D3.5.1
Integration of Multimodal Analytics

Work package	**WP3 Multimodal Analytics and Assessment**
Task	**T3.5 Integration of Multimodal Analytics**
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Public / confidential	**public**

Project PLAYTIME

The research leading to these results has received funding from the AAL Programme of the European Union and by the Austrian BMVIT/FFG under the Agreement no 857334, ZonMw (the Netherlands) and funding from Brussels (Belgium). It reflects only the author's view and that the Union is not liable for any use that may be made of the information contained therein.

28/02/2018

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Contents

1 Executive Summary

The integration of multimodal analytics as being conceptualised and implemented in Task 3.5, such as, from psychosocial, sensorimotor, gaze and emotion analytics, considers the definition of a state of human well-being, mental processes and performance and will provide the basis for diagnostic analytics as well as underlie the rule base of the recommender system (Task 4.5). JRD and GGZ will define in this deliverable the dementia relevant features for state definition features and JRD will implement the interface to the front-end and back-end systems.

This deliverable determines firstly the basic health care oriented and neuropsychological considerations that will underlie the continuous assessment of the mental and physical state of a PwD under intervention, and secondly describes the specific information that is provided by several components of the PLAYTIME suite for multimodal data driven analytics. Furthermore, the lines of integration of the information from individual analytical components are described. Finally, an implementation plan provides the milestones and functionalities of next system integration steps for the purpose of multimodal analytics.

2 Introduction

The integration of multimodal analytics, such as, from psychosocial, sensorimotor, gaze and emotion analytics, considers the definition of a state of human well-being, mental processes and performance and will provide the basis for diagnostic analytics as well as underlie the rule base of the recommender system (Task 4.5).

JRD and GGZ will define the dementia relevant features for state definition features and JRD will implement the interface to the front-end and back-end systems.

3 Multimodal analytics and dementia

3.1 Continuous monitoring of state of PwD

Dementia is a broad category of neurocognitive disorders that cause a long term and often gradual decrease in the ability to think and remember that is great enough to affect a person's daily functioning. Adequate, sufficient and economically feasible care is currently one of the greatest technological and social challenges (Sütterlin et al., 2011).

A key problem in developing knowledge about dementia and its impacting factors is the lack of data about the mental processes and the psychophysiological dependencies as they evolve over time. The individual trajectories of dementia are often suspected to be rather specific, however, longitudinal quantitative studies about dementia are rare.

The reason to perform continuous, pervasive monitoring of the mental and also physical state of PwD is, firstly, to receive as early as possible indicative information about possible unpredicted developments, such as, if the mental state would rapidly decrease– due to some not adequate conditions in the environment – which is in theory possible according to the experience of multiple cases of PwD reported by the formal caregivers in Austria and The Netherlands. The registration of such an alerting state could then automatically trigger the activity of caregivers if not medical experts in order to adjust the situation into a better scenario. Secondly, knowledge about the daily, weekly and monthly course of mental state of individual PwD is still today unknown and represents a black box for further derivations on how to apply adequate health care to the PwD.

3.2 Multimodal stimulation and decision support

3.2.1 Single versus multi-component intervention

There is no cure for dementia (Burns & Iliffe, 2009), however, cognitive and behavioral interventions may be appropriate, educating and providing emotional support to the caregiver is important. Physical exercise programs are beneficial by activities of daily living and potentially improve outcomes (Forbes et al., 2013). Cognitive and also physical, sensorimotor stimulation is decisive for a meaningful treatment of dementia, in particular, lack of exercise is one of the major risk factors for the dementia development (Norton et al., 2014). Therefore, multi-component interventions are important, even being accompanied by community settings (Graessel et al., 2011; Korczak et al., 2013).

Dementia is a complex syndrome that affects a heterogeneous population and carries various risk factors. Therefore, trials which target multiple domains in combination are likely to be more effective than those that use single component interventions (Berry et al., 2015). To date, only a few multi-domain or multi-intervention trials have evaluated the effects of behavioral interventions on dementia prevention.

3.2.2 Large multicomponent dementia prevention trials

There are three large dementia prevention trials in Europe, as follows,

- The Prevention of Dementia by Intensive Vascular Care study is a cluster randomized controlled trial (RCT) evaluating the effect of multicomponent nurse-led vascular care versus usual care in the non-demented middle-old (Richard et al., 2009). The primary outcomes are incident dementia and disability.
- The Multi-domain Alzheimer Preventive Trial is a RCT aimed at evaluating the effects of multicomponent intervention on change in cognitive function in the middle- to old-old with subjective memory complaints (Carrie et al., 2012).
- The Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER) evaluates the effect of interventions delivered using a combination of individual and group sessions on cognition in at-risk young- to middle-old (Kivipelto et al., 2013).

