When it comes to gender, users have the general tendency to choose avatars of the same gender to represent them. In a study, 255 participants expressed their preference through a series of avatars in a static context in terms of among other characteristics also gender. The results showed that people reported a preference for human avatars that matched their gender. In a more recent study using data from the game League of Legends (n = 15.392) reflecting more than 5 million avatar gender choices, results showed that there is a strong preference of same gender selection especially among women who were found to have stronger preferences for avatar gender consistency than men.

Age can be also an important characteristic in virtual agents. Studies that examined the effects of the virtual agent's age showing in their appearance, when focused on younger, college-aged users found that student tend to favor younger avatars, perhaps due to negative stereotypes about aging (Yoo, Pena and Drumwright 2015; Oh, Bailenson and Weisz 2016). In another study that include sample with older people 60+ showed that there is not certain preference for the age of the avatar, however, the match of the age between two avatars interacting increase trust (Lee, Xiao, and Wells 2018). Thus, we are expecting to see in pilot sites if these claims are validated again.
Taken all together, the AVC is enhanced with different versions for our platform varying in the following features: gender (female, male) and age (young, elder).

In the following picture, all features involved to the AVC's cognition are presented along with the interactions the AVC has with the rest of the project's components.

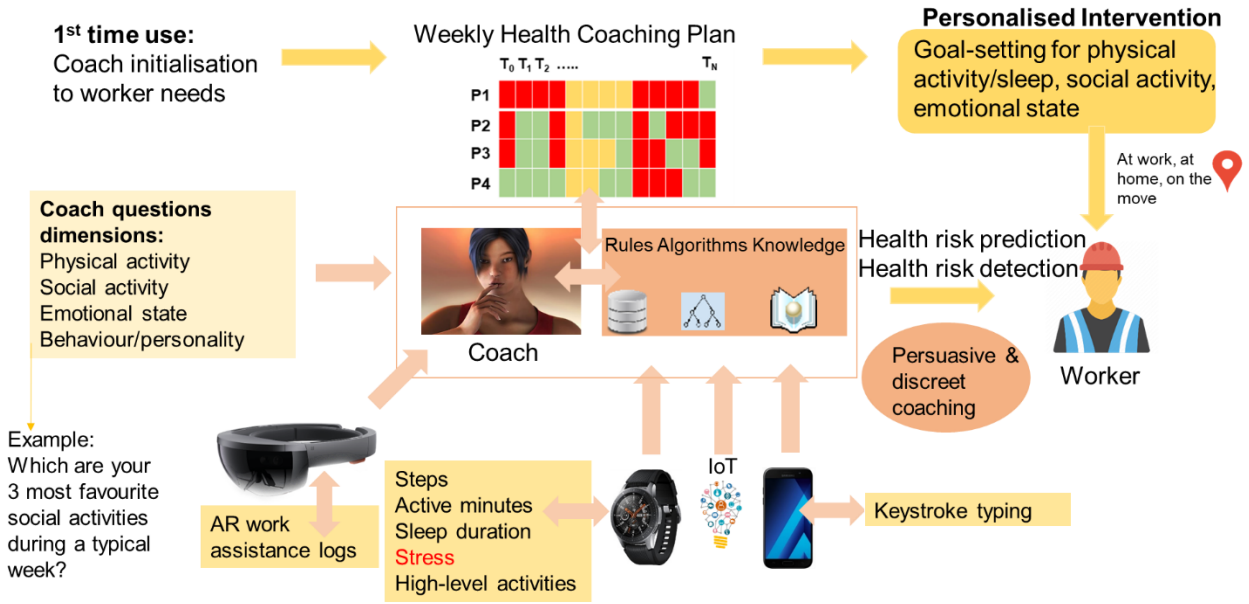

Figure 1. Ambient Virtual Coach (AVC) cognitive functions

The AVC is initialized by some fundamental information considering demographic, physiological, psychological and social parameters provided by the worker through the VUM Questionnaire described in ANNEX I of D3.2 Ageing@Work Dynamic Virtual Worker and Workplace Models. Thus, once the worker provides his/her demographic information to the VUM questionnaire, age, gender and personality traits

are available, thus this avatar embodies into the AVC with mirroring cognitive characteristics. Behavioral mapping rules according to collected data from the questionnaires and mobile applications/sensors form the personalized behavior of the AVC which stores the successful and unsuccessful recommendations in its historic data.

The rule-based logic for the ambient virtual coach performs a pre-screening before starting to exercise with the worker, so as to propose the most suitable exercise. The purpose of pre-screening is to prevent injury or other serious adverse events like musculoskeletal trauma falls or cardiovascular events while letting the worker benefit the maximum from the physical activity. Thus, based on the information taken by wVUM, the ambient coach can identify medical problems in order to prevent the worker from performing exercises that are not appropriate. In **Table *2***, we present the information that the ambient coach takes into consideration before starting exercising with the worker. Health issues are taken from wVUM according to the health questions that the worker should answer for optimizing the functionality of the ambient coach and increase the benefits the worker can receive. The recommended exercises are taken from Resnick et al., 2006 study regarding preventative care and the benefits are offered by the coach as a motivational action.

Table 2. Screening rules for prescribing an appropriate exercise program

Health Issue	Recommended exercise	Benefits
Cardiovascular health (blood pressure, angina, congestive heart failure etc)	Increasing physical activity with aerobic activity, walking more and using stairs.	• Improves myocardial performance • Increases peak diastolic filling • Increases heart muscle contractility • Reduces premature ventricular-contractions • Improves blood lipid profile • Increases aerobic capacity • Reduces systolic blood pressure • Improves diastolic blood pressure • Improves endurance • Improves muscle capillary blood flow • Decreased claudication
Body composition/ Muscle mass/ Metabolism	Increasing physical activity with aerobic activity, walking more and using stairs.	• Decreases abdominal adipose tissue • Increases muscle mass • Increases total energy expenditure • Reduces cholesterol/very low density lipoproteins
Psychological well-being	Increasing physical activity with aerobic activity, walking more and using stairs.	• Improves perceived well-being and happiness and vitality • Decreases levels of stress-related hormones • Improves attention span • Improves cognitive processing speed • Increase slow-wave, rapid eye movement sleep and sleep quality • Provides sense of accomplishment

		• Decreases anxiety and improves overall mood
Muscle weakness and functional capacity	Increasing physical activity through resistance and balance training	• Reduces risk of musculoskeletal disability • Improves strength and flexibility • Reduces risks of falls • Improves dynamic balance • Improves physical functional performance
Preventing falls and fear of falling	Increase physical activity through resistance, aerobic and balance exercises	• Decreases falls and fear of falling

The ambient coach also does a pre-screening check before starting exercises by showing to the worker an informative message regarding precautions they should take and tips on how to make the best out of the exercise session. The message that appears is the following:

"*Important!*

Before starting exercise, you should consult your doctor to determine what physical activity is allowed for your current health condition. If you are in pain or have been diagnosed with MSDs, consult your doctor or physical therapist to discuss the appropriate exercises. Exercise responsibly. If any exercise is too hard for you - don't do it. Or try to make an easier version. The following stretching exercises may also be the final part of your training. Watch your body. You will not do every exercise right away. Be patient. The technique of performing the exercises is very important. Badly done exercises can do more harm than help. Take your time. Perform each exercise carefully and calmly."

Based on the targets defined for the workers, parameters that influence user's trust and decision making are defined and included in the design of the coach's framework. These parameters form the basis on which the rules for the cognitive functions of the coach are implemented. Starting from the age and gender of the worker, the cognitive framework separates the available activity exercises. Moreover, stress levels are taken into consideration and sleep duration. Information about the social activity is also essential since the recommendations are adapted to them.

3.1 AVC's support based on prediction of sedentary activity

Physical inactivity is a major public health issue especially important for elder workers, which is linked to higher chances of health impairments and morbidity. With the evolution of ICT technologies, this challenge can be faced by implementing systems which can prevent sedentary activity. The prevention can be achieved by a two-step procedure, first detect and predict sedentary behavior and second, offer attractive and appropriate recommendations based on cognitive systems that take into consideration the worker's location, time and preferences. In order to enhance the AVC's cognitive functioning, a machine learning approach is introduced for predicting sedentary behavior of a worker by using historic daily steps which

are counted by wearable devices. Thus, an ambient intelligent system is used to first detect and second predict the possibility of sedentary activity the next day.

