Information Technologies for Cognitive Decline

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Abstract

Information technology (IT) is used to establish a diagnosis and provide treatment for people with cognitive decline. The condition affects many before it becomes clear that more permanent changes, like dementia, could be noticed. Those who search for information are exposed to lots of information and different technologies which they need to make sense of and eventually use to help themselves.

In this research literature and information available on the Internet were systematically analyzed to present methods used for diagnosis and treatment. Methods used for diagnosis are self-testing, sensors, Virtual Reality (VR), and brain imaging. Methods used for treatment are games, websites with information and media, Virtual Reality (VR), sensors, and robots.

The resulting concept of knowledge was the basis of an artifact whose main goal was to present the facts to the broad public. This implied that a user-friendly artifact was developed through three iterations using the Design Science framework. A total of nine users and IT usability experts have evaluated the artifact returning the SUS score of 85,83 for users and 87,5 for IT usability experts. Nielsen´s heuristics were assessed by IT usability experts only, returning an average score of 4,28. The general response was positive regarding both the content and the attempt to present methods used in cognitive decline. It reminds to be seen how to bring this knowledge to those who are most affected by the decline.

Keywords. Cognitive decline, information technology (IT), interaction design, dementia, artifact, diagnosis, treatment, design science.

Abbreviations

AAA – Animal-Assisted Activities

AAT – Animal-Assisted Treatment

AD – Alzheimer´s Disease

AI – Artificial Intelligence

BAN – Body Area Networks

BNT – Boston Naming Test

BOLD – Blood Oxygen Level-Dependent

CST – Computerized Self-Test

CT – Computerized Tomography

DOBA – Detection of Behavioral Anomalies

DOLA – Detection of Locomotion Anomalies

DTI – Diffusion Tensor Imaging

EEG – Electroencephalogram

e.g. – For example

eHealth – Electronic Health

EMS – Event Monitoring System

fMRI – functional Magnetic Resonance Imagining

Gait Analysis – Analysis of movement

GRE – Gradient-Recalled Echo

HC – Healthy Control

HCI – Human-Computer Interaction

HRV – Heart Rate Variability

IADL – Instrumental Activities of Daily Living

IT – Information Technology

KIST – Korea Institute of Science and Technology

MCI – Mild Cognitive Impairment. Initial stages of cognitive decline

Mini-Cog – Mini-Cognition

ML – Machine Learning

MMSE – Mini-Mental State Examination

MoCA – Montreal Cognitive Assessment

MOCIA – Maintaining Optimal Cognitive Function in Ageing

MRI – Magnetic Resonance Imagining

MTL – Medial Temporal Lobe

Multimorbidity – People with multiple health conditions

NSD – Norwegian Centre for Research Data

OERS – Observed Emotion Rating Scale

PD – Proton Density

PDA – Personal Digital Assistant

PET – Positron Emission Tomography

PIR – Passive Infrared

PP – Paper and Pencil

PTSD – Posttraumatic Stress Disorder

RQ – Research Question

SAC – Self-Assessment of Cognition

SAGE – Self-Administered Gerocognitive Exam

SCD – Subjective Cognitive Decline

SG – Serious Game

SPECT – Single Photon Emission Computerized Tomography

SUS – System Usability Scale

SVM – Support Vector Machine

UCD – User-Centered Design

UI – User Interface

UML – Unified Modeling Language

UX – User Experience

VaD – Vascular Dementia

VR – Virtual Reality

VUI – Virtual User Interface

VUM – Virtual User Model

WMH – White Matter Hyperintensities

XAI – Explainable Artificial Intelligence

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Chapter 1

1 Introduction

Memory lapses are the first indicators of Cognitive Decline. This can be attributed to exhaustion or stress alone, and is frequently linked to more serious brain abnormalities, which can lead to long-term problems (Allan et al., 2017).

Clinical research is focusing on the early diagnosis of illness development, however it can be difficult to establishing a diagnosis, especially in early phases (Lin et al., 2019). Clinical tests are an objective technique for documenting symptoms. Doctors and psychologists sometimes utilize other tests. Most of them appear to be done on paper and during doctor's visits. When it comes to therapy, several strategies and procedures are employed in clinical practice, but it is less obvious how to recognize cognitive decline, evaluate its severity, and keep it under control. Choices of proper diagnostic and treatment approaches are a concern for both health care professionals and patients.

Information Technology (IT) provides lots of tools, but it is not always clear which ones are the best for the situation. Even medical experts are frequently questioned about IT-based options for assisting patients in monitoring and treating their conditions. Games (Manera et al., 2017), Virtual Reality (VR) (D´Cunha et al., 2019) (Morganti and Riva, 2014), and personalized service robots (Goda et al., 2020) are just a few of the IT solutions created for patients.

This research project explores what can be done to conceptualize tests of cognitive decline, describe information about IT solutions, and design an artifact that can make knowledge more accessible. Experts and some potential users were used to evaluate the IT design solutions generated during the research. We aimed at formulating what user demands IT solutions could be able to address, and how (Allan et al., 2017). The goal of this study was to evaluate various IT solutions for detecting cognitive decline and preventing it from progressing to disorders like dementia.

1.1 Research Questions Background

When addressing the topic *"Information Technology Solutions for Cognitive Decline"* there are two main areas that need to be covered in this research project. One practical which focuses on the IT solutions for cognitive decline, and another technical, which focuses on interaction design.

1.2 Research Questions

These are the Research Questions (RQ) formulated for this research project:

RQ1: *How to structure concepts and scopes of the current IT solutions used in the assessment and treatment of cognitive decline?*

RQ2: *What are the IT solutions that could be offered to support establishing diagnosis and treatment of people in whom the decline is objectively confirmed?*

RQ3: *How are degrees of cognitive decline influencing the design of the IT solutions?*

RQ4: *What is the clinical staff´s perspective on the usage of the IT solutions?*

RQ5: *Is there any user-friendly way to inform potential users about the available IT technology?*

1.3 Contribution

This research project contributes with information, knowledge, and an artifact to share and inform about possibilities that IT can contribute to the field of cognitive decline. The research will employ methodologies and methods of Information Science to organize findings and create an artifact.

1.4 Thesis Outline

The outline of this research project:

Chapter 2: Medical Theory describes cognitive decline from the clinical point of view.

Chapter 3: Literature Review presents articles and other sources of information relevant to this research project.

Chapter 4: Methodologies and Methods explains the methodologies and methods used throughout this research project to first summarize the results of the literature review and then develop an artifact. The Design Science framework is described here.

Chapter 5: Requirements presents the ethical considerations, target group, participants of the project, as well as functional and non-functional requirements.

Chapter 6: Prototype Development displays tools used for prototyping and the three design iterations.

Chapter 7: Evaluation summarized the results gathered from the third design iteration. Results of the System Usability Scale (SUS) and Nielsen´s heuristics are presented here.

Chapter 8: Discussion goes through all the methodologies and methods used, as well as the development process. This chapter answers the research questions.