The FINGER 2-year results found a positive effect of the multicomponent intervention on change in cognitive function. Estimated mean change in neuropsychological test battery (NTB) total z-score at 2 years was 0.2 (standard error [SE], 0.01; standard deviation [SD], 0.51) in the intervention group and 0.16 (SE, 0.01; SD, 0.51) in the control group (Ngandu et al., 2015). FINGER also found that after 2 years, participants in the control group increased their risk of cognitive decline compared with those in the intervention group (NTB, odds ratio, 1.31; 95% confidence interval, 1.01–1.71). However, the overall effects of multimodal interventions need to be disentangled to understand the contribution of individual components.

The Cambridge Institute of Public Health, a very influential institution in the field of dementia health care, is one member of ongoing international collaborations committed to repurposing existing population cohort studies of late middle age to older age groups to investigate dementia prevention. Such international collaborative projects to date include EURODEM, 21st Century EURODEM, EU–HATICE (Healthy Ageing Through Internet Counselling in the Elderly, www.hatice.eu), The European Dementia Prevention Initiative, and European Prevention of Alzheimer's disease. Specifically, the experts of the Cognitive Function and Ageing Studies (CFAS) are fundamentally involved in the monitoring and evaluation of international studies.

Given the available evidence on multiple treatment interactions and effects, the CFAS experts (Olanrewajua et al., 2015), funded by the Medical Research Council, UK (MRC), recommended that a multimodal intervention approach addressing the aforementioned domains is likely to be more effective compared with single-domain treatment.

3.2.3 PLAYTIME multi-component games and assessments

PLAYTIME develops a pilot system that will firstly focus on the highly positive affection achieved from social engagement in playful group gatherings, enriched through personalised game play and moderating caregivers. Secondly, caregivers will visit players at home, involving them in multimodal training units with cognitive, physical, olfactory, tactile as well as social interaction aspects. Finally, a complementary suite of serious games offers the user playful experience and exciting engagement during the remainder of the week when the caregiver will not be available anymore. The content of these playful units is in part a projection from units performed at social gathering and from the joint training with the caregiver. Furthermore, PLAYTIME will focus on the involvement of activities of daily living (ADL). User feedback in terms of continuous measurements about sensorimotor coordination and gaze behavior will provide diagnostics as a basis to determine personalised recommendations with the objective to optimise the user experience.

By multi-component assessment, we specifically refer to the acquisition of multiple aspects of the state of the PwD, i.e., the cognitive state (amicasa and MIRA), the physical (amicasa), sensorimotor state (MoveTest/Monitor), and the socio-emotional state (SERES).

In the following Sec.4, the contribution of each of PLAYTIME's components of the suite of games will be presented to the overall acquisition of the PwD's actual state.

4 Multimodal analytics for dementia assessment

4.1 Information about socio-emotional data

MBY analyzed the internationally accepted NICE Guidelines to determine the key domains of impairment in dementia, which can be categorized as cognitive, behavioral, and functional (National Collaborating Centre for Mental Health, 2011). In turn, MBY mapped the standardized outcome measures through which these domains of impairment are evaluated (e.g. MMSE, NPI, BADL). In turn, psychosocial assessments were integrated to capture the psychosocial perspective (e.g. CDS, QOL-AD), which is critical in the case of dementia. This served as the basis for MBY's SERES serious game and, in particular, its AI engine. This concept has not been fully integrated into the current version of SERES that will be implemented in the FT2 study but will be applied in the final version of PLAYTIME.

In order to operationalize these findings towards a serious game, MindBytes analysed each PwD psychosocial measure and collected the items of the measure (parameters) and categorized the parameters into groups (parameter categories).

This resulted in the following psychosocial parameters: physical health, emotions, social relationships, function, and behaviour. As users complete the standard outcome measures, which will be added to the SERES database, the AI engine will have a baseline for all users in both the measure as a whole and the specific parameters defined by MindBytes. Then, users make decisions in the serious game, which result in changes in the parameters (pre-defined by MBY in collaboration with clinical experts). Both the baseline and ongoing psychosocial parameter scores are tracked in the SERES database and can be evaluated to understand relationships between decision choices, or score evolution, and user status (including from other modules in PLAYTIME).

This data can provide input into the psychosocial status of caregivers and PwD over time (within a session or between sessions). Moreover, the change from baseline can be reviewed to evaluate the trajectory of change in psychosocial parameters for populations (based on clinical input from other modules) or within a single user. This may provide data on, for example, psychosocial parameters and their link – in caregivers or PwD - to disease status, as defined by MMSE score, gait, etc. Research literature has documented that Cg burden, for example, is most impacted by PwD behavioural impairment (including emotional dysregulation) as opposed to cognitive or behavioural (Brodaty, Woodward, Boundy, Ames, & Balshaw, 2014; Naglie et al., 2011). This maybe the case at a population level but may not be the case with individual caregiver. Nevertheless, this type of finding at a population level could be supported with data collected by the multimodal analytics employed within PLAYTIME.

