



Memory Loss and Gains of Older Adults

H2020: Deliverable 1.4

Tallinn 2017

Disclaimer: *This activity is co-financed by H2020 through an SME Instrument Open and Disruptive Innovation. H2020 does not take any responsibility for the contents of this document.*



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Abstract

The current study on short-term memory in later life was conducted within the framework of the EU funded project “SENTAB: Combatting Senior Loneliness through Fun and Entertaining Technology”. The research evidenced that older adult’s self-assessment of their cognitive capabilities tended to be lower than objectively proved. On average senior people assessed their cognitive condition to be fair (1.3 out of 4 possible). Results based on objective memory tests conducted on the Sentab TV system indicated that on average users were able to retrieve information correctly in 66%-70% of cases, which was good (2.8 out of 4 possible). 69% of the pilot cohort felt that their memory improved somewhat or significantly after playing memory games over a 4-week period. The research tested the users’ Cognitive Index©’s over the period of 3 months of Sentab TV usage and evidenced a gradual improvement from 5.59 points in November 2016 to 6.07 points as of end of January 2017.

The authors of this study ran a correlation analysis between different indexes used within the Sentab Index. The analysis proved that there is little correlation between the level of physical activity and cognitive capabilities, which supports a previous study whereby a convincing connection between those two areas was not found. However, there is more significant correlation between the cognitive index and social interaction that leads us to believe that people with healthier social exposure are generally displaying better cognitive capabilities.

1. Introduction

As people age, several changes will occur, biologically and psychologically. It is not primarily about the behavioral or cognitive concomitants of those changes. Nevertheless, there is ample evidence to suggest that alterations in brain structure and function are intimately tied to alterations in cognitive function (McDowd & Shaw, 2000).

Cognitive processes are considered the processes needed for understanding the world and receivable information, including; perception, memory, language, attention, thinking, problem solving, inference, formation of associations, imagination, etc.

Age-related changes in cognition are not uniform across all cognitive domains or across all older individuals. The basic cognitive functions most affected by age are attention and memory. Neither of these are unitary functions, however, and evidence suggests that some aspects of attention and memory hold up well with age while others show significant declines. Perception (although considered by many to be a precognitive function) also shows significant age-related declines attributable mainly to declining sensory capacities. Deficits at these early processing stages could affect cognitive functions later in the processing stream. Higher-level cognitive functions such as language processing and decision making may also be affected by age. These tasks naturally rely on more basic cognitive functions and will generally show deficits to the extent that those fundamental processes are impaired (*Ibid.*, 2000).

Attention is a basic but complex cognitive process that has multiple sub-processes specialized for different aspects of attentional processing. Some form of attention is involved in virtually all other cognitive domains, except when task performance has become habitual or automatic. Declines in attention can therefore have broad-reaching effects on one's ability to function adequately and efficiently in everyday life (*Ibid.*, 2000)

Older adults show significant impairments on attentional tasks that require dividing or switching of attention among multiple inputs or tasks. The tasks on which older adults show impairments tend to be those that require flexible control of attention, a cognitive function associated with the frontal lobes. Importantly, these types of tasks appear to be amenable to training and show benefits of cardiovascular fitness (Glisky, 2007).

Short-term memory or working memory is a multidimensional cognitive construct that has been hypothesized as the fundamental source of age-related deficits in a variety of cognitive tasks, including long-term memory, language, problem solving, and decision making. In fact, the majority of theories of cognitive aging seem to implicate working memory.

Older adults exhibit significant deficits in tasks that involve active manipulation, reorganization, or integration of the contents of short-term memory. Many complex everyday tasks such as decision-making, problem-solving, and the planning of goal-directed behaviors require the integration and reorganization of information from a variety of sources. It seems likely that attention, speed of information processing, and the ability to inhibit irrelevant information are all important functions for effective performance of these higher-level cognitive tasks (Glisky, 2007).

The present Project, funded by the EU H2020 project "SENTAB: Combatting Senior Loneliness through Fun and Entertaining Technology", focuses on the research of short-term memory and attention of older adults using the SentabTV platform for such investigation. The hypothesis of the study is that active engagement with memory related tests and exercises via an electronic display device such as SentabTV helps to increase short-term cognitive agility of people in their later life.

This report will give an overview of the results of the H2020 project on how using SentabTV affects people's short-term memory and attention. The results presented in the report are from a 3 months observation period between November 2016 - January 2017.

2. Studies on short-term memory of older adults

2.1. Classification of memory

Memory refers to an individual's ability to gain and retain useful skills, take on habits, acquire new information and knowledge (Tulving, 2002,).

If people could not remember past events, they could not learn or develop language, relationships, nor personal identity (Eysenck, 2012).

From an information processing perspective there are three main stages in the formation and retrieval of memory:

1. **Encoding** or registration: receiving, processing and combining of received information;
2. **Storage**: creation of a permanent record of the encoded information in short term or long term memory;
3. **Retrieval**, recall or recollection: calling back the stored information in response to some clue for use in a process or activity (Tulving, 2002).

Often memory is understood as an informational processing system with explicit and implicit functioning that is made up of a sensory processor, short-term (or working) memory, and long-term memory (Baddely, 2007).

Memory researchers have classified memory into categories: short- and long-term memory; semantic and episodic memory; implicit and explicit memory.

Short-term memory – stores only certain amount of information until it is being repeated (Tulving, 2002) and until brain processes it. It is only worthwhile to measure and train short-term memory as forgetting and not remembering things that are supposed to be stored in short-term memory is the most disturbing in everyday life.

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Short-term memory allows recall for a period of several seconds to a minute without rehearsal. Its capacity is also very limited: George A. Miller (1956), when working at Bell Laboratories, conducted experiments showing that the store of short-term memory was 7 ± 2 items. Modern estimates of the capacity of short-term memory are lower, typically of the order of 4–5 items (Covan, 2001), however, memory capacity can be increased through a process called chunking.

