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TeNDER

affecTive basEd iNtegrateD carE for betteR **Quality of Life (TeNDER)**

D3.2- First version of Patient interface interaction and Pathways tracking

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Disclaimer

The TeNDER consortium consists of the following Partners.

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[1] **R:** Document, report; **DEM:** Demonstrator, pilot, prototype; **DEC:** Websites, patent fillings, videos, etc.; **OTHER**; ETHICS: Ethics requirement; ORDP: Open Research Data Pilot.

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1 EXECUTIVE SUMMARY

TeNDER is a multi-sectoral project funded by Horizon 2020, the EU Framework Programme for Research and Innovation, developing an integrated care model to manage multi-morbidity in patients with neurodegenerative and cardiovascular diseases. TeNDER will create an integrated care ecosystem for assisting people with chronic diseases of Alzheimer's, Parkinson's, Cardiovascular Diseases, and – where present - comorbidities, through the use of affect based micro tools. These micro tools will be able to recognize the mood of a person and thus adapt the system's probes to the person's needs via a multi-sensorial system, even in the most severe cases, and match with clinical (from Electronic Health Records EHRs) and clerical patient information, while preserving privacy, monitoring the ethical principles, providing data protection and security, with the result of an increased quality of life. In addition to the quality of life (QoL) for patients, this deliverable will contain caregivers' QoL assessments and health and social professionals' working conditions assessments since all of them are involved in an integrated care approach.

In order to achieve this general goal, TeNDER will perform 5 large-scale pilots in order to test services targeting patients, their caregivers and care professionals. At each pilot setting (in Slovenia, Italy, Germany and Spain), patients will be monitored according to the use cases and scenarios defined. TeNDER's technical, legal and ethical experts ensure that all personal data is protected according the General Data Protection Regulation (GDPR).

The patient will interact with TeNDER in multiple ways. The amount of interaction will be measured to extract via a Digital Behavior Analysis module. This module will register all patient actions such as clicks, moves, time-spend at certain screenshots, time to check a content among others, to perform a digital interaction analysis of the patient with the multiple interfaces will be analyzed. For this purpose, a Knowledge base will be built accumulating interaction behavioral use of the platform. Additionally, a sensorial-based submodule (smartphone and sensors) will be created to track the patient pathway, creating an API to connect with the High-Level modules.

This deliverable will describe the methods created to track the patient via interaction with interfaces as well as the report of events related to the care chain. For this purpose, this deliverable will contain all the data sources, as well as how the data collected will be processed to be transformed into pathways for patients. For this ambition, TeNDER will rely on the data from the sensors deployed (a.k.a. Low-Level Subsystem). Additionally, the medical information ingested into TeNDER (via online forms and stored in the EHR) will be used and finally, the data collected from the interaction of the patients and caregivers.

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2 INTRODUCTION

With the main goal of the project being the creation of an integrated care ecosystem for assisting people with chronic diseases of Alzheimer's, Parkinson's and comorbidity with Cardiovascular Diseases, TeNDER will leverage the use of affect-based micro tools capable of recognising the mood of a person and thus adapt the system's probes to the person's needs via a multi-sensorial system, with the result of an increased quality of life.

TeNDER aims at performing patient's analysis on three different axes:

a) **Indoor daily activity analysis by** employing depth sensors, visual sensors as well as binary sensors attached to doors, furniture among others;

b) **health status** by using biosensing devices such as wearable devices measuring heartbeat rate, body temperature, blood sugar levels or blood pressure, and

c) **emotional status using** multiple modalities from different devices (such as smartphones, RGB-D sensors and wearable devices).

All the collected data will be analysed using novel algorithms in order to allow the system to understand how the patient's kinetic, health and emotional status evolve. The system will create personalized models for each patient to identify abnormalities by detecting deviations from the expected behavior and raising alerts for a rapid intervention in case of need. This deliverable is the first version of the description of the methods created to track patients via the interaction with interfaces as well as the report of events related to the care chain.

The information from the indoor daily activity is collected with the sensorial system deployed at patients' home, or day care centres & hospitals. The idea, is to extract all information to model the patients activity, permitting to match it with the patients style of life.

The health status ifnromation is obtained from the sleep tracker and the smartbands attached to the patient's body. Finally, the emotional status is extracted from the data interaction obtained from the patient via the depth sensor (also visual sensor via landmarks and voice speech recognition).