4.2 Information about executive functions

4.2.1 Assessment from executive functions

Progressive neurological diseases, such as, the Alzheimer, Parkinson, Huntington or Wilson, are well known for the decrease in eye movement behavior (White et al., 1983; Fletcher & Sharpe, 1988). The characteristics of the impairment support clinicians to localize brain lesions as well as to determine diagnostics about the trajectory of the diseases (White et al., 1983). Dysfunctionality in the continuous tracking of stimuli was already associated with Alzheimer dementia by (Kaufmann et al., 2010). (Crawford et al., 2005) has identified the important indication that Alzheimer patients are characterized with a significant impairment of their inhibitory functionality of eye movements, due to neurodegeneration of frontal and prefrontal lobes which are responsible for inhibitory effects (Kaufmann et al., 2010; Pierrot-Deseilligny et al., 2004). In early stages of Alzheimer disease, the antisaccade task is known to identify Alzheimer. This task requires from the test person a voluntary turning away from an actual stimulus and analyses the eye movement behavior further (Simpkins, 2008). Figure 3a depicts a test person during the task with the amicasa serious game. Figure 3c depicts the case of position tracking of a test person's correct antisaccade behavior (red) for a stimulus to the right (blue), and Figure 1shows incorrect behavior by following the position of the stimulus instead of turning away.

The antisaccade test error is characterized by a large correlation with the MMSE test Shafiq-Antonacci et al., 2003. However, a direct classification of Alzheimer patients in early stages is not straight forward because the results were extracted from a statistic group comparisons and the individual trajectory can be rather different (Shafiq-Antonacci et al., 2003; Crutcher et al., 2009). Further investigations on the 'Visual Paired Comparison' (VPC) Test with evaluation of eye movements in a visuospatial cognitive control task (Lagun et al., 2011) that the behavior of persons with mild cognitive impairment is significantly different from dementia-free persons. Lagun et al. (2011) demonstrated that a classifier can be extracted from existing patient data using machine learning techniques with a classification rate of 87%.

Our approach to the evaluation of the antisaccade test procedure is characterized through a pervasive measurement paradigm. The PwD is performing the training and serious game units at home, not in a laboratory environment. Consequently, the input data have to be filtered in order to gain the maximum quality for further processing and evaluation.

Paletta et al. (2018) - work that has been partially supported by PLAYTIME - applied in their approach a measurement frequency of about 5 Hz as a threshold to sort out meaningful data from noise prone (ca. 40%) data. Various eye movement features were extracted from the data. Areas of interest (AOI) were designed with respect to prosaccade and antisaccade behavior. Errors were determined from the violation of the antisaccade condition, i.e., turning attention on the opposite site of the visual stimulus.

From this we conclude that eye movement features can be successfully applied to cover relevant aspects of executive function features, such as, inhibitory functionality, and hence provide indicators for Alzheimer diagnostics, considering two independent studies that both showed the discriminative power to classify into dementia and non-dementia participants exclusively from gaze data. Future work will involve larger number of participants in field trials to get more robust estimators for Alzheimer classification. Furthermore, multiple eye movement features will be used for estimation and classification. In addition, multimodal sensing should even lead into better estimates, for example, by incorporating features from movement studies.

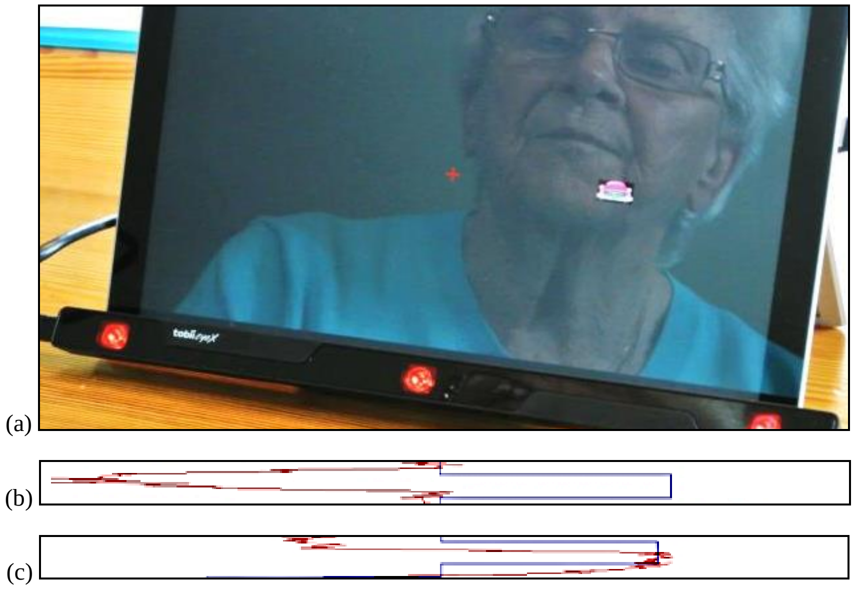

Figure 1 Cognitive control test for Alzheimer impairment of inhibitory functionality [19]. (a) The person with dementia is playing the antisaccadic test. (b,c) Tracking of test person's antisaccade behavior (red) and the stimulus (blue) with (b) correct and (c) incorrect behavior according to the requirements.

