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D3.1 Interim report on behavioural representation and virtual individual modelling

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Abstract

Deliverable 3.1 (interim report on behavioural representation and virtual individual modelling) describes the key areas of interest for building the Virtual Individual Model (VIM) in PRECIOUS. The VIM is based on ubiquitous sensor data and user inputs regarding different lifestyle related factors. These include the user's personal details, technology affinity, physical activity level, stress level, sleep and recovery, diet, alcohol, smoking, wellbeing, location, environmental factors, psychological distress, social networks, motivational status for behavioural changes, as well as current goals and plans. Therefore, the VIM is a regularly updated comprehensive view of the user's risk factors for type 2 diabetes (T2D) and cardiovascular diseases (CVDs). The VIM can be used to tailor preventive lifestyle interventions for the users of PRECIOUS.

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Abbreviations

ANS: Autonomic Nervous System

BMI: Body Mass Index

CVD: Cardiovascular disease

EEG: Electroencephalogram

MI: Motivational interviewing

NCD: Non-communicable disease

PA: Physical activity

PCOS: Polycystic ovary syndrome

PRECIOUS: PREventive Care Infrastructure based On Ubiquitous Sensing

REM: Rapid eye movement sleep

TAM: Technology Acceptance Model

TAS: Technology Affinity Survey

TRI: Technology Readiness Index

T2D: Type II diabetes

VIM: Virtual Individual Model

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1. Executive summary

PRECIOUS is a motivational system built on ubiquitous sensing of individual health related data, which aims to prevent lifestyle related disorders, in particular type 2 diabetes (T2D) and cardiovascular diseases (CVDs).

For individually accurate feedback, based on the sensor data and lifestyle intervention recommendations, a Virtual Individual Model (VIM) is constructed from users of the PRECIOUS system. The principal idea of the VIM is to combine data from different sources preferably through ubiquitous sensors in order to build an individual risk profile that can be used to recommend individually tailored services in terms of content, timing, and specificity.

The present interim report on behavioural representation and virtual individual modelling describes which data is collected for building the VIM, along with their inputs and outputs. Therefore, the parameters that are used for the VIM are presented. In the future work of the PRECIOUS project the comprehensive procedure for building the VIM will be defined. This work will be reported in the final document of the behavioural representation and virtual individual modelling (D3.2).

The main building blocks for the VIM are physiological, psychological, nutritional, social and context-related. More specifically, for example data on users' physical activity level, stress, recovery and sleep, diet and food composition, location and environment, psychological distress, physical and psychological wellbeing, and motivational status for behavioural change are utilised for the VIM.

When behaviours that increase the users risk for T2D and CVD are noticed by the VIM, the PRECIOUS can use various methods to facilitate beneficial lifestyle changes. The VIM will therefore be utilised in the PRECIOUS services that apply motivational techniques and gamification elements to encourage beneficial behavioural change. These behavioural change techniques and gamification elements that are presented with more details in the D3.3 "Interim motivational service design document" where also the role of VIM as a source of decision support for the system is discussed.

2. Background and objectives

Work package (WP) 3 of the project focuses on lifestyle, environmental, socio-psychological and physiological factors that are connected to type 2 diabetes (T2D) and cardiovascular problems as shown in Figure 1. These individually modifiable risk factors include for example physical activity level, stress, sleep quality, food intake and substance use, as well as living environment. The present deliverable aims to define these different risk factors, discuss the various data sources that will be used to measure them, and to describe how they are utilised to build an individual model that is used as the basis for personalised services and follow-up of the user within PRECIOUS.

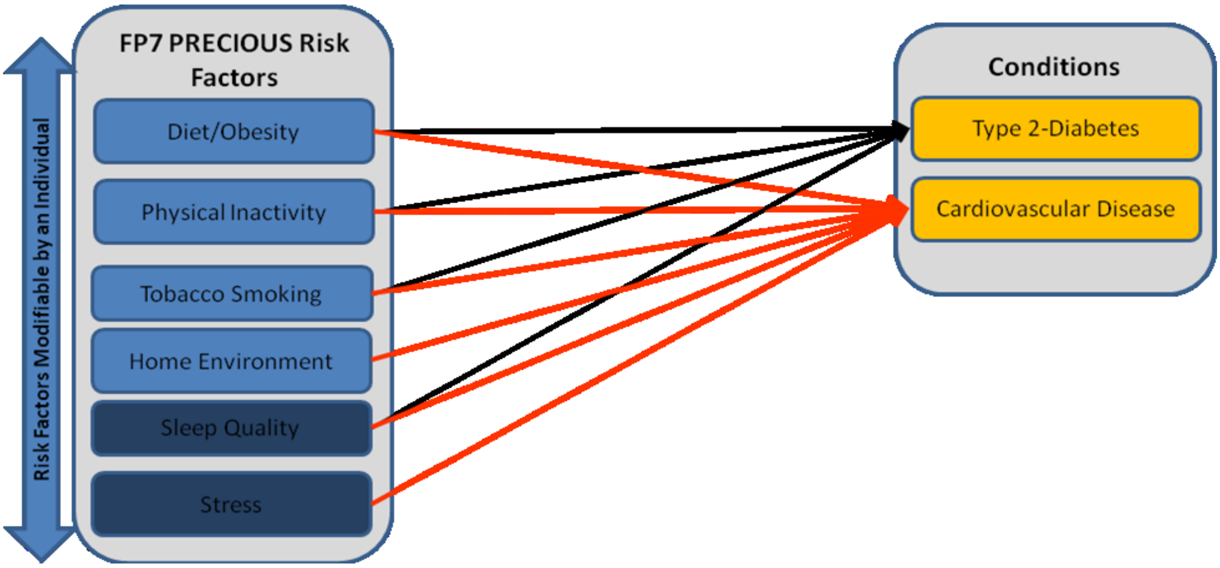

Figure 1. Modifiable factors associated with a risk for type 2 diabetes and cardiovascular diseases.

T2D is global epidemic, affecting 285 million people in 2010, and it has been estimated that the number of people with the disease will increase by about 69% in developing countries and 20% in developed countries from 2010 to 2030 (Shaw et al 2010). T2D has several causes (Becker 2007); however, genetics and lifestyle are the most important ones. A combination of these factors can cause insulin resistance, the most common cause of T2D. Regarding genetics, several studies have indicated a greater chance of developing T2D when a family medical history of diabetes exists. However, the specific genetic mutations that lead to increased risk of T2D are still unclear.

Risk factors for T2D include:

- Family history: T2D has an important hereditary factor. If a close family member has (or had) it, he/she is more likely to develop it. Individuals who have a family history of diabetes can have two- to six-fold the risk of T2D compared with individuals with no family history of the disease (Bishop, Zimmerman & Roesler, 1998; Harrison et al., 2003; Annis et al., 2005).

- Race/ethnicity: Certain ethnic groups are more likely to develop T2D, including African-Americans, Hispanic Americans, Native Americans, and Asian Americans. Compared with non-Hispanic white adults, the risk of diabetes is 18% higher in Asian-Americans, 66% higher in Hispanics/Latinos, and 77% higher in non-Hispanic African-Americans according to U.S Department of Health and Human Services (National Diabetes Fact Sheet, 2011).
- Age: Older individuals are more prone to develop T2D. At age 45, the risk starts to rise, and after age 65 the risk is even higher. In the U.S. more than a decade ago (1998) the prevalence rates for diagnosed diabetes per 1.000 persons were among different age groups as follows (men/women): 0-44 years: 8.5/9.2, 45-64 years: 71.8/76.1, 65-74 years: 130.8/138.6, and older than 75: 108.4/125.8 (Geiss 1999). Therefore, the 45 to 64 age group has almost 10-fold and 65 to 74 about 15-fold higher prevalence rate for diabetes than the youngest age group.
- Gestational diabetes: Development of diabetes while pregnant increases the risk of developing T2D later on. It has been presented that reported rates of gestational diabetes range from 2% to 10% of pregnancies, and that 5-10% of women with gestational diabetes are found to have diabetes, usually T2D, immediately after pregnancy (National Diabetes Fact Sheet, 2011). Furthermore, the women who have had gestational diabetes have a 35% to 60% chance of developing diabetes in the next 10–20 years (National Diabetes Fact Sheet, 2011).
- Polycystic ovary syndrome (PCOS): PCOS raises the risk for T2D because it's related to insulin resistance. In PCOS, many cysts form in the ovaries and one possible cause is insulin resistance. The review of 2192 studies examining PCOS and the risk of metabolic syndrome and T2D found that the odds of metabolic disturbance were more than two to four times as high for women with PCOS compared with controls (Moran et al. 2010).

Despite the influence of genetics, certain lifestyle choices greatly influence how well the body uses insulin. Therefore, healthy behaviours are extremely important in preventing T2D. In this especially physical activity and dietary choices must be considered as lack of exercise/being sedentary and overweight/obesity as well as unhealthy dietary choices, such as high fat meals and lack of fibre, increase the likelihood of insulin resistance. Moreover, lifestyle interventions have been shown to be effective in reducing diabetes among high-risk groups (Knowler et al. 2002). Therefore, PRECIOUS focuses on promoting healthy nutrition and physical activity, amongst other lifestyle related interventions.

