## DELIVERABLE 8.6

Citizen platform – Final version

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TABLE OF CONTENTS

TABLE OF CONTENTS .......................................................................................................................... 3
1. INTRODUCTION ........................................................................................................................... 4
2. SOFTWARE DESIGN ..................................................................................................................... 6
   2.1. DATA TIER ............................................................................................................................ 6
   2.2. LOGIC TIER ......................................................................................................................... 7
   2.3. PRESENTATION TIER .......................................................................................................... 7
   2.4. COMMUNICATION WITH EXTERNAL SERVICES ................................................................ 8
3. CITIZEN PLATFORM .................................................................................................................... 9
   3.1. CITIZEN PORTAL MAIN VIEW (VPH-DARE@IT) ............................................................. 9
   3.2. INFORMATION MODULE .................................................................................................. 10
   3.3. WEB-BASED COGNITIVE TEST “MUISTIKKO” .............................................................. 11
      3.3.1. Immediate verbal task .................................................................................................. 12
      3.3.2. Corsi block test ........................................................................................................... 12
      3.3.3. Reaction time tests ..................................................................................................... 12
      3.3.4. Trail-making test ......................................................................................................... 13
      3.3.5. Trail-making test A ..................................................................................................... 13
      3.3.6. Trail-making test B ..................................................................................................... 14
      3.3.7. Delayed verbal memory task ...................................................................................... 14
      3.3.8. Verbal recognition task .............................................................................................. 14
   3.4. GAMES ............................................................................................................................... 14
      3.4.1. Memory Card Game ..................................................................................................... 15
      3.4.2. Crossword Hunt Game ............................................................................................... 15
      3.4.3. Tap Fast Game ............................................................................................................ 16
   3.5. DATA ENTRY MODULE (VPH-DARE@IT) ...................................................................... 16
   3.6. VISUALIZATION MODULE (VPH-DARE@IT) ................................................................. 17
      3.6.1. Time trends ................................................................................................................ 18
      3.6.2. Fingerprint Module ..................................................................................................... 18
4. VALIDATION .................................................................................................................................. 20
   4.1. METHOD .............................................................................................................................. 20
   4.2. RESULTS ............................................................................................................................. 20
5. DISCUSSION .................................................................................................................................. 23
1. INTRODUCTION

Early diagnosis of memory disorders is essential because any pharmaceutical or psychosocial treatments should be started at the early phase to be efficient. This is especially important in neurodegenerative diseases which injure and finally destroy brain cells. Early diagnosis is needed both for detecting individuals for treatments or (secondary) prevention, and for developing efficient treatments.

Detecting individuals for therapies, i.e., making clinical diagnosis of memory disorders, is not a trivial task. However, making the diagnosis immediately after the symptoms appear is not enough for solving the problem because pathological processes are known to start even decades before the symptoms in Alzheimer’s disease, the most common neurodegenerative disease (Fig. 1). Therefore, the ultimate goal is to detect the disease already at the pre-symptomatic phase.

![Figure 1. The timeline of Alzheimer’s disease (MCI=Mild Cognitive Impairment). The timeline has been adapted from 1.](image)

In addition to traditional neuropsychological measures, different diagnostic biomarkers are attracting interest in diagnosis. They can be divided into two categories:

1. biomarkers of amyloid-beta (Aβ) accumulation, such as amyloid positron emission tomography imaging (amyloid-PET) or low cerebrospinal fluid (CSF) Aβ42 protein, and
2. biomarkers of neuronal degeneration or injury, such as flurodeoxyglugoce (FDG) PET or atrophy measured with structural magnetic resonance imaging (MRI).

These biomarkers become abnormal during the disease progression indicating that the biomarkers of amyloid-beta accumulation become abnormal already pre-symptomatically. The challenge of the CSF- and PET-biomarkers is that they are relatively expensive to acquire and that they are also invasive. This limits their use in screening.

There is a need for finding non-invasive low-cost biomarkers for the diagnosis or at least for detecting individuals at high-risk for developing memory disorders. These cases at-high risk would form an enriched population whom advanced but more expensive biomarkers could be acquired. There are multiple possible sources for such low-cost biomarkers, e.g., blood, measuring the amyloid via the fundus of the eye, computerized cognitive tests or games, changes in the gait pattern. For example, it has been shown that cognitive measures decline faster in the group of cases with Alzheimer’s disease than in the group without. The difference in the rate of decline can be observed at the population level already even a decade before clear memory problems appear.