Several of these major objectives will be tackled under the coverage of the PLAYTIME project. In particular, we intend to correlate eye movement features collected from the home settings with questionnaire outcomes from the neuropsychological test battery. This would primarily refer to standard measures of outcome in dementia diseases, such as, the Mini-Mental State Exam, and questionnaires investigating certain aspects of executive functions, such as, the Go/No-Go Test (Milner & Ettlinger, 1972), the Stroop Test (Stroop, 1935), and the Trail Making Test (TMT; Reitan, 1958).

4.2.2 Output parameters of executive function training

One important aspect of the output of executive function training is to be able to correlate its data with appropriate executive function tests of neuropsychological test battery.

Tests that measure inhibition include the Go/No-Go Test (Milner & Ettlinger, 1972) and the Stroop Test (Stroop, 1935). In the Stroop Test participants are presented with a list of color names that are printed in different color (e.g., the word 'green' is printed in blue ink), and instructed to say the ink colors that the word is printed in without reading the word, thereby inhibiting the automatic urge to response in a prepotent manner. Participants' response reaction times on the congruent conditions are subtracted from their reaction times on the incongruent conditions to obtain an estimate of their inhibition abilities.

The Go/ No-Go task requires individuals to perform an action or say a word during the "Go" condition, but resist the impulsive urge to perform that action or say that word during the

“No-Go” condition. There are numerous variations of the Stroop and the Go/No-Go tasks, with varying degrees of complexity and difficulty, and geared towards different age groups.

Table 1 provides a list of some selected output parameters of executive function training for assessment.

JOANNEUM RESEARCH will collect data during the second field trial of PLAYTIME from the eye tracking, in specific, from the eye tracking data that are measured during attention game play, and provide the results into the central database (Sec. 5.2). Furthermore, the results collected from the neuropsychological test battery, such as, from the Go / No-Go test, TMT and Stroop-test, will be associated with the anonymized profiles of the test participants. There will from this be opportunity to analyse these data in detail, also in relation to data from other components, such as, with respect to data from the movement and the psychosocial test components.

Table 1. Output parameters of executive functions training for assessment.

Parameter	Indicator
Frequency of antisaccade errors	Performance of inhibitory function, a very important executive function functionality which is typically impaired in Alzheimer
Rate of antisaccade game scores	Performance of inhibitory function
Rate of spot-the-difference scores	Failure in working memory functionality

4.3 Information about cognitive and physical training

A substantial innovation in the playful training suite PLAYTIME is represented via the integrated, multimodal training unit concept of amicasa. Tasks with the purpose to stimulate cognitive processes are not separated from the tasks that excite physical activities but, in contrast, are in a functional context for the end user. The global task with cognitive, auditive, visual, social and sensorimotor aspects is within the focus and integrated through the serious game framework, i.e., the motivation to gain points through training. Amicasa is an interaction platform with an already very high number of task units (200) that is continuously increasing through additional themes that incorporate an exciting database for knowledge and exercises. The game character of the training engages the player and motivates for “knowledge acquisition and physical activities”.

The following multimodal unit categories are currently already contained in the overall pool of units:

- Training of memory and remembrance
- Visual memory
- Completing gaps in texts
- Interactive associations (pictures, form, color, content)

- Search games (visual comparison)
- Physical activities
- Playful cognitive test

In this sense, amicasa enables already a multimodal training, and based on the feedback and data logging about the performance of the individual units within it also enables a multimodal data assessment from playing the game.

Amicasa will provide data loggings from the reaction times of the PwD, from the scores associated with each of the playful units, and descriptions of the caregivers' observations of the physical activities of the PwD.

4.4 Information about emotion

Emotion measurements will be performed in PLAYTIME in several different ways (see Deliverable D3.4.1). Self-assessment methods are broadly employed in emotion research for the collection of subjective affective ratings. By leveraging on state-of-the-art user interfaces and meta-communicative pictorial representations, (Betella & Verschure, 2016) developed the Affective Slider (AS), a digital self-reporting tool composed of two slider controls for the quick assessment of pleasure and arousal. The AS has two added advantages over comparable implementations: the AS does not require written instructions and it can be easily reproduced in latest-generation digital devices, including smartphones and tablets. Secondly, 'Pick-A-Mood' (PAM; Desmet et al., 2012) is a cartoon-based pictorial instrument for reporting and expressing moods. The use of cartoon characters enables people to unambiguously and visually express or report their mood in a rich and easy-to-use way.

4.5 Information about movements

The MoveMonitor (MM) and MoveTest (MT) provide an overall picture of the physical function of the patient. The MT provides insight into what the patient can do, and the MM monitors what the patient actually does in daily life. They work on the same data platform. McRoberts uses a conceptual framework to describe relations between parameters that can be measured using both systems. For an elaborated view on the state-of-the-art in sensomotory functionality, assessment and dementia has been given in Deliverable D4.3.1.