Chapter 9: Conclusion concludes the project with a summary.

Chapter 10: Future Work describes future work recommendations.

Chapter 2

2 Medical Theory

Cognitive decline is a condition that makes the people who suffer from it face numerous difficulties. Memory loss, orientation, language, and comprehension are only a few of the difficulties (WHO, 2021).

At first the disease damages neurons and their connections in memory-related areas of the brain, such as the entorhinal cortex and hippocampus. It then influences the parts of the cerebral cortex that control language, logic, and social behavior. Other parts of the brain are eventually affected. The disease causes a person's ability to live and function independently to deteriorate over time. The sickness is lethal in the end (National Institute of Aging, 2017).

Cognitive decline ranges from mild to severe. People with Mild Cognitive Impairment (MCI) may perceive changes in their cognitive skills but continue to be able to carry out their daily activities. Severe decline, such as Alzheimer´s Disease (AD) or other forms of dementia, can result in the loss of the ability to understand the meaning or relevance of things, as well as the ability to speak or write, making it impossible to live independently (U.S. Department of Health and Human Services, 2011).

Most cases are related to old age (Strand, 2021), and with the world´s aging population the health community is being challenged to be proactive, as the world is also witnessing increased demands on health and social services. Health professionals can aim to limit future implications of cognitive decline, AD, and associated dementias on health and wellness by working swiftly and strategically to encourage needed changes in systems and surroundings. This is especially essential because concerns can affect not only elderly people, but also their caregivers, family, and friends (Schmitter-Edgecombe et al., 2013). The purpose of treatment is to slow the decline and make the life of cognitively declined people free from suffering.

2.1 MCI, Dementia, and Healthy Aging

MCI is frequently referred to as a stage between the typical cognitive decline that comes with aging and the more serious cognitive loss that comes with dementia. Even though MCI is not considered dementia, about 10% -15% of people with MCI develop dementia each year, including AD (Mayo Clinic, 2020). Between 60% and 80% of dementia cases are caused by AD. The most prevalent cause of dementia is AD, a degenerative brain illness that always leads to dementia over time (Helsedirektoratet, 2022).

The intensity of symptoms determines the differences between MCI, AD, and other types of dementia, as compared to healthy aging (Cafasso, 2020). Table 1 shows the differences between MCI, AD, and other types of dementia, and healthy aging.

	Mild cognitive impairment	Alzheimer's disease and other types of dementia	Healthy aging
Occasionally forgetting a date, word, appointment, or task	✓	✓	✓
Slight difficulty paying attention or multitasking	✓	✓	✓
Forgetting important info that you usually would've recalled easily, such as recent events or the name of a good friend	✓	✓	
Having more trouble coming up with words than others of the same age	✓	✓	
Struggling with more complex planning or tasks, like balancing a checkbook	✓	✓	
Difficulty with basic activities, like using the bathroom, eating, or getting dressed		✓	
Problems with language or trouble carrying on a conversation		✓	
Odd or inappropriate behaviors		✓	
Personality changes		✓	
Problems with balance and coordination		✓	
Repeating a question or story multiple times		✓	
Excessive tripping, falls, or tremors		✓	
Wandering or getting lost		✓	

Table 1. Differences between MCI, AD and other types of dementia, and healthy aging (Cafasso, 2020).

Dementia is a considerable risk for those with MCI, but it is not a foregone conclusion. Every year, roughly 1% - 3% of the population over the age of 65 develop dementia (Mayo Clinic, 2020).

2.2 Prevalence

Increased age is one of the biggest risk factors for getting cognitive decline (Alzheimer´s Society, n.d.), although there is no single cause of cognitive decline (Mayo Clinic, 2020). Other medical diseases and lifestyle factors have been associated with a higher risk of cognitive decline, such as diabetes, smoking, obesity, high blood pressure, and depression (Alzheimer´s Society, n.d.).

More women than men are affected. Reasons for this might be that women live longer than men and that the hormone estrogen is reduced in women after menopause (Alzheimer´s Society, n.d.). According to newer data from Norway, 16% of women over the age of 70 have dementia, for men, this number is 13% (Gjøra et al., 2020). With age, the percentage between genders widens, and after the age of 85 years, women have a larger incidence than men of the same age (Strand, 2021).

Table 2 shows that the amount of people who has dementia increases sharply with age. It is estimated that in Norway 0,7% in aged 65-69 years old have the disease, and 48% among people 90 years and older. A total of 8% of the Norwegian population over the age of 59 have dementia. 6,8% are men, and 9,1% are women (Gjøra et al., 2020) (Strand, 2021). The numbers in Table 2 are based on numbers from a survey from 2020 in Trøndelag, Norway, and are standardized against national figures on age (*Alder, år*), gender (*Menn/Kvinner*), and education. It is clear from the table that the disease strikes most people after the age of 69.

Alder, år	Totalt	Menn	Kvinner
30-64*	0,1	0,1	0,1
60-64*	0,3	0,3	0,3
65-69*	0,7	0,6	0,9
70-74	5,6	6,4	4,8
75-79	9,5	10,0	9,0
80-84	17,9	17,8	18,0
85-89	33,0	30,4	34,6
90+	48,1	41,5	50,9
70+	14,6	13,0	15,9
60+	8,0	6,8	9,1

Table 2. Percentage prevalence of dementia cases in Trøndelag, Norway in 2020 (FHI, 2021). The column "Total" gives the percentages of the total population affected by dementia.

Table 3 shows age specific estimates of numbers of dementia cases in Norway in years (*År*) 2020, 2050, and 2100 if the proportion of dementia in the various age groups remains constant over time, and if the population follows the main trends from Statistics Norway's projections (FHI, 2021).

Alder, år	År 2020	År 2050	År 2100
30-64	2108	2203	2095
65-69	2008	2383	2489
70-74	14 493	17 153	18 277
75-79	16 691	29 774	29 512
80-84	203 80	49 866	55 267
85-89	23 675	64 498	97 093
90+	21 762	70 912	175 402
Totalt	**101 118**	**236 789**	**380 134**

Table 3. Estimated numbers of dementia cases in Norway in 2020, 2050, and 2100 (FHI, 2021).

From Table 3 one can see that there are 101 118 people (1,88% of the population) living with dementia today and that the numbers are expected to double in 2050, due to the increasingly growing population of elders (Strand, 2021). Figure 1 illustrates the prevalence in the different areas of dementia in Norway in 2020 and the estimation for 2050. It is estimated that 238 499 people (3,99% of the population) in Norway will have dementia in 2050 (Demenskartet, n.d.).