2.1 TECHNOLOGIES THAT WILL BE USED

The different scenarios in the project will have different technologies equipment and setup (Minimal and Full), therefore different devices and sensors dedicate, listed in the table 1.

Table 1: list of sensors used in TeNDER and type of Data captured.

Sensor	**Type of data captured**

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RGB Sensor	id, Session, Client, SensorID, Timestamp, Skeleton, JointsCoords, FaceMeshCoords, PredictedEmotion, PredictedEmotionProbability ,PredictedAction, PredictedActionProbability, BodyFrame, WidthColor, HeightColor, WidthGray, HeightGray, MaxBodies, MaxJoints
RGBD Sensor	id, Session, Client, SensorID, Timestamp, Skeleton, JointsCoords, FaceMeshCoords, PredictedEmotion, PredictedEmotionProbability ,PredictedAction, PredictedActionProbability, BodyFrame, WidthColor, HeightColor, WidthGray, HeightGray, MaxBodies, MaxJoints
RGBD Sensor 2	id, Session, Client, SensorID, Timestamp, Skeleton, JointsCoords, FaceMeshCoords, PredictedEmotion, PredictedEmotionProbability ,PredictedAction, PredictedActionProbability, BodyFrame, WidthColor, HeightColor, WidthGray, HeightGray, MaxBodies, MaxJoints
Microphone	Audio recordings, synthetized in features such as the spectrogram, or the Mel coefficients.
Position Tracker	RSSI (Received Signal Strength Indicator, expressed in dbms) , timestamp (time unit), last_time_ping (time unit)
Sleep Tracker	respiration_rate, heart_rate, sleep_state, snoring_rate
Smart band	Band_id (unique identifier uuid), Timestamp (date format), Heart rate (bpm), steps (#steps a day) ,calories, quality sleep (#hours in REM mode), accelerometer (inertial measurements per axis: ax,ay,az).
Speaker	N/A
Binary (door opening) sensors	datetime, open/closed status, id of door/window
Gateway	datetime, open/closed status, id of door/window, temperature and humidity status in the room
Xiaomi Mi Band	Band id (unique identifier uuid), heart rate (bpm).
Environmental sensor	It will include the sensor identifier, the timestamp of the measurement registered, the temperature and humidity status in the room

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Tablet	In the Tablet and the smartphone, all services will be displayed to the users. Additionally, for the purpose of pathways creation, the report of messages is shown via TeNDER app. Furthermore, the information from the patient interaction will be collected in order to: 1) adapt the interfaces to the user needs. 2) Create interaction patterns that allow to estimate the degree of cognitive skills and 3) to create pathways based on the interaction.
Smartphone	

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3. DIGITAL BEHAVIOUR ANALYSIS

According to the World Health Organization (WHO)[3], assessing someone's functional ability, or the combination of their physical and mental capacities together with their environment, is a stronger measure of their overall health than what the diseases state. Maintaining functional ability across the life course is the definition of "healthy ageing", also according to the WHO, since health becomes more complex with age, in terms of physical and mental capacities (referred to as "intrinsic capacity"), and functioning. The experience of chronic diseases does not tell the whole story of one's health, or the impact it is having on one's life. In addition, so-called multi-morbidity, or experiencing numerous chronic conditions at the same time, can lead to health concerns that traditional disease classifications fail to capture. Health technology innovation like the electronic medical record, as well as precision medicine make use of a patient's genetic profile and environment in order to diagnose and provide treatment, aiming at achieving one of TeNDER's main goals: to improve the quality of life for the patients and his/her family and caregivers as well as the working conditions of health and social care providers and health professionalsin order to address the risks of frailty, falls and depression along with assistive interventions. TeNDER's integrated technology modules will monitor and support older adult's physical (daily/nocturnal) and emotional status towards the decrease of the related risks and increase their quality of life.

According to scientific literature, several parameters extracted from data collected from sensors and devices could be useful in order to highlight cognitive, sensory and motor changes in chronic diseases.

- **Finger tapping speed and typing errors**: Finger tapping speed have long been probed as potential early signs of AD. While tapping speed normally decreases with age at a rate of −0.03 taps/y, the speed after the inflection point (2.66 y prior to clinical manifestation of the disease) dramatically decreased to a rate of −0.15 taps (Lampros et al, 2019). Active tapping task have been performed for detecting medication response in PD (Vega et al, 2017; Neto et al, 2016).