4.5.1 MoveTest

The MT is designed to easily and reliably assess standardized physical performance tests under supervised (controlled) conditions. It consists of hardware (DynaPort MT), software for data analysis and a data management platform. The DynaPort MT consists of a tri-axial accelerometer, tri-axial gyroscope, temperature sensor, air pressure sensor, a magnetometer and Bluetooth. The DynaPort MT is worn on the lower back using an elastic strap. This location is close to the Centre of Mass (CoM), representing whole body movement (in contrast to arm worn sensors where limitations can occur due to absence of arm swings or arm swings unrelated to whole body movements). In Playtime, the Short Physical Performance Battery (SPPB) is used. This test battery consists of 3 parts:

- Balance: 3 conditions, increasing in difficulty. The subject can score points for each conditions, with a maximal of 4 points for balance in total
- Gait: 2 gait sections of 4 meters. The fastest time of the 2 is compared to reference data. The subject can score a maximum of 4 points.
- Repeated chair rise: The subjects has to stand up repeatedly (5 times) from a chair as fast as possible. The time the subject takes is compared to reference values and a maximum of 4 points can be scored.

4.5.2 MoveMonitor

The MM is designed to measure physical activity in daily life (i.e. unsupervised and uncontrolled conditions) and This MM consist of hardware (DynaPort MM)), software for data analysis and a data management platform. The MM is used in international research projects, pharma trials, and clinical practice to measure many aspects of mobility in the real world on a long-term basis.

The DynaPort MM consists of a tri-axial accelerometer, temperature sensor, air pressure sensor, and magnetometer. For research purposes, the DynaPort MM+ is also available which had an additional 3-axial gyroscope compared to the DynaPort MM. The DynaPort MM is worn on the lower back using an elastic strap. This location is close to the Centre of Mass (CoM), representing whole body movement (in contrast to arm worn sensors where limitations can occur due to absence of arm swings or arm swings unrelated to whole body movements). We developed and validated non-wearing detection as well.

With the MM it is possible to assess a subjects' physical activity in daily life, for up to 14 consecutive days. We provide a broad range of physical activity parameters, e.g. time spent in postures and movements, amount of steps and movement intensity.

5 Integration of multimodal data

5.1 PLAYTIME integration aspects

Figure 2 depicts a schematic sketch of the back-end component of the PLAYTIME system (from PLAYTIME Deliverable D4.1.1) that represents the integrating aspects. In particular, the components "Central Database", "Recommender", "Multimodal Diagnostics" and "Motivation Analytics" provide implementations that operate on inputs from various components and generate output of concern for an integrated view of the intervention and assessment system features.

- The "Central Database" (CD) component as a relational database will receive all type of data input via a secured internet connection from the various sensing components. The data will preferably represent meta-data in terms of features that were computed within the external components on the basis of the originally measured data. Its integrating aspect relates to the potential to perform any analytics on the basis of its multimodal data input that finally, i.e., until project end, will be extended with the users' results from the neuropsychological test battery applied at the begin and at the end of the field trial.
- The "Recommender" (REC) component reads actual data – i.e., those that are time-stamped within a specific time interval (typically, last week / month) - from the CD and applies a rule base in terms of a simple decision tree on these data. Based on the selected data the Recommender computes recommendations on the difficulty level of specific PLAYTIME several components for a forthcoming time interval (typically, for next week / month).
- The "Multimodal Diagnostics" (MMD) component receives multisensory based meta-data from the CD component and applies a rule base that provides a simple assessment score that relates to last week's cognitive, physical, emotional and socio-emotional state of the person with dementia (and possibly also of the caregiver). This information will provide feedback to the formal and possibly also the informal caregiver, as well as to the person with dementia herself.
- The "Motivation Analytics" (MOA) component receives multisensory based meta-data from the CD component and computes a score that principally relates emotion and performance data. This score relates to a global state estimate in the context of user engagement and provides feedback to the professional caregiver in order to adjust the configuration of the training scheme based on more information on motivation differential related to specific PLAYTIME components or units. The motivation state reflects the overall activation state of the person with dementia and moreover provides feedback about the disposition of the PwD to engage in the PLAYTIME training.