In summary, the combination of the above factors - genetic susceptibility and lifestyle choices - increase the risk of developing insulin resistance, which in turn leads to the symptoms associated with T2D (Becker 2007). T2D and other metabolic problems then significantly increase a risk for CVD, and the American Heart Association has even stated that "In fact, from the point of view of cardiovascular medicine, it may be appropriate to say, "diabetes *is* a cardiovascular disease."" (Grundy et al, 1999). It has been found that the risk of death is twice as high among persons who have diabetes compared to persons with similar age but without diabetes (National Diabetes Fact Sheet, 2011).

The majority of CVDs are caused by risk factors that can be controlled, treated or modified, for example the leading risk factor is raised blood pressure (to which 13% of global deaths is attributed), followed by tobacco use (9%), raised blood glucose (6%), physical inactivity (6%) and overweight and obesity (5%). It is possible to modify all of these leading causes through healthier choices. Further modifiable risk factors include an unhealthy diet, raised total cholesterol/LDL cholesterol, low HDL/LDL ratio, and abuse of drugs or substances such as alcohol (Mendis, Puska & Norving, 2011; World Heart Federation).

Among the non-modifiable risk factors are:

- Age: CVD becomes increasingly common with advancing age when the persons' heart undergoes subtle physiologic changes, even in the absence of disease. According to data from the Framingham Heart Study, at 50 years of age, lifetime risks were 51.7% for men and 39.2% for women, with median survivals (=death without a CVD) of 30 and 36 years, respectively. With more adverse levels of single risk factors, lifetime risks increased and median survivals decreased. Compared with participants with ≥2 major risk factors, those with optimal levels had substantially lower lifetime risks (5.2% versus 68.9% in men, 8.2% versus 50.2% in women) and markedly longer median survivals (>39 versus 28 years in men, >39 versus 31 years in women). Therefore, the absence of established risk factors at 50 years of age is associated with very low lifetime risk for CVD and markedly longer survival. These results should promote efforts aimed at preventing development of risk factors in young individuals (Lloyd-Jones et al. 2006).
- Gender: males are at greater risk of heart disease than pre-menopausal women. The risk of developing CHD at age 40 years is 50% for men and 33% for women during the lifetime (Lloyd-Jones et al., 1999). Following the menopause, a woman's risk is similar to a man's. Risk of stroke, however, is similar for men and women.
- Family history of CVD: If a first-degree blood relative has had coronary heart disease or a stroke before the age of 55 years (for a male relative) or 65 years (for a female relative), the CVD risk increases. However, neither the evaluation nor the interpretation of family history as a risk factor for CHD are completely established (Roeters van Lennep et al., 2002).

Based on current knowledge, it is apparent that unhealthy lifestyle behaviours are at the root of the global burden of non-communicable diseases (NCDs), especially T2D and CVDs. Therefore, there has been increased interest in evaluating the benefit of adhering to 'low-risk lifestyle' behaviours and ideal 'cardiovascular health metrics' (Kushner & Sorensen 2013). It has been shown for example that comprehensive lifestyle interventions effectively decrease the incidence of T2D in high-risk patients (Schellenberg et al. 2013). Although a healthy lifestyle has repeatedly been shown to reduce morbidity and mortality, the population prevalence of healthy living remains low, and thus new approaches and tools are needed to support healthy living.

PRECIOUS aims to provide new innovations in preventive health care such as:

- A new automated service that analyses user health and ambient data to identify present and future risk factors
- A novel motivational system that boosts the required user actions to reduce unhealthy habits and promote healthy ones

- An innovative gamified user interface, including key motivation elements from the gaming industry to trigger and maintain behavioral change

The Virtual Individual Model (VIM) is the central mechanism through which these objectives are to be reached. Figure 2 (see next page) illustrates the PRECIOUS system overview, including the role of the VIM. First, user data is collected by different sensors, ideally in a seamless and transparent way, which is then followed by data aggregation, pre-processing, and producing different parameters described in the present document. The third phase of building the VIM involves using these parameters to track individual risk factors, which is described in detail in the final deliverable regarding the VIM (D3.2). This phase will create and update the personally tailored VIM with the associated risk factors. Finally, a feedback and response component that utilize different behavioural change techniques, elements of motivational interviewing, and gamification will interact with the user to promote the actions selected by the analysis and modelling component, foster the user's healthy habits, encourage behavioural change, and minimise risk behaviours.

The specific objectives for the present document are to:

- Highlight the relevance of the VIM in relation to the whole design of the system
- Describe the key parameters that are used to build the VIM
- Define the inputs and outputs of the VIM

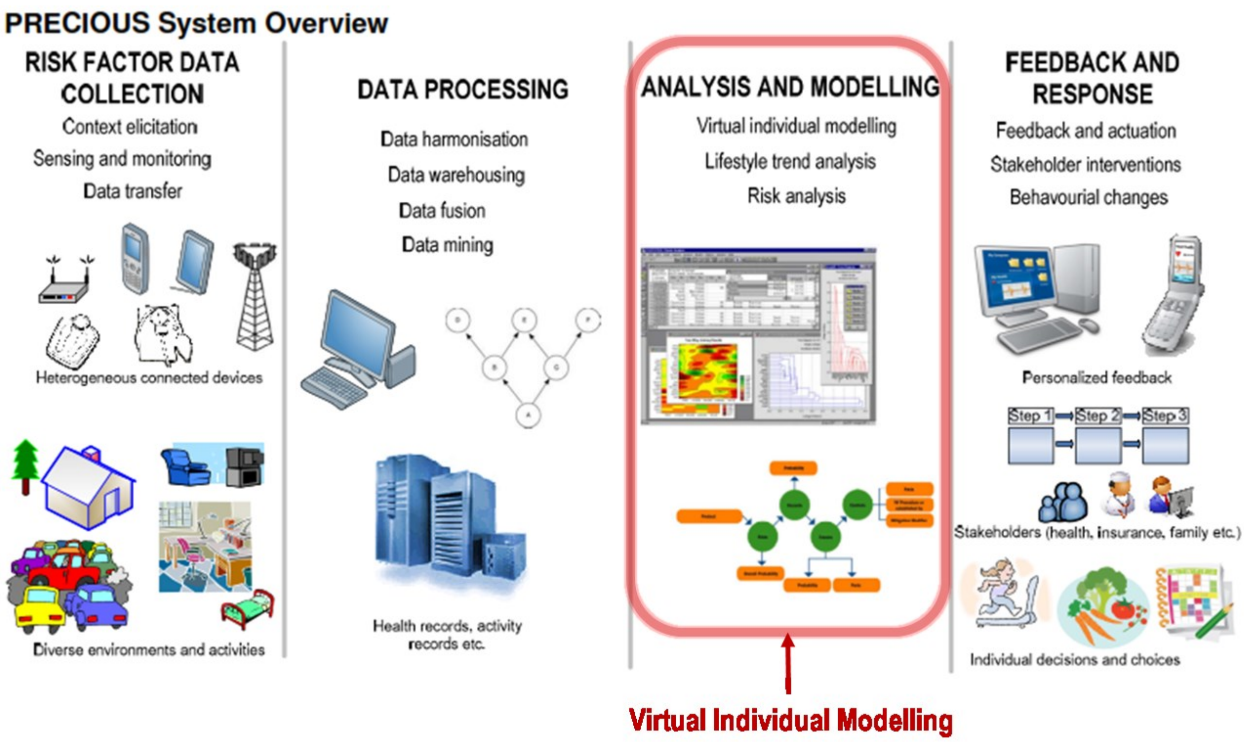

Figure 2. Schematic illustration of the PRECIOUS system with virtual individual modeling highlighted.

3. Virtual Individual Model (VIM)

3.1 Overview of the VIM

The PRECIOUS VIM provides a regularly updated representation of the user's health and behavioural status (see Figure 3). The leading idea of the system is that the user is in the centre of action with the factors that affect his/her everyday life such as diet, activity, personality, personal goals as well as family relationships and socio-economic status. Then the PRECIOUS uses preferably unobtrusive and ubiquitous sensors and devices to track the daily behaviours related for example to exercising, eating, social interaction, and mood in different contexts during the lifetime. This data is the used for building the VIM that can give the system information of the needs of the specific users. The outer circle of the figure 3 represents the logic that interprets the data collected around the user in order to define the inference model or interaction model with the user.

The VIM can be used for user profiling, giving appropriate recommendations, eliciting motivation and supporting change of daily behaviours and routines if needed. The VIM can be updated whenever new data is available for the user. It consists of physiological, nutritional, psychological, societal and environmental components. The parameters that are collected with different technologies are described with more details in the following sections of the present document and also shortly represented within figure 3.