This work has been described in detail, in deliverable 3.2 Dynamic Virtual Worker and Workplace Models, where the data that feed the system are explained, along with the machine learning techniques to train the models that were involved. The main result of the study regarding sedentary prediction is that the ensemble models outperformed baseline models which led to the achievement of higher accuracy scores. Thus, with this machine learning modeling, prediction of sedentary behavior based on day-to-day step counts, as recorded by the worker's smartwatch, is feasible and is used by the AVC in order to be triggered and offer proactive recommendations for promoting physical activity. More specifically, the threshold of 5000 steps/day is being used to denote a threshold (Tudor-Locke et al., 2013) below which, next-day sedentary behavior is indicated.

3.1.1 Recommendations for physical activity

Once prediction for sedentary behavior is performed, the AVC runs through the wVUM to obtain the necessary information for the personalization of the recommendations. Recommendations are adapted in terms of text, time of the day and location of the worker while the AVC adapts its appearance in terms of age, gender and extroversion level. The available recommendations for physical activity regard:

- Daily duration of physical activity
- Intensity (light, moderate, vigorous)
- Recommended goals
- Type of exercise (aerobic, muscle strengthening)

Physical activity when performed even for a few minutes, counts toward better health since it helps the workers feel better, move better and sleep better based on the American College of Sports Medicine (ACSM). Thus, the AVC is the user interface which is used for engaging the worker into performing recommended exercises (e.g., running) for their benefit. Therefore, in order to ensure the appropriateness of the recommendation and enhance the possibility to be followed, the AVC takes into consideration if the worker is outdoors, at work, or at home along with the time of the day. Thus, exercises are separated into three categories: 1) outdoor aerobic exercises (e.g., running), 2) home exercises and 3) workplace exercises in terms of both location and time.

There are ten exercises provided by the ambient coach and they are separated by level of difficulty and location appropriateness. Home exercises are considered all the exercises including those that need a mat thus, maybe it is easier to be performed at home. These exercises are mostly for stretching purposes and/or balance-training in order to enhance balance and prevent fear of falls. On the other hand, there are exercises that are appropriate for being performed at workplace and concern both stretching of the muscles and balance enhancement. All of the workplace exercises can be performed easily either in a sitting position or in a standing position.

Targeted muscles regarding the exercises are:

- Upper Trapezius Stretch - standing or sitting position
- Seated Clasped Neck Stretch – sitting position
- Seated lower back rotational stretch
- Cross-Body Shoulder Stretch - standing or sitting position
- Forearm Stretch– sitting or standing position
- Quadriceps Stretch - standing position
- Piriformis Stretch - sitting position on the floor
- Knee to Chest Stretch – lying position
- Lunge With Spinal Twist – standing position
- Calf Stretch – standing position

In **Figure *2*. Available exercises for home and workplace.**, the thumbnails of the available exercises, along with the house icon to separate those for performance at home, are shown in case the worker wants or is needed to perform one.

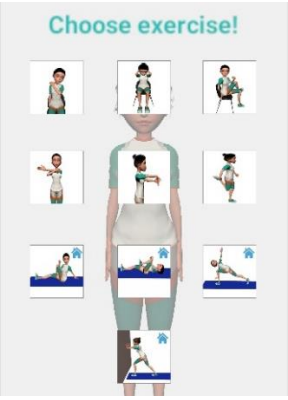

Figure 2. Available exercises for home and workplace.

Moreover, based on location, the AVC cognition system can adapt some recommendations if it knows that there are stairs either at home or at work to take. This information is saved at wVUM in order to offer more personalized recommendations based on the distinctiveness the locations have where the worker goes daily.

The available recommendations are the following:

- Breaks at work (or home during working hours), every hour of continuous immobility. A 5-minute break every hour is recommended according to the scientific literature (Hengel et al., 2012).
- Stretching exercises, if previous break recommendations were skipped.

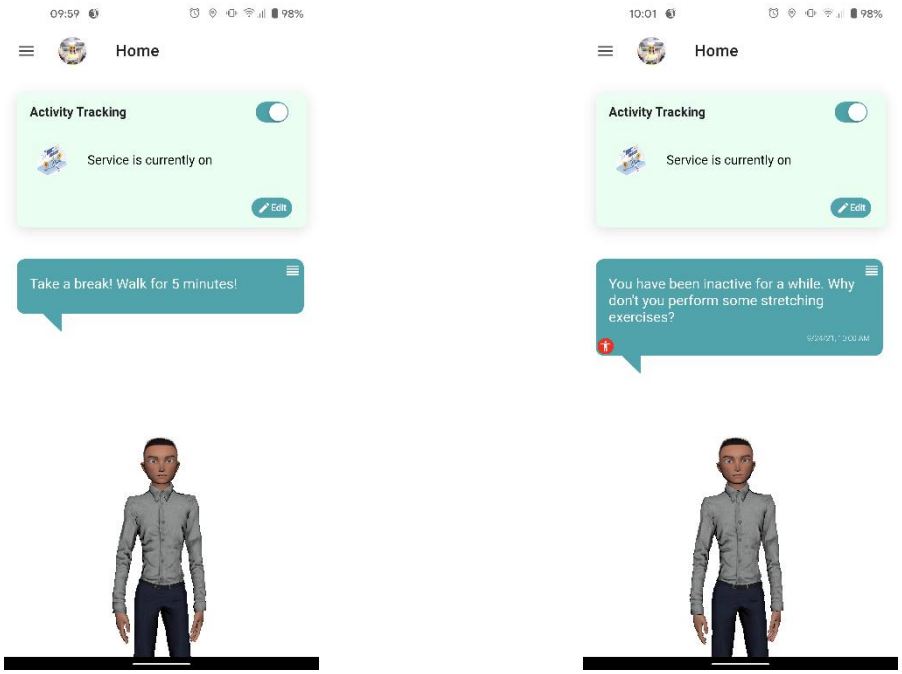

Figure 3. Physical activity recommendations for worker – Left: 5 minutes break recommendation at workplace after 1 hour of sitting, Right: Stretching exercises recommendation.

- Steps goal monitoring with recommendations to go outdoors for leisure walks (during afternoon and if not in workplace). User can also ask coach for recommended nearby locations/points of interest (POIs) to perform physical activity. 10000 steps/day is the recommended level of physical activity and below 5000 steps/day, sedentary behavior is denoted (Tudor et al., 2011).
- Stair climbing, if not performed this day, whenever entering home or workplace with stairs.
- Deliberate exercise detection and congratulation message, by measuring activity's intensity (light, moderate, vigorous). 150 minutes of moderate-to-vigorous physical activity on a weekly basis, is the recommended level of physical activity (who, 2021).

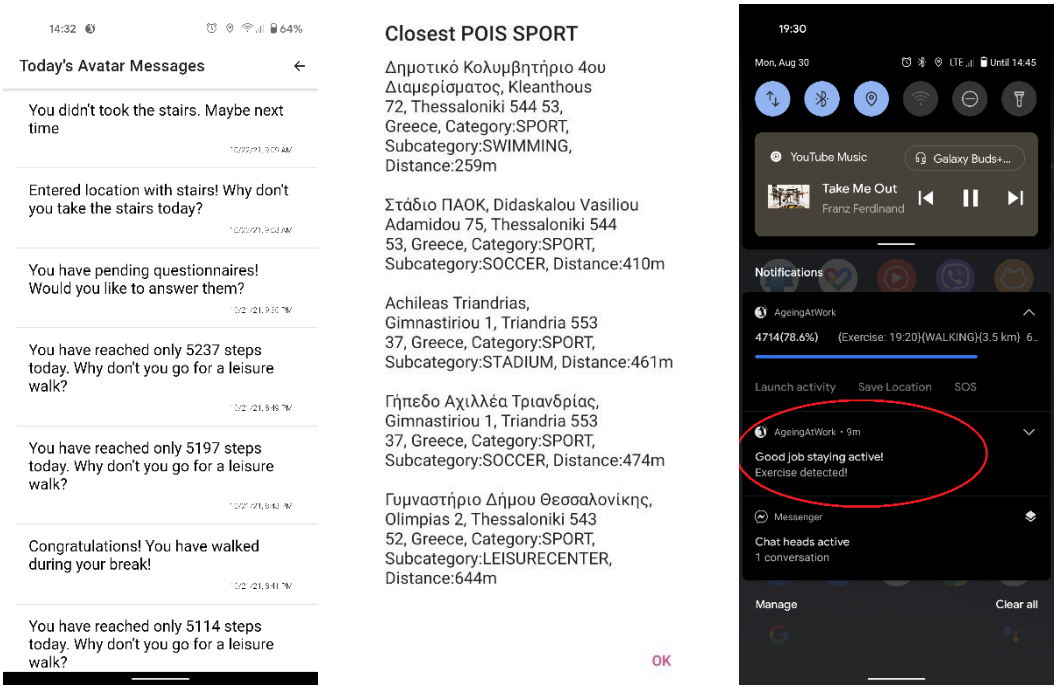

Figure 4. Outdoor physical activity recommendations – Left: Steps monitoring, Centre: Closest Points of Interest (POIs) to perform physical activity, Right: Detection of exercise (walking).