- **Keystrokes text per minute and pauses while typing** in dementia: More recently, it has been shown that the text keystrokes per minute (excluding non-text keystrokes) as well as the number of pauses while typing, can discriminate between cognitive impairment (128.48 ± 35.03 keystrokes per minute) and healthy controls (63.65 ± 32.64 keystrokes per minute). The profile of computer use behaviors was significantly different in cognitively impaired compared with cognitively healthy control participants including more frequent pauses, slower typing, and a higher proportion of mouse clicks (Lampros et al, 2019; Stringer et al, 2018).

- **Fine motor control**: Fine motor control can also be probed by looking at the accuracy of a digital pen motion, as in a tracing test, administered with a digital pen and tablet; the standard delineation (RMS

[3] Ageing and health https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

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distance) from the actual shape is calculated and was found to correlate with visuomotor performance and age. (Lampros et al, 2019; Stirling et al, 2013).

- **Neuropsychiatric behavioral disruptions**: These neuropsychiatric disruptions cause early impairment to more complex activities of daily living and can precede the dementia phase. Similar decreases in time spent outside of the house. (Lampros et al, 2019).

- **Smartphone use**: specific types of smartphone use (news consumption and social networking (Elhai et al, 2017) have been shown to correlate with depressive symptom severity, that may be related to AD and PD patients.

- **Task-switching or the ability to shift between multiple goals** is a component of executive function, that may be compromised both in AD and PD patients (Hofmann et al, 2012). Human Computer Interaction studies have started examining passive user-specific app re-visitation rates as well as the time-overhead cost from switching between applications that can be considered a naturalistic example of task-switching. Vigilance, or the ability to sustain attention on a task, is a measure of overall attention and studies have been able to correlate level of alertness to temporal rhythms of application usage. (Lampros et al, 2019).

- **Login time**, related to the executive function (impaired in AD and PD patients).

3.1 THE DIGITAL BEHAVIOUR ANALYSIS IN TeNDER

The technology that will be used to collect the data for the digital behavior analysis is Firebase. Firebase is a platform for creating mobile and web applications developed by Google. At the core of Firebase is Google Analytics, a free and unlimited analytics solution. Google Analytics helps you understand how people use your app on the web, iOS or Android. The Software Development Kit (SDK) automatically captures a range of events and user properties and also allows you to define your own custom events to measure things that matter uniquely to your business. Once captured, the data is available in a dashboard via the Firebase console. This dashboard provides detailed information about your data, from summary data such as active users and demographics, to more detailed data such as identifying the most purchased items. More technical details will be described during the development phase.

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4. PATIENT PATHWAY TRACKING

Pathway registering is in charge of tracking administrative (quotidian) events on the patient to have a history of their visits to the doctors. This module will employ information from the different interfaces in TeNDER to detect the attendance to primary care, positioning data, specialists, collecting metrics that will be available for all entities in TeNDER with the ambition of speed up the data access to professionals in terms of patient visits to health care institutions.

TeNDER will be capable of linking large amounts of important sensed information during the interventions most of which were not previously available to the healthcare professionals, so that they can be mined, analysed and modelled. This analysis will provide the healthcare professionals with additional information and pertinent feedback on demand to make more accurate and informed decisions in relation to older adult's healthcare. This makes the health professional an informed consultant, who, assisted by the ICT-based interventions' outcome, better supports the older adults, in a personalised way, in achieving his/her optimal quality of life. The continuous tracking and the personalised interventions will make the patient feel safer and more autonomous, with TeNDER also aiming at improving the life of the patient's family, since the patient's increased autonomy will ease the burden of their caregivers.

Several information can be evaluated for the pathway tracking. Rehabilitation exercises, the Serious Games and the Physical and Medical Data have been evaluated in this deliverable as potential outputs of the pathway tracking analysis in TeNDER system.

4.1 REHABILITATION EXERCISES

4.1.1 Introduction

Rehabilitation exercises for neurological CVD patients with Stroke

About 40% of the stroke Patients leads to permanent impairment of the functions of daily life, for example as a result of paralysis of the arm (Busch & Kuhnert, 2017). A partial or complete paralysis of the arm, triggered by a stroke, represents a significant restriction in everyday life and can lead to loss of independent living. The consequences are a major impact on the patient's autonomy and quality of life, which also places a burden on their personal environment as well as the healthcare system. Furthermore, repeated standing-sitting exercises are known to contribute to cardiovascular adjustment and improved musculoskeletal status, especially in impaired patients. A regular mobilization, for example through simple regular-up standing (Bajd, 1999), alleviates immobilization-related complications and leads to improved level of consciousness, as well as better cognitive and motor functions (Adler & Malone 2012).