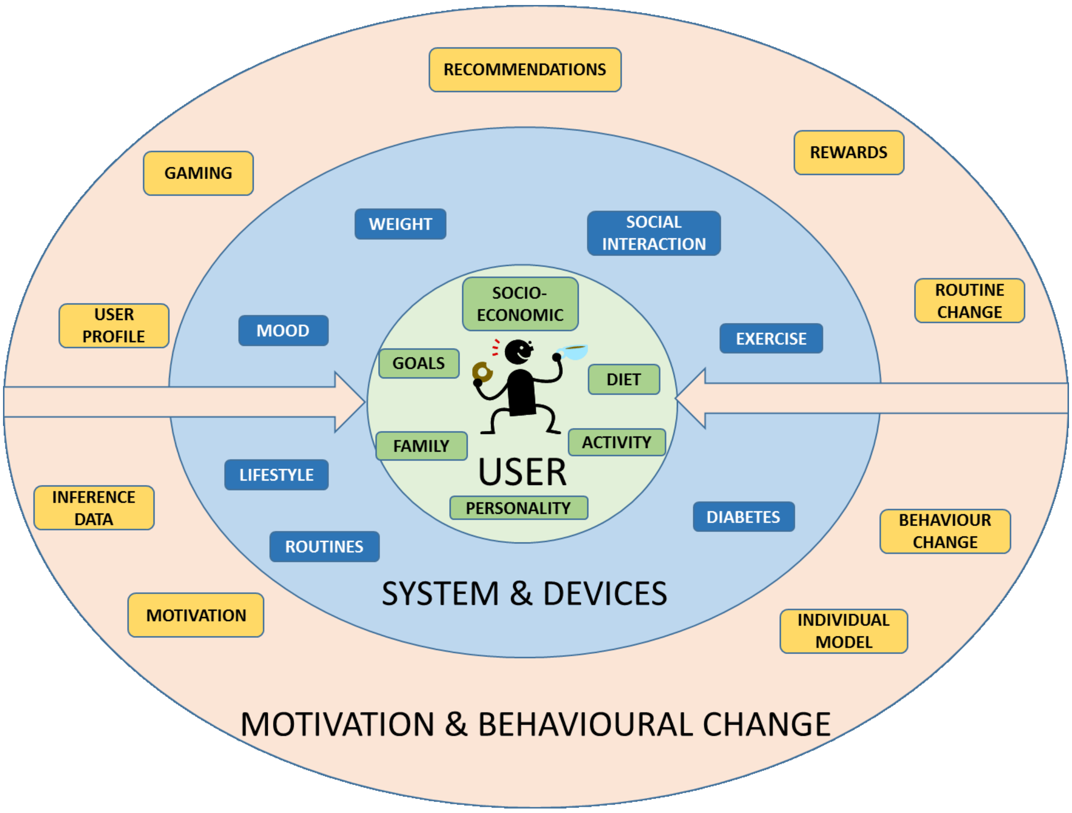

Figure 3. Components of the VIM that will be used to represent the users' health and behavioural status.

3.2 Areas of interest for producing the VIM

Next the main areas or parameters that will be collected and processed to produce the Virtual Individual Model (VIM) are described. These parameter consist of background details such as age, gender, weight, height, activity level, and family unit, which are complemented with other contextual, physiological, psychological and social parameters.

3.2.1 Personal background details

Some personal background details need to be collected from the users of PRECIOUS in order for the VIM to produce and provide individually accurate feedback. These background parameters can be collected with electronic questionnaires when the user starts to use the system. The basic parameters needed are the user's age, gender, weight, height, self-reported physical activity class, and family unit. The user's weight and height will be used to calculate body mass index (BMI). Although BMI has some limitations (the exact body composition in terms of muscle and fat mass cannot be defined) it can be used as an indicator of overweight and obesity. The family unit refers to information about whether the person is living alone or with someone else (e.g. is he/she a single working professional/student/retired couple/not retired/has children etc.).

3.2.2 Technology affinity

With every technological system an important aspect to be considered is the potential user's willingness and abilities to use such technologies (Davis 1989). Thus, PRECIOUS requires consideration of the end user's predisposition towards continuous usage of technology assets (mobile apps, physiological sensors etc.) for monitoring health risks and adopting healthy lifestyles. Herein, we refer to this as technology affinity. For the purpose of parameterising raw technology affinity data for the VIM, we are currently considering the following methods:

- Technology Affinity Survey (TAS): This approach was inspired by the need for a tool to reliably measure use of connected digital tools – affinity for technology and immersive technology use – with a particular focus on mobile technology tools (Mills et al. 2013). The TAS survey typically includes questions to determine aspects such as frequency of usage of, and level of addiction to, certain technologies.

- Technology Readiness Index (TRI): The TRI approach was proposed by Parasuraman (2000) more than a decade ago and is based on four personality dimensions (optimism, innovativeness, discomfort and insecurity) that affect a user's tendency to initially embrace and utilise new technologies. (To that end, optimism and innovativeness function as mental enablers, while discomfort and insecurity are mental inhibitors, in accepting new technologies. Recently, Parasuraman & Colby (2014) has proposed a more simplified TRI 2.0 index that reduces the number of survey items from a 36-item scale in TRI 1.0 to a 16-item scale in TRI 2.0.

The TAS and TRI approaches described above are not to be confused with the classical Technology Acceptance model (TAM) that determines user's perceptions of a technology (usefulness and ease-of-use) after a period of actual usage of the technology. Furthermore, recent developments in tools, such as mobile app usage trackers, allow for some of the TAS and TRI survey inputs or statistics to be gathered in the background with little or no need for users to respond to surveys directly.

The VIM outputs for the technology affinity inputs are still under consideration. One possibility is the adaptation of the TRI user segmentation (Parasuman & Colby 2014), whereby, users may fall in any of the following categories based on their TRI score:

- Sceptics: have a detached view of technology, with less extreme positive and negative beliefs;
- Explorers: have a high degree of motivation and low degree of resistance (inhibition);
- Avoiders: have a high degree of resistance and low degree of motivation;
- Pioneers: have both strong positive and negative views about technology;
- Hesitators: have low degree of innovativeness.

3.2.3 Physical activity level

According to commonly used physical activity recommendations (see more on the next page), people should be engaged in approximately 30 minutes of physical activity on most days of the week to remain healthy and/or to improve their aerobic fitness. Aerobic fitness level has been strongly associated with health and longevity. Regular physical activity has been shown have multiple positive effects such as (Kravitz 2007):

- Reduced risk for CVD
- Increased insulin sensitivity, improved glucose metabolism and reduced risk for diabetes
- Improved blood pressure in hypertensive
- Favorable impact on blood lipid (blood triglycerides, HDL cholesterol, LDL cholesterol)
- Lower risk for stroke
- Lower risk for cancer (Colon, Breast, Lung and Multiple Myeloma Cancers)
- Stimulus for bone formation and reduced risk for osteoporosis
- Musculoskeletal health and reduced age-related loss of muscle mass and strength (Sarcopenia)
- Improved body composition and weight control (reduced obesity)
- Treatment modality for arthritis
- Improvement psychological wellbeing (depression, anxiety, self-esteem)
- Reduced stress, and improved mood

Sensors that collect heartbeat data can be used to assess the physical activity level of a person. For both health and fitness, the target exercise intensity and duration need to be individually tailored to have positive effects. A positive health effect means that, in addition to maintaining one's physical condition, it also reduces the risk of chronic diseases, particularly those related to cardiovascular health (Schuler et al. 2013). The following physical activity recommendations have been published by World Health Organization (WHO 2010) for adults (table 1) and older adults (table 2).

Table 1. Physical activity recommendations for adults (18–64 years old)

For adults of this age group, physical activity includes recreational or leisure-time physical activity, transportation (e.g. walking or cycling), occupational (i.e. work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities. In order to improve cardiorespiratory and muscular fitness, bone health and reduce the risk of NCDs and depression the following are recommended: 1. Adults aged 18–64 years should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity. 2. Aerobic activity should be performed in bouts of at least 10 minutes duration. 3. For additional health benefits, adults should increase their moderate-intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity. 4. Muscle-strengthening activities should be done involving major muscle groups on 2 or more days a week.

Table 2. Physical activity recommendations for older adults (65 years old and above).

For adults of this age group, physical activity includes recreational or leisure-time physical activity, transportation (e.g. walking or cycling), occupational (if the person is still engaged in work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities. In order to improve cardiorespiratory and muscular fitness, bone and functional health, and reduce the risk of NCDs, depression and cognitive decline, the following are recommended: 1. Adults aged 65 years and above should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity. 2. Aerobic activity should be performed in bouts of at least 10 minutes duration. 3. For additional health benefits, adults aged 65 years and above should increase their moderate intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous intensity activity. 4. Adults of this age group with poor mobility should perform physical activity to enhance balance and prevent falls on 3 or more days per week. 5. Muscle-strengthening activities should be done involving major muscle groups, on 2 or more days a week. 6. When adults of this age group cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow.