In VPH-DARE@IT, WP8 is developing two platforms for enabling earlier diagnosis of neurodegenerative diseases: a clinical platform and a citizen platform. These platforms are

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referred in the project as the Patient Care Platform (PCP) to differentiate the work done in WP7 related to the Clinical Research Platform (branded the MULTIX Platform). The clinical platform provides tools for quantifying imaging data and interpreting heterogeneous patient data by comparing them to the large number of previously diagnosed cases. The clinical platform is targeted especially for memory clinic specialists. On the other hand, the citizen platform is a step towards the detection of memory diseases already at the pre-symptomatic phase. The citizen platform is a web-based service that provides tools to assess brain health. The focus of the citizen platform is on the primary care setting or even in empowering citizens to evaluate their brain health independently. Potential underlying business models or use case scenarios, in more detail, form part of D9.7. The key objective of VPH-DARE@IT has been to develop further the citizen platform concept and validate it in research settings.

This document (D8.6 “Citizen platform – Final version”) describes the citizen platform at the end of the VPH-DARE@IT project. The previous work has been described in D8.3 “Citizen platform – 1st prototype”, and the clinical platform in D8.2 “Clinical platform – 1st prototype” and D8.5 “Clinical platform – Final version”. The web-portal is a multi-project effort in which VPH-DARE@IT has contributed in the following four domains:

- developing a web-portal which provides one-point-access to all different services available in the portal (web-based cognitive test Muistikko, three games, the information module, the data entry module and the visualization module),
- developing the data entry module for acquiring information for the late-life CAIDE risk score²,
- developing the visualization module for presenting the data acquired in the portal to the end user, and
- validating the citizen portal approach with the VPH-DARE prospective cohort.

The Muistikko test, the games and the information module have been developed in two previous self-funded projects at VTT Technical Research Centre of Finland and the PredictND project (www.predictnd.eu).

2. SOFTWARE DESIGN

The aim of the citizen platform is to provide one-point-access to several tools for assessing brain health. Therefore, it is designed to combine multiple modules and to integrate with external services as well. The clinical platform (see D8.5) is an example of such external applications or services. A three-tier architecture is followed in the development, which divides the platform into three conceptual tiers: data tier, logic tier and presentation tier (Figure 2). This architectural approach allows the developing of software in a modular fashion and makes it easier to manage and extend. The presentation tier is responsible for providing the user interface (UI) within a web-based environment and handle user interaction. The logic tier manages communication between presentation and data tier as well as implements various operations to manipulate and process data before transferring it to the presentation or the data tier. A web-service developed for external communications is also a part of the logic tier. The data tier represents a database where the data are stored.

![Citizen platform architecture](image)

**Figure 2.** Citizen platform architecture.

2.1. DATA TIER

The Data tier is responsible for providing persistent storage, mainly for games’ data. The Microsoft SQL Server\(^3\) is used as a relational database management system for both games and the Muistikko databases. Figure 3 depicts a high-level data model of the citizen platform. The Entity Framework (EF)\(^4\) followed by a code-first approach is used to design the database. This approach allows the developing of the database independently of the underlying database management system (any SQL Server can eventually be used). Thus, all data entities are defined as data model objects in the logic tier (see next section).

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\(^4\) [https://entityframework.codeplex.com/](https://entityframework.codeplex.com/)
2.2. LOGIC TIER

The logic tier contains a definition of domain objects, which represents the data model of the citizen platform and dictates the creation and layout of the database. This tier provides a number of commands and functions that are invoked by controllers of the presentation tier (see next section). Through these commands, the controller can send either data to the database for storage or request data to show it to a user. The logic tier manipulates and organizes the data into the respective domain objects before sending it to the controller or database. Furthermore, this tier is also responsible for sending and receiving data from external services and applications using a web service. The web service allows flexible integration of the citizen platform with external services. For example, the logic tier sends cognitive test and games data to the Patient-Care Platform. It also fetches Muistikko cognitive test data for the visualization module of the citizen platform.