Standing training allows patients to adopt a standing position and thus maintain or improve mobility and stability of the hip, knee and ankle joints and if they are depended on walking or standing aids, it would relieve pressure on the shoulder girdle. (Paleg, 2015).

Moreover, regular targeted balance and strength training can significantly reduce the number of falls (Karlsson et al. 2013). Individualized mobilization, stance and balance training play therefore a major role in the treatment of patients with stroke (Eng and Tang 2007). There is high evidence that standing training programs for home use, have a positive impact on joint range of motion and lower extremity muscle activity

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(Paleg, 2015). In the course of this project, we want to help neurological CVD patients to active train the transfer from sitting to standing, their balance in standing position and integrate it into everyday life via the TeNDER-system.

Rehabilitation exercises for patients suffering from Parkinson's disease

Rehabilitation in Parkinson's disease is almost as important as medication (Abbruzzese G, et al. 2016). Although there are more and more technological tools that help rehabilitation professionals (especially physiotherapists), these are not usually integrated into any system. And in general, most motor performance evaluations are usually made through the subjective assessment of therapists.

In this sense, the information collected by the depth camera and the smart-band compared with a performance pattern previously incorporated into the system, can give us an objective measurement of the person's performance and evolution over time.

This comparison with preestablished patterns will give us information about the situation of the motor symptoms in Parkinson's disease and the comparison between the different executions of the subjects will give us a historical evolution of those symptoms. Physiotherapists can objectively assess about 5 people at a time, saving costs and offering objectivity to the assessment. The report should be sent to the physiotherapist to make the appropriate clinical decisions.

The information on medication change should be cross referenced with other information on physical performance so that the therapist is warned if the performance varies significantly.

4.1.2 Rehabilitation exercises evaluation tool

The purpose of the rehabilitation tool is to provide an objective analysis of patients' movement to physiotherapists. These real-time measurements can be recorded and summarized per person and exercise, thus providing objective movement evolution results. These results can contribute to the physiotherapists' existing decision-making process regarding the patients' exercise plan.

The tool is organized into two different sections: Angle Measurements and Set Positions. Angle measurements involves defining a set of important angles for each exercise, which the tool calculates in real-time using the Kinect tracked skeleton. The Set Positions section allows the user to set three positions on the floor and link them with a user id in order to identify who was standing in each position and to have a matching across different rehabilitation sessions of the same persons. This allows the results of different sessions to be linked together.

The system monitors the patient's evolution of their ability to realize physical personalized exercises. Furthermore, the system is able to assess the exercise in both quantitative and qualitative ways. The former is used to process how far/close a member (Arms or legs) are separated from the normal (stand up) position as shown in Figure 1. Furthermore, a qualitative evaluation is being performed by a graphical illustration (purple bar in Figure 1) to allow physiotherapists and patients themselves a clear idea of how well is the exercise performed.