Overall, across all the age groups, the benefits of implementing the above recommendations, and of being physically active, outweigh the harms. At the recommended level of 150 minutes per week of moderate intensity activity, musculoskeletal injury rates appear to be uncommon. In a population-based approach, in order to decrease the risks of musculoskeletal injuries, it would be appropriate to encourage a moderate start with gradual progress to higher levels of physical activity.

For health-promoting physical activity, the required level is at least 40% of the person’s maximal aerobic capacity (VO_2max) and in order to improve one’s fitness, the intensity should be at least 50%. In addition, carrying out regular light physical activity during the day can accumulate to provide good health benefits, whereas long periods of immobility have been suggested to have adverse health effects. Exercise intensity can be measured by heart rate based measurements. The results can highlight the requirement to increase exercise intensity for health benefits; for example walking the dog or a casual evening walk might not raise the heart rate sufficiently. In these cases, to get optimal benefits from the activity, the intensity level should be increased by increasing the speed or by choosing a hillier terrain for the walk.

For example, strength, speed and coordination training, although beneficial to the user’s musculoskeletal system, do not typically cause significant elevations in heart rate. Similarly, most Pilates and Yoga classes do not stress the cardiorespiratory system despite being excellent training for muscle balance, coordination and mobility. Therefore these type of activities can be challenging to recognise based on heart rate data analysis, and may require assessments via movement sensors or questionnaires.

Physical activity points (0-100) may be used to describe how well physical activity carried out during the measurement period has fulfilled the general aerobic physical activity goal; taking into consideration exercise duration, continuity and intensity. The goal is not to reach 100 points every day; instead, the recommended level is reached if the points are in the ‘Good’ level (>60 points) on most days of the week. This can be reached with 30 minutes of exercise at >40% of VO_2max, or a longer duration of slightly lighter exercise. 100 points can be reached with 60 min of exercise at an intensity of >40%. As previously mentioned, fitness-promoting exercise means an intensity that is over 50% of one’s VO_2max. This type of exercise not only has good health effects, but also a significant effect on improving fitness level. In addition to aerobic, endurance-type exercise (e.g. walking, jogging, biking), it is also recommended that strength and coordination exercises are included in the weekly exercise programme, for example group exercise classes, weight training or Yoga.

3.2.4 Physiological stress

The analysis of the physiological stress state of the user is based on utilising heart rate variability (HRV) information to produce a physiological model of the user (Firstbeat Technologies 2014). HRV has been universally accepted as a non-invasive method to analyse autonomic nervous system (ANS) activity (Task Force 1996). When considering stress, it is important to remember that it is a normal physiological reaction that allows a person to respond effectively to the challenges and demands that the environment presents.

In the short term, stress improves a person's ability to perform and helps them to cope with challenges. However, stress becomes harmful when the individual feels that their resources are not sufficient to cope with the situation and/or when the overload continues for too long without sufficient recovery. Recovery occurs when the physiological arousal is diminished for long periods, for example during sleeping.

Physiological stress means an elevated activation level in the body, caused by external or internal stress factors and is regulated by the ANS and hormonal responses. During a stress reaction sympathetic activity of the ANS is dominant and parasympathetic activity is recessive.

A stress reaction can be either positive or negative. During positive stress the individual feels excited and motivated and is in a positive frame of mind. Negative stress can be either a strong, acute state or a chronic situation during which the person experiences unpleasant negative emotions. It is not possible to separate positive and negative stress based on heart rate measurements because the physiological reaction to both is similar, thus further highlighting the importance of recovery as a sign that the stress has not been too high (as the person is still able to recover after the stress reactions).

When interpreting sensor-based stress, it is important to remember that the system measures a physiological reaction that reflects the activation status of the autonomic nervous system and can be caused by numerous factors. A stress factor can be physical, psychological or social, and is reflected via complex processes of the ANS.

3.2.5 Sleep and recovery

Sufficient, high-quality sleep is the basis of health and coping. During sleep, the body is revived, physical fatigue subsides and learned things are saved in long-term memory. After having slept sufficiently, a person's mind is energetic and their mood is positive. In contrast, insufficient sleep can cause weight gain and predispose a person to various diseases. Insufficient sleep, combined with excessive alcohol use, also predisposes individuals to depression. For overall stress management, sleep is very important, and thus, should be the main focus when interpreting the effects of daily stress on recovery.

The body's ability to react to external and internal stressors is called resources. Resources accumulate when we recover, whereas stress reactions consume our resources. In order for the resources that we typically use during the day to build up, there needs to be a sufficient amount of recovery in a 24-hr period. The average requirement for sleep is at least 7 hours per night, which seems to produce the lowest mortality rate based on a study using data of more than 1.1 million persons (Kripke et al., 2002). This 7 hours translates to approximately 30% of recovery. If the sleep period is long enough and sleep quality is good (showing up as recovery state in heart rate variability–based analysis), this is normally enough for the consumed resources to recover by the morning. If the sleep period is very short or the quality is very poor, the significance of recovery during the daytime can be emphasised. In these cases, it is good to take a longer break during the day or even a nap after work, to allow the brain and the body to recover sufficiently.

Frequent and/or excessive stress factors during the day can mean that the body is still alert during the first few hours of sleep. Factors that typically disturb the early sleep period include late, intensive exercise, taking a sauna/using a steam room for a long time, a hectic work day, late meals, and alcohol. Often the factors that cause poor recovery during sleep can be found and pinpointed easily, and the explanations do not necessarily cause too much concern.

Regarding alcohol, it is good to be aware that in the long term, regular alcohol consumption depletes the body's mental and physical resources, in addition to its other harmful effects. Typically two or more units of alcohol can impair recovery during sleep. Heavier drinking the previous night can also affect the following day's and night's results. In addition, acute illnesses, for example flu and fever, typically worsen sleep and recovery. Pre-onset illness, or recovery from an illness, can also be indicated through greater stress during sleep. Moreover, significant overweight, combined with a poor physical condition and/or a physically strenuous day, overloads the body and can result in poor recovery during sleep. Overweight is a chronic stress factor itself, and when combined with other stressors, it can have a dramatic effect on recovery. Chronic disease or prolonged stress can also cause a decreased level and amount of recovery reactions. In cases of repeated poor results, it is suggested that the user consults a health professional.

Short breaks in hectic activity during the day are important for recovery because they reduce the production of stress hormones and aid recovery. Therefore, even a short break during the work day can have positive effects. Furthermore, the more stressful the day has been, the more important it is to take a short break after work. A physically fit and healthy body recovers more easily and reacts to breaks more effectively. Additionally, physical activity is an excellent way to break up stress and forget work matters. It can be an easy, refreshing walk in the outdoors or a more intensive "stress buster" session. However, if the work day has been physically or mentally challenging, it is best to keep the intensity level of the exercise session fairly low.

Short breaks during the day do not necessarily compensate for poor sleep time recovery, but their role in building up resilience for the rest of the day and refreshing the body and mind can be significant. For this reason, good-quality sleep should be supplemented by regular "recharging" breaks. Taking breaks might require active learning and scheduling, otherwise they are easily forgotten.

3.2.6 Energy and nutrient intake

Diet is an important contributor to health and wellbeing, with poor dietary practices (for example excess energy intake, high fat, sugar and salt consumption, and lack of fibre, fruit and vegetables intake) being linked to numerous lifestyle-related disorders, such as CVD and T2D. Numerous applications (both free and paid for) are available which offer measurement of energy and nutrient intake through completion of food diaries and/or the use of barcode scanners. PRECIOUS will offer the ability to connect with external applications currently in use by the user, or will suggest relevant applications. An assessment of applications will be carried out in this sector, looking for those with enhanced potential to encourage dietary change, and, from the scientific point of view, that could adapt to PRECIOUS. The system will preferably suggest free applications so as not to financially burden the user. The data collected from these applications can be compared against EU (EFSA 2010) and national government (for example UK) dietary reference values guidance on dietary intakes (see e.g. Department of Health 1991).

This type of self-monitoring of food intake is associated with improvements in diet (Ngo et al. 2009); however, there is also evidence that such applications are typically only used in the short term (2 - 6 weeks) due to the recording burden placed on the user (Aizawa et al. 2014). A key benefit of PRECIOUS is its use of new technologies and motivational techniques to assist the user in making longer term behavioural changes. This approach is ideally directed to a more educational level so that the user can, over time, learn from mistakes and make healthier choices. In relation to food intake, the following approaches will be used to supplement food diary-based applications and to collect information on the users' diet and build motivation to make healthier choices:

- Development of a tool that can estimate dietary intake using digital images captured by a smart watch

Within the project the use of digital image capture via a smart watch, and processing of images to estimate dietary intake, will be explored. The intention is to develop a more transparent tool for tracking daily food intake without burdening the user. We intend to create a tool that can give immediate feedback and help the user to select healthier options. This tool is currently under development and progress will be reported in future public deliverables (D4.3 Development of mobile applications and feedback tools and D5.2 System validation report).