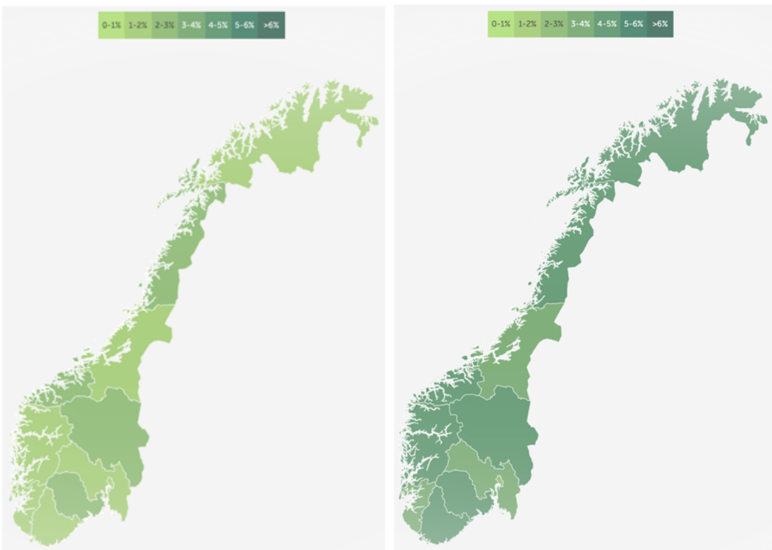


Figure 1. The left picture shows the prevalence of dementia in Norway in 2020, with percent ranging from 1-3%. The right picture shows the expected prevalence of dementia in Norway in 2050, with the percentage expected to range between 3-5% (Demenskartet, n.d.).

Worldwide it is estimated that more than 55 million people live with dementia This number is expected to increase. It is estimated that there will be 78 million dementia cases worldwide in 2030, and 139 million in 2050 (WHO, 2021).

In the U.S., 11,1% of people above the age of 45 have Subjective Cognitive Decline (SCD), which is defined as clinically established decline. SCD affects 11,7% of people aged 65 and older, and 10,8% of people aged 45 to 64 in the country (U.S. Department of Health & Human Services, 2019). Figure 2 shows the prevalence of SCD in the U.S.

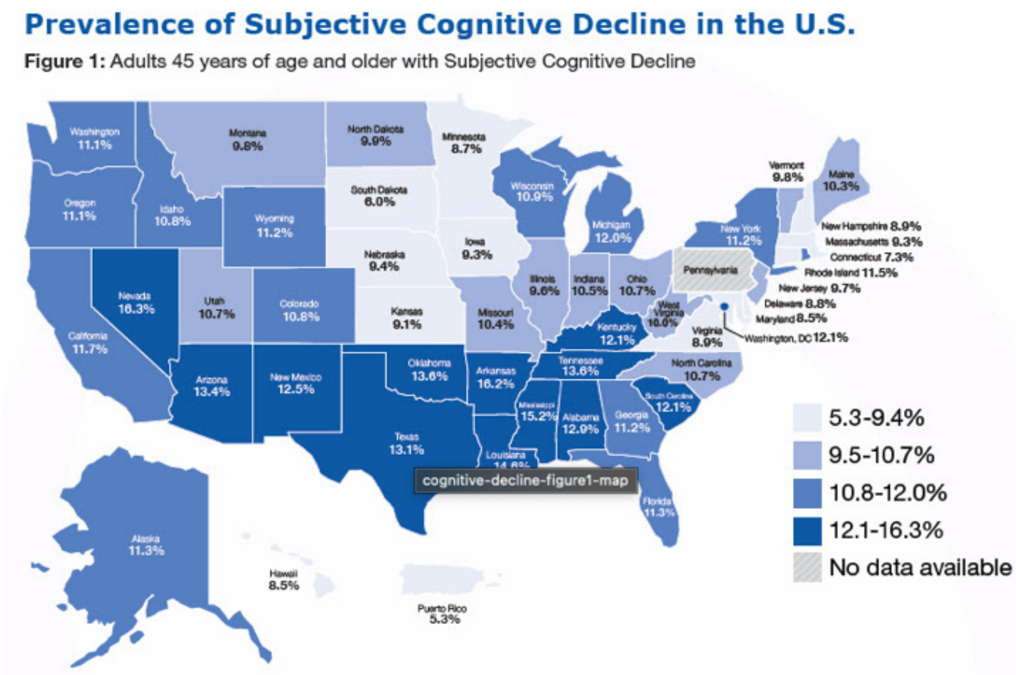


Figure 2. Prevalence of SCD in the U.S. for adults above the age of 45 (U.S. Department of Health & Human Services, 2019).

Changes in cognitive decline and the disease following it are a heavy burden for people and families, but also societies. There are costs relating to the diagnosing, treatment, and care regardless of the dept of the cognitive decline. Loss of independence comes with increasing impact and consequences for society at large. The population projections suggest that cognitive loss ought to be considered a growing problem (WHO, 2021).

2.3 Medical Technology

There is a variety of technology for understanding and identifying cognitive loss. Especially with the milder forms of loss, it is possible to use inexpensive solutions coming from electronic Health (eHealth), a term used to describe electronic medical and mental health information and services over the Internet. App- and Web-based eHealth solutions can assess at-risk individuals and/or provide self-help intervention or clinical referrals for a variety of health issues. The growth of eHealth technology has been aided by dramatic improvements in access to and use of the Internet and mobile phone technologies. In 2022 over 88% of the population in Europe and 66,2% of the world´s total population have access to the Internet, and mobile phones are now used by majority of the world's population. Between 2000 and 2022, Internet usage in Europe increased by 608%, and 1355% for the world in total (Internet World Stats, 2022).

Improvements in health safety, increased health care efficiency and effectiveness, lower costs, improved decision making, access to distant clinicians, and medical mistake reduction are all potential benefits of eHealth apps (Botha et al., 2014). Health apps provide a lot of potential benefits, but they also have a lot of potential risks. Most of the eHealth apps on the market are unknown in terms of quality, safety, and effectiveness. eHealth tools are typically produced without the involvement of health professionals, and they are frequently generated without adequate validation (Charalambous et al., 2020).

With respect to tools for self-identification of cognitive impairment symptomatic of dementia, uncertainty in the quality of eHealth tools is concerning. Furthermore, if the test is not thoroughly validated, there is a possibility of false-positive results, which can generate unnecessary concern, or false-negative results, which can lead to a dementia diagnosis being overlooked. Formal studies are urgently needed to determine the potential benefits of eHealth technologies and mitigate their risks (Charalambous et al., 2020).

Another concern is the speed and dept of decline that might be impossible to capture and support using eHealth solutions. There are other sophisticated technologies provided by the health care staff to assess the patient situations and determine whether the patient can make sense of eHealth. In this project, the aim was to review and understand possibilities available for assessing patient and suggesting a proper kind of treatment. Hence, the research project is not focused only on eHealth.

2.4 Gerontechnology

Gerontechnology is an academic and professional subject that combines gerontology with technology. Gerontechnology is the study of aging and technology to create a better living and working environment for the elderly and their caregivers, as well as tailored medical care. Technology has the potential to improve the lives of older people by promoting independent living and social participation, as well as enhancing their health and well-being. Neuropsychologists and clinicians can use technology to collect continuous real-time assessment data, develop more ecologically valid assessment methodologies, provide more daily interventions, and track real-world reactions to therapy (Schmitter-Edgecombe et al., 2013).