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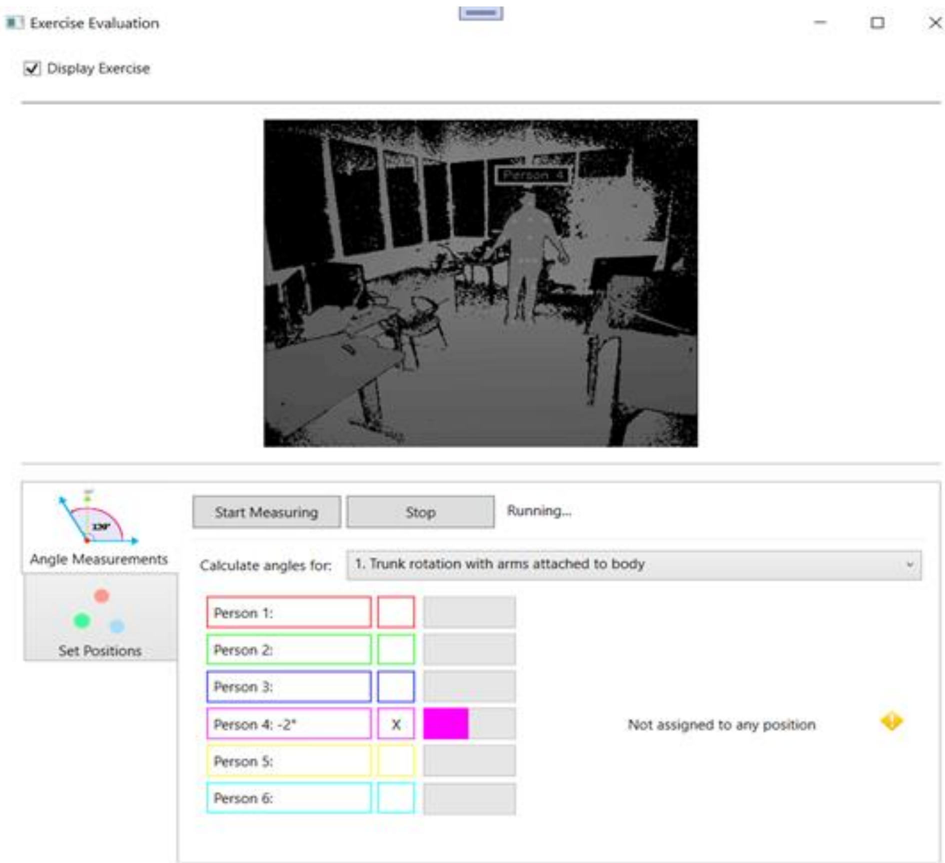

Figure 1: Angle Measurements interface.

Angle Measurements provides different types of exercises such as below:
1.Trunk rotation with arms attached to body
2.Trunk rotation with arms to waist
3.Trunk lateral bending with arms to waist
4.Trunk flexion / extension with arms to waist
5.Two-hand alternating shoulder flexion / extension
6.Two-hand simultaneous shoulder flexion / extension
7.Two-hand simultaneous shoulder abduction / adduction
8.Two-hand alternating elbow flexion / extension
9.Two-hand simultaneous elbow flexion / extension
10.Shoulder rotation with elbow at 90 degrees
11.Knee flexion / extension with thigh facing to the front
12.Knee flexion / extension with thigh facing down
13.Hip flexion / extension
14.Hip abduction / adduction

In the Set Positions tab the patient positions are adjusted. This process is used to mark and singularize the position of the patients to be monitored. The system is able to measure up to 3 patients simultaneously and up to 6 due to Microsoft Kinect limitations.

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Figure 2: Interface showing the positions adjustment.

4.1.3 Rehabilitation exercises description and data collected for the Pathway tracking

In this section the exercises listed above will be briefly described as well as the data (angles) that are measured and stored.

- Trunk rotation with arms attached to body

- Trunk rotation with arms to waist

In these exercises the person rotates the upper body to each side, while the lower body remains in its original position. The tool measures the angle difference between the upper body in the original position and the final bent position. The only difference between these exercises is the positioning of the hands.

Trunk lateral bending with arms to waist

In this exercise the person positions the arms at the waist and bends the upper body laterally, while the lower body remains in its original position. The tool measures the angle difference between the upper body in the original straight position and the final bent position.

Trunk flexion / extension with arms to waist

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In this exercise the person positions the arms at the waist and bends the upper body forwards or backwards, while the lower body remains in its original position. The tool measures the angle difference between the upper body in the original straight position and the final bent position.

Two-hand alternating shoulder flexion / extension
Two-hand simultaneous shoulder flexion / extension
In these exercises the person initially positions the arms straight down and close to the body. Then moves the arms to the front as far as possible, and to the back as far as possible. Depending on the variation (alternating / simultaneous), the arms follow opposite movements / the same movement. The tool measures the angle of the arms in relation to the original vertical position.

Two-hand simultaneous shoulder abduction / adduction
In this exercise the person initially positions the arms straight down and close to the body. Then raises simultaneously both arms laterally until they almost meet at the top and then back down again. The tool measures the angle of the arms in relation to the original vertical position.

Two-hand alternating elbow flexion / extension
Two-hand simultaneous elbow flexion / extension
In these exercises the person positions both arms close to the body, with wrists facing to the front at 90 degree angle with the rest of the arm. Then moves the wrists up and then down without moving the elbows. The tool measures the angle between the shoulder & elbow and elbow & wrist.

Shoulder rotation with elbow at 90°
In this exercise the person positions the arm close to the body, with the wrist facing to the front at 90 degree angle with the rest of the arm. Then moves the wrist laterally both outward and inward without moving the elbow. The tool measures the angle of the wrist in relation to the original position which was facing to the front.