- Education of the user with respect to key healthy eating guidelines

In order to educate the user, PRECIOUS should provide information about healthy eating guidelines in a succinct and simple manner, and provide them with suggested alternatives. Guidelines for healthy eating will be taken from European Commission documentation, as well as national government guidance, and will include suggestions such as 'consume more wholegrain cereals' and 'reduce consumption of sugar sweetened beverages'. PRECIOUS will also link to applications that are already available, such as FoodSwitch UK, an application that allows the user to scan the barcode of a product and receive information on the content of four important nutrients (fat, saturated fat, sugars and salt). The application also suggests healthier alternatives based on the contents of fats, sugars, salt, protein and fibre in similar products.

Gamification techniques will also be used to help reinforce learning. Within the project we will develop and test a game that asks multiple choice questions and rewards correct answers with the award of points and/or progression to the next level of the game and/or improvements in the health of an avatar.

3.2.7 Alcohol consumption

Alcohol consumption will also be measured in PRECIOUS and will be monitored by the same mechanisms as for energy and nutrient intake. Alcohol intake in the WHO European Region is the highest in the world (WHO 2013). Harmful use of alcohol is related to premature death and avoidable disease, and is a major preventable risk factor for neuropsychiatric disorders, CVDs, cirrhosis of the liver and cancers. In the European Union, alcohol accounts for about 120,000 premature deaths per year, which is equivalent to 1 in 7 in men and 1 in 13 in women. Most countries in the Region have adopted policies, strategies and plans to reduce alcohol-related harm (WHO 2013).

Even with occasional use, it is important to remember the negative effect of alcohol on recovery. In particular, acute heavy alcohol consumption affects sleep in many ways, for example brain activity, as measured by an electroencephalogram (EEG), does not show normal sleep stages. Heavy drinking before bedtime cancels out REM sleep, which is important for psychological well-being. If drinking continues for several weeks, REM sleep is seen in the morning hours in short bursts. Sleep is restless and broken up with frequent waking. Eventually it can become difficult to fall asleep, or go back to sleep after waking up. Alcohol also loosens the muscles of the upper respiratory tract and throat. In smaller amounts, it can cause snoring and in larger amounts, collapsing of the respiratory tract and interrupted breathing (sleep apnea).

Since the consumption of alcohol is likely to be present in the majority of potential users, the evaluation of the consumption of alcohol is one of the features provided in PRECIOUS. It is expected that the service will be capable of providing information through social responsibility messages, warning messages or the latest guidelines on alcohol consumption as published by the European Commission/WHO.

3.2.8 Smoking

Smoking is the most significant preventable cause for the development of CHD among men and women (Julian, Wenger & Hennekens, 1997). Smoking harms several organs of the body and diminishes a person's overall health. It is a leading cause of cancer and premature death, as well as of several comorbidities that increase the likelihood of developing other chronic health conditions (U.S. Department of Health and Human Services 2010 & 2004). Smoking also causes heart disease, stroke, aortic aneurysm (a balloon-like bulge in an artery in the chest), chronic obstructive pulmonary disease and other pulmonary and respiratory pathologies (U.S. Department of Health and Human Services 2010 & 2004 & 2006). Despite this some studies have demonstrated that smokers who quit at about age 30 can reduce their chance of dying prematurely from smoking-related diseases by more than 90 percent (Peto et al. 2000 & Doll et al. 2004).

Additionally, the immediate health benefits of quitting smoking are substantial, such as:

- Lowering blood pressure and heart rate levels which are typically elevated among smokers

- Improvements in lung function and reduction in the level of carbon monoxide in the blood
- Decrease in coughing and wheezing
- Improvements in the sense of smell and taste
- Improved skin health

Ideally every smoker should be offered evidence-based advice and treatments to help them quit smoking. Indeed it has been shown that health professionals and health care settings can play a significant role in motivating and assisting smokers to quit (Miller & Wood 2003).

3.2.9 Location

The term location in this context refers to a geographical location. To that end, PRECIOUS adapts a general definition of geographical location information from the Internet Engineering Task Force (IETF 2005), which implies a physical position in the world that may correspond to the past, present, or future location of a person, event, or device. In PRECIOUS, continuous location information is a valuable element in determining an individual's context (are they cycling, in a fast-food restaurant etc.) and the relationship to a particular risk factor.

The raw geographical location information may be based on one or more of the many existing formats such as civic locations (street address, postal code etc.) and geographic coordinates (e.g. latitude and longitude). The VIM outputs could be location type categories for fixed places (home, office, restaurant etc.) and trajectories, that is, the path that a moving object follows (e.g. the jogging route taken by an individual).

3.2.10 Environmental factors

The environmental factors considered are those that relate to thermal comfort, air quality, humidity, noise pollution, and lighting quality. Moreover, the focus is on the indoor home environment due to fact that it is the location in which an individual spends most of their time. A demographic survey in the US indicated that the fraction of time spent indoors varies from 57% (16-21 years) to 81-95% (over 64 years), with figures from Europe showing similar trends (Institute of Medicine of the National Academies 2011). Each of the environmental factors is associated with some of the other risk factors considered in PRECIOUS (which in turn are linked to cardiovascular diseases). Below we provide a brief description of these associations and explain how these factors manifest in the home environment.

Thermal comfort: The idea of thermal comfort is grounded on the fact that humans have varied thermal sensations (from hot to cold) from environmental conditions which meet their thermal satisfaction (ANSI/ASHRAE 2013). Exposure to conditions outside this range will lead to feelings of thermal discomfort. The environmental factors affecting thermal comfort are temperature, relative humidity and air speed. Relative humidity is the ratio of the partial pressure of water vapor in the air to the saturation vapor pressure of air at a defined temperature. The relative humidity in the indoor air is influenced by both air temperature and the water vapor content of the air and is usually expressed as percentage. The thermal comfort measure is further influenced by personal factors, namely, metabolic rate and amount of clothing (thermal insulation). Control of thermal comfort in home environments can be through centralized HVAC (Heating, Ventilation and Air Conditioning) systems, natural ventilation and various home dweller interventions (opening windows, fans, adding/removing extra clothing etc.). The models and recommended levels for thermal quantities are typically based on guidelines from various national and regional standardization bodies, notably, for US Standard 2013 (ANSI/ASHRAE Standard 55), Europe Standard 2007 (EN 15251) and International Standard 2005 (ISO 7730).

Noise pollution: There is now sufficient evidence linking exposure to high noise levels with cardiovascular effects in humans, elevation of stress levels and reduced sleep quality due to increased heart rates, arousals, sleep stage changes, awakening etc (WHO 2009). The level of risk also varies with time of day, for instance, noise exposure at night might be more strongly associated with cardiovascular effects compared to daytime exposure (WHO 2009). Noise pollution in the home environment may be attributed to neighborhood noise (e.g. music), construction activities, transportation noise (from nearby roads, aircraft etc.) and so on. At this stage we intend to consider European WHO guidelines on night noise for linking different noise levels to health (WHO 2009). This may include the instantaneous noise level from an individual event (e.g. passing truck) or average noise level for given period of time (expressed in dB(A) per unit time).

Light quality: The exposure to artificial lights in indoor environments has many benefits in terms of enhancement of visual performance in various indoor activities. However, the unnecessary exposure to light could also be considered light pollution and it could have adverse effects on health by destabilizing circadian rhythms (Stevens et al. 2007). The circadian rhythm refers to the endogenous (built in) 24-hour physiologic, metabolic, or behavioral rhythms that can be adjusted by local environmental cues such as light, seasons and so on. The disruption of circadian rhythms has a strong influence on human physiology, impacting on sleep quality, diet and mood, which consequently heighten the risk of conditions such as T2D and cancers (Stevens et al. 2007). The idea of lighting quality has been introduced to indicate the extent to which lighting meets the objectives of users and designers (IEA 2010). These objectives include enhancing visual performance, creating specific impressions, generating desired patterns of behaviour and ensuring visual comfort (IEA 2010).

In addition to these environmental factors, indoor air quality is another critical factor for health. However, it is currently not being considered within PRECIOUS. Indoor air quality is degraded by the presence of air pollutants (volatile organic compounds and particulate matter) (IETF 2005), and it links strongly to respiratory diseases, which are outside the initial scope of PRECIOUS.