Chunking is a process by which individual pieces of information are bound together into a meaningful whole (Neath & Surprenant, 2003). A chunk is defined as a familiar collection of more elementary units that have been inter-associated and stored in memory repeatedly and act as a coherent, integrated group when retrieved (Tulving & Craik, 2000).

For example, in recalling a ten-digit telephone number, a person could chunk the digits

into three groups: first, the area code (such as 123), then a three-digit chunk (456) and lastly a four-digit chunk (7890). This method of remembering telephone numbers is far more effective than attempting to remember a string of 10 digits; this is because people are able to chunk the information into meaningful groups of numbers. This may be reflected in some countries in the tendency to display telephone numbers as several chunks of two to four numbers (16).

Long-term memory – storing and retrieving information of life events that took place years ago. Long-term memory can store much larger quantities of information than short-term memory for potentially unlimited duration (sometimes a whole life span). Its capacity is immeasurable.

Procedural, semantic and episodic memory are all types of long-term memories:

1. Procedural memory – unconscious memory of skills (incl. reading, writing);
2. Semantic memory – general world knowledge;
3. Episodic memory – memory of autobiographic events.

Semantic and episodic memory store information very quickly and it has got the worth of the truth (Tulving, 2002).

Explicit and implicit memory help to retrieve events and skills from the past. Explicit and implicit functions of memory are also known as declarative and non-declarative systems. Declarative memory is the conscious storage and recollection of data and the primary process thought of when referencing memory (Eysenck, 2012).

Memory is dependent on concentration. Memory will not activate if a person does not concentrate (Arden, 2009).

To retrieve information from memory there first has to be information that is stored in memory and secondly, information that is used as an incentive to retrieve. An incentive as well as stored information are both necessary for retrieving, but first there has to be an engram (Tulving, 2002).

What a person remembers depends largely on what he/she perceives, learns, thinks, feels or experiences. Thus, memories are very similar to what he/she sees or thinks. The way a person perceives things, depends on prior knowledge. Memory controls perception and other mental activities.

Everyday functioning of an elderly person depends on their intellectual and mental capabilities. One of the most obvious changes that accompanies aging is the increase of response time. The fact that, irrefutably, almost everyone's response time increases with age does not mean that all other mental capabilities are in decline as well. Scientists are convinced that the main reason behind the decline of mental capabilities in old age is the general deceleration of thinking process. It is believed that slow thinking is caused by lower performance of the brain cells (Bragdon & Gamon,, 2011).

In comparison to younger people, elderly people perform memory related exercises worse even if there is no time limit. For instance, they struggle to remember the details of a newspaper article, while younger people do not. Researchers believe that slower information processing is a typical reason for memory impairment. They claim that as information processing is slow, some of it will get lost before it gets processed and stored. In this case the brain is not able to form the bits of information into a whole that is important for memorizing facts (*Ibid.*, 2011).

2.2. Memory loss and forgetting

Memory loss is not an inevitable part of the aging process. The brain is capable of producing new brain cells at any age, so significant memory loss is not an inevitable result of aging. But just as it is with muscle strength, people have to use it or lose it. The lifestyle, health habits, and daily activities have a huge impact on the health of brain. Whatever the person's age, there are many ways he/she can improve his/her cognitive skills, to prevent memory loss (Covan, 2011).

Three causes of age-related memory loss are:

- The hippocampus, a region of the brain involved in the formation and retrieval of memories, often deteriorates with age;
- Hormones and proteins that protect and repair brain cells and stimulate neural growth also decline with age;
- Older people often experience decreased blood flow to the brain, which can impair memory and lead to changes in cognitive skills (*Ibid.*, 2011).

For most people, occasional lapses in memory are a normal part of the aging process, not a warning sign of serious mental deterioration or the onset of dementia (*Ibid.*, 2011).

The following types of memory lapses are normal among older adults and generally are not considered as warning signs of dementia:

- Occasionally forgetting where you left things you use regularly, such as glasses or keys;
- Forgetting names of acquaintances or blocking one memory with a similar one, such as calling a grandson by your son's name;
- Occasionally forgetting an appointment or walking into a room and forgetting why you entered;
- Becoming easily distracted or having trouble remembering what you've just read, or the details of a conversation;
- Not quite being able to retrieve information you have "on the tip of your tongue." (*Ibid.*, 2011).

The loss of memory is described as forgetfulness. Each day of a person's life consist of a series of episodes and each episode in turn, consist of a series of events. What happens to memory when a person tries to recall a full and detailed story?

First, the story a person recalls will be selective. People do not recall everything they are capable of remembering in most instances (Marsh, 2007). The reasons for this selectivity are multiple, but it is often the case that selective remembering occurs, not just overtly, but also covertly.

Second, because remembering is selective, a person will recall some aspects of a memory and not others. The positive effect of rehearsal on memory is perhaps one of the most well-established principles in the psychology of memory. What happens to those memories that person does not recall, that remain mnemonically silent? The absence of rehearsal allows the unrecalled memories to decay. Not all mnemonic silences are mnemonically equal. After selectively recalling person will be more likely to forget (or at least, fail to remember) unmentioned events related to the recalled memories than unmentioned, unrelated events, a pattern of remembering and forgetting referred to as "retrieval-induced forgetting" (Andreson *et al*, 1994).

The usual psychological account of the retrieval-induced forgetting phenomenon involves inhibition (Storm & Levy, 2012).

When a person remembers selectively one thing, he/she ends up inhibiting the other memory. It is not that person aware of that the memory is inhibited, but successful remembering involves inhibiting competing responses. As a result of the selective inhibition, there is selective forgetting (Kattago, 2015).

2.3. Memory training in later life

With constant training it is possible to improve memory up to a certain extent. There are two aspects of memory training: specifics of processing and specifics of a task. Memory improvement that is achieved by using a scientific strategy, only concerns a part of one certain type of memory, not memory as a whole. It is possible to improve a person's memory by refining different memory components.