2.5 Establishing Diagnosis

It is important to obtain a diagnosis of cognitive decline early so treatment and therapy can begin as soon as possible. Early treatment and therapy can help slow the process of cognitive decline (NASEM Health and Medicine Division, 2017). It is vital to alleviate the suffering caused by the disease on patients and society (Allan et al., 2017) (Centers for Disease Control and Prevention, 2019) (Lin et al., 2019). Once the disease has been diagnosed it is commonly treated with medication. However, it is beneficial to allow non-pharmacological inventions to be implemented to change the natural history of the disease, and thus delay its development (Mancioppi et al., 2019).

IT solutions are discussed in the paper "Novel Technological Solutions for Assessment, Treatment, and Assistance in Mild Cognitive Impairment" by Mancioppi et al. (2019), particularly the usage of IT in the neuropsychological profession. IT has been employed as assessment tool and as cognitive invention instrument. This is to help individuals with AD develop or retain their cognitive abilities (Mancioppi et al., 2019). The authors state that *"in the assessment, treatment, and monitoring of Mild Cognitive Impairment (MCI) patients, technology should play a critical role"*. It should also allow for the integration of cognitive and physical treatment, as well as the integration of stimulation protocols with the subject's regular activities. According to the authors, technology should be able to assist with data collection on changes in the patient's autonomy, physical, and cognitive abilities, as well as provide feedback to patients and stakeholders. The necessity to develop technology that can be employed in a patient's home without the presence of a therapist is critical in this regard.

As a result, these technologies should be integrated into the user's daily life to create a coupled system with the user himself or herself, resulting in a richer environment (Mancioppi et al., 2019).

The main purpose of evaluating people with early cognitive decline is to distinguish it from normal aging and dementia which is a severe form of cognitive decline. Because health and pathology overlap, separating them can be challenging (Allan et al., 2017).

If cognitive decline is suspected, the patient should have a thorough evaluation that includes history, cognitive, mental, physical, and neurological examination. In addition, medication review and laboratory testing are performed. Once dementia is diagnosed it means that irreparable neurological damage is established. To identify additional, reversible manifestations or circumstances of cognitive decline, such as depression and B12 insufficiency, a thorough examination is required. Reversible factors account for 9% of all dementia cases and are a major cause of cognitive impairment (Albert, 2011). Sophisticated medical technology such as structural brain imaging can be used to rule out other causes of cognitive impairment as well as to learn more about the underlying pathology and prognosis (Allan et al., 2017).

Even though a pathological examination is required for a definitive diagnosis, recent advances in imaging techniques may aid in the early detection of cognitive decline and AD. New magnetic resonance techniques, like as Diffusion Tensor Imaging (DTI) and Proton Density (PD) weighted imaging, as well as advances in image analysis software, have provided health care staff and relatives with a potential tool for detecting subtle microstructural, perfusion, and metabolic changes in the brain (Jack et al., 2005) (Yin et al., 2013).

Various criteria should be considered when diagnosing someone with cognitive decline. There is no single specific test that can validate the diagnosis at this time, so physicians must determine if the symptoms are caused by cognitive decline or not. This can be done based on information and findings from several tests. The Mini-Mental State Examination (MMSE) and the Mini-Cognition (Mini-cog) are two regularly utilized self-tests.

The following criteria, determined by a team of worldwide specialists, are used by many physicians and psychologists to detect potential cognitive decline:

- Patients have memory or mental function problems
- Patients have memory and mental function that have deteriorated over time
- Patients´ general mental function and daily activities are unaffected
- For patients´ age and education level, mental status testing reveals a low level of impairment (Mayo Clinic, 2020).

A neurological exam is also carried out to assess the functions of the brain. Reflexes, eye movements, walking, and balance may all be tested during the neurological exam. A doctor may order a brain imaging scan such as a Magnetic Resonance Imagining (MRI) or Computerized Tomography (CT) scan to look for signs of a brain tumor, stroke, or bleeding. Testing for mental status is also an option. Doctors require participants to complete certain tasks and answer a series of questions throughout the exam, such as naming today's date or following a printed instruction (Mayo Clinic, 2020).

2.6 Prevention

MCI is sometimes unavoidable. However, research has discovered several environmental elements that may influence the likelihood of having the disease. As a remedy measure could be suggested to help the situation such as limiting alcohol consumption, limiting exposure to air pollution, quitting smoking, practicing good sleep, taking care of health issues, eating nutritious food (A Mediterranean diet is desirable), exercising, being social, and keeping one´s mind active (Mayo Clinic, 2020) (Hicks, 2022).

The Maintaining Optimal Cognitive Function in Ageing (MOCIA) project aims to identify those who are at a higher risk of cognitive decline and design a customized lifestyle intervention at home to help them avoid it. The MOCIA initiative aims to produce a customized lifestyle intervention that can detect an elevated risk of cognitive decline and improve prevention. This major program will evaluate a multi-domain lifestyle intervention in elderly Dutch persons (MOCIA, 2022).

Chapter 3

3 Literature Review

This chapter presents relevant research on IT solutions for cognitive decline focusing on diagnosis and treatment. It summarizes what is already known and documented. Finding the literature was done by searching online libraries for papers, books, and other related documents using keywords. This literature review includes more than eHealth publications due to the importance of early diagnosing and treatment that is not limited only to eHealth approaches, e.g., there are also papers that present deeper clinical knowledge and put the light on the success of different methods in terms of accurately diagnosing and efficient treatment.

3.1 IT Solutions for Diagnosing Cognitive Decline

The first glance at the literature has shown how many different approaches were used to understand and establish cognitive decline. Therefore, a systematic literature review was performed using keywords such as cognitive decline, diagnosing, information technology (IT), and dementia.

The results are presented according to the main approaches identified in the literature. Later the findings were systematically structured using qualitative data analysis.

3.1.1 Self-testing

3.1.1.1 Match, Flanker and Stargazer Tests

Tsoy et al. (2020) conducted an intriguing study on the clinical and scientific value of self-administered computerized cognitive testing. The potential utility of this is becoming increasingly apparent. The study consisted of 27 participants where nine participants reported *"never using a smartphone",* two reported *"using it most of the time",* and sixteen reported *"using one always"* (Tsoy et al., 2020). Of the nine participants stating, *"never using a smartphone"*, eight of them also stated, *"never using a tablet"* (Tsoy et al., 2020). These eight participants were categorized into a *"low familiarity"* group, while the other nineteen participants were categorized into a *"high familiarity"* group (Tsoy et al., 2020). Participants that already had established cognitive disorders were excluded.

Several executive functions were tested such as processing speed test *(Match)*, cognitive inhibition (*Flanker)*, and spatial working memory (*Stargazer).* In Figure 3 descriptions of the tasks is shown. The test was performed on an iPad and administrated on a TabCAT software platform[1] (Tsoy et al., 2020).