3.2.11 Psychological distress

Psychological distress is a general term used to describe unpleasant feelings or emotions that affect daily activities. It is generally understood as a continuum, with “mental health” and “mental illness”' at opposing ends. Severe psychological distress can lead to very negative views of yourself, other people, and the environment. Sadness, anxiety, distraction, and depression are common expressions of psychological distress (Ridner 2004; Russ et al., 2012). However, psychological distress is a subjective experience; therefore, the severity of this distress is dependent upon the situation and how the individual perceives it. The most common sources of psychological distress include:

- Cancer and other severe medical illness such as CVD or diabetes
- Mental illness
- Adverse life situations or small stressful events such as:
    - Divorce
    - Starting a new job
    - Joblessness
    - Financial problems
    - Being a victim of mobbing or other types of abuse
    - Adverse work/school experiences
    - Infertility
    - Traffic accidents
    - Natural disasters

The most common symptoms of psychological distress are the following:

- Changed weight
- Anger management problems
- Sleep disturbances
- Anxiety
- Depressed mood and sadness
- Decreased pleasure in daily activities (previously enjoyed)
- Decreased pleasure in sexual activities
- Obsessive thoughts or compulsions
- Strange or unusual behaviours
- Physical symptoms not explained by other medical conditions

Poor mental health has been frequently associated with heightened cardiovascular risk, because depressive symptoms or disorders increase the risk of coronary heart disease and vice versa (Nicholson et al., 2006). The development of vascular imaging techniques has made it possible to assess subclinical atherosclerosis, which can help delineate the relationship between mental health and CVD. However, the specific mechanisms of these associations are still unclear. Various etiological pathways have been suggested, which link depression to accelerated atherogenesis and ultimately result in CVDs. In addition, unhealthy lifestyles can accelerate this process or increase risk (Bonnet et al., 2005). In summary, although the possibility of confounding can never be completely excluded, after adjusting for several “lifestyle” factors and CVD risk factors, some authors have found a dose-response association between psychological distress and death from CVD. This has important implications for prevention.

The use of both qualitative and quantitative methods to assess psychological distress has been employed. In the present project, the aim is not to carry out a comprehensive or focused assessment of psychological distress but to screen it. The screening involves a pro-active rapid identification of key indicators that allow for further assessment and appropriate referral. The most common practice is to screen psychological distress through self-reported measures such as visual analogue scales or numeric scales (distress thermometers). The distress thermometer is a scale on which the individual can directly circle their level of distress (response ranging from 0 = No distress to 10 = extreme distress). Some distress thermometers also allow the user to indicate the specific parts of their life in which they are having problems. The distress thermometer has been tested in many studies and found to work well (Stewart-Knight et al., 2012).

3.2.12 Physical and psychological well-being

There is no consensus around a single definition of well-being, but there is general agreement that at a minimum, well-being includes the presence of positive emotions and moods (for example contentment, happiness), the absence of negative emotions (for example depression, anxiety), life satisfaction, fulfilment and positive functioning. In brief, well-being integrates mental health (mind) and physical health (body) resulting in more holistic approaches to disease prevention and health promotion being considered (Diener, 2000; Ryff & Keyes, 1995).

Psychological well-being refers to how people evaluate their lives. According to Diener (1996), these evaluations may be in the form of cognitions or affect. The cognitive part is an information based appraisal of one's life and it happens when a person gives conscious evaluative judgments about satisfaction with life as a whole. The affective part is a hedonic evaluation guided by emotions and feelings, such as frequency with which people experience pleasant/unpleasant moods/feelings in their lives. The assumption behind this is that most people evaluate their life as either good or bad, so they are normally able to offer judgments. Further, people invariably experience moods and emotions, which have a positive or a negative effect. Thus, people have a level of subjective well-being even if they do not often consciously think about it, and the psychological system offers a virtually constant evaluation of what is happening to the user.

Physical well-being is directly connected to mental and emotional health. When someone improves his/her physical health, he/she will automatically experience greater emotional well-being. This is explained by the fact that physical activity not only strengthens and improves the physical condition, but also the psychological state through endorphins and other hormones that lift mood and increase vigour and vitality.

As in the case of psychological well-being, the physical evaluation comprises the objective acknowledgement of one's functionality and health status and also, the subjective interpretation of health according to expectations, needs and desires. Physical well-being can typically be modulated and explained by the following factors:

- Get enough rest and sleep
- Learn about good nutritional habits and practice them
- Undertake regular physical activity
- Reduce the consumption of toxic substances (for example limit alcohol intake, avoid cigarettes, avoid other drugs and substances, etc.)

- Achieve autonomy in daily activities
- Spend time in natural environments and get regular exposure to sunlight

Well-being is a valid population outcome measure (beyond morbidity, mortality, and economic status) that tells us how people perceive their own life. Advances in psychology and neuroscience suggest that well-being can be measured accurately (Diener et al., 2009). Scientific research has also proven that well-being correlates with self-perceived health, longevity, healthy behaviours, the occurrence of mental and physical illness, social connectedness, and productivity in different environments (Diener & Seligman 2004; Lyubomirsky, King & Diener, 2005).

Since well-being is subjective, it is typically measured with self-reports. However, the use of both objective and subjective measures, when available, are desirable for public policy purposes (Diener, Lucas, Helliwell, 2009; Eid 2009).

There are many instruments available that measure self-reported well-being, and the choice depends on whether one measures well-being as a clinical outcome, a population health outcome, for cost-effectiveness studies, or for other purposes. Some studies support the use of single items or visual analogue scales to measure well-being using limited resources. Peer reports, observational methods, physiological methods, experience sampling methods, ecological momentary assessments, and other methods are used by psychologists to measure different aspects of well-being (Eid 2009). In the present research, global self-reported ratings will be administered to explore both physical and psychological well-being across time.

3.2.13 Social networks

PRECIOUS will aim to demonstrate to the user the relationship between environmental factors/influences, nutrition and physical activity behaviours. Nevertheless, identifying the user's environment and the way it affects food intake and physical activity is not easy. People live and interact in multiple environments; family unit, school, work, sports clubs etc, and these often overlap.

It may be possible to use social information to help the user plan behavioural changes. For example, if it is detected that every Tuesday the user eats with a colleague in a specific place, PRECIOUS could provide some achievable guidance in accordance with the user's setting, goals and objectives. In addition, with regard to couples and family units, the system could help to synchronize activities, helping multiple users to plan behavioural changes together.

Social media (for example Facebook) is another valuable aspect as the system could collect detailed information regarding the user's social media groups and activities. Based on this information the system could suggest participation in a sports competition or could suggest organisation of a jogging session with friends/family.

3.2.14 Motivational status for target behaviours (stages of change)

National guidelines and target behaviours for prevention of CVD and T2D

Earlier we addressed risk factors for T2D and CVDs, some of which are not modifiable such as age, family history (genome) and ethnic background. However, individuals can affect modifiable risk factors such as weight, waist circumference, and glucose status by making lifestyle changes. A European multidisciplinary systematic review of T2D prevention concluded that the main modifiable risk factors are obesity and sedentary lifestyle (Paulweber et al. 2010). Therefore, healthy diet and physical activity are chosen as key target behaviours for PRECIOUS. International guidelines for physical activity for adults are two and half hours (150 minutes) of moderate-intensity physical activity every week (WHO, 2014). This can be performed in several sessions, for example 30 minutes, five days a week.

The national guidelines for diet vary according to the food culture of each country. However, the general overriding principles are as follows; a) decrease fat and saturated fat intake b) increase fruit and vegetable intake (5 a day, or half a kilo per day), c) decrease sugar intake d) increase fibre e) decrease salt. An individuals' total energy intake is particularly related to weight management. In order to assist weight management it is generally recommended that individuals should eat regular meals, not skip breakfast, decrease snacking, decrease alcohol intake and reduce portion sizes.

Motivational status (stages of change)

There are several theories that assume behaviour change happens through qualitatively different stages. These models for stages of change (DiClemente & Prochaska, 1998; Gollwitzer 1990; Schwarzer 2008; Vries et al. 2005; Weinstein 1988) have a common structure that involves three stages; pre-intention, intention and action (Schüz et al. 2009). These three stages, which include two critical transitions, are supported by strong evidence (Schüz et al. 2009). Recognizing an individuals' stage of change may help to target interventions that address either the transition from not intending, to having formed an explicit behavioral intention, or the transition from intending to act, to actually acting (Schüz et al. 2009).

The individuals that use the PRECIOUS service are most likely to have shown basic motivation for monitoring and measuring themselves and thus left the pre-intention stage. Thus, the PRECIOUS service will focus on bridging the gap between intentions to act and the actual behaviour. This focuses the service on behaviour change techniques that are proximal factors of behaviour. The PRECIOUS behaviour change service is focused on engaging people to undertake behaviour change and, importantly, to maintain healthier behaviours.

When people have started to use system, but are not ready to make changes, there are several different strategies and interventions that can be used to increase awareness of risk factors and encourage change. The more aware people are about the pros and cons of their behaviours, the more probable is that they will make lifestyle changes.

The key aim of lifestyle changes is that they are internalised according to the principles of the self-determination theory (Deci & Ryan, 2000). According to this theory, autonomously motivated behaviours are practiced as they are goals and resources for wellbeing themselves (Deci & Ryan, 2000, 2008). Internalised goals and values help people in achieving lifestyle changes. Behaviours that are performed for the inherent pleasure of the activity itself, and without any external motives, are defined as intrinsically regulated behaviours. Despite, or due to, their voluntary nature, these behaviours can be effective instruments to achieve other goals (weight loss, health etc).

3.2.15 Goal setting, self-monitoring and planning

Target behaviours in PRECIOUS are related to physical activity and diet. In the process of behaviour change the users must become aware of the current status of their behaviour and actively formulate behavioural goals. These goals can be defined as future valued outcomes and they should be specific, measurable and achievable (Locke & Latham 2006). Defining goals and making plans for action are behaviour change techniques in themselves and therefore the user should be encouraged to do this, rather than relying on the service to suggest goals and plans.