1. **Encoding:** An effective method to help memorize a read material is to ask questions about it. It reflects the level of concentration and understanding the information. Reading or listening to the text again with more attention helps, if the person cannot answer the questions straight away. Repeating is the best way to memorize something.
2. **Retrieving:** Retrieving is dependent on hints and incentives that stimulate recalling. These hints can be conscious (explicit) or unconscious (implicit).
3. **Storing:** Forgetting characterizes the difference between stored information and retrieved information. Most of the psychologists believe that forgetting in sensory memory is in correlation to fading of sensory information as old information in

short-term memory is superseded by new information. Forgetting in long-term memory, if it is not caused by difficulties of accessing the stored information, is caused by interference, i.e. decline of retrieving due to acquiring new information (Tulving, 2002, p 102).

The present project is built on the premise that regular exercise of encoding and retrieving, and in some cases storing, helps to improve the short term memory and contribute to the improvement or maintenance, as opposed to deterioration of cognitive capabilities over certain time interval. Obviously, the study period is far too short to make a convincing arguments about the applicability or non-applicability of the hypothesis, but it reveals some interesting feedback from the pilot user group that helps authors to study the process further.

3. Methodology of the Study

3.1. Participant profile

The following criteria were defined towards the older adults, who were enrolled into Sentab study:

1. Age 64 years and over;
2. Access to Internet as Sentab TV device requires online connectivity;
3. Availability of flat screen TV that acts as an interface to SentabTV box;
4. Confirmation of free will of participating in the study by signature of Informed consent letter.

The enrolled were expected to participate in follow-up questionnaires for qualitative analysis and be available for one-to-one interviews.

There were 28 older adults in total participating in the project – 16 people were from Estonia and 12 from the UK. Different onboarding methods were used in UK and Estonia. In Estonia, most of the participants were found and solicited to participate in the project via participation in an annual 65+ fair for older adults. In UK, most of the people onboarded into the study were older adults living in Croydon area, where the onboarding was assisted by Croydon council. The users were not paid for their participation, but were given the Sentab TV device and activity monitor for free for the period of the project. The people were also assisted with installing Sentab TV and provided an onboarding tour over the functionalities that the system had.



Figure 1. Sentab TV as a display device

The project group consisted of 7 men and 21 women. All the participants were answering self-evaluation question about their memory condition that was brought to them via Sentab TV on a 7-day interval. Participants were asked to play three memory games weekly, which are available via the Sentab environment, and answer the post-video questions about the video content.

The approach taken to validate the encoding and retrieval practices was based on the proven approach of using memory exercises, with the novel approach of delivering those over a TV based display device, whereas the results of those activities were automatically collected and represented in Sentab Cognitive Index©. Also, the project used a novel approach of posting questions to the user after the user watched a certain piece of media. It tested both, the attention as well as storing and retrieval capability of a user and aggregated these results into Sentab Cognitive Index©.

Since the 12 users from the UK joined the project only in December, their data is not added to the report due to the short term of user involvement. However, their data will be included into the final report that will be done by the project ending in March 2017.

Therefore, this report summarizes the answers from the self-evaluation questionnaires filled by 16 Estonian participants, including 14 women and 2 men.

3.2. Research methods

3.2.1. Quantitative approach

The **quantitative** study is built up on collecting data from Sentab system on the basis of research questions and statistical analysis of the data retrieved from the use of the system. Quantitative data is an objective data received from memory tests and exercises that users engaged into that was aggregated via automated algorithms. One of the hypothesis of the study was that using memory games and post-video questions on Sentab system helps older people improve their short-term memory.

During the quantitative study the information that is being collected from the Sentab system, includes:

Table 1. Data collected from Sentab TV

Data collected from Sentab	
1	Weekly responses on self-evaluation questions
2	Post-video response (memory questions)
3	Picture test results
4	Word test results
5	Sudoku game results
5	Cognitive Index dynamics
6	Correlations between Indexes

Memory tests

Research topic:	Memory Loss / Gain of older people
Research question:	To what extent do users' short-term memory improve / worsen when using Sentab? This question aims to provide information on the effects that Sentab system might have on users' mental health and memory agility

Within three months (Nov 2016 – January 2017) users have played memory games on a daily basis and answered self-evaluation questions once a week.

The most common tests to measure memory are the ones that require retrieving and recognizing the presented data. This data may be visuals, media, text etc. Sentab has designed experimental tests and games for its TV interface, primarily as a means to engage people with no other tools to access online services, although it was observed that even people with online access were eagerly using the large screen device for these exercises. The tests designed by Sentab are primarily focused on testing and developing encoding and retrieval skills, and are based on frameworks recognized by cognitive researchers. During the development of these tests, however, it was necessary to accommodate the tests for the said TV interface, i.e. support D-pad navigation and interaction via remote.

1. Encoding

The best way to memorize read/heard/seen information is to ask questions about it or evoke exercises that require some sort of encoding to be able to retrieve the information. The example of the memory test requiring encoding is the word test, which displays 9 words and requires memorizing and marking them in the next screen.

2. Retrieval: training and measuring short-term memory

Retrieval is evoked by hints and incentive. Incentives may be conscious (explicit) or unconscious (implicit). The incentives used by Sentab are around gamification that present feedback to users on how they did. Also, the results are captured in Cognitive

Index© that users can monitor dynamically. With poor test results the Index will decrease and, accordingly, with better precision the results will improve. The examples of the exercises requiring retrieval are the word test, the picture test, questions after media clips.

These memory exercises are described in more details below.

Tests used by Sentab

Sentab test 1: Answering to questions about watched material

On one hand it is an encoding exercise, but on the other hand it is based on recognizing in the condition of forced choices. It shows how successfully the user can recall what he/she saw, to find correct answers to the questions among given options.