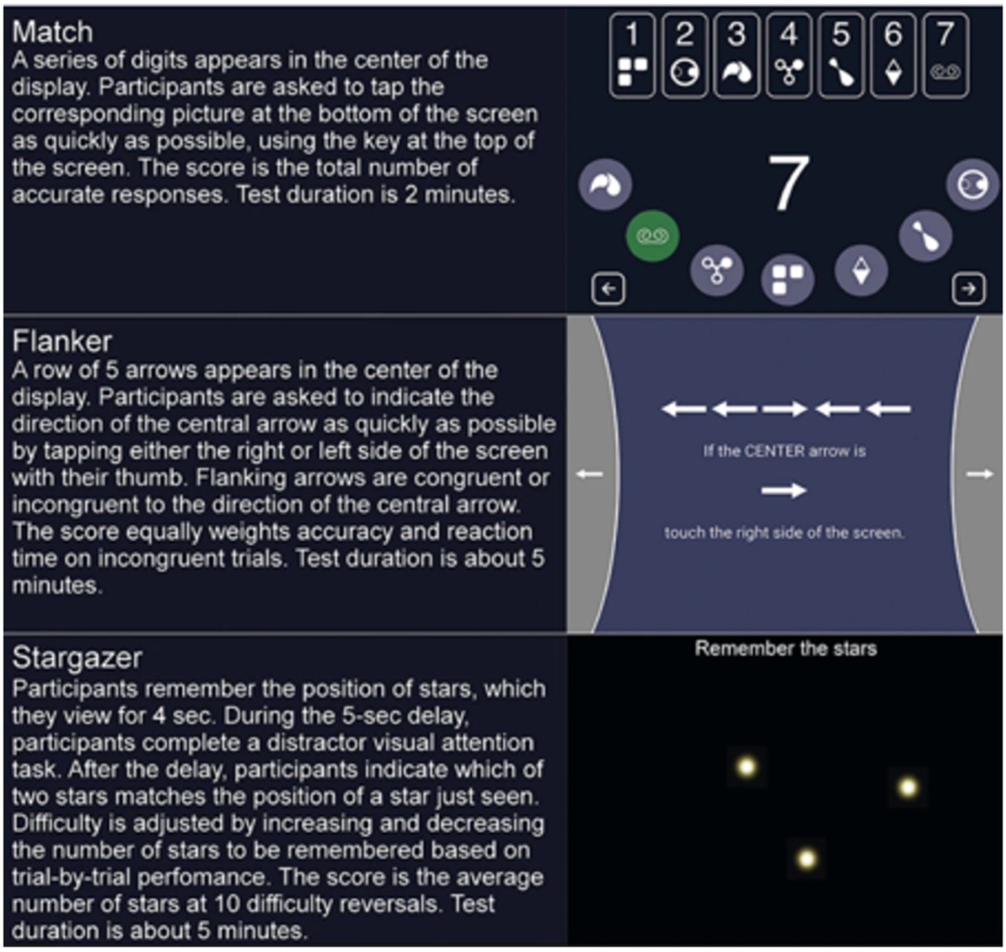


Figure 3. Task description of the tests (Tsoy et al., 2020).

"Match" gave the highest reliability and consistency estimates. This could be linked to the fact that the test focuses on widely distributed brain networks, involves several cognitive processes, and collects many responses in a short period while also having simple instructions. *"Stargazer"* on the other hand had lower consistency among the *"low familiarity"* group. The participants described the task as confusing or unclear as the instructions are complex. For unsupervised at-home applications of cognitive testing in elderly persons, this emphasizes the significance of simple, user-friendly interfaces and instructions (Tsoy et al., 2020).

[1] memory.ucsf.edu/tabcat

The current findings suggest that elderly persons with multimorbidity self-test at home can acquire consistent cognitive scores. The findings revealed that all three individual measures and the executive composite had strong test-retest reliability across examiner-administered and self-administered sessions. Even though two participants experienced technical difficulties, resulting in incomplete data from the two participants, the findings propose the benefits of computerized cognitive tests. This includes increased precision, less examiner bias, and lower personnel costs. The findings also demonstrate that persons with and without prior experience with touchscreen computer devices have similar levels of consistency. Tsoy et al. (2020) claim that this supports the idea that elderly persons, regardless of prior expertise with technology, can use unsupervised computerized assessment (Tsoy et al., 2020).

3.1.1.2 Computerized Self-Test

According to Mancioppi et al. (2019), the research of Dougherty et al. (2010) was one of the earliest cases in which PC-based tests were utilized in MCI assessment. Dougherty et al. (2010) examined correlations between the participants´ performance on traditional self-tests (MMSE and Mini-cog) and a novel PC-based neuropsychological battery known as Computerized Self-Test (CST). CST is an interactive, web-based tool for assessing functional cognitive domains affected by AD and MCI. A screenshot from the test can be seen in Figure 4.

The study shows that the CST correctly diagnosed 96% of cognitively impaired people, while the MMSE and the Mini-Cog correctly diagnosed 71% and 69%, respectively. Furthermore, the CST correctly diagnosed 91% of the six experimental groups (control, MCI, early AD, mild to moderate, moderate to severe, and severe forms of the disease), while the MMSE and Mini-Cog could only reach an accuracy of 54% and 48%, respectively. This shows that PC-based cognitive screening tools may aid in MCI early diagnosis in the primary care context, and they may provide an appropriate baseline from which to track cognitive changes over time due to their ease of use and interpretation (Dougherty et al., 2010) (Mancioppi et al., 2019).

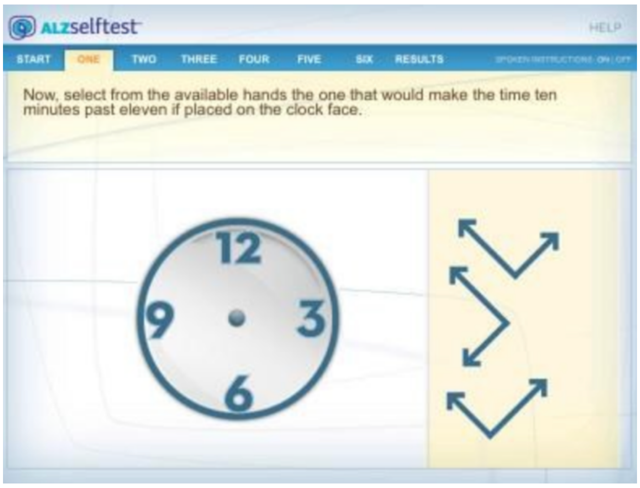


Figure 4. A screenshot of the CST (Credit: Rex Cannon and Andrew Dougherty/University of Tennessee, 2010).