The wording of the suggestions or congratulate messages can be adjusted to the worker's level of extroversion in order to maintain a mirroring way of behavior and preserve worker's engagement. In Results and Outcomes of this deliverable, the UI of the AVC offering additional recommendation, as well as the exercises, are presented.

3.2 AVC's recommendations of worker based on job scheduling

Although the job scheduling tool does not monitor individual worker parameters directly, the weekly schedules produced do take into account worker preferences and other data stored in the vWUM and also communicated to the manager platform through the Ageing@Work Worker App, and the generated schedules take these into account, whenever it is possible, i.e. in cases where preferences do not cause problems in production. In summary, the inputs that are queried by the Job Scheduling Tool when generating shift schedules are as follows:

- Worker Preferences: These are inputs to the system initiated by the worker, with respect to positive or negative preference towards individual work shifts throughout the week. Through this option, the worker may introduce to the system which shifts they would prefer and which they would not, so as to influence the facility-wide schedule towards their satisfaction. These inputs are modelled in the problem as soft constraints.

- A@W App-proposed schedule inputs: These are suggestions coming from the A@W app or the AVC, and which have been accepted by the worker. These suggestions may refer to e.g. taking a day off or changing shifts. These suggestions are also modelled as soft constraints, but once the worker has accepted them, they have greater importance (i.e. associated weight in the problem definition)
- Health and OSH expert suggestions: These are direct inputs from the Health and OSH platform concerning changes in worker schedule. They occur if e.g. an OSH expert decides it is for the best of the worker's health to abstain from work, or to work from home etc. These are modelled as hard constraints, where they need to be satisfied for the schedule to be feasible. In case of schedule infeasibility (e.g. if for a task workers are not available), managers and OSH experts should be notified to deliberate the situation
- Manager suggestions/ acceptance of worker requests: These are either manager suggestions or acceptances of worker requests (e.g. for leave), which are introduced as hard constraints to the system. Similarly to the previous, in case of schedule infeasibility, managers should be notified to deliberate the situation

In addition to the job scheduling tool, the personalized scheduling tool is also used to enable personalized suggestions to workers to improve their overall outlook. The personalized tool monitors several inputs namely:

- Workability
- Job Performance
- Stress
- Satisfaction with sleep
- Concentration
- Self-efficacy
- Satisfaction with personal relationships
- Socialization in private life
- Motivation and involvement at work
- Cognitive Demands
- Conflicts
- Vibrations from hand tools, machinery etc.

These inputs are monitored and suggestions are generated accordingly. After being cross-referenced with their ability to be realized in the common facility schedule, the worker received the suggestion in the mobile app. Suggestions are made in the following fields:

- Suggestion to work from home
- Suggestion to take the day off
- Suggestion to take a break
- Suggestion to adjust shift

The relation between input value and trigger of suggestion has been based on an extensive literature study in combination with consulting with OSH experts from the project consortium.

3.3 AVC's cognition regarding stress of worker and recommendations of coping techniques

Rules regarding stress identification collected from questionnaire data leverage various different aspects of stress, coping ability and personality. Eight questions taken from a monthly questionnaire identify a stress level, covering frequency of stressful feeling, support networks, sleeping issues, and locus of control among other things. This help form a monthly stress level which then also considers individuals personality traits, most notably conscientiousness as this can help indicate one's ability to deal with perceived stress. Additional data like emotional states – particularly negative emotional states which are correlated to stress – and variables from wearable technology are also incorporated, however, to a limited extent currently. These factors help to determine the level of stress each month of a user and indicate if any action should be taken to help reduce their stress.

If a low level of stress is identified nothing occurs, however, if a medium level of stress is identified then a user is provided with a link to a document containing some limited cognitive behavioral therapy (CBT) exercises. If a high level of stress is detected, then the rules will consider the latest additional data from the PHQ-9 questionnaire which is answered fortnightly. This is a clinical questionnaire which assists in identifying the severity of depression and stress disorders. If this data indicates a low level of severity nothing occurs, if it indicates a medium level then the user is sent a link to a document containing more extensive CBT exercises. Finally, if the PHQ-9 indicates high severity then the user is referred to seek professional help. A more detailed description of the system is found in deliverable 4.2.

3.3.1 Recommendations for handling stress based on the CBT protocol.

As described above, the recommendations from the agent for combating stress or depression are dependent upon stress symptoms, personality traits, and emotional status. There is no additional specific targeting for demographic variables like age and gender as the recommendations used are broadly applicable and effective.

The limited CBT exercises, recommended from the agent as per section 3.4, contain exercises regarding behavioral activation, stress coping, and cognitive restructuring. When the agent has identified a higher level of stress management is needed and sends the more extensive exercises, it includes in addition to the aforementioned exercises an awareness text and a behavioral experiment for the individual to complete. The agent will then follow up to ensure the individual has completed the exercise and monitor the future stress levels to make sure they have reduced. If they have not, then the agent will recommend either the more extensive CBT exercises or that the individual contact a profession for more tailored assistance. Full details of the CBT exercises can be found in deliverable 4.2.

3.3.2 Stress Management Techniques

The following techniques are methods which include cognitive, behavioral and psychological efforts to deal with stress. All of them have been evaluated and used in the past. They have been tested in various

(recent) studies, with a quite diverse sample of participants and settings, which are published in top tier journal. They have been found to yield different benefits (apart from stress relief) such as headache/migraine relief, reduced systolic hypertension, improve cardiac rehabilitation, decreased fatigue, immediate effect on specific phobias and depression. The AVC offers the following stress management techniques at the worker's convenience as educational material to enhance their self-care and self-awareness.

3.3.2.1 Autogenic Training (AT)

In AT the individual learns a set of directions/exercises that command the body to relax and control breathing, blood pressure, heartbeat, and body temperature. AT consists of six standard exercises that - with the use visual imagination and verbal cues- make the body feel warm, heavy, and relaxed. The person learns each exercise by reading about it or watching a teacher, then practicing it for a few minutes several times a day. Mastering the exercises, either from an instructor or on one's own, usually requires 4 to 6 months

3.3.2.2 Progressive Muscle Relaxation (PMR)

The physical component involves the tensing and relaxing of muscle groups over the legs, abdomen, chest, arms and face. In a sequential pattern, with eyes closed, the individual places a tension in a given muscle group purposefully for approximately 10 seconds and then releases it for 20 seconds before continuing with the next muscle group. The mental component requires that the individual focuses on the distinction between the feelings of the tension and relaxation. With practice, the patient learns how to effectively relax in a short period of time. Relaxation must be attempted in order to reduce pain or pain perception and tension, create a pleasant mental state, reduce anticipatory anxiety, reduce anxiety as a response to stress, increase parasympathetic activities, increase knowledge concerning muscle tension and autonomous stimuli, improve concentration, increase the feeling of control, improve the ability to block inner talk, energize and improve sleep, decrease the cardiac index, lower blood pressure, warm or cool body parts, enhance performance of physical activities and help in the relationship with others. Therefore, the individual is taught by a trained professional, manual or audio how to progressively relax major muscle groups and performs the sequence 2- 3 times daily for 15-20 minutes per session (Jacobson, 1938).