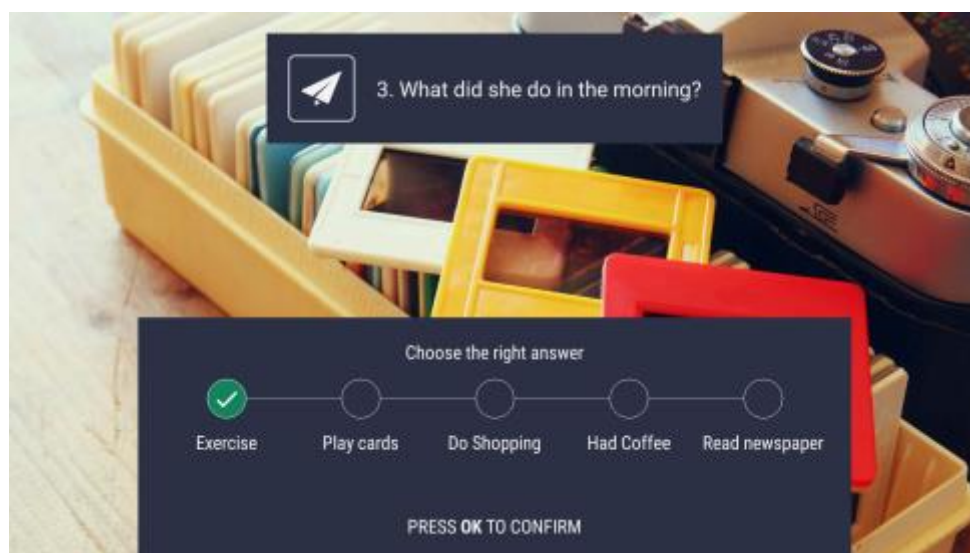


Figure 2. Post media questions

As a result of the test it will become evident how many times after watching the video the user has answered questions and how many of them were correct, which indicates how well he/she was able to memorize the material.

Table 2. Grading scale based on post-media questions

Remembering i.e saving the material	Scale	
Memory questions answered (number)	0	Bad
	1-5	Fine
	6-10	Good
	11 and more	Very Good
Questions answered correctly (%)	0	Very Bad
	1-19	Bad
	20-39	Fine
	40-59	Good
	60-79	Very Good

	80-100	Excellent
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Sentab test 2: Word retrieving test

The idea of the Word test is taken from SHARE¹ (Survey of Health Ageing and Retirement in Europe) initiative and was adjusted for the Sentab TV interface. This test was an encoding test in SHARE, but in Sentab it is both encoding (although using visual encoding) and also a recognition test, because it is difficult to receive and process a verbal response via TV.

The following snapshot illustrates the first screen of the word test, where 9 random words are shown during 20 seconds that the subject has to memorize the words. These words are shown in a local language, such as Estonian for Estonians participating in the project, and English for the English speakers.

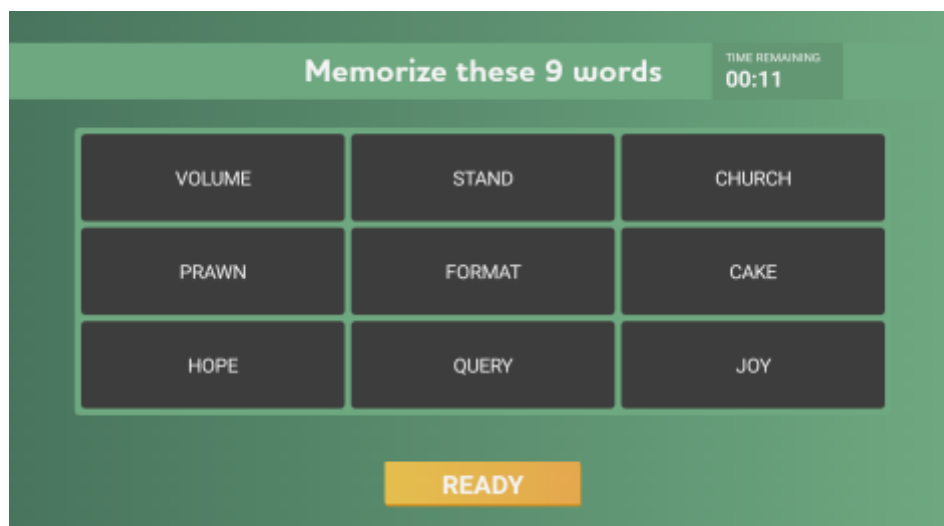


Figure 3. Word test, first screen

In the next screen, 20 words are displayed, including 9 words that were previously shown. The subject must recognize these 9 words by clicking on the words and finally submitting his or her response via pressing Done button below the matrix table.

¹ SHARE - The Survey of Health, Ageing and Retirement in Europe is a multidisciplinary and cross-national panel database of micro data on health, socio-economic status and social and family networks of more than 123,000 individuals (approximately 293,000 interviews) from 20 European countries (+Israel) aged 50 or over.
<http://www.share-project.org/data-access-documentation.html>

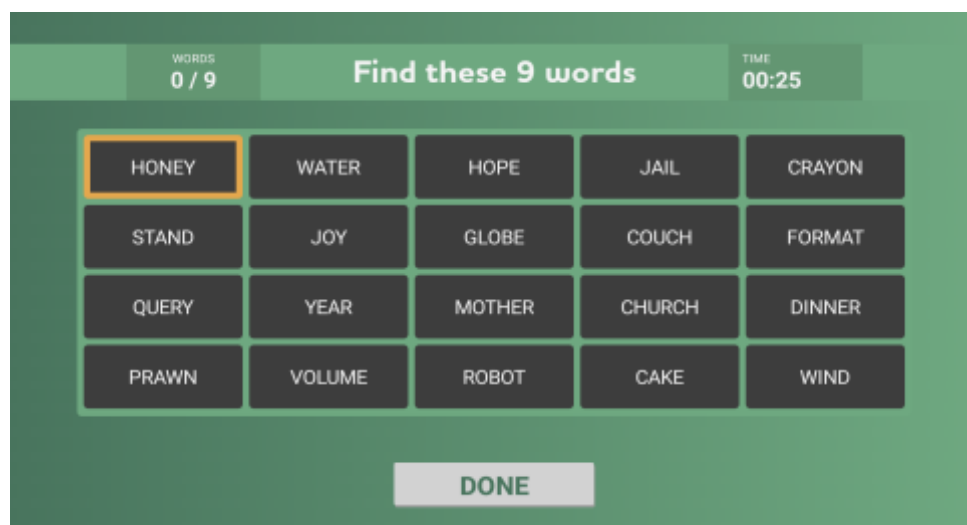


Figure 4. Word test, second screen

The word test measures both the recognition of words as well as the reaction time of the participant. combined result is displayed by showing the total score. However, the Sentab Cognitive Index© accounts only for the correct number of words selected out of 20 available ones and does not currently include reaction time.