PRECIOUS may help users to grade their goals based on their internal values. As self-efficacy is central for the actualisation of behavioural change goals (Ashford, Edmunds & French 2010), we will consider how self-efficacy can be encouraged in the PRECIOUS service. Additionally, the provision of feedback has been associated with higher levels of self-efficacy in physical activity (Ashford et al. 2010).

Regarding physical activity, people can set a variety of different goals (number of weekly gym sessions, number of steps during the day). However, what is truly important for sedentary individuals, is that any amount of physical activity is better than no physical activity. It is also beneficial to set a number of different dietary goals. For example in the Finnish diabetes prevention study (Tuomilehto et al. 2001), participants were given three diet related goals, as well as one goal for physical activity (>30 min PA per day) and one for weight loss (5% weight loss). Diet related goals were 1) less than 30% energy from fat, 2) less than 10% energy from saturated fat, and 3) at least 15g/1,000 kcal of fibre. During the one year follow-up none of those in high risk group who achieved all 5 goals developed type II diabetes. In the PRECIOUS service people will be encouraged to make goals that are suitable for them and to change those goals as their situation/state of wellbeing changes.

The VIM will collect data to form a broad model of the user behaviour, motivational status, and overall goals. The PRECIOUS service will then offer customised tools to aid specific goal setting, to measure physical activity and diet, and to receive feedback in order to monitor target behaviours. The behaviour change techniques used in PRECIOUS follow the recommendation of the principles of the WHO:

“Interventions promoting lifestyle changes are more effective if they target both diet and physical activity, mobilize social support, involve the planned use of established behaviour change techniques, and provide frequent contacts” (WHO, 2014).

The service is designed around three groups presented in a health psychological taxonomy (Michie et al., 2013). These groups are (1) feedback and monitoring, (2) goals and planning, and (3) social support. This choice is based on findings that techniques derived from Control Theory (Carver & Scheier, 1982; Gardner, Whittington, McAteer, Eccles, & Michie, 2010), especially self-monitoring, are effective techniques for healthy eating, physical activity (Michie et al., 2009 King 2001; Sniehotta, Scholz & Schwarzer 2005), as well as weight control intervention (Boutelle et a. 1999). Self-monitoring can include tracking of behaviour and it involves a comparison of the actual performance against a behavioural goal. Self-monitoring and feedback of specific proximal goals enable the observation of goal achievement and attainment. The Control Theory is a based on the idea of a discrepancy reduction loop (Figure 4), in which individuals aim to decrease the difference between their actual state of behaviour and their behavioural goal. A discrepancy leads to adjusting behaviour or environmental factors (Carver & Scheier 2012).

Planning has also been identified as a central technique for overcoming the gap between good intentions and action (e.g. Gollwitzer 1999; Hagger & Luszczynska 2013; Sniehotta et al. 2005). There is compelling evidence to suggest that Planning may be divided into action planning and coping planning. Action planning typically consists of plans of when, where, how, whereas coping planning is preparing for setbacks with “if-then” rules, that is, how to achieve the planned behavior when facing difficulties. For example, an individual who tends to eat unhealthy snacks might make a coping plan to keep low-energy snacks with them to avoid the risk situation. Overall, action planning can facilitate the realisation of intentions (Gollwitzer & Sheeran 2006) and coping planning has been associated with effective maintenance of new lifestyles (Bartholomew et al. 2011).

Another important technique that helps people to make behavioural changes is motivational interviewing (MI) (Miller & Rollnick 2012). In different clinical settings, this method has been shown to be more effective than other approaches in encouraging people to make behavioural changes and improve health outcomes (Lundahl et al. 2013). MI is defined as “a person-centered counseling style for addressing the common problem of ambivalence about change” (Miller & Rollnick 2012). The PRECIOUS service will take into account the four processes defined in this method:

1) Engage users in behavior change (engaging)
2) Help the user to set their own goals (focusing)
3) Encourage them to use their own resources and ideas to change (evoking) and
4) Guide them through a suitable plan of change (planning).

Moreover, this method uses different micro skills that will be adapted to offer accurate feedback to the user.

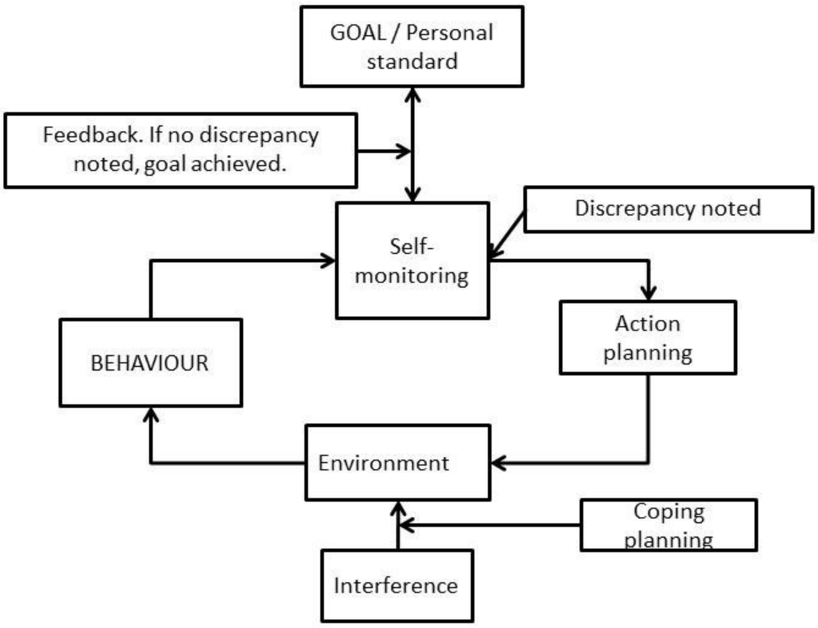

Figure 4. Control theory: discrepancy reducing feedback loop (modified from Gardner et al. 2010).

More information regarding different behavioural change techniques and how they can be implemented into gamification elements of the PRECIOUS can be found in the deliverable 3.3 “Interim motivational service design document”.

3.3 Summary of parameters for building the VIM

Previously we have discussed the areas of interest that will be covered when producing the virtual individual model (VIM) in the PRECIOUS. Table 3 describes how the risk factors for T2D or CVDs could be monitored in the PRECIOUS system.

Table 3. Risk factors that could be monitored with different technologies and sensors and utilized for the VIM.

PRECIOUS Risk Factor	Risk factor attributes monitorable for (or by) the Individuals	What will be monitored in PRECIOUS	How attributes will be monitored in PRECIOUS
Diet/Obesity	• Trends in body weight, body mass index BMI, waist circumference, waist: hip ratio, body fat percentage • Food intake and food composition • Food quality • Food stocks at home • Shopping routine	• Trends in body weight, body mass index BMI, waist circumference, waist: hip ratio, body fat percentage • Food intake and food composition	• Weight scale (manual, automated, seamless monitoring) • Food intake sensor (automated, wearable) • External applications etc. utilization of camera for taking pictures about food and analysing the food content
Physical Inactivity	• Physiological signals (blood pressure, heart rate etc.) • Exercise caloric burn, distance, elapsed time, etc. • Indoor activity or movement • Outdoor movement or mode of transport car, bicycle, etc.	• Heart rate (RR data) • 3D activity (accelerometer, other) • Spatio-temporal data (location, trajectory, speed)	• Heart rate sensor (automated, wearable) • GPS device (handheld, wearable) • Accelerometer (wearable) • Indoor activity sensor (embedded in home, pervasive)
Home Environment	• Indoor temperature of home environment • Indoor air quality carbon monoxide, nithumidity, molds, etc. • Indoor lighting quality intensity, color spectrum etc. • Indoor noisy environment. This includes noise for instance from home appliances or out of building noise that penetrates indoors. • Other indoor risks/accidents	• Indoor temperature of home environment • Indoor air quality carbon monoxide, nitrogen dioxide, humidity, molds, • Indoor lighting quality intensity, color spectrum etc. • Indoor noisy environment	• Thermometer (networked/automated) • Air quality sensor (networked/automated) • Smoke sensor (networked/automated) • Light quality sensor (networked/automated) • Sound/noise sensor (networked/automated)

PRECIOUS Risk Factor	Risk factor attributes monitorable for (or by) the Individuals	What will be monitored in PRECIOUS	How attributes will be monitored in PRECIOUS
Stress	• Physiological signals: blood pressure, ECG, heart rate variability, galvanic skin response etc. • Stress level, stress appraisal measure, perceived stress level etc.) trends from questionnaires or other user-provided feedback	• Heart rate (RR data) • Other	• Heart rate sensor (automated, wearable) • External applications • Other
Sleep Quality	• Physiological signals pulse oximetry, breathing sounds, ECG, etc. • Sleeping posture body movement, sleeping positions, etc. • Trend of sleeping quality indicators e.g. Sleep Efficiency Index	• Heart rate (RR data) • Accelerometer data (movements)	• Heart rate sensor (automated, wearable) • Movement sensors (automated, wearable • External applications

Table 4 describes the monitored parameters with greater details including inputs and outputs for PRECIOUS. The parameters will be used to form a VIM that represents the users risks for T2D and CVDs, and the VIM can be used to suggest services or interventions that support healthy lifestyles or possible lifestyle changes. The services or interventions will utilise gamification elements and motivational interviewing to maintain the user's interest towards using PRECIOUS and to facilitate behavioural change.