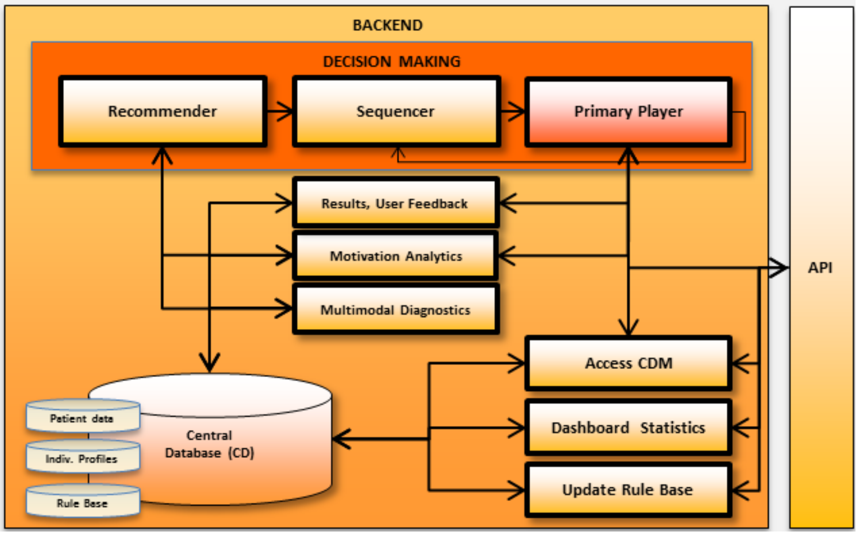

Figure 2. Schematic sketch of the PLAYTIME back-end component (from PLAYTIME Deliverable D4.1.1) that represents the integrating aspects. In particular, the components "Central Database", "Recommender", "Multimodal Diagnostics" and "Motivation Analytics" provide implementations that operate on inputs from various components and generate output of concern for an integrated view of the intervention and assessment system features.

5.2 Central database

Based on the analysis of the data structures that were required by individual PLAYTIME components JOANNEUM RESEARCH has developed a first draft of the data model of the component "Central Database" (see Figure 3). In this data model, there is an entity for the subject and related to this several entities with results from the different games or other analyses. These data will be stored in a relational database, like using the MS SQL Server. On this database a business logic layer will be built upon where the components of the recommendation system, i.e., the recommender and the sequencer, will be built in (see Deliverable D4.5.1).

The Application Programming Interface (API) will be implemented using a Representational State Transfer (REST[1]) type interface. REST is an architectural style that defines a set of constraints to be used for creating web services. Web services that conform to the REST architectural style, or REST-ful web services, provide interoperability between computer systems on the Internet. REST-compliant web services allow the requesting systems to access and manipulate textual representations of web resources by using a uniform and predefined set of stateless operations. In a REST-ful web service, requests made to a resource's URI will elicit a response with a payload formatted in either HTML, XML, JSON, or some other format. The response can confirm that some alteration has been made to the stored resource, and the response can provide hypertext links to other related resources or collections of resources. When HTTP is used, as is most common, the operations available are GET, POST, PUT, DELETE, and other predefined CRUD HTTP methods.

[1] https://en.wikipedia.org/wiki/Representational_state_transfer

By using a stateless protocol and standard operations, REST systems aim for fast performance, reliability, and the ability to grow, by re-using components that can be managed and updated without affecting the system as a whole, even while it is running.

It is suggested implementing this service with the .NET platform, because this platform and software development environment provides a very good support for handling and building REST based services and handling the database. Recently, the .NET-platform has been emerged to be one of the most used web application servers. Within this framework PLAYTIME also gets included appropriate security support[2].

For the prototype that will be applied in field trial 2, the key structure of the database and software for the manual input to the database will be prepared and be fully operational. In the last project year, a risk based approach for the data input will be investigated, conceptualised, developed and finally implemented still in project time so that this approach will be used in a future product prototype.