Figure 5. Word test, final screen

Table 3. Grading scale for the word game results

Measured by system	Scale	
Test: Memorizing (recognition of) words - number of tests done	0	Bad
	1-2	Fine
	3-4	Good
	5 and more	Very good

Test: Memorizing (recognition of) words - result of the tests	0	Bad
	1-4	Fine
	5-7	Good
	8-9	Very good

Sentab test 3: Repeated image test

The test measures a user's short-term memory and is based on recognition in condition of free choice. A series of images will appear during the test. In total, there are 50 consecutive images based on 25 different pictures. These pictures are repeating randomly and the user has to recognise when the image is repeated. The number of images or how many times a particular image might repeat is unknown to the user. The user is required to click on the image if the image has already been displayed at least once before.

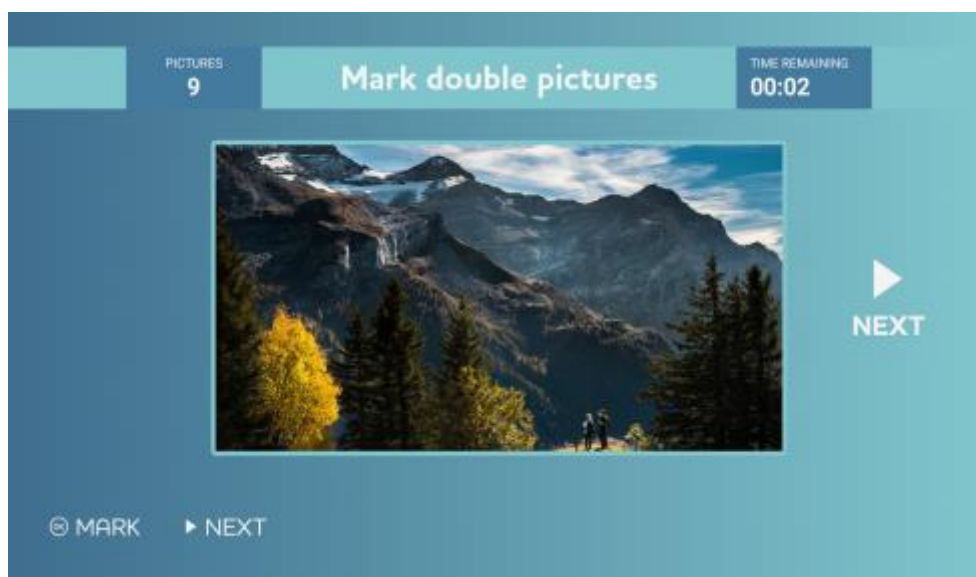


Figure 6. Image recognition test, example screen

The results are presented as a number of correct answers out of 50 correct possible, displaying also the highest score that was previously achieved by the same user.

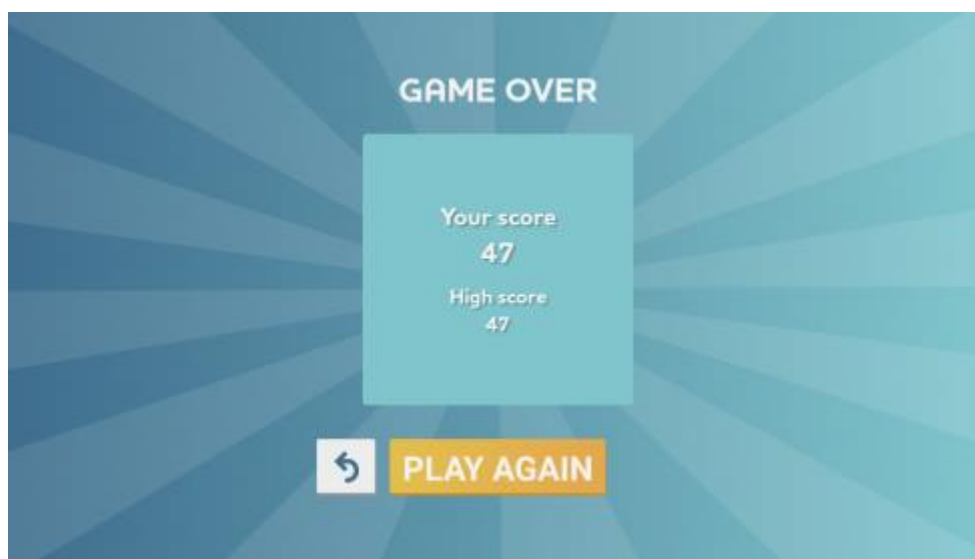


Figure 7. Image recognition test, final screen

A very good performance is considered to be 90% correct answers based on 50 views, meaning 45 or more correct answers.

Table 4. Grading scale for the image recognition test

Measured by system	Scale	
Test: Slideshow: Picture recognition test - number of tests played	0	Bad
	1-2	Fine
	3-4	Good
	5 and more	Very good
Test: Slideshow: Picture recognition test - results	0	Very bad
	1-24	Bad
	25-34	Fine
	35-44	Good
	45-50	Very good

Sentab test 4: Sudoku

Sudoku is a logic-based, combinatorial number-placement puzzle. Sudoku develops users' attention and concentration.

The user can choose between four levels: Tournament (3 x easy levels + 3 x medium levels + 3 x hard levels), easy (4 by 4 sudoku), medium (6 by 6 sudoku), hard (9 by 9 sudoku) levels.