3.3.2.3 Mindful breathing (MB)

This exercise is based on a script used in Mindfulness-Based Cognitive Therapy (Segal et al., 2002) and in a laboratory study by Arch and Craske (2006). Participants are guided to become aware of physical sensations especially those associated with the process of breathing and to observe them without the intention of altering them. Participants are asked to notice in an accepting, non-judgmental manner when their minds wander to something other than the exercise and to gently return focus to the sensations of breathing when this occurs. This basic meditation exercise embodies the central features of mindfulness practice: intentionally paying attention to moment-by-moment experience with an attitude of acceptance (Shapiro et al., 2006).

3.3.2.4 Loving-kindness meditation

This exercise is adapted from scripts developed by Salzberg and Goldstein (2001) based upon ancient Buddhist meditation practices. The purpose of the exercise is to create feelings of social connection and compassion for oneself and others. First, participants are guided to mentally repeat the phrase "May I live in safety. May I be happy. May I be healthy. May I live with ease." Participants are then guided to visualize a good friend and mentally direct a similar wish for wellness to them using a variant of the phrase used previously. Next, participants are guided through visualizing a series of people ("someone you know who's having a difficult time," "a person in your life that you don't know very well," and "a person who is mildly difficult or irritating") and asked to wish them wellness using a similar series of phrases. Finally, the participant is asked to imagine sending similar wishes of wellness to "all beings everywhere." During the 3 min of silent practice, the participant is asked to repeat the series of visualizations and wishes for wellness to each of the individuals until they are instructed to stop.

3.3.2.5 Diaphragmatic Breathing

Diaphragmatic breathing, or abdominal or belly or deep breathing is marked by expansion of the abdomen rather than the chest when breathing. Diaphragmatic breathing is defined as a manipulation of breath movement, contributing to a physiologic response characterized by (a) the presence of decreased oxygen consumption, decreased heart rate and blood pressure, and (b) increased theta wave amplitude in EEG recordings, increased parasympathetic activity accompanied by the experience of alertness and invigorating. It is hypothesized that voluntary slow deep breathing functionally resets the autonomic nervous system through stretch induced inhibitory signals and hyperpolarisation currents propagated through both neural and non-neural tissue which synchronizes neural elements in the heart, lungs, limbic system and cortex. Patients are taught by a trained professional, manual or audio how to inhale and exhale deeper and slower. They need to practice several times a day, or as needed, for a few minutes to see immediate benefits (Jerath, Edry, Barnes, Jerath 2006).

3.3.2.6 Transcendental Meditation

The Transcendental Meditation technique is simple and easily learned, requiring to be practiced for 20 minutes twice daily while sitting with eyes closed and repeating a mantra', a meaningless sequence of sounds specific to each individual, to promote a natural shift of awareness to a wakeful but deeply restful state (Jevning, Wallace, Biedebach 1992). TM is not a religion or philosophy and is taught through a seven step course of instruction by a certified TM teacher. During the TM practice, a reduction in mental and physical activity occurs and that is the result of the individual's experience of a mental state called —transcendental consciousness, which is different from usual waking, dreaming, or sleep states. This experience is deemed responsible for the restoration of normal function of various bodily systems, especially those involved in adapting to environmental —stressors or challenges. TM increases frontal and alpha central activity (Jevning, Wallace, Biedebach 1992) and neuroimaging studies indicate increased regional cerebral blood flow measures during meditation (Cahn and Polich 2006).

3.3.2.7 Emotional Freedom Technique (EFT)

EFT works by a person tapping on nine of acupoints, while speaking aloud a specific, meaningful short phrase. A key part of the therapy is calibrating the intensity of either physical or emotional pain, which allows both therapist and patient a tangible scale by which to measure progress in pain or emotional distress reduction. According to the literature, imaginal exposure, paired with acupressure, reduces midbrain hyperarousal and counterconditions anxiety and traumatic memories. Exposure therapies like EFT first elicit the midbrain's anxiety reflex and then replace it with a relaxation response, in order to —reciprocally inhibit anxiety (Lane 2009). It is also indicated that manual stimulation of acupuncture points produces opioids, serotonin, and gamma-aminobutyric acid (GABA), and regulates cortisol, the stress hormone (Lane 2009). These neurochemical changes lead to reduction of pain, slowing of the heart rate, decreased anxiety, shutting off the fight of flight response, and regulation of the autonomic nervous system, as well as to the creation of a sense of calm (Lane 2009).

3.4 Cognitive functioning from self-assessment: Depressive Symptoms

The AVC's proactive functioning in terms of mental health considers the depressive status of the worker by evaluating preliminary psychometric data. Depression is also taken in consideration through the usage of PHQ9. The PHQ-9 is the depressive module which scores the 9 different DSM-IV criteria in a scale from 1 (Not at all) to 4 (Nearly every day) and is used for monitoring the depressive symptoms and their severity. The mechanism behind the AVC's behavior for depressive symptoms of a worker is separated into three levels. First level of depressive feelings does not require any support or treatment thus the AVC does not perform any action. For mild depression level, the AVC offers cCBT exercises as described in deliverable 4.2, which are effective when dealing with mental disorders such as either anxiety or depression (Morgan et al., 2017; Newby & McElroy, 2020). However, for high levels of stress or depressive symptoms, the AVC recommends seeking for professional help since it is not supposed by the project's requirements to offer a clinical mental health program.

Apart from the self-reporting regarding depression, pilot sites will provide the consortium with data regarding typing style of workers, since a custom keyboard which records keystroke timing information was included within the application. Thus, it is scheduled that these data will be analyzed in order to extract typing patterns that may enhance and/or predict the results of the PHQ-9 questionnaire. These results will be examined under the Big Five Model too, to investigate whether there are correlations amongst depression by self-reporting, typing style and personality traits. Moreover, MoodZoom questionnaire is also used to collect daily reporting of emotional state and could be also examined to find correlations with the keystroke typing features. The behavioral mapping rules that deal with the depression symptoms at the moment are based on the PHQ – 9 questionnaire and offer recommendations using cCBT exercises through the AVC.

The AVC uses a multi-modal user interface including both visual and auditory cues to communicate the recommendations with both verbal and non-verbal features. The AgeingAtWork approach is influenced by

the communication science and the Brunswick Lens model (Dar & Bernardet, 2020) which presents three bipolar dimensions of communication:

- Verbal (e.g. speech type) / nonverbal (e.g. head nods)
- Intentional (e.g. verbal, facial expressions) / unintentional (e.g. physical posture, tone of voice)
- Implicit (e.g. utterances) / explicit (e.g. questions, imperative commands)

which are expressed by various channels of communications either visual or non-visual. These channels include verbal, non-verbal communication, different prosodies, gestures, gazes, proxemics and physiology. In section 3, there is a detailed description of the way the Brunswick model is deployed in terms of AgeingAtWork for enhancing the persuasiveness of the AVC's behavior.

3.5 Socializing recommendations for mental-health protection

Research has found that socializing plays a significant role in overall health and especially in mental health since it provides a strong foundation of compassion and trust. Benefits from being social include the increase of mental alertness, fights depression, relieves physical discomfort, creates a support system and extends life. In terms of the project's rule system, the AVC takes into consideration information stored in the wVUM regarding duration of activity events. In case of long-term stay-at-home detection, the AVC examines the nearby locations that were categorized as "SOCIAL" by the location categorization API, as well as new ones if worker's locations do not contain any "SOCIAL" categories, and offers reminders to engage to one of them. Additionally, the AVC suggests meeting friends and family.

Figure 5. Locations that are detected close to the worker's POIs

As shown in **Figure *5***, the AVC suggests nearby locations in with category social.