2.3. PRESENTATION TIER

The presentation tier is responsible for displaying processed data to the user in a graphical format within a web-browser. ASP.NET is used as a development framework following a MVC\(^5\) (Model-View-Controller) design—which is one of the programming models that are supported by ASP.NET. The ASP.NET facilitates developing web applications with HTML, CSS and JavaScript. To develop client-side components, the Microsoft Razor view engine is used to create HTML.

The View in MVC design is responsible for creating visualizations of data. The Controller is responsible for intercepting all requests invoked by a user through the user-interface (View). A Controller sends the user input to the logic tier and in turn, the logic tier returns the requested data in the form of domain objects. JavaScript and JQuery\(^5\) are used in the presentation tier to improve user experience as well as perceived performance of the citizen platform. Some requests and responses to and from the server (respectively), are handled through AJAX\(^6\) (Asynchronous JavaScript and XML) calls.

### 2.4. COMMUNICATION WITH EXTERNAL SERVICES

The citizen platform can access external services using a web-service. The web-service allows the citizen platform to send data to the Patient-Care Platform and to receive data from the Muistikko database. The citizen platform can also communicate with other external services and applications by using this web-service.

The web-service is implemented by using Microsoft ASP.NET Web API\(^6\) framework. This framework allows building HTTP services that can be accessed by external applications for sending and receiving data. Thus, external tools can access or send data to the citizen platform without the knowledge of the underlying internal logic of data handling.

Web API controllers are responsible for handling all requests from external tools. The citizen platform exposes only a specific URL and by using that URL, external tools can send data in the form of JSON\(^7\) object to the citizen platform. Web API controllers forward the received data to the logic tier for further processing or for storing it to the database.

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\(^5\) [http://jquery.com/](http://jquery.com/)
\(^7\) [http://www.json.org/](http://www.json.org/)
3. CITIZEN PLATFORM

This chapter briefly describes the current version of the citizen platform from the functional point of view. In the final version of the citizen platform, the user interface has been redesigned for better usability and new modules and games have been added to it. The word “VPH-DARE@IT” has been added to the titles of the sections in which the VPH-DARE@IT project has made clearly contributions.

3.1. CITIZEN PORTAL MAIN VIEW (VPH-DARE@IT)

Figure 4 shows the main view that is shown to a user after launching the application from a web browser. Different modules of the platform can be selected from the buttons on the left. The visual appearance of a web page changes on selecting a particular module and the information related to it loads into the right panel. The use of varying colour schemes and themes for modules helps especially elderly users to distinguish easily between different modules of the platform. The main view provides access to the cognitive test Muistikko, games and visualization module. The basic information about different modules is accessible without login into the system. However, the user need to provide the login information to play games, to take the Muistikko cognitive test or to view the results in the visualization module. A login screen appears when the user tries to access one of these modules (Figure 5).

The platform is available in five different languages, and the user can select a specific language from the main view. The platform is designed in such a way that more languages can be incorporated easily if required.

![Figure 4. The main view of the citizen platform.](image-url)
3.2. INFORMATION MODULE

The module provides information about memory diseases and the purpose of the citizen platform. The contents of the information module are provided by partner Alzheimer Europe from the PredictND consortium. Alzheimer Europe is a patient organisation specialised in communicating memory disorder related information to citizens.

The information in this module is organized under different headings and questions, which are grouped by using, expand/collapse panels for better navigability. The user can expand one panel at a time (Figure 6).

Figure 5. The Login view. The user can access the citizen platform modules after providing valid credentials.

Figure 6. The main view of the Information module. One panel is expanded in the view.
3.3. WEB-BASED COGNITIVE TEST “MUISTIKKO”

This module provides a cognitive test (Muistikko) that is designed by neuropsychologists. The Muistikko was a separate system, which is now integrated into the citizen platform. After integration, the system was modified for better management of the Muistikko tasks, studies and users. The test can be taken after a particular interval of time, for example, every six months to avoid learning effects. After a successful login into the system, the user can access the Muistikko test. The user can start the test by clicking on the “Play” button (Figure 7) and the test opens in a new browser tab and a list of ten tasks is shown to the user (Figure 8).