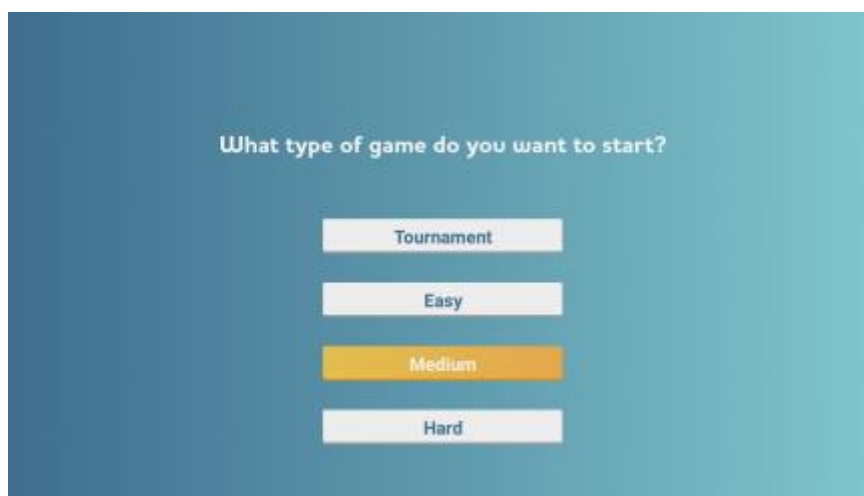


Figure 8. Sudoku

User can do 4 mistakes on an easy level, 6 mistakes on a medium and 9 mistakes on a hard level.

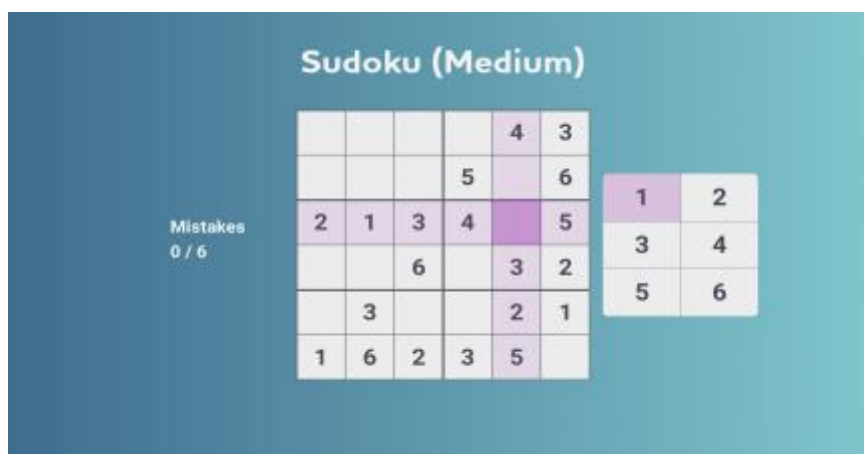


Figure 9. Sudoku

The algorithm for calculating and capturing the results of Sudoku within the Sentab Cognitive Index© was changed in January 2017. As such the results of Sudoku are not reflected in this report. They will be presented in the final report.

2.2.2. Qualitative approach

The qualitative study is built up on the self-evaluation question about memory on the weekly basis. The question that pops up once a week on the user's screen is: "How would you rate your memory during past 7 days?". The options vary between Bad to Great.



Figure 10. Rating memory over Sentab TV interface

Both qualitative and quantitative results of the study are presented as Cognitive Index© within Sentab Index©. This is explained in more details in the next section – otherwise the reader can jump over the section and proceed to the results of the study.

Sentab Index© captures also Social Index© and Physical Index© that are discussed in separate papers that can be found on Sentab’s web page (www.sentab.com).

3.3. Indicators and outcomes

3.3.1. Sentab Cognitive Index

Sentab have developed the Sentab Index© – way of capturing and representing behavioral and wellbeing data over Sentab devices.

The SentabTV platform was chosen as a data input device for several reasons – firstly, on average, the demographical group benefitting from this data interpretation is generally older. Older adults spend on average more than 4 hours a day viewing TV. Sentab is willing to transform this experience by adding more social interface to the TV, but also making use of the time spent with TV to feedback useful statistics to the viewer.

The Sentab Cognitive Index© is a dynamic score on a scale of 1 to 10 that measures user’s cognitive state and is represented in an easy to understand numeric form. It is based on empirical findings about the cognitive state in maintaining higher quality of life.

The Cognitive Index© is represented through a value with an explanation of what that value entails. Users can also benchmark their results towards historic values and make a conscious judgment about their progress. At present the system does not help to develop the encoding capabilities of users’, although it is planned to add this section to SentabTV to enable people to systematically develop this skill.

There are natural limitations to Sentab's approach. Sentab can generate meaningful data analysis about person's cognitive condition only through the use of Sentab technology that enables to aggregate and interpret the data accordingly.

Sentab Cognitive Index© is based on the algorithms analyzing the results from cognitive tests pushed by the system, queries on watched media and navigational analysis.

Table 5. The indicators measured by Sentab Cognitive Index©

The measurable indicators in Sentab
Self-evaluation
Self-evaluation questions on perceived memory condition
Measured by system
Test 1: Memorizing words- number of tests passed
Test 1: Memorizing words- results
Test 2: Picture recognition test - number of tests passed
Test 2: Picture recognition test - results
Test 3: Sudoku - number of tests
Test 3: Sudoku - results
Remembering i.e saving the material
Number of videos watched
Memory questions – number of questions answered
Post video questions answered correctly (%)

The cognitive section is in constant development and increasing data points are being adopted for an aggregated representation of behavioral and cognitive state of the user.

Presenting the data to the user

User level access to cognitive information is organized through a “Statistics” module in Sentab. Users who have been included in the statistics group receive information about their cognitive condition in the format of Sentab Index© and Cognitive Index©.

Both qualitative and quantitative indicators are collated under the Cognitive Index© alongside with motivational feedback. Users can compare their results with two previous months.