4. Persuasive Framework for supporting elder workers

4.1 Concept, Design and Architecture

Affective technology is widely investigated lately by creating space for examining more empathic and human-like behaviors from virtual agents. The main target is to create human and agent interaction which evolves seamlessly, effortlessly and is satisfying for the user. In order to do so, the communication science has been taken into consideration along with the parameters that the literature claims to affect it. Empathic intelligence is the key parameter for more human-like behavior in virtual agents also known as understanding the emotional state of the interlocutor. In other words, the perception of emotional state of another human being by oneself is the first step into performing empathic behavior. This has been studied extensively in human psychology, however little is known in terms of human agent interaction. Thus, based on human psychology and communication science, the project's approach is based on Brunswick Lens Model which helps in the embodiment of virtual characters and is used to explain the various communication dimensions between humans. The AVC is designed based on this model's dimensions and feelings of trust and likeability have been investigated in an attempt to increase its persuasiveness.

The Brunswik Lens Model (Brunswik, 1956) is used in various fields for examining how observers use communicational cues to perceive physical or social reality. It started for interpreting the visual perception but was immediately applied to judgement analysis in fields like decision making (Hammond 1955). Meanwhile, observer's perception was rapidly oriented towards interpersonal dispositions like personality (Gifford, 1994), intelligence (Reynolds & Gifford, 2001), rapport (Bernierri & Gillis, 2001) and emotions (Juslin & Laukka, 2003) elicited. Thus, the project's AVC focused on the **cues** that are used for emotional communication and the dispositions that affect the differences which arise between the intended and the perceived reality. The implementation behind the AVC aimed at collected the appropriate communicational cues from the communication channels which are classified along three dimensions presented in **Figure *6*. The three communication dimensions that classify cues**(Dar & Bernardet, 2020). Afterwards, the perception of these cues was examined in an attempt to find the amount of matching intention between expressed communication cues and attributed communication cues under the Big Five Model for personality. In **Figure *6***, the Brunswik Lens dimensions of human communication shows how the three bipolar dimensions of human communication interact. The project's approach for enhancing persuasion focused on implicit, verbal and non-verbal communication in order to form the AVC's behavior.

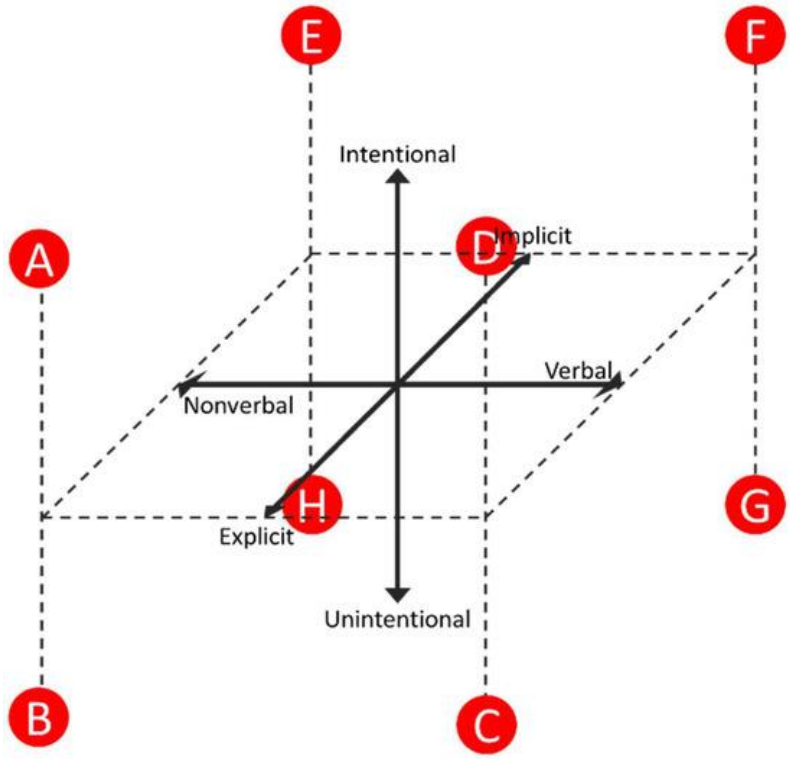

Figure 6. The three communication dimensions that classify cues

The persuasive framework which is behind the AVC's behavior includes motivational strategies like tracking and monitoring, audio, visual and textual feedback, persuasive messages and reminders as described in section 3, rewards, positive reinforcement suggestions and advice (Orji & Moffatt, 2018). A multimodal UI system is used to detect predefined main aspects of worker's personal and working life in order to adapt the persuasive methods of the AVC. The aforementioned methods constitute the interaction between the AVC and the worker, which is adapted based on best practices according to the worker's age, gender, level of extroversion and emotion. Adaptations are constituted by changes in facial expressions, body posture, speech and gestures in order to create a positive first impression which is essential for creating rapport with virtual agents (Cerekovic, A. et al., 2016).

Therefore, in terms of tracking and monitoring, the IoT system of Ageing@Work is utilized to keep up to date the wVUM which stores all the necessary values of the workers daily activities. Feedback is given in the form of personalized notifications which welcome the worker by using his/her name. Based on the questionnaires, the AVC knows the worker's preferences regarding leisure time, thus once a reminder is needed, the suggestion is targeted to what the worker enjoys doing so that the possibility to do it is increased. Moreover, since location is tracked as well, once the worker starts visiting frequently a new place that is not declared to the VUM's questionnaire, this place is added to the historic data. Thus, with this learning process, once a frequently visited place stops being visited so often, the AVC sends a reminder for visiting it.

The persuasive framework benefits of audio, visual and textual feedback as shown in Figure 7, where the AVC's user interface architecture (Kampman, O., 2019) is presented. Initialization of the AVC's behavior is achieved by self-reports of questionnaires that ask about demographics, personal life, working life, health status (physical and mental), job skills and personality traits. These parameters help in creating a mirroring virtual coach which based on the literature described in previous sections, may increase motivation in following the coach's recommendations and trust it. Thus, the AVC extracts the parameters from the wVUM and synthesizes its appearance according to them. Based on the worker's personality and emotional recognition (positive/negative) six possible profiles are created in terms of extroversion (introvert/neutral/extrovert) and emotion. The AVC manages its dialogue, auditory and visual modules to adapt to the worker's needs and at last, the rapport scale is measured to evaluate the system.

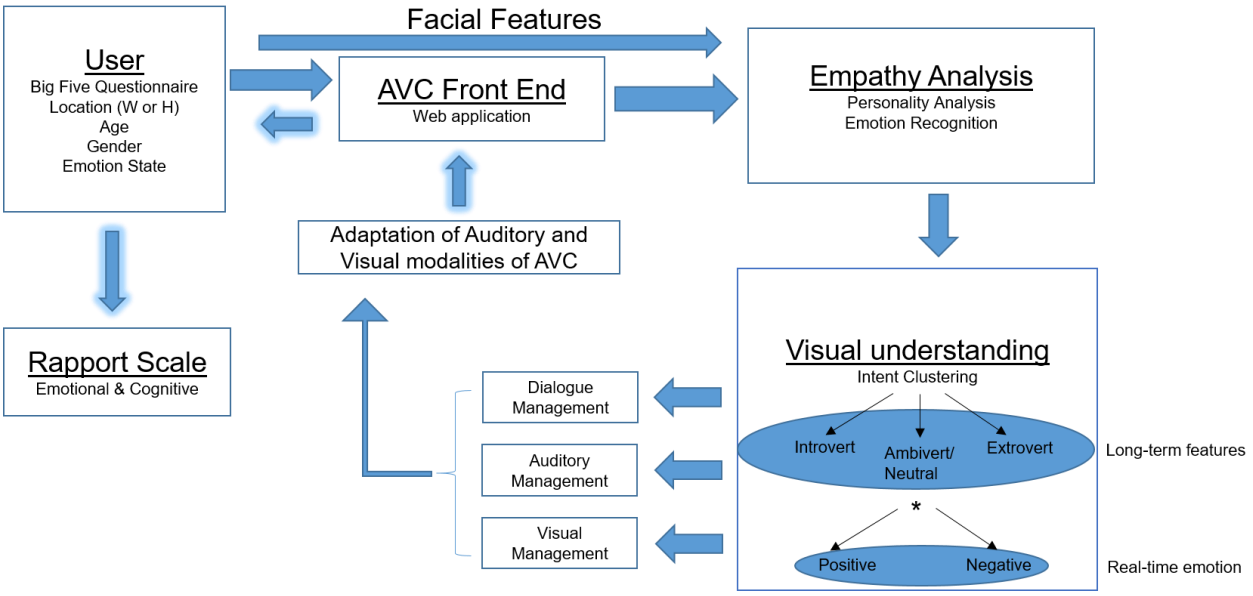

Figure 7. Ambient Virtual Coach Persuasive Framework Architecture

To measure a self- reported feeling of rapport, the post-interaction questionnaire is used which evaluates the quality of interaction, degree of rapport and degree of liking the AVC (Cerekovic, A. et al., 2016). This questionnaire includes 15 items which are measured by a Likert Scale from 1 to 5 and are presented in **Table *3***.