Knee flexion / extension with thigh facing to the front
Knee flexion / extension with thigh facing down
In these exercises the person starts with the knee bent at 90 degrees and then extends the ankle forwards until it is in the same line with the hip and knee and then backwards to the other direction. The difference between the two exercises is the direction the knee faces: in the first case it faces forward and in the second down towards the floor. The tool measures the angle between the hip & knee and knee & ankle.

Hip flexion / extension
In this exercise the person moves the leg to the front as far as possible and then to the back as far as possible, without bending the knee. The tool measures the angle of the leg in relation to the original vertical position.

Hip abduction / adduction
In this exercise the person moves the leg laterally as far as possible and then back to the beginning, without bending the knee. The tool measures the angle of the leg in relation to the original vertical position.

4.2 SERIOUS GAMES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 875325.

Serious games are physical or digital games that can be used for entertainment but also have other important purposes, such as training and educating, communicating, or promoting the use of cognitive, physical and social abilities. As boredom and lack of activity is frequently reported from people with dementia, engaging in games can increase positive emotions. Moreover, serious games can be specifically designed and targeted at people with dementia; however, more recent research has suggested that commercially available gaming technology can also be used to benefit the well-being of people with dementia and their care partners.

The re-learning of motor skills is the main goal of neurorehabilitation in order to increase the function, activity, participation and thus independence of the patients with stroke. For this purpose, according to current evidence-based findings, the nervous system must be stimulated in a targeted manner via active movement adapted to the patient's current abilities and a high number of repetitions (Veerbeek et al., 2014). Especially the implementation of a high number of repetitions should be very well implemented. With the help of serious games and the artificial reality technology, training of ADLs can be implemented particularly well through the combination of real environment and virtual objects in addition to playful training (Colomer, Llorens, Noe, & Alcaniz, 2016; Rohrbach et al., 2019).
In the Alzheimer's Therapy Center (ATZ) at the Schön Klinik Bad Aibling, we have a tied and tested therapy strategy which, with the involvement of relatives, contributes to prolonged self-preservation. The concept of the so-called self-preservation therapy (SET) is not only concerned with the individual dysfunctions, but with all systems that are perceived by the affected person as "ME". The SET therapy program for patients includes memory work, creative, music and also movement-oriented activities (Wenz, 2018). In people with Alzheimer's disease, physical activity has been shown to prevent progressive cognitive deterioration, improve quality of life, and prevent falls. "Serious games" such as the Nintendo Wii Fit console, can improve balance, physical performance, and also gait as well as targeted gait training (Padala, 2012).

Due to the COVID-19 situation the implementation of serious games could be an alternative or complement group therapy sessions in order to avoid number of contacts between the patients and caregivers. It is also of high importance to introduce serious games during hospitalisation to allow continuity during the transition phase and for long-term treatment at home. The support given during hospitalisation will enable the patients and caregivers to use serious games independently at home and therefore transfer and prolong beneficial effects from the hospitalisation even after discharge.

At SPO, serious games are combined in different dimensions: games for orientation, games for attention, games for perception and gnosis, simple memory games, games for language skill training and physical games. In general, the best results are obtained, if games are done in the group, so that social interaction is also included. These activities help people with dementia to stay active and occupied and help slow down the cognitive impairment. Playing in groups strengthens social relationships, improves motivation, communication and mood. The main goal for using serious games with people living with dementia at SPO is that by games people have fun, get in touch with novel devices and challenge themselves to master new and sometimes complex skills. Engagement in games promotes mental and cognitive stimulation, does physical exercise and builds social interaction, as well as enhances mood of people living with dementia. People increase self-confidence by challenging perceptions of their own capabilities and also interact with younger family members by playing games.

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Serious games can reduce disorder-related symptoms (Ho Ming Lau et al 2017). Stimulating leisure activities are accepted to enhance the cognitive reserve (Stern Yaakov 2012). For example, foreign language training as cognitive therapy, impacting decision-making, multitasking, concentration, and communication, are areas of active research (Eleni Poptsi et al, Mark Antoniou 2013). Further, games that that are combined with art tasks are also well accepted, as art-therapy is well recognized to have benefit on people with dementia (WHO: What is the evidence on the role of the arts in improving health and well-being? Deshmukh et al, 2012. From French and USA studies, board games had impact on cognitive performance and board game players had significantly less cognitive decline and less incident depression than non-players (Dartigues et al, 2013, Joe Verghese at al 2003). Therefore, several benefits of involving people with MCI or dementia in serious games are well recognized and also some implications, that when tasks are designed to match peoples' abilities, learning can happen (Tziraki et al). The option to use the serious game for the digital tracking is however a new field of the research. Devices using touchscreen interfaces have been assessed with people with dementia from 1986 (Carr et al, 1986). Furthermore, in (Joddrell et al, 2016) and several tests for cognitive assessment screening tests have been studied.