The below screen-capture is an example of Sentab Cognitive Index© presented to users via Sentab.



Figure 11. Cognitive Index© representation

2.2.3. Results from the Study

The **quantitative indicators** are collected through SentabTV interface and quantified based on the outcomes of memory exercises and post-video memory questions. The **qualitative indicators** are based on field questionnaires that were filled in by users after the first observation period and information collected from Sentab TV interface about one's memory condition (self-evaluation).

The hypothesis we wanted to test during the study was whether routine practice of memory exercises and stimulating memory by asking media related questions via Sentab TV system helps older people to improve their short-term memory condition and attention attributes.

The first interesting outcome of the conducted study is that similarly to the previous findings about the responses on one's health condition (see previous study conducted by Sentab on Physical Activity in Later Life), older adults tend to be very conservative regarding their cognitive capabilities. When they were asked a weekly question about their memory condition "How would you rate your memory during the past 7 days?", the average response was between "fine" and "good" with a numerical representation of 1.31 out of 4 possible (see Table 6 below).

Table 6. The scale and results for self-evaluation

Self-evaluation of memory (Avg)	
1.31	
Scale	
0	Bad
1	Fine
2	Good
3	Very good
4	Great

As evidenced shortly by quantitative analysis, on average users were able to retrieve information correctly in 66%-70% of the cases and around 80% in the case of image retrievals, which indicate that their cognitive capabilities are in fact between “good” and “very good” by Sentab’s classification. In numeric representation that would be 2.8 out of 4 possible. Hence, the conscious feeling of respondents about their memory condition was on average 1.5 points lower based on qualitative assessment compared to the quantitative one.

61% of the same pilot users (8) felt that their memory did improve somewhat after being asked if playing memory games influenced their memory (and attention) during the past 4 weeks. 7.7% (1) considered that exercises have significantly improved their memory and attention. The rest of the people considered their memory remained the same, however it is important to also mention that they were the ones who did not use or used rarely the memory training part of the system.

The people who regularly used memory exercises all observed improvement in their short-term memory condition. It is subjective feedback though. To test that feedback, the study observed also the dynamics in Sentab Cognitive Index©, which summarized the quantitative results from memory exercises.

The Cognitive Indexes© of Sentab individual users are shown in the Figure 12 alongside months. Indeed, it can be seen that there is slight month-over-month improvement in Sentab Cognitive Index© as per Table 7. Also, Figure 12 indicates that the improvement happened primarily with the individuals who started off with a Cognitive Index© levels between 4 to 7, whereas the ones who started off at very high points, above 7 generally were maintaining similar cognitive agility.

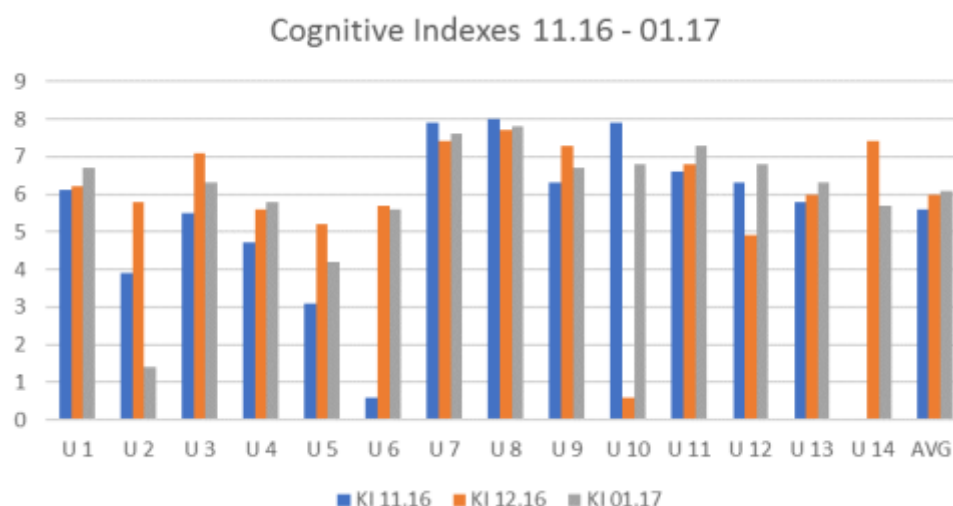


Figure 12. Cognitive Index© per user in the project

The index for the month of November 2016 was 5.59 out of 10 possible, while it slightly increased by end of December 2016 to 5.98 and finally to 6.07 by end of January 2017. This is showing a positive trend towards improvement, that is statistically relevant and confirming the subjective feedback from the project participants where a majority of the respondents felt that their memory has somewhat improved.

Table 7. The month-on-month dynamics of the Cognitive Index©

Cognitive Indexes			
Users	KI 11.16	KI 12.16	KI 01.17
AVG 14	5.59	5.98	6.07

Getting into higher granularity of the memory exercises, Table 8 summarizes the findings over the observation period of 72 days. The people in the cohort were engaged in memory exercises between 14 to 16 days during that time period. On average that is every fifth day or roughly one to two times a week. As seen in the below table, some users were more pro-active in exercising and were engaging regularly, while others were occasionally.

Table 8. The user level insights to memory exercises

Users	Picture game				Words game				Sudoku		
	Days	Games	Result	Games per day	Days	Games	Result	Games per day	Days	Games	Games per day
U 1	31	99	44.97	3.2	30	161	7.63	5.4	16	38	2.4
U 2	7	12	45.58	1.7	6	10	5.90	1.7	2	5	2.5
U 3	7	9	45.11	1.3	7	15	8.00	2.1	0	0	0.0
U 4	22	37	43.70	1.7	24	199	7.61	8.3	16	24	1.5
U 5	15	15	42.33	1.0	17	33	7.58	1.9	0	0	0.0
U 6	5	9	43.78	1.8	3	7	8.43	2.3	1	2	2.0