Table 3. One-Factor Solution for the Human-Agent Rapport Questionnaire

Items
1. I got along with the AVC pretty good.
2. I did not want to get along with the AVC.
3. I was paying attention to the way that AVC responds to me and I was adapting my own behavior to it.
4. I felt that AVC was paying attention to my mood.
5. The interaction with the AVC was smooth, natural and relaxed.

6. I felt accepted and respected by the AVC.
7. I think the AVC is likeable.
8. I enjoyed the interaction.
9. The interaction with the AVC was forced, awkward and strained.
10. I felt uncomfortable during the interaction.
11. The AVC often said things completely out of place.
12. I think the AVC finds me likeable.
13. The interaction with the AVC was pleasant and interesting.
14. I would like to interact more with the AVC in the future
15. The AVC offered useful recommendations which helped me.

After the pilot studies, it is planned to perform analysis in terms of AVC's profile and creation of rapport feeling in correlation to the worker's personality as well. Furthermore, an investigation in rapport feelings and actual performance of the activity suggested by the AVC will be done too. Data for the latter investigation will be achieved through the AVC's system which can store whether an action was actually performed so that we could measure the self-report of rapport and find possible correlations with persuasive strategies.

4.2 Results and Outcomes for the AVC cognitive and persuasive behaviour

First of all, after designing the appearance of the avatar which embodies the AVC, a study that was conducted and described in deliverable 5.1, revealed that trust and likeability, which affect rapport feeling, of the avatars could be predicted by the perception the worker has regarding the avatar in comparison to his/her own extroversion level. Thus, we found two promising models which we used to produce the AVC's profile in a way to achieve both trust and likeability personally adapted to each worker. We focused on facial expressions and specifically on eyebrows, eye's aperture and mouth to distinguish the character of an introvert AVC and an extrovert AVC. In terms of introvert, we exploited the sub facets that refer to a serious character while in terms of extrovert we exploited the facets that refer to an enthusiastic character.

In terms of **trust**, we examined the correlation matrix, Table 4, to see if there are significant variables that can describe the variations in scores.

Table 4. Correlation Matrix for facial cues, gender and extroversion trait regarding trust

Correlations					
	Avatar's Appearance Pearson Corr. (sig. 2-tailed)	Participant's Extroversion Pearson Corr. (sig. 2-tailed)	Participant's Perception of the Avatar Pearson Corr. (sig. 2-tailed)	Trust Pearson Corr. (sig. 2-tailed)	Gender Pearson Corr. (sig. 2-tailed)
Avatar's Appearance	1	.047 (.420)	**.121 (.038)**	-.076 (.197)	-.075 (.200)

Participant's Extroversion	-	1	**.240 (.000)**	**.197 (.001)**	-.020 (.734)
Participant's Perception of the Avatar	-	-	1	**.196 (.001)**	**-.429 (.000)**
Trust	-	-	-	1	-.064 (.277)
Gender	-	-	-	-	1

Correlation revealed three variables that, in terms of facial expressions, are significant. These are:

a) perceived extroversion level of the avatar
b) worker's extroversion
c) gender

A multiple linear regression was calculated to predict trust (T) based on gender (G), participant's extroversion level (PEL) and Avatar's perceived extroversion level (AEL). A significant regression equation was found (F (3, 194) = 19.326, p < .000), with an R^2 of .230. Participants' predicted trust is equal to -0.440 + 0.558 (AEL) + 0.684 (PEL), where PEL and AEL are measured as products of a questionnaire's scores in scale and trust is measured in scale as well. Participant's trust increased 0.588 unit for each unit of AEL and 0.684 for each unit of PEL. Both AEL and PEL were significant predictors of trust whereas gender was not thus, we did not include it. Predicted values of this model and trust were found to be positively correlated, r(198) = .478, p = .000, corresponding to the R model.

In terms of **likeability**, similarly we created a correlation matrix for facial.

Table 5. Correlation Matrix for facial cues, gender and extroversion trait regarding likeability

Correlations					
	Avatar's Appearance Pearson Corr. (sig. 2-tailed)	Participant's Extroversion Pearson Corr. (sig. 2-tailed)	Participant's Perception of the Avatar Pearson Corr. (sig. 2-tailed)	Likeability Pearson Corr. (sig. 2-tailed)	Gender Pearson Corr. (sig. 2-tailed)
Avatar's Appearance	1	.047 (.420)	**.121 (.038)**	-.001 (.988)	-.075 (.200)
Participant's Extroversion	-	1	**.240 (.000)**	**.292 (.000)**	-.020 (.734)
Participant's Perception of the Avatar	-	-	1	**.515 (.000)**	**-.429 (.000)**
Likeability	-	-	-	1	**-.195 (.001)**
Gender	-	-	-	-	1

Correlation revealed two variables that, in terms of facial expressions, are significant. These are

a) perceived extroversion by the Avatar's appearance
b) level of user's extroversion.

A multiple linear regression was calculated to predict likeability (A) based on participant's extroversion level (PEL) and Avatar's perceived extroversion level (AEL). A significant regression equation was found ($F(2, 195) = 34.222$, $p < .000$), with an R^2 of .260. Participants' predicted trust is equal to -1.675 + 0.968 (AEL) + 0.601 (PEL), where PEL and AEL are measured as products of a questionnaire's scores in scale and likeability is measured in scale as well. Participant's likeability increased 0.968 unit for each unit of AEL and 0.601 for each unit of PEL. Both AEL and PEL were significant predictors of likeability. Predicted values of this model and likeability were found to be positively correlated, $r(198) = .510$, $p = .000$, corresponding to the R model.

Since trust and likeability were affected by the user's extroversion level and the avatar's perceived extroversion level, we examined the interaction effect between these two dependent variables. We examined how trust and likeability changes in terms of extroversion level and perceived extroversion level of the avatar. Results described in deliverable 5.1 showed that participants trusted the avatar which was perceived with similar extroversion level while they liked more the one perceived with high extroversion level.

Thus, apart from mirroring the gender and the age of the worker based on literature, the virtual coach is embodied by an avatar that mirrors the level of extroversion that the worker has based on visual and auditory cues to further investigate into this idea. Therefore, the AVC is the enriched profiles of this study which suggests the visual and auditory adaptations of extrovert and introvert behavior for empowering trust.

Consequently, there are 12 profiles of AVC based on age*gender*extroversion level which are listed as:

- male/young/extrovert, male/young/introvert, male/young/neutral
- male/elder/extrovert, male/elder/introvert, male/elder/neutral
- female/young/extrovert, female/young/introvert, female/young/neutral
- female/elder/extrovert, female/elder/introvert, female/elder/neutral

The main target it to assess user preferences and correlate them with wVUM's parameters in order to achieve stronger engagement models.

In Table 6, the verbal and non-verbal parameters that are used to operationalize the contrasting personalities of the AVC in terms of extroversion. Speech rate, volume, frequency and pitch are taken from Liew and Tan study in 2016 where a learner-agent was implemented to adapt its personality in a virtual learning environment.