![Figure 7. The main view of the Muistikko module.](image)

The user cannot select the tasks individually from the list. Instead, the system moves to a next task in an orderly manner after the completion of each task. The system continuously stores the information into a database as the user starts completing the tasks. At the beginning of each task, a short description is displayed to the user along with the instructions related to the task. The user can complete all the tasks in one session or in multiple sessions. After each login, the test starts from the same task where the user left in the last session. However, it is
strongly recommended that the user should complete all the tasks in one session for better results. The following sections provide details about each Muistikko task.

3.3.1. Immediate verbal task

The first task is a verbal immediate task in which words are shown to the user along with pictures one by one, and the user has to type as many words as he/she remembers at the end of the task (Figure 9).

Figure 9. The First task of the Muistikko.

3.3.2. Corsi block test

The second task is a Corsi block task, which measures visuo-spatial short-term working memory. A visual sequence of glowing yellow circles is shown to the user, and the user has to repeat the sequence in the same order (Figure 10).

Figure 10. The Corsi block task of the Muistikko. The user has to repeat the sequence as shown on the screen.

3.3.3. Reaction time tests

It is a reaction time task (Subtask 3), in which the letter “R” is displayed on the screen after a random interval of time and the user needs to hit the right arrow button on the keyboard each time the letter appears on the screen (Figure 11). The letter “R” means “Right”. This letter can be different based on the selected language of the citizen platform. This task lasts for a duration of sixty seconds. In Subtask 4, both the letter “L” (Left) and “R” (Right) are shown. Subtask 5 shows also distractors.
### 3.3.4. Trail-making test

Subtask 6 is a trail-making task, in which a number of rectangles is displayed on the screen, and the user has to select a rectangle that turns green. After the selection, the rectangle becomes grey. The user has to keep selecting the rectangles until all rectangles become grey (Figure 12).

**Figure 11.** The reaction time task of the Muistikko. The user has to hit the right arrow button on the keyboard each time the letter appears on the screen.

**Figure 12.** The sixth task of the Muistikko. The user has to select the rectangle that turns into green.

### 3.3.5. Trail-making test A

In Subtask 7, twenty-four numbered rectangles are displayed randomly on the screen at different locations, and the user has to select the rectangles in a sequence from “1” to “24” (Figure 13).

**Figure 13.** The seventh task of the Muistikko. The user has to select the rectangles in a sequence from “1” to “24”.
3.3.6. Trail-making test B

This task is a complex version of the seventh task. A randomized set of numbered twenty-four squares and twenty-four circles are presented to the user. The user has to select the circles and squares alternatively to complete a set of twenty-four circles and squares (Figure 14).

![Figure 14](image)

**Figure 14.** The eighth task of the Muistikko. The user has to select the circles and squares alternatively to complete a set of twenty-four circles and squares.

3.3.7. Delayed verbal memory task

This task assesses delayed verbal memory. In this task, the user has to re-type as many words as possible that he/she can remember from the first task within a ninety-second duration (Figure 15).

![Figure 15](image)

**Figure 15.** The ninth task of the Muistikko. The user has to re-type as many words as possible that he/she can remember from the first task within a ninety-second duration.

3.3.8. Verbal recognition task

The tenth task is a verbal recognition task. In this task, the list of words and pictures from the first task is again shown to the user in a randomized manner. However, the list contains not only the words from the first task but also contains an equal number of other random words. The user has to identify the words that belong to the first task by answering “Yes” or “No”.

3.4. GAMES

At present, the citizen portal has three different games, which are the Memory Card game, the Crossword Hunt game and the Tap Fast game. More games can be added to the citizen platform, if needed. Each game is described in more detail in the following sections.
3.4.1. Memory Card Game

The user can access and read short description/instructions about the memory card game from the main view of the citizen platform. In this game, the user has to find the two matching cards by turning cards as quickly as possible from a set of shuffled face down cards (Figure 20). Two different modes of the game are available, “Image” and “Sum”. In the image mode, the user has to find two cards with same image, and in the sum mode user has to find a pair of cards, which sum up to 20. The user can also select different sizes of the game grid to increase the complexity and the top five scores of the user displayed on the screen as well.