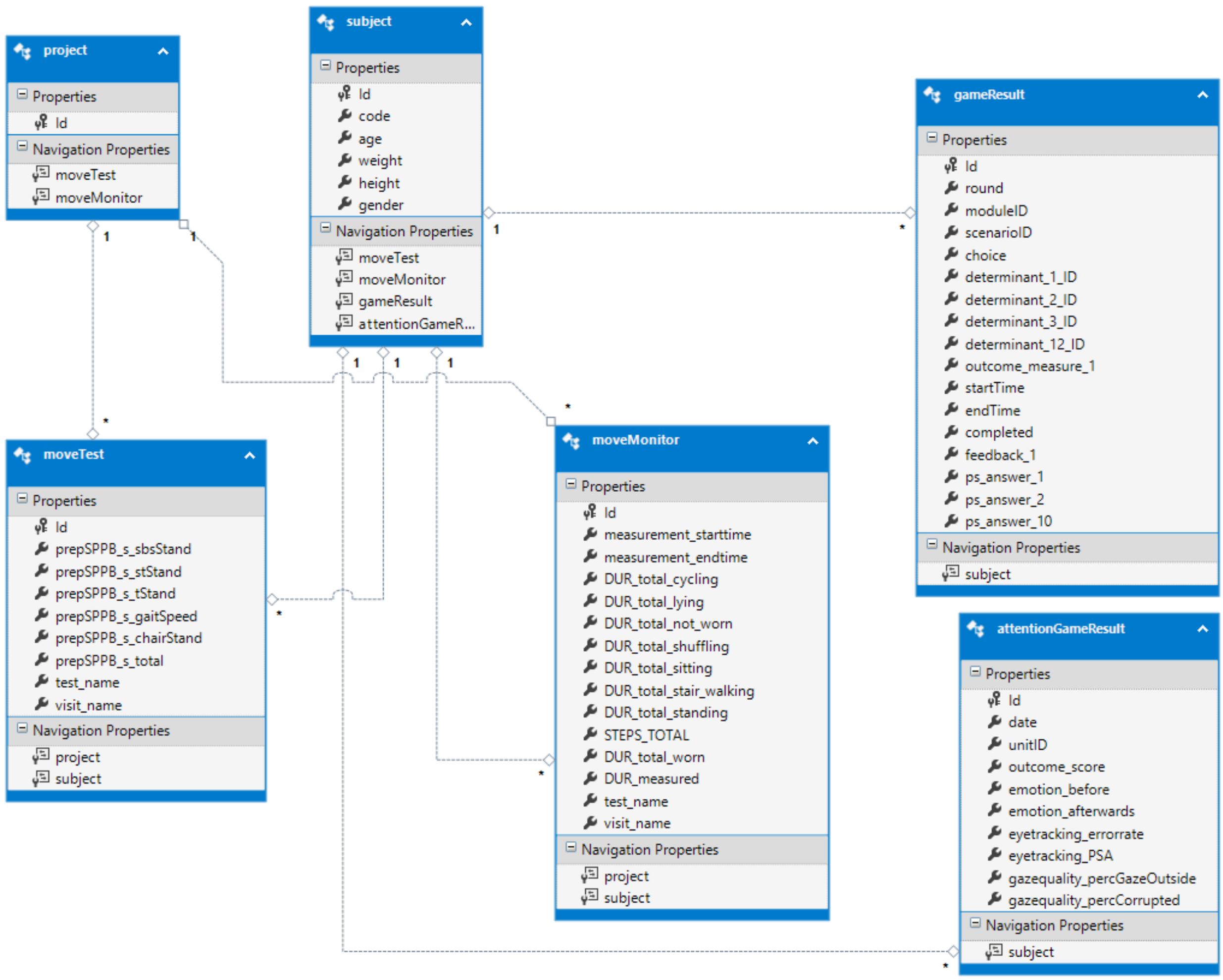

Figure 3. Data structure entity (draft version) that relates input from all PLAYTIME components into the context of a single – anonymized – user, i.e., PwD.

[2] https://en.wikipedia.org/wiki/.NET_Framework#Security

5.3 Recommender functionality

The “Recommender” (REC) component reads actual data – i.e., those that are time-stamped within a specific time interval (typically, last week / month) - from the CD and applies a rule base in terms of a simple decision tree on these data. Based on the selected data the Recommender computes recommendations on the difficulty level of specific PLAYTIME several components for a forthcoming time interval (typically, for next week / month).

The REC rule base is based on the user profile that indexes into the behavioural matrix provided by the dementia training expert. Based on features in the user profile - such as, “age”, “gender”, “mental state exam”, “physical status”, “social situation”; “level of motivation”, etc. – the behavioural matrix will associate a respective recommendation on the kind of PLAYTIME play: these recommendations will be on parameters, such as, “total playing time”, “number of units”, “level of difficulty”, “kind of units”, “past performance profile”, etc.

More details of the REC functionality are described in PLAYTIME Deliverable D4.5.1.

5.4 Multimodal diagnostics

In principle, the “Multimodal Diagnostics” (MMD) component receives multisensory based meta-data from the CD component and applies a rule base that provides a simple assessment score that relates to last week’s cognitive, physical, emotional and socio-emotional state of the person with dementia (and possibly also of the caregiver).

The information of assessment scores will provide feedback to the formal and possibly also the informal caregiver, as well as to the person with dementia herself. The feedback, however, will be filtered by a classification scheme that is motivated by psychology, as outlined in the following.

5.4.1 Motivation from psychology

PLAYTIME Deliverable D3.1.1 argued and illustrated the cognitive profile of different types of dementia, contrasting early and late stage of disease developments. In that Deliverable it is shown that in early stages, it is possible to differentiate among domains that are unimpaired or mildly impaired and those that are distinctly abnormal: in other words, as dementia progresses from early to late stages, symptom domain boundaries become blurred and distinctive profiles are difficult to discern. Therefore it was concluded that a one-size-fits-all stimulation/training is unlikely to be the most useful approach. Instead, there is merit to a more fine-grained assessment of functional impairments that is used to inform which aspects of cognitive performance could be targeted through training.

Functional impairments referred to in the psychological tract are now listed in Table 2. The table represents a functional matrix relating individual analytical assessments via PLAYTIME serious game components (columns) versus clustered functional impairments in dementia (rows).

This table is fundamental in the sense that assessment from the individual components will **indicate** about the status of individual functional impairments. This indication in principle informs which aspects of cognitive performance could be targeted through training.

Table 2. Functional matrix of analytical assessments via PLAYTIME serious game components (row) versus clustered functional impairments in dementia.

Functional impairment	amicasa	SERES	MIRA	MOVE
Attention			√	
Mood affect		√	√	
Language	√			
Visual perception	√		√	
Explicit memory	√			
Executive functions			√	√[3]
Comportment		√		
Activities of daily living (ADL)				√

The aspect of a highly **individual distribution** on the set of potential **functional impairments** in dementia will be emphasized particularly using the aforementioned measured data, classifications and associations.