Below is a list of games, memory tests, which are to be integrated into the app with a small description, the link to access, the demo and the technical specifications.

Table 2: List of serious games.

Name	Type	Link	Demo	Brief description	Technical Specifications
Luke's Famous Memory Game	Memory game	link	link	Memory game in which gamers have to find right combination of figures that initialy are laid face down. The object of the game is to turn over pairs of matching figures.	Written in following languages: TypeScript & HTML5 ; TypeScript 51.9%; HTML 40.9%; CSS 7.2%
MurhafSousli/memory	Memory game	link	N/A	A simple yet fun card game in which all of the cards are laid face down on a surface and two cards are flipped face up over each turn. The object of the game is to turn over pairs of matching cards.	Written in following languages: Powered by Angular2; TypeScript 55.0%; CSS 24.3%; HTML 15.5%; JavaScript 5.2%.
leftstick/ angular6-memory-game	Memory game	link	link	Famous memory game of finding matching pairs of cards.	Written in following languages: AngularJS; TypeScript 55.0%; CSS 24.3%; HTML

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					15.5%: JavaScript 5.2%.

4.2.1 Serious Game integrated into TeNDER for the Pathway tracking

The integration of serious games in Tender will be carried out using the IONIC framework. Ionic Framework is the open-source mobile app development framework that makes it easy to build top quality native and progressive web apps with web technologies. Ionic Framework is based on Web Components and comes with many significant performance, usability, and feature improvements over the past versions. Using Web Components, Ionic provides custom components and methods for interacting with them. One such component, virtual scroll, allows users to scroll through a list of thousands of items without any performance hits. Another component, tabs, creates a tabbed interface with support for native-style navigation and history state management.

4.3 PHYSICAL AND MEDICAL DATA

Several outputs have been proposed in scientific literature for the pathway tracking in Electronic Health Monitoring systems:

- **Heart rate variability**: An important marker of ANS balance is Heart Rate Variability (HRV), a measure of the time intervals between heartbeats, resulting from the dual modulation of the heart by the sympathetic and parasympathetic systems. Due to the bidirectional vagal innervation between the heart and the brain, HRV has also been put forward as an index of cognitive function and stress. In healthy adults, lower Heart Rate Variability (and thus suppressed parasympathetic activity) was correlated with cognitive function, attention and working memory, mental stress and social cognition (Lampros et al, 2019). Heart rate variability as a non-invasive dynamic metric of the autonomic nervous system is an independent risk factor for cardiovascular death. Wrist-worn tracking devices using photoplethysmography (Fitbit) provide the potential of continuously measuring surrogates of sympathetic and parasympathetic nervous system activity through the analysis of interbeat intervals. Diverse metrics of cardiac autonomic health can be derived from wrist-worn trackers. Empirical distributions of heart rate variability can potentially be used as a framework for individual-level interpretation of CVD associated factors (Natarajan et al., 2020).
- **Sleep patterns**: A commonly reported feature of AD and PD has been circadian rhythm disruption in the form of sundowning or sleep fragmentation. (Lampros et al, 2019).
- **Fall detection**: Approximately 10% to 20% of falls result in injury, (prolonged) hospitalisation or even death (Pirker & Katzenschlager, 2017). In hospitals, fall rate ranges from 3.3 to 11.5 falls per 1,000 patient days (Bouldin et al., 2013). In a prospective study by Stolze et al. (2004), falls in neurological in-patients are twice as frequent as in an age-matched population living in the community. Patients with hemiparesis after stroke have a higher risk of falling, therefore, fall detection should be applied to patients with stroke (Lee & Stokic, 2008). A recent master thesis from Simone Hinterholzer at SKBA has shown that a great proportion (70%) of falls in the clinic happened unobserved, indicating the

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need for a fall detection system in order to prevent (fatal) damages arising by lying on the ground for a certain time.