![Memory Card Game](image)

**Figure 16.** The play mode of the Memory Card Game.

3.4.2. Crossword Hunt Game

The user can access and read short description/instructions about the crossword hunt game from the main view. “Word” and “Image” are two different modes of the game. In the word mode, the task is to find a given word from a grid of letters as fast as possible by indicating the location of the word by clicking the first and last alphabet of the word in the grid. When the word has been found, a new grid of alphabets is formed with another word in it (Figure 17). The image mode is similar to the word mode. However, the user has to find a given image sequence from the grid instead of a word. The user can change the size of the grid to increase the complexity of the game.
3.4.3. Tap Fast Game

The user can access and read short description/instructions about the tap-fast game from the main view. In this game, the user has to tap any single key on the keyboard using one finger as fast as possible for 15 seconds. The score is the number of tapping performed within 15 seconds (Figure 18).

3.5. DATA ENTRY MODULE (VPH-DARE@IT)

The data entry module (Figure 19) under “Entries Form” is designed to save a user’s late life risk factors to the database and visualize these factors in the fingerprint module when computing the late-life dementia risk score developed in VPH-DARE@IT. After filling all available values and submitting them, the fingerprint machine learning module under the
visualization module calculates the disease-state fingerprint visualizations of the late-life dementia risk\(^8\).

\[ \text{Figure 19. Form to enter data for computing late-life dementia risk score.} \]

3.6. VISUALIZATION MODULE (VPH-DARE@IT)

The visualization module was designed to represent graphically the patients’ scores from the Muistikko and the games to assess the degree of the brain health. This module consists of two ways to visualize the data: time trends and disease-state fingerprint visualization.

3.6.1. Time trends

The time trend visualization shows all the scores obtained from the games and Muistikko over time by blue dots. If the number of data points is high enough, the tool estimates the trend from the measurements. The user can zoom the data both in the time and the value axis. Figure 19 shows the visualization of the memory card game score. The values visualized are

- global cognitive score (see Section 4) in the Muistikko cognitive test,
- time for finding all cards in the Memory card game,
- number of words found in the Crossword hunt game,
- number of keyboard strokes in the Tap Fast game,
- brain health index summarizing the results from Muistikko and games.

![Figure 20. Visualization of memory card game score over time.](image)

3.6.2. Fingerprint Module

The fingerprint module contains two visualizations modes: brain-health fingerprint and fingerprint for the late-life dementia risk score. In the fingerprint, each node of the tree consists of three parts: the coloured rectangle on extreme left, the name of variable in the middle and the score of this field on extreme right scaled between 0-1. The size of the rectangle represents the relevance/importance of this field in calculating the total fingerprint score, while its colour shows whether the variable studied has a good value (blue) or the value needs to be improved (red). Figure 21 shows an example of the brain health fingerprint visualized for a citizen and the late-life dementia risk score for the same citizen.
Figure 21. Brain health fingerprint (left) and late-life dementia score (right).
4. VALIDATION

We validated the Muistikko test battery in three cohorts (Table 1): PredictND and VPH-DARE@IT cohorts (memory clinic patients) and FINGER cohort (healthy cases at risk). In the VPH-DARE@IT prospective study (WP1), data from 80 memory clinic patients were acquired.

Table 1: Diagnostic characteristics of the PredictND, VPH-DARE@IT and FINGER cohorts.

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4.1. METHOD

To quantify cognitive disorders, we developed first a global cognitive score (GCS) composed of age, sex, MMSE, digit span, RAVLT, trail-making and animal fluency tests. The GCS was defined as the disease-state index computed for the group of cognitively normal (CN, N=138) and Alzheimer’s disease subjects (N=275) from the independent Amsterdam Dementia Cohort. GCS is a score that aims to differentiate cognitively normal subjects from Alzheimer’s disease subjects as well as possible. Thereafter, the GCS was computed for all cases in the three cohorts.

Next, the GCS (independent variable) was estimated for all the subjects of the three cohorts from five (dependent) selected Muistikko variables, denoted by MGCS, using linear regression model developed from the PredictND data. In validation, the correlation coefficients between the GCS and the MGCS were defined for the three cohorts. In addition, for VPH-Dare@IT cohort, classification accuracies between cognitively normal (CN) and mild-cognitive impairment (MCI), and CN and dementia subjects were computed for the MMSE, GCS, and MGCS.