3.1.1.3 Webapps

Webapps, such as *Husketest, BrainTest, BrainCheck, MemTrax, Self-Assessment of Cognition (SAC),* and *Cogniciti,* are all examples of memory tests that can help users determine how well they remember things and detect MCI and early dementia (Charalambous, 2020). *BrainTest* is the digital version of the Self-Administered Gerocognitive Exam (SAGE), which is a screening tool for early indicators of cognitive, memory, and thinking problems. It assesses a person´s cognitive ability and assists specialists in determining how effectively the brain is functioning (Wexner Medical Center, n.d.).

3.1.1.4 Traditional Self-tests

Traditional self-tests for cognitive impairment include the MMSE and Mini-Cog. These self-testing tools for cognitive impairment, which use App- or Web-based tools, could help detect people who might be developing cognitive impairment and refer them to the right health and social care services (Lecturio Medical, 2017).

The MMSE (Figure 5) is a 30-point questionnaire that is used to assess cognitive impairment in clinical and research settings. The test on its own was not designed to establish a diagnosis, but rather to be used to test for cognitive impairment, and for measuring the level of progression of cognitive impairment. The test can be used to track an individual´s cognitive changes over time, making it a useful tool for documenting a patient´s reaction to treatment. The test takes about 10-15 minutes to perform and looks at abilities like registration, attention and calculation, recall, language, ability to follow simple commands, and orientation. A score of 25 out of 30 or higher shows normal intellect. Scores below this can indicate cognitive impairment (NHI, 2022).

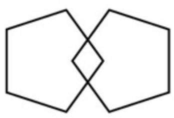
MINI MENTAL STATE EXAMINATION (MMSE)

Name:

DOB:

Hospital Number:

One point for each answer	DATE:		
ORIENTATION Year Season Month Date Time	....../ 5	....../ 5	....../ 5
Country Town District Hospital Ward/Floor	....../ 5	....../ 5	....../ 5
REGISTRATION Examiner names three objects (e.g. apple, table, penny) and asks the patient to repeat (1 point for each correct. THEN the patient learns the 3 names repeating until correct).	....../ 3	....../ 3	....../ 3
ATTENTION AND CALCULATION Subtract 7 from 100, then repeat from result. Continue five times: 100, 93, 86, 79, 72, 65 (Alternative: spell "WORLD" backwards: DLROW).	....../ 5	....../ 5	....../ 5
RECALL Ask for the names of the three objects learned earlier.	....../ 3	....../ 3	....../ 3
LANGUAGE Name two objects (e.g. pen, watch).	....../ 2	....../ 2	....../ 2
Repeat "No ifs, ands, or buts".	....../ 1	....../ 1	....../ 1
Give a three-stage command. Score 1 for each stage. (e.g. "Place index finger of right hand on your nose and then on your left ear").	....../ 3	....../ 3	....../ 3
Ask the patient to read and obey a written command on a piece of paper. The written instruction is: "Close your eyes".	....../ 1	....../ 1	....../ 1
Ask the patient to write a sentence. Score 1 if it is sensible and has a subject and a verb.	....../ 1	....../ 1	....../ 1
COPYING: Ask the patient to copy a pair of intersecting pentagons	....../ 1	....../ 1	....../ 1
TOTAL:	....../ 30	....../ 30	....../ 30



MMSE scoring
24-30: no cognitive impairment
18-23: mild cognitive impairment
0-17: severe cognitive impairment

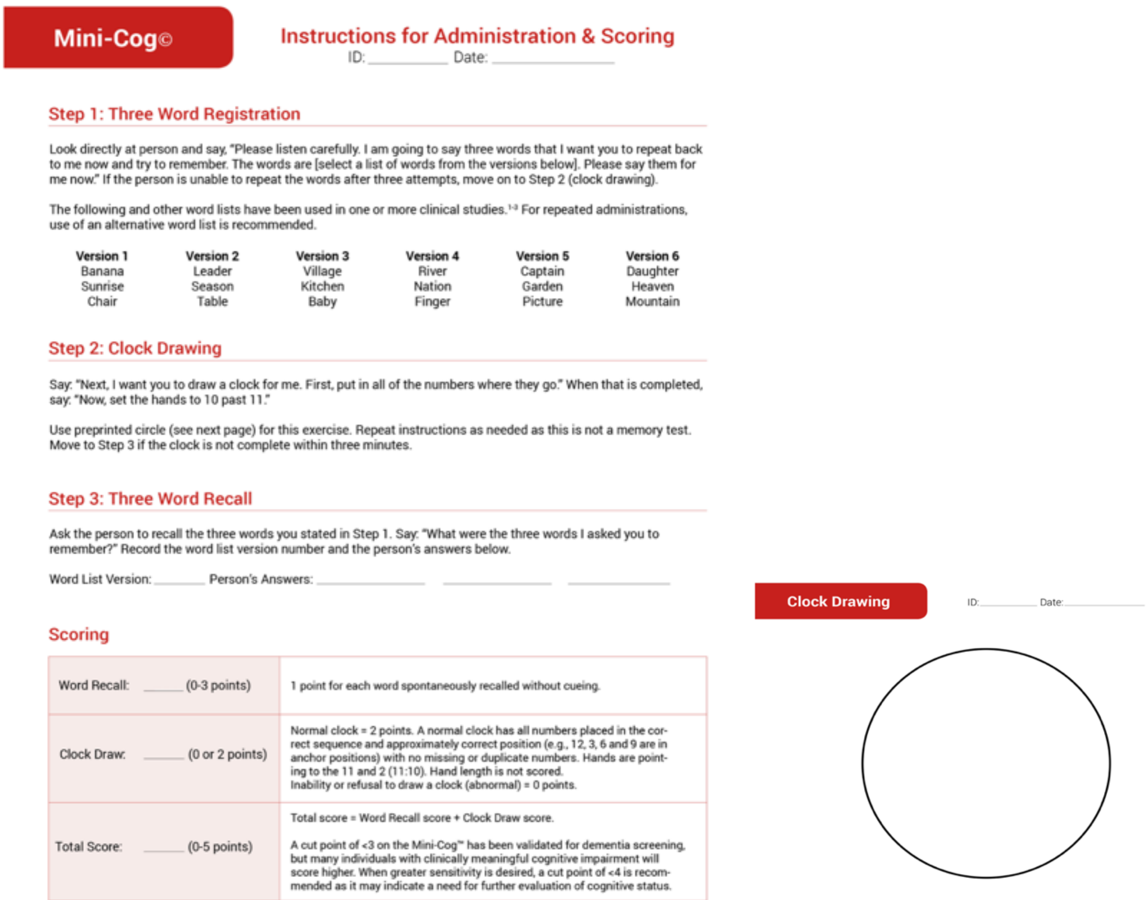
OME Oxford Medical Education

Figure 5. The MMSE (Oxford Medical Education, n.d.)

The MMSE test has several advantages, including that it does not require any special equipment or training to perform. It is effective for cognitive testing in the clinician's office or at the bedside due to its quick administration period and ease of use. However, MMSE has drawbacks since it is influenced by demographic characteristics, with age and education having the biggest impact. The most common criticism of the MMSE is that it is insensitive to modest cognitive impairment and fails to adequately distinguish people with MCI from normal patients (Wikipedia, 2022).