Table 6. Communication cues for addressing the different profiles and behaviors of the ambient coach

Verbal Cues	Non Verbal Cues
Motivational Text	Speech rate -> Extrovert : 216 WpM , Introvert -10% [1]
Feedback Text -> Successful Case	Volume -> Extrovert : Original Level, Introvert -10% [1]
Feedback Text -> Abort Case	Frequency -> Extrovert : 140 Hz, Introvert -10% [1]
	Pitch -> Extrovert : 40 Hz, Introvert -10% [1]
	Gaze
	Hand Gesturing

Motivational texts and feedback are differentiated based on Tapus et al. work where the communication style is either nurturing or neutral or challenging for introvert, neutral or extrovert AVC correspondingly. Each worker, based on their extroversion level, is assigned a specific version of the virtual coach (Tapus, A. et al., 2008; Esteban, P.G., et al., 2021). In Table 7, the variations of motivators, feedback text, gaze and gesturing (Gratch et al., 2007; Tapus et al., 2008; Liew & Tan, 2016; Ivaldi et al., 2017) are presented:

Table 7. Verbal and behavioural cues for introvert/neural/extrovert profiles of the AVC

	Introvert	Neutral	Extrovert
Motivational Text	Hey! I know, including a new stretching routine might be overwhelming. Maybe you think it is hard to find the time and motivation. No worries, I will work with you to create a stretching plan that works best for you. Keep calm and press the button to start."	"Welcome to the stretching section. Push the button to see the available exercises"	"Hello there! You probably know that motivation is what gets you started. However, habit is what keeps you going. Let's make stretching a habit and become better and better! Here is the button, push it and try to stretch with me!"
Facial Expression/ Gaze	Conservative smiley/ Gaze in front while talking, then look the button to proceed to the exercises	Neutral face	Wide smile/ Gaze in front while talking, keep gazing in front and use deictic gesture to the button to proceed to exercises
Welcome Gesturing	Hands in front, holding one another during the whole talk. Small head movements to feel natural	Default hands	Hands lifted up during the "Hello there!". Hands open, vivid- "welcome" movements. See photos ->
Feedback/ Done/ Text	"Very nice, keep up the good work!"	"Well done!"	"Great! Next time let's go a bit outside the comfort zone. You can do it!
Feedback/Done/ Gesturing	Head nods once with a gentle bend of the body	Default hands/ Default face	Open hands, raised eyebrows and wide open smile for "Great! Next time let's go a bit outside the comfort zone!" and comes closer to the camera and blinks one eye for "You can do it!"
Feedback/Later/ Text	"I know it may seem hard, ok, let's try later"	"See you in a while"	"Can't wait to get back to do some more stretching exercises together!"

4.3 The AVC in action

Once the worker registers to the application, the system asks him/her to provide a consent form which informs him/her about the data that are going to be tracked from his/her behavior. Moreover, the wVUM questionnaire is asked to be completed so that the AVC can start with an initial customization of the recommendations. The wVUM questionnaire includes demographics data and personal preferences in terms of leisure time which are useful for targeted recommendations. Besides, from the registration form the AVC knows the age, gender and name of the worker in order to form the main appearance and greeting style. In **Figure *8***, the initial screens of the AVC's functionality appear where the worker needs to accept

the consent form's terms and conditions and then start completing the necessary questionnaires in order to have a more personalized experience with the coach. These questionnaires concern physical and social activity, emotional state, behavior and personality and the coach offers them based on the required frequency. On the right side of the figure, the first screen with the AVC is shown which welcomes the worker. From this screen the worker has the right to disable activity tracking if it feels obtrusive.

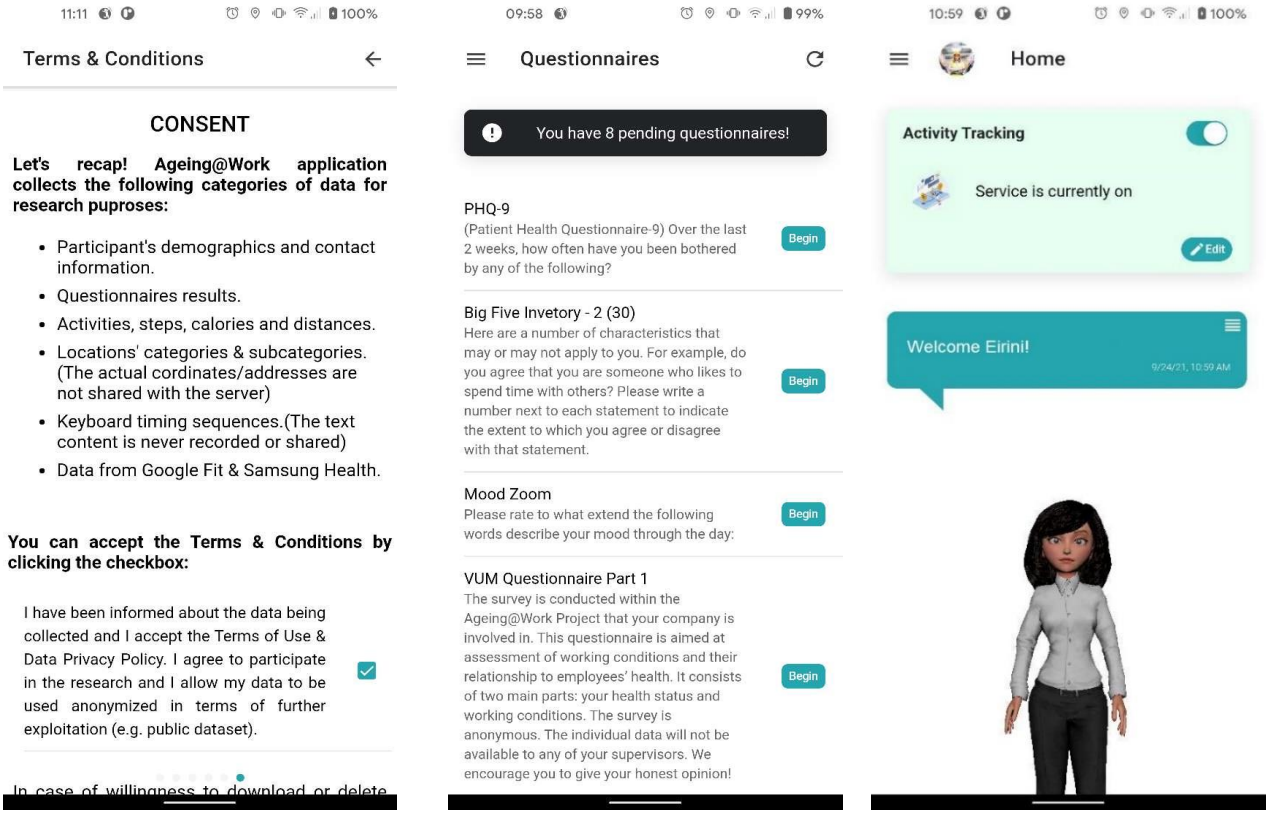

Figure 8. Consent form, questionnaires and first screen of the AVC

The AVC starts functioning as a discreet counselor regarding main aspects of the worker's life which constitute a holistic dimension of Quality of Life. As described both in section 3 of this deliverable and more detailed in deliverable 4.2, the AVC system is fed with information about the worker's behavior and state. This information is the result of rules that check either his/her working life or his/her personal life and offers either proactive coaching or effective recommendations in real-time. In **Figure *9***, we present the scene of action of when the AVC detects inactivity that crosses a predefined threshold which is the accepted duration for a worker. A background process runs to catch the time of the day and the location of the worker while calculating the behavioral data to evaluate duration since the last break at work. Thus, if the worker has been working for more than one hour the AVC appears to inform him/her that it is recommended to take a break and do some stretching exercises. If the worker accepts the recommendations, then the AVC changes outfit to match an athletic style and opens the menu with the available exercises. The worker chooses an exercise and the AVC gives the appropriate instructions by combining visual and auditory features which illustrate how to perform the exercise and which muscle should be targeted. If the exercise is performed and the worker verifies it, the coach rewards him/her with

cheering real-time feedback otherwise the coach leaves a comment to preserve engagement and motivate the worker to do the exercise later.