Being able to identify a specific **individual pattern of** as set of potential **functional impairments** in turn enables to perform a **functional personalisation of the training** on the basis of this information.

5.4.2 Social aspect of dementia

It has been noted that multi-component interventions are important and should be accompanied by community settings in social environments (Graessel et al., 2011; Korczak et al., 2013).

One specific objective of multimodal analytics is to analyse the impact of social gatherings on the emotional and, in particular, socio-emotional state of the PwD. For this purpose, emotion measurements are undertaken before and after group gatherings with the interactive mat, and before and after the single user gatherings, exclusively accessible to caregivers. The dynamics of the socio-emotional state, in dependency on the social and single user gatherings, will be analysed in detail in this PLAYIME Task 4.5.

5.5 Motivation analytics

The “Motivation Analytics” (MOA) component receives multisensory based meta-data from the CD component and computes a score that principally relates emotional and performance data. This score relates to a global state estimate in the context of user engagement and provides feedback to the professional caregiver in order to adjust the configuration of the training scheme based on more information on motivation differential related to specific PLAYTIME components or units. The motivation state reflects the overall activation state of the person with dementia

[3] If performed as dual task.

and moreover provides feedback about the disposition of the PwD to engage in the PLAYTIME training.

The MOA determines the level of motivation of the user computed from the emotional, attentional and performance related data.

- The motivational value is impacting the probability of expected engagement with the game and reaching certain training objectives. For the measurement of engagement, we will measure the physical engagement using the movement analysis. The probability of behavior change is derived from a long-term motivation level derivation.

For a more extensive motivation analytics we will follow a simple model, i.e., the expectancy-value theory (EVT) of Atkinson (Atkinson, 1957).

Expectancies are specific beliefs individuals have regarding their success on certain tasks they will carry out in the short-term future or long-term future. The expectancies an individual has shaped their behaviours as well as the choices they make.

EVT has three basic components.

- First, individuals respond to novel information about an item or action by developing a belief about the item or action. If a belief already exists, it can and most likely will be modified by new information.
- Second, individuals assign a value to each attribute that a belief is based on.
- Third, an expectation is created or modified based on the result of a calculation based on beliefs and values. For example, a student finds out that a professor has a reputation for being humorous. The student assigns a positive value to humor in the classroom, so the student has the expectation that their experience with the professor will be positive. When the student attends class and finds the professor humorous, the student calculates that it is a good class.

EVT also states that the result of the calculation, often called the "attitude", stems from complex equations that contain many belief/values pairs (Fishbein and Ajzen, 1975).

A resulting tendency or **motivation for behaviour change**, such as, for using the PLAYTIME serious game suite, is as follows,

$$RT = (M_s \times I_s \times P_s) - (M_f \times I_f \times P_f),$$

where M_s is the individual motive for success, M_f the motive for failure, I_s / I_f the incentive for success / failure, and P_s / P_f the probability for success / failure.

For the implementation of the prototype, we will design a **motivation matrix** with inputs in the frame of potential individual inputs that would specifically relate to a certain degree to serious game and training components in the PLAYTIME serious game suite. Type and weight of motives as well as degree of potential incentives in the game suite will be queried from the PwD and stored in the user profile. The probability for success or failure will be initialised with an individual default estimate and then updated according to supporting parameter that will be derived from the data analytics from the second field trial.

6 Implementation plan

6.1 Prototype for the field trials

The prototype for the field trials will incorporate the following components

- Central Database: the key structure of the database and software for the manual input to the database will be prepared and be fully operational.
- Multimodal analytics: Identification of components that support the training to care for specific functional impairments.
- Motivation analytics: setup of a motivation matrix with the query of individual motives and identification of components that would support them.

6.2 Data analysis based on field trials

The prototype until the project end will incorporate the following components

- Central Database: in the last project year, a risk based approach for the data input will be investigated, conceptualised, developed and finally implemented still in project time so that this approach will be used in a future product prototype.
- Multimodal analytics: analytics with respect to the dynamics of specific functional impairments as associated with the assessment of the game statistics in the data from the field trials.
- Motivation analytics: identification of the motives as collected from the data with the motives expressed and identified by the PwD. Investigation of the correlation between these data and conclusion whether this relation had changed dynamically over time.

7 Conclusions and outlook

This PLAYTIME Deliverable reported on the various dimensions of multimodal analytics, involving several integrating components of the PLAYTIME games suite.

The individual integration components were identified, described in more detail, however, these are still prototypical sketches.

A detailed description of the concrete implementations, as referred to in the Conclusion Section, will be included in the PLAYTIME Deliverable D3.5.2

8 Abbreviations

Table 1. *Abbreviations.*

Abbreviation	Description
CD	Central Database
MM	MoveMonitor
MT	MoveTest
PwD	Person with dementia

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