4.2. RESULTS

The correlation coefficient between the GCS and the MGCS were 0.79, 0.76 and 0.62 for the PredictND, VPH-DARE@IT and FINGER cohorts, respectively, using the regression model developed from the PredictND data. Figures 22 and 23 show the distribution of the GCS and the MGCS for different diagnostic groups in the PredictND and VPH-Dare@IT cohorts, respectively.


Figure 22. Distribution of GCS and MGCS shown for different diagnostic groups in the PredictND cohort.

Figure 23. Distribution of GCS and MGCS shown for different diagnostic groups in the PredictND cohort. The dementia group (n=24) includes AD, FTD and VAD patients.

Table 2 represents the computed Pearson correlations between selected Muistikko features and MGCS for VPH-Dare@IT cohort (in columns), and neuropsychological measures, GCS, CSF measures and MRI features (in rows).

Table 2: Comprehensive table of correlation between neuropsychological measures, developed GCS and selected Muistikko features and estimated GCS (MGCS).

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<td>0.52</td>
<td>-0.54</td>
<td>0.69</td>
<td>0.47</td>
<td>-0.52</td>
<td>0.70</td>
</tr>
<tr>
<td>DigitSpanForward</td>
<td>0.28</td>
<td>-0.28</td>
<td>-0.30</td>
<td>0.30</td>
<td>-0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>DigitSpanBackward</td>
<td>0.36</td>
<td>-0.46</td>
<td>-0.45</td>
<td>0.25</td>
<td>-0.37</td>
<td>0.45</td>
</tr>
<tr>
<td>RAVLT/CERAD Learning</td>
<td>0.61</td>
<td>-0.35</td>
<td>-0.38</td>
<td>0.51</td>
<td>-0.38</td>
<td>0.56</td>
</tr>
<tr>
<td>RAVLT/CERAD Recall</td>
<td>0.53</td>
<td>-0.27</td>
<td>-0.35</td>
<td>0.51</td>
<td>-0.24</td>
<td>0.47</td>
</tr>
<tr>
<td>FluencyAnimal</td>
<td>0.53</td>
<td>-0.50</td>
<td>-0.47</td>
<td>0.48</td>
<td>-0.35</td>
<td>0.60</td>
</tr>
<tr>
<td>TMT- A</td>
<td>-0.54</td>
<td>0.64</td>
<td>0.60</td>
<td>-0.43</td>
<td>0.49</td>
<td>-0.67</td>
</tr>
<tr>
<td>TMT- B</td>
<td>-0.53</td>
<td>0.56</td>
<td>0.62</td>
<td>-0.47</td>
<td>0.41</td>
<td>-0.68</td>
</tr>
<tr>
<td>GCS</td>
<td>0.64</td>
<td>-0.47</td>
<td>-0.57</td>
<td>0.60</td>
<td>-0.37</td>
<td>0.70</td>
</tr>
<tr>
<td>Csf-AB</td>
<td>0.27</td>
<td>-0.03</td>
<td>-0.06</td>
<td>0.35</td>
<td>-0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>Csf-Tau</td>
<td>-0.40</td>
<td>0.12</td>
<td>0.14</td>
<td>-0.49</td>
<td>0.21</td>
<td>-0.32</td>
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<tr>
<td>Csf-pTau</td>
<td>-0.25</td>
<td>0.11</td>
<td>0.04</td>
<td>-0.30</td>
<td>0.13</td>
<td>-0.31</td>
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<tr>
<td>MRI-HippoVolume</td>
<td>0.11</td>
<td>0.03</td>
<td>-0.02</td>
<td>0.37</td>
<td>0.13</td>
<td>0.10</td>
</tr>
<tr>
<td>MRI-LateralVentricle</td>
<td>-0.28</td>
<td>0.37</td>
<td>0.32</td>
<td>-0.22</td>
<td>0.29</td>
<td>-0.40</td>
</tr>
</tbody>
</table>

Tables 3 and 4 show classification results when using MMSE, GCS and MGCS to separate subjects with CN from MCI and dementia subjects in the PredictND and VPH-DARE@IT cohort, respectively.
Table 3: Classification accuracies between cognitively normal (CN) and dementia cases (DEM) and between CN and mild cognitive impairment (MCI) cases using MMSE, GCS and MGCS in the PredictND cohort.