Expert interviews conducted within this research have pointed out weaknesses of using the MMSE as being not sensitive to MCI. Another bias comes from higher education which helps people perform well due to their educational background (O´Bryant et al., 2008). Interviewed experts suggested another clinical test, namely the Montreal Cognitive Assessment (MoCA) (Section 3.1.1.5).

The other traditional self-test, Mini-Cog, is a quick and easy screening test that can help detect dementia early on and help doctors and other health professionals discover possible cognitive decline in people in as little as three minutes. This increases the chances of early detection and treatment for patients who are beginning to show signs of cognitive decline. Mini-Cog is easy to use and can assist in determining when a more comprehensive cognitive test is required. It consists of two components, a 3-item recall test for memory and a simple scored clock drawing test, shown in Figure 6. The purpose is to identify patients with cognitive deficiencies that could have gone unrecognized or undetected. (Mini-Cog, n.d.).



Mini-Cog©

Instructions for Administration & Scoring

ID: ________ Date: ____________

Step 1: Three Word Registration

Look directly at person and say, "Please listen carefully. I am going to say three words that I want you to repeat back to me now and try to remember. The words are [select a list of words from the versions below]. Please say them for me now." If the person is unable to repeat the words after three attempts, move on to Step 2 (clock drawing).

The following and other word lists have been used in one or more clinical studies.[1-3] For repeated administrations, use of an alternative word list is recommended.

Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
Banana	Leader	Village	River	Captain	Daughter
Sunrise	Season	Kitchen	Nation	Garden	Heaven
Chair	Table	Baby	Finger	Picture	Mountain

Step 2: Clock Drawing

Say: "Next, I want you to draw a clock for me. First, put in all of the numbers where they go." When that is completed, say: "Now, set the hands to 10 past 11."

Use preprinted circle (see next page) for this exercise. Repeat instructions as needed as this is not a memory test. Move to Step 3 if the clock is not complete within three minutes.

Step 3: Three Word Recall

Ask the person to recall the three words you stated in Step 1. Say: "What were the three words I asked you to remember?" Record the word list version number and the person's answers below.

Word List Version: ______ Person's Answers: __________ __________ __________

Scoring

Word Recall: ______ (0-3 points)	1 point for each word spontaneously recalled without cueing.
Clock Draw: ______ (0 or 2 points)	Normal clock = 2 points. A normal clock has all numbers placed in the correct sequence and approximately correct position (e.g., 12, 3, 6 and 9 are in anchor positions) with no missing or duplicate numbers. Hands are pointing to the 11 and 2 (11:10). Hand length is not scored. Inability or refusal to draw a clock (abnormal) = 0 points.
Total Score: ______ (0-5 points)	Total score = Word Recall score + Clock Draw score. A cut point of <3 on the Mini-Cog™ has been validated for dementia screening, but many individuals with clinically meaningful cognitive impairment will score higher. When greater sensitivity is desired, a cut point of <4 is recommended as it may indicate a need for further evaluation of cognitive status.

Clock Drawing ID: ________ Date: ________

Figure 6. On the left, the Mini-Cog test. On the right the clock drawing test (Mini-Cog, n.d.).

3.1.1.5 The Montreal Cognitive Assessment

The MoCA is a tool for determining whether someone has dementia or not. It is a 30-question test that takes about 10-12 minutes to finish. The test was developed by a group of McGill University researchers who spent several years working in memory clinics in Montreal. The test was published in 2005 and is reportedly simple to administer and understand with sufficient instructions. As a screening test for cognitive decline, the MoCA is quick, easy, and accurate. It assesses executive function, which is an important aspect of dementia that the MMSE does not assess (Rosenzweig, 2022).

Figure 7 shows a breakdown of what the MoCA evaluates, how it is scored and interpreted, and how it can help with dementia detection (Rosenzweig, 2022).

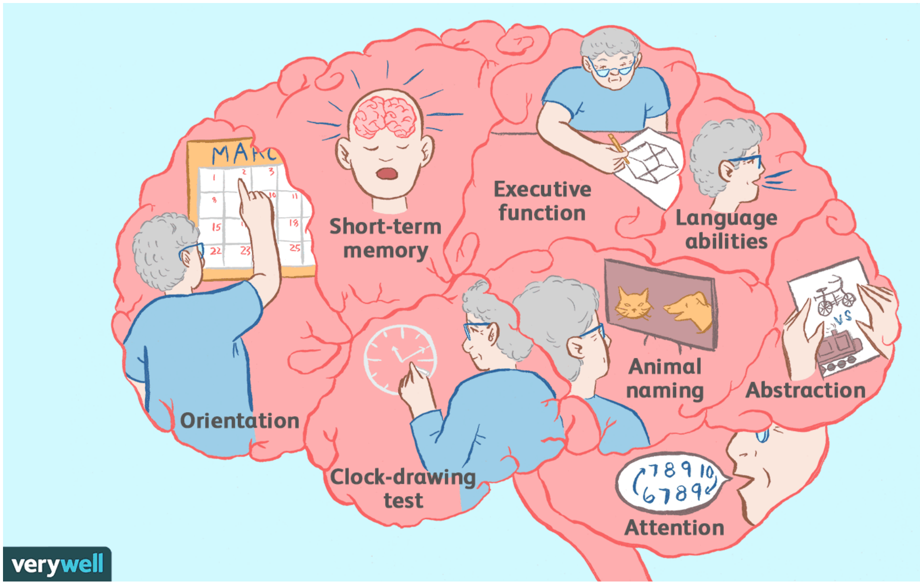


Figure 7. What the MoCA evaluate (Rosenzweig, 2022).

The MoCA aids medical professionals in swiftly determining whether a person's thinking ability is damaged. It also aids them in determining whether an in-depth AD diagnostic workup is required. It seems to be more sensitive than some other tests, such as the MMSE, since it tests executive function (MoCA, n.d.).

The MoCA assesses a variety of cognitive and reasoning abilities such as orientation, abstraction, attention, and language. Table 4 shows an overview of the different types of cognitive and reasoning abilities. Figure 8 shows what the MoCA looks like (Rosenzweig, 2022) (Lim et al., 2018).

Orientation	The participant will be asked to state the date, month, year, day, place, and city by the test administrator
Delay recall/short-term memory	The participant gets five words to read. They then must be repeated by the participant. The participant is then asked to repeat each of the five terms once more after completing additional chores. If they are unable to recall them, they are given a hint as to which category the term belongs to.
Executive function/visuospatial ability	The Trails B Test assesses these two abilities. It requires the participant to draw a line to arrange alternate digits and letters in a certain order (1-A, 2-B, etc.). They must also draw a cube shape on the test.
Language	The participant must accurately repeat two sentences in this task. It then asks the participant to write down all the words that begin with the letter "F" in the sentences.
Abstraction	The participant is asked to describe how two objects, such as a locomotive and a bicycle, are similar. This tests the abstract reasoning, which is often hampered in dementia patients. Another technique to assess these abilities is to take a proverb interpretation test.
Animal naming	Three animal photos are given. Each one is given a name and the participant is requested to name them. It is primarily used to assess verbal fluency.
Attention	The participant is instructed to recite a series of numbers forward and then backward. This challenge puts their ability to pay attention to the test.