- **Mobility and pulse rate tracking** is important for the treatment of patients after stroke, as a sedentary lifestyle is one of the major risk factors for CVDs (Gelimanis et al., 2009).
- **Location variance** in terms of time and location extracted from the GPS sensors of smartphones (PMID 28344895) and trajectory information: detection of normal and abnormal behavior based on trajectory information in an indoor environment for PD and AD patients (Alvarez et al, 2017).
- **Emotion recognition** from Social Daily activities and relationship activity service (social behavior), also by using the Extraction of data from the calendar (remembering and keeping track of multiple goals and sub-goals of a daily activities/the diary) (Jekel et al, 2015). Other approaches that can be considered for the future analysis are presented, using Physical activity parameters (percentage of walking, standing, sitting, lying; duration of single walking, standing, and sitting bouts (Schwenk et all, 2014), including temporal correlations of features collected (Kun Hu et al, 2009), reviewed in (Kun Hu et al, 2016) (Huber et al, 2019).

4.3.1 Physical and medical collected by TeNDER for the Pathway tracking

TeNDER will continuously collect data from a wide set of sensors and more specifically

- **Heart beat rate**: Heart beat rate data can be acquired using the smart-band and during the patient's sleep using the sleep sensor. Heart beat rate graph will be displayed to the medical professionals and they can correlate it with other data from the pathway tracking (e.g., rehabilitation for patients suffering from CVD) and extract useful results.
- **Sleep patterns**: Sleep patterns can be detected by the smart-bands and the sleep sensors (which provide more accurate and more detailed data).
- **Fall detection**: currently it is measured using three different devices, the microphone (audio), the RGBD camera (body skeleton) and the smart-band (accelerometer). Besides the notifications, TeNDER platform will collect all the incidents and display the condensed information to the medical professionals.
- **Location information:** It can be measured using different types of sensors. RGBD camera can identify the patient's location given that he/she is in the camera field of view. This information is accurate and it can not only identify the user presence in the field of view of the camera but also detect and identify if the user if moving. Additionally, the localization sensors can identify the user presence in each room while the binary sensors possible movement from one room to the other. Finally, within the project activities, we can explore alternative measurements collected such as the smart-watch can count the user steps that can indicate the user activity.
- **Emotion** will be detected from audio (microphone) and/or face image (camera). Besides this, the mood of the user will be estimated using movement information (low movement level may indicate bad mood).

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5. CONCLUSIONS

In this deliverable, the main features that will be extracted within the TeNDER project to create ICT supported patient pathways are outlined. The pathways creation is tackled from multiple perspectives according to the information generated/collected in the project. The ambition of TeNDER is to use all information available to generate tools that support the patient activity for: 1) rehabilitation, by tracking the patient activity of personalized exercises to follow-up their rehabilitation as well as empowering them with their own information. Additionally, the interaction with TeNDER system and the exploitation of data of some existing applications (i.e. serious games) will enable the assessment of their skills, as well as to create behavioral patterns. Finally, the information collected in the EHR, will allow to create evidence on the inferences provided as well as complement the findings of the tools proposed for pathway tracking.

In section 4 the patient pathway tracking is presented which highlights the importance of rehabilitation exercises for improving the patient's motor skills both for patients suffering from CVD and Parkinson's disease. Furthermore, it points out the need of having tools for accurate and objective assessment of these skills. Finally, the first version of the TeNDER rehabilitation exercise assessment tool is presented which currently supports 14 exercises. This tool will be used in the first pilot and in parallel more exercises will be supported based on the medical professional needs and the capabilities of the system.

In addition to the physical exercises that are related to mobility skill evaluation, TeNDER also supports at set of serious games can be played by the user from his/her smartphone or tablet. These mainly target the patients suffering by Alzheimer's disease since they are selected to test the user's mental skills.

Finally, the physical and medical data are collected not in order to identify abnormal values but to provide to the medical personnel a complete picture of the collected data during time.

All the information that is provided through the three categories of pathway tracking (rehabilitation exercises, serious games and physical and medical data) are collected for a long period of time and displayed to the medical personnel through the TeNDER web application. Of course, although this information does not constitute a diagnosis, it is important since it can trigger the medical personnel in the case of a considerable change of the collected data. Another significant use of the pathway tracking is that is enables the medical personnel identify possible correlations of the acquired data with changes to the patient's medical record (e.g., improvement/deterioration of the patient's mobility/mental skills or biological values after medication change).

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