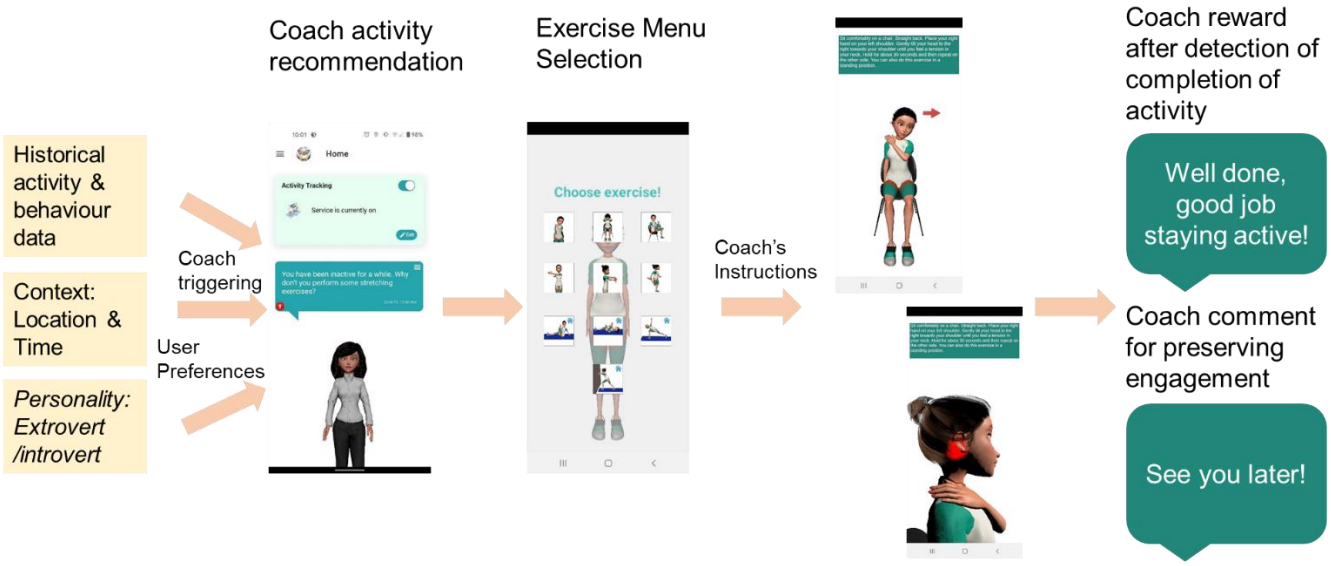

Figure 9. The AVC detects long inactivity and offers recommendation

The enhancement of persuasion includes also the three different personality behaviors of the AVC based on the extroversion level of the worker. As mentioned in section 4.2 and specifically in **Table *7***, the AVC's different personalities vary amongst texting, facial expressions, gesturing and prosodic features. In order to support results from study described in deliverable 5.1, we are enhancing the features that distinguish the personalities of the AVC in order to assess preferences. Furthermore, there will be an investigation regarding correlations that may explain preferences between workers and AVC's different personalities. An example of the AVC's adaptation is shown in **Figure *10*** where the coach is shown to adapt the motivational welcome text, its gesturing while talking and its rewarding feedback in case of successfully performing the exercise. In case of an introvert worker, the coach is using a nurturing communication style with smooth gesturing and conservative facial expressions while the extrovert coach uses a more challenging communication style along with enthusiastic facial expressions and vivid gesturing. The neutral coach is offering plain recommendations without using any persuasive methods or techniques, mainly is used for the control group of the study.

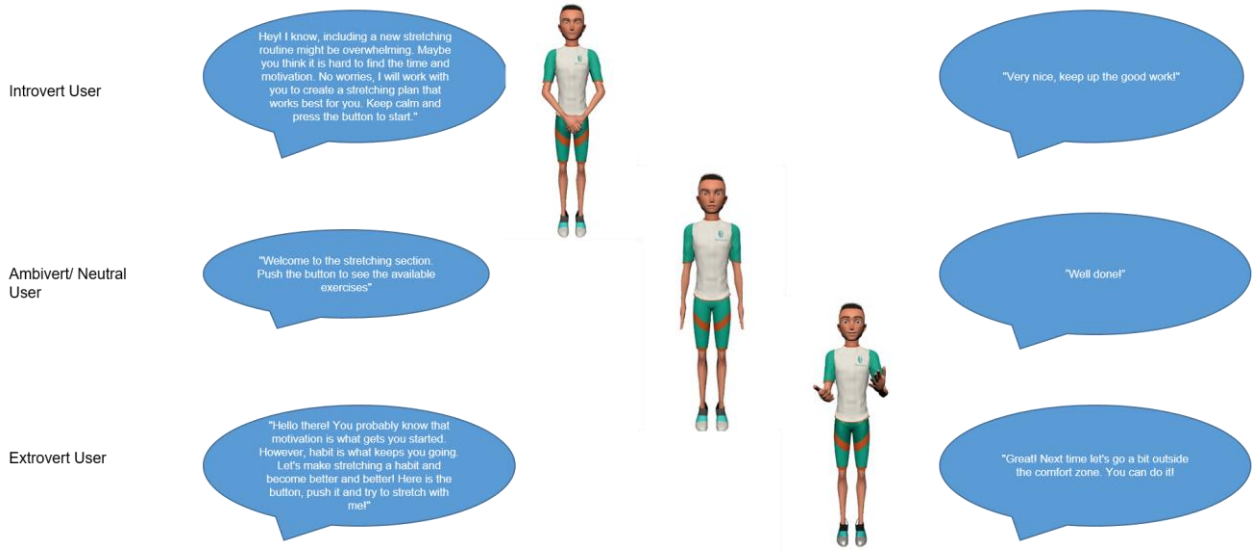

Figure 10. The AVC behaving as introvert, neutral and extrovert character

Exercises are separated into categories regarding level of difficulty (easy, intermediate or difficult) and location that they can be performed (workplace or/and home). As mentioned in 3.1.1, there are available exercises for either sitting position or standing position or on a mat as shown in **Figure *11***.

Figure 11. Three different thumbnails for distinguishing the initial positions of the exercises

Workers are informed however, about improper selection of exercises with respect to their profile and based on international recommendations. In Table *8*, the actions taken by the AVC to prevent workers from getting injured are presented, however it depends on their final decision whether or not they will proceed with performing an exercise or not.

Table 8. Parameters taken into consideration by AVC before starting exercising with worker

Physical health problems	Recommendations	Exercises to prefer
Lifting arms	"Start strengthening the shoulders"	• Lunge With Spinal Twist – Without lifting the arm in the beginning, just strengthen the supporting arm
Dizzy or lose concentration	"Prefer sitting exercises"	• Upper Trapezius Stretch • Seated Clasped Neck Stretch • Seated lower back rotational stretch • Cross-Body Shoulder Stretch • Forearm Stretch- • Piriformis Stretch - • Knee to Chest Stretch
Backache	"Stretching should be pain free. Avoid bouncing."	• Piriformis Stretch • Knee to Chest Stretch
Muscular pains in shoulders, neck and/or upper limbs	"Try to stretch the injured muscles"	• Upper Trapezius Stretch • Seated Clasped Neck Stretch • Cross-Body Shoulder Stretch • Forearm Stretch
Muscular pains in lower limbs (hips, legs, knees, feet etc.)	"Try to perform exercise in sitting position"	• Upper Trapezius Stretch • Seated Clasped Neck Stretch • Seated lower back rotational stretch • Cross-Body Shoulder Stretch • Forearm Stretch- • Piriformis Stretch - Knee to Chest Stretch

5. Conclusions

In this deliverable, the integrated ambient virtual coach (AVC) is presented for encompassing both working and personal life of ageing workers and workplace models. The AVC's core aspects are separated into two important modules, its cognitive system and its persuasive framework. Both modules have as target the unobtrusive monitoring of the worker's behavior and the discreet interference in case it is needed. Cognition system enhances the worker's self-cognition regarding crucial detected aspects like increased stress, reduced physical activity, symptoms of depression and socializing activity. The AVC adapts its behavior through recommendations that are based on the interaction with the worker. It is available to the user also beyond work-time which gave the opportunity to involve the coach into further important aspects of the worker's life like leisure related activities.

In order to be user-friendly and enjoyable, the AVC's design and implementation includes as well results described in D5.1, where apart from age and gender, the coach adjusts its characteristics and gestures according to the extroversion level that is detected for workers. Two personas are used in terms of extroversion thus apart from the neutral AVC, these are the extrovert AVC and the introvert AVC as well. Along with personalized salutations and recommendations based on worker's preferences retrieved from VUM, visual and auditory modules described in the deliverable create the persuasive framework. The next step is to evaluate the AVC in the pilot studies of the project in order to prove its usefulness for the older workers in real-life environments.

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