U 7	2	2	48.50	1.0	1	5	7.40	5.0	2	3	1.5
U 8	56	135	43.97	2.4	56	787	7.47	14.1	33	86	2.6
U 9	3	4	36.25	1.3	2	8	7.38	4.0	2	2	1.0
U 10	7	14	37.71	2.0	3	7	7.43	2.3	0	0	0.0
U 11	30	40	44.98	1.3	3	3	6.67	1.0	17	83	4.9
U 12	1	1	34.00	1.0			0.00	0.0	0	0	0.0
U 13	2	2	45.50	1.0	23	131	7.18	5.7	29	63	2.2
U 14	5	5	38.60	1.0	3	14	7.00	4.7	0	0	0.0
U 15	62	278	47.97	4.5	42	192	7.23	4.6	17	94	5.5
U 16	1	1	22.00	1.0			0.00	0.0	0	0	0.0
AVG	16	41.4	41.6	1.7	13.75	98.3	6.4	3.9	8.4	25.0	1.6

From type of exercises preferred by the users, it is seen that word test was the most popular one. If we exclude the passive memory trainees, we can see that the exercise was played from low tens to a whopping 787 times by one pilot user. It can be also seen that there are 5 very active group members who engage systematically into memory training. We consider though the percentage of active users still very good, as normally less than 5% of online users engage into playing games.

On average, older adults were able to retrieve correctly 71% of the words with an average outcome of 6.4 correct words per 9 words displayed. This is considered as “good” by Sentab scale.

The second most popular exercise was image retrieval game that was played between low tens to 278 times. On average, this was 41 times per single user, which means that when a user entered the memory exercises section they likely played a sequence of 3 picture games at a time.

On average, they answered correctly in 41.6 cases out of 50 – or slightly above 80% of the cases. This is classified as “good” by Sentab grading scale.

Sudoku was running behind word recognition and image retrieval exercises. It was however likely due to the length of the single game, and time-wise that users spent on the system Sudoku accounted for the most. Hence, while it was played the least, it can be considered the most engaging exercise or game.

The authors were also interested to learn what type of methodology people were using to encode the information. It is important to mention that the users were not given any instructions on how to memorize words. When asked about the methods that users were applying for the encoding, 6 users said that they read all the words line by line and tried to find connections between them. 2 people tried to group words according to the first letters, where possible. 2 people were finding associations with each individual word they went through, so that these associations could be evoked when the selection of 20 words were displayed. Hence, people are consciously finding encoding techniques to improve their memory, when the situation calls for it. This is also a good way how to stimulate people to improve their short term memory agility.

The authors of the study wanted to also test long term memory or the storage element of the memory classification. Hence, a sample of 5 pilot users were approached without any advice notice and were asked the memory game questions they had answered a month ago to validate if the information had been stored correctly in users' memory. 2 pilot users (40%) out of 5 remembered the answers to all the 3 questions asked, 2 people remembered two correct answers (40%) and 1 person (20%) remembered one correct answer. Considering that about 80% of respondees remember either all or 2/3-s correctly, that was showing also a good level of long term memory condition.

Another quantitative method used in the project was based on probing the questions after a certain media clip was viewed by the user. The selected media was typically few minutes long and the question was related to the contents of the media. As short term memory was tested, it usually concerned a matter that was displayed in the midst of the media clip and a responder had multiple answers to choose from. In total, 7 videos were loaded into the system and these were viewed by 9 people out of 13 in total for 61 times. The videos covered different topics such as nature, health and healthcare, books and Christmas topics (as the observation period included Christmas).

Of these 61 views, people responded on the questions correctly in 36 cases. This is around 60% of the time. However, the nature of the memory test in the present case was somewhat different from the previous ones as post-media questions also relied on the attention of a person and users had limited possibility to encode the information in a structured approach like they did it with the games.

Therefore, we can conclude that using different tests and approaches we saw that on average people were capable of retrieving information correctly between 60%-70% of time. The best result was 71% and the lowest one was 50% of correct answers.

The authors also run a correlation analysis between different indexes used within Sentab Index. The analysis proved that there is a little correlation between the level of physical activity and cognitive capabilities, which generally proves the previous studies which did not find a convincing connection between those two areas. However, there is somewhat more significant correlation between cognitive index and social interaction that leads to believe that people with healthier social exposure are generally displaying better cognitive capabilities.

Table 9. Correlations between different Sentab indexes

Indexes	Correlation
Cognitive and Physical Indexes	0.276
Social and Physical Indexes	0.431
Cognitive and Social Indexes	0.511

Key Findings

- Older adults tend to be conservative in their estimation of their cognitive capabilities. The qualitative feedback from older adults rated their short-term memory at 1.3 points out of 4 possible, the quantitative study proved it to be closer to 2.8 out of 4 possible. On average users were able to retrieve information correctly 66%-70% of the time and around 80% for image retrievals, which indicates that their cognitive capabilities are in fact between “good” and “very good” by Sentab’s classification;
- 61% of the pilot users felt that their memory did improve somewhat after being asked if playing memory games influenced their memory (and attention) during the past 4 weeks. 7.7% considered that exercises have significantly improved their memory and attention. This was also backed up by observing quantitative data – the index for the month of November 2016 was 5.59 out of 10 possible, while it slightly increased by end of December 2016 to 5.98 and finally to 6.07 by end of January 2017. This shows a positive trend towards improvement, that is statistically relevant and confirms the subjective feedback from the project participants where the majority of the respondents felt that their memory has somewhat improved;
- The improvement happened primarily with the individuals who started off with a Cognitive Index© levels between 4 to 7, whereas the ones who started off at very high points, above 7 generally were maintaining similar cognitive agility;
- The people in the cohort were engaged in memory exercises between 14 to 16 days during that period. On average that is every fifth day or roughly one to two times a week;
- The authors also ran a correlation analysis between different indexes used within Sentab Index©. The analysis proved that there is a little correlation between the level of physical activity and cognitive capabilities, which generally proves the previous studies which did not find a convincing connection between those two areas. However, there is more significant correlation between the cognitive index and social interaction that leads us to believe that people with healthier social exposure are generally displaying better cognitive capabilities.

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