Table 4. Different parameters of PRECIOUS that will be used to produce the VIM

Parameters of virtual individual model	Description	Input	Output
Date of birth	• Date of birth of the user	• User input	• Date (XX.YY.ZZZZ)
Gender	• Gender of the user	• User input	• Category number
Activity class	• Typical level of physical activity over the last 3 months	• User input	• Activity class (0-4)
Height	• Height of the user as meters	• User input	• Height (X.YY)
Weight	• Weight of the user as kilograms	• User input • Automated tracking / seamless monitoring	• Weight (X.YY)
Body mass index	• Body mass index calculated with height and weight from user input	• Height and weight	• BMI as a number (X.YY)
Physical activity level	• Individual physical activity (PA) level during the specific period (e.g. daily, weekly, monthly) compared to international PA recommendations	• Beat-to-beat HR • Accelerometer data (wristbands) • User input	• % of achievement of recommendations (0-100%) • Physical activity points (0-100 pts)
Stress duration	• Duration of physiological stress state during the measured period	• Beat-to-beat HR	• % of the measured period (0-100%)
Stress intensity	• Individually scaled intensity of stress reactions when stress state is detected	• Beat-to-beat HR	• % (0-100)
Recovery duration	• Duration of physiological recovery state during the measured period	• Beat-to-beat HR	• % of the measured period (0-100%)
Recovery intensity	• Individually scaled intensity of recovery reactions when recovery state is detected	• Beat-to-beat HR	• % (0-100)

Parameters of virtual individual model	Description	Input	Output
Sleep quality	• Sleep quality during the previous night	• User input • Accelerometer data (wristband)	• % (0-100%)
Food intake	• Self-reported consumption (via food diary applications), data collected from digital images and comparisons against EU and national dietary reference values	• User input • Digital image data	• Energy intake (kJ and kcal) • Macronutrient intake (g) • Micronutrient intake (mg/µg) • % of dietary reference values • Fat, carbohydrate and protein as a % of total energy
Alcohol intake	• Alcohol intake compared with national guidelines for alcohol consumption	• User input	• Units of alcohol consumed
Physical & psychological well-being	• Self-reported overall perception of the user's physical and psychological well-being (mental and physical health)	• User input	• 0-100
Vigour	• Self-reported vigour to indicate energy level on users	• User input	• 0-100
Mood	• Self-reported hedonic evaluation to indicate presence of pleasant mood/feelings (scores >60%) versus unpleasant mood/feelings (scorers < 50%)	• User input	• 0-100
Goals	• Users self-chosen goal or goals	• User input	• Number representing a category or a specific goal from a list of options
Goal achievement	• How well the goal(s) have been achieved	• User input • Sensor data (HR, HRV, accelerometer)	• % (0-100)
Motivation	• How motivated the user is to make changes in the specific life areas	• User input	• 0-100

Parameters of virtual individual model	Description	Input	Output
Barriers	• The self-reported barriers for changing behaviour of the user	• User input	• Number representing a category or a specific barrier from a list of options
Noise pollution	• The noise level of the environment of the user	• Measured noise level (dB)	• European WHO noise level thresholds are considered option (e.g. NOAEL or No Observed Adverse Effect Level NOAEL)
Light quality	• The light level (photometric measure) of the environment of the user	• Luminous flux • Luminous intensity • Illuminance • Daylight factors etc.	• Lighting quality guidelines under study
Thermal comfort	• The temperature and relative humidity of the environment of the user	• Room temperature • Relative humidity • Optionally: user input	• Mapping to ranges in thermal comfort standards (ASHRAE-55, ISO 7730 or EN 15251)
Location	• Location of the user	• Geographical coordinates (e.g. latitude and longitude) • Civic locations (e.g. street address)	• Location category number (e.g. home, office, grocery store) • Trajectory (e.g. route and speed of cyclist)
Technology affinity	• Propensity or predisposition towards embrace new technology	• Survey scores (e.g. Technology Readiness Index)	• Technology affinity category (e.g. explorer, avoider, sceptic, etc.)

3.4 Virtual Individual Model as the basis for behavioural change

The purpose of creating the VIM is to offer the system a model of the user that can answer the following key questions:

- Does this individual have a lifestyle that elicits a high risk for T2D or CVDs?
- What areas of lifestyle represent the highest risk and thus need the most improvements in this user?
- What individual attributes need to be taken into account when aiming to facilitate lifestyle change through technologies (for example what gamification elements could be used)?
- What is the user’s motivation to make changes in the specific areas?
- What are the goals of this user?
- Has the user made progress in the specific areas / individual goals?

Based on the VIM, PRECIOUS will facilitate concrete steps towards healthier lifestyles through algorithms and rules. These can lead to technological solutions that include hints or notifications, guidance, education, and other concrete ways to convert the collected data and knowledge about the user into realistic plans and actions in user's life. The actions facilitated by PRECIOUS are in line with other preventive lifestyle interventions, for example the guidelines for cancer prevention (International Agency for Research on Cancer 2014).

It is intended that PRECIOUS will facilitate the following actions and benefits:

Body weight:

- Take action (diet and physical activity) to achieve a healthy body weight.

Physical activity:

- Be physically active in everyday life. Limit the time you spend sitting.
- Make exercise routines part of your day
- Avoid strenuous, high-intensity exercise late at night (including heavy physical work)
- Exercise refreshes your body and mind and promotes physical and mental resilience.
- A physically fit person recovers more quickly and efficiently than an unfit person. Thus, improving your fitness level enhances recovery and helps to cope with stress.

Diet and alcohol:

- Have a healthy diet:
    - Eat plenty of whole grains, pulses, vegetables and fruits
    - Limit high-calorie foods (foods high in sugar or fat) and avoid sugary drinks
    - Avoid processed meat; limit red meat and foods high in salt
- Take care of your fluid balance during day. The need for hydration increases during physical work and during busy times
- If you drink alcohol, limit your intake.
- Follow recommended guidance for alcohol, for example do not drink regularly more than 3 - 4 units [men] or 2 – 3 [women] of alcohol a day (UK guidance).
- Be aware that alcohol reduces sleep quality
- Avoid heavy meals before going to bed

Sleep and relaxation:

- Try to avoid stress before going to bed (mental stress, e.g. thinking about work, reading e-mails or solving relationship problems can elevate your stress hormone levels).
- Try to achieve 7-9 hours of sleep each night.
- Respect your need for sleep
- Utilise relaxation methods if you have difficulties getting to sleep
- Even short breaks during the day decrease the production of stress hormones
- Close your eyes and take a moment to relax. You will feel better after a few minutes!

Social relationships:

- Spend time with your family and friends.
- Laugh and joke with your colleagues.
- Doing things that are important to you and that you enjoy recharges you mentally.

Planning and making actions:

- Start small and be realistic about your goals
- Make sure you get plenty of variety
- Make your timetable realistic. Leave some allowance for schedule delays and changes.
- Set reminders where you can see them
- Keep an eye on your progress
- Reward yourself
- Hold on to your leisure time: set a ”no later than” time for leaving from work
- Learn to say NO!

3.5 Future work for the VIM

The present interim report on behavioural representation and virtual individual modelling described different parameters related to user’s background details, and data on physiology, psychology, context, as well as motivational status. Those parameters will be used, through the VIM, to model the user’s risk for T2D or CVD. The PRECIOUS concentrates on preventive lifestyle related factors, and therefore the parameters that best describe these lifestyle-related factors are used. For many of the parameters of VIM, already significant amount of data modeling is required before the output parameters are constructed from the original raw data. This applies especially for the physiological sensor data.

Future work regarding virtual individual modelling will contain precise definition of different applications and platforms used in PRECIOUS, and the specification of the model used for building the VIM from different parameters. Possible approaches for how to utilize the sensor data include: 1) categorization of the users to different user categories, 2) ranking of the lifestyle areas or specific parameters to importance order based on noticed risk factors or the user’s motivation status, or 3) producing algorithms for defining T2D or CVD risk values or ratios based on comprehensive view the user’s lifestyle. This future work will be reported in the final document for behavioural representation and virtual individual modelling (D3.2).

4. Conclusions

PRECIOUS is built on the idea of individually tailored services and is based on identified risk factors for T2D and CVDs from ubiquitous sensor data. Based on the collected data, a virtual individual model (VIM) is produced and utilised to tailor interventions and services. This document describes the different parameters that will be used to build the VIM. In addition, the likely inputs and outputs for these parameters are presented.

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