<table>
<thead>
<tr>
<th></th>
<th>CN (N=201) vs. MCI (N=83)</th>
<th>CN (N=201) vs. DEM (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MMSE</td>
<td>GCS</td>
</tr>
<tr>
<td>AUC</td>
<td>0.77</td>
<td>0.83</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.86</td>
<td>0.76</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.58</td>
<td>0.74</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.77</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Table 4: Classification accuracies between cognitively normal (CN) and dementia cases (DEM) and between CN and mild cognitive impairment (MCI) cases using MMSE, GCS and MGCS in the VPH-Dare@IT cohort.

<table>
<thead>
<tr>
<th></th>
<th>CN (N=19) vs. MCI (N=38)</th>
<th>CN (N=19) vs. DEM (N=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MMSE</td>
<td>GCS</td>
</tr>
<tr>
<td>AUC</td>
<td>0.81</td>
<td>0.75</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.72</td>
<td>0.75</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.64</td>
<td>0.69</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.88</td>
<td>0.81</td>
</tr>
</tbody>
</table>

In summary, this validation shows that the Muistikko web-based cognitive test battery provides useful information about cognitive decline.
5. DISCUSSION

The key idea behind the citizen platform concept is that it provides a one-point-access to various services for people interested in brain health, including both citizens and clinicians. In addition to providing information about cognitive disorders, the citizen portal should provide efficient tools for assessing brain health. In the future, the platform could provide also tools for personalized life-style interventions to reduce risk factors in the future. Although there are numerous apps and web-tools available for assessing cognition, they are not often evidence-based and certified which limits their use in any serious management of brain health in clinical practice. Today, citizens enthusiastic enough are using these different apps or web-tools of variable quality while clinicians are using their own set of tools for assessing cognition, typically traditional ones with a pen and paper. The ultimate vision behind the citizen platform is to link these two groups in a seamless way which is essential for efficient management of cognitive disorders at early phase. In other words, citizens need to be empowered and efficient modern tools acceptable to clinicians need to be provided.

The citizen platform is not supposed to be a closed system but provide a platform to which external services, such as third-party games or data from different health gadgets, could be plugged in. Only services proven efficient based on scientific evidence should be used. On the other hand, enabling efficient management of cognitive disorders requires that data from the citizen platform is made available for healthcare specialists. In VPH-DARE@IT, we demonstrated communication between the citizen platform and the clinical platform designed for clinical decision support. The citizen can view trends of her/his test and game results in the citizen platform using the new visualization module while a clinician can get a more detailed diagnostic view on the data in the clinical platform. Communication between the platforms was implemented using web-services which could be used also in communication between third-party applications in the future.

The validation of the platform showed very interesting and promising results. The results indicate that the performance is corresponding to the tests used in clinical practice today. This provides strong evidence on the potential of Muistikko in early diagnostics and screening. Muistikko does not only seem to detect dementia cases but is able to separate relatively well also early cases, i.e., subjects with mild-cognitive impairment from cognitively normal subjects. Therefore, the citizen platform has great potential in providing tools for the early detection of memory disorders, one key objectives of VPH-DARE@IT. The platform could be a cost-efficient tool for initial assessment of a patient in a primary care setting, used even independently by citizens at home for assessing their brain health, and be a tool in clinical trials for enriching populations for cost-efficient patient selection. The potential of the tool is demonstrated also by several hospitals indicating their interest to use especially the web-based cognitive test Muistikko both in research and clinical practice.

There are obviously different possible avenues for launching a commercialized version of the citizen platform for memory disorders. The key question is whether citizens or clinicians should be targeted first. Our opinion is that focusing on clinicians is a more straightforward path to start. The project partner Combinostics has recently (7/2017) launched a product based closely on the clinical platform technology developed in VPH-DARE@IT. The citizen platform, especially the cognitive test Muistikko, would be a natural extension in the product offering moving focus more on the primary care setting. The use in the primary care setting would then lead naturally to use cases where citizens would use the tools independently. For example, one use case identified is the group of subjective memory complainers who could use the citizen platform to follow up their progression reducing the need for follow-up visits in clinic.