Table 4. List of the different types of cognitive and reasoning abilities in the MoCA (Rosenzweig, 2022).

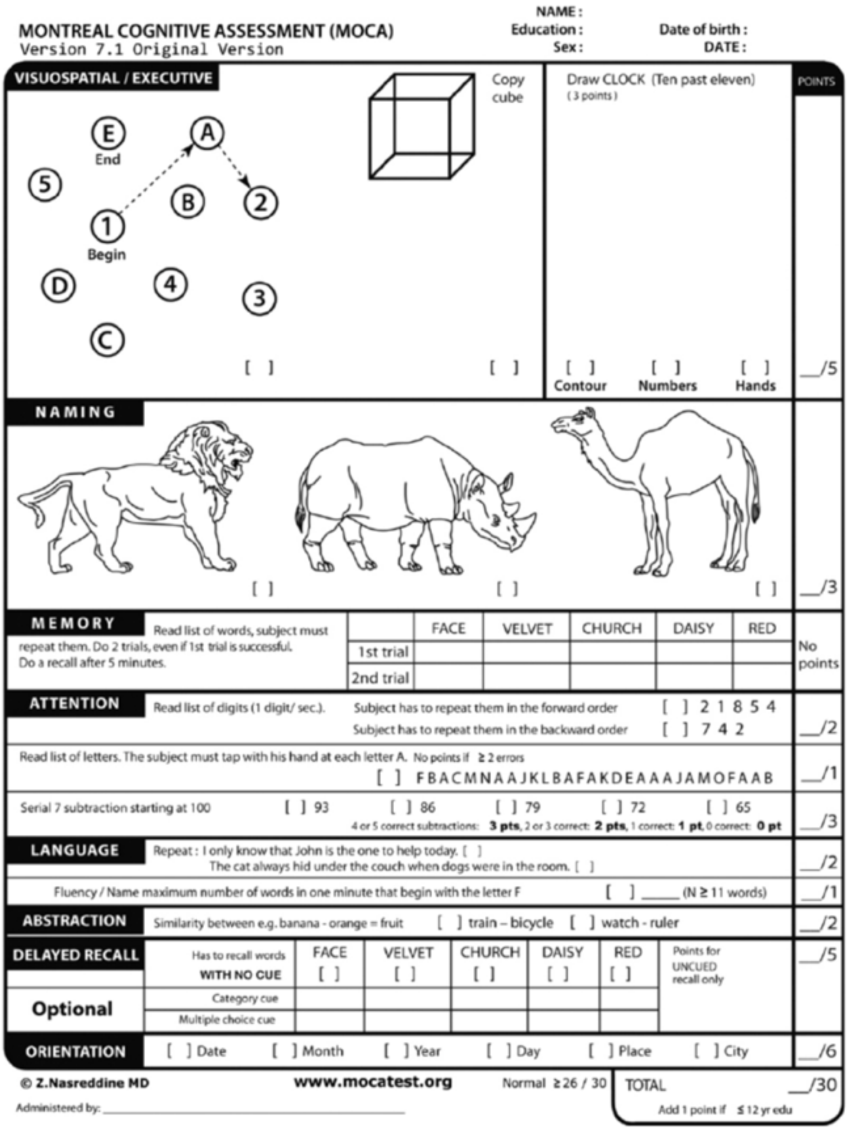


Figure 8. The MoCA (MoCA, n.d.).

The test is used by healthcare experts to determine how effectively a person's thinking abilities are working. Normal is defined as a score of 26 or higher. Table 5 shows the breakdown of the scores:

Orientation	6 points
Delay recall/short-term memory	5 points
Executive function/visuospatial ability	5 points
Language	3 points
Abstraction	2 points
Animal naming	3 points
Attention	6 points

Table 5. Scores of the MoCA test (Rosenzweig, 2022).

If the test-taker has less than 12 years of formal education, 1 point is added to their score. The participants are also required to sketch a clock reading ten past eleven (Rosenzweig, 2022).

The MoCA has the disadvantage of taking a little longer to administer than the MMSE. To diagnose dementia, it should be combined with a variety of additional screens and testing. However, health care providers can use it to quickly decide when someone needs more extensive testing for AD or dementia (Rosenzweig, 2022).

3.1.2 Sensors

3.1.2.1 Automatic Speech

Speech, the primary approach to human communication, has enormous promise for monitoring dementia patients, as speech and language traits may serve as behavioral indicators for dementia types (Forbes-McKay et al., 2013).

König et al. (2015), aimed to identify vocal markers correlated to the participants' cognitive status. They investigated the analysis of speech using software that takes audio recordings from a clinical consultation as input. The speech analysis tool, when combined with additional approaches like video surveillance and actigraphy, has the potential to become a valuable, noninvasive, and simple method for early dementia detection. These technologies allow for real-time, accurate, and low-cost monitoring. Noninvasive diagnosis methods will help relieve the strain on the healthcare system and increase the chances of early dementia detection (König et al., 2015).

To investigate the statistical aspects of vocal data, a classifier was created using a Support Vector Machine (SVM). The classifier found which characteristics distinguish distinct illness stages. The major goal of the study was to see if automating speech and voice pattern analysis improves the accuracy, reliability, and affordability of early detection of AD.

The feature selection technique was implemented before running a classifier. The goal of the feature selection technique was to pick the most important voice features and leave out the *noisy* ones that do not add much to classification accuracy and may even harm it if incorporated. This process was put to the test to ensure that the results were accurate. Three distinct classification scenarios involving the three pairwise combinations of the three groups (Healthy Control (HC), MCI, and AD) were evaluated:

- HC vs. AD: identifying AD in a population with both HC and AD
- HC vs. MCI: identifying MCI in a population with both HC and MCI
- MCI vs. AD: identifying AD in a population with both MCI and AD

Each participant completed four oral tasks while being recorded as part of an ongoing research protocol. A counting backward task, a sentence repetition task, an image description task, and a verbal fluency task were among the challenges, as shown in Figure 9. These challenges were chosen based on the results of earlier research.

No.	Task	Description
1	Countdown	Count backward 1 by 1 from 305 to 285 without making a mistake
3	Picture description	Look at a picture and describe it as detailed as you can in 1 minute
2	Sentence repeating	Repeat 10 short sentences after the clinician (1 at a time); the first 3 are "La montagne est enneigée en ce mois de mars" "Le chien a fait une longue promenade ce matin" "Le Schtroumpf grognon est très content aujourd'hui"
4	Semantic fluency (animals)	Name as many animals as you can think of as quickly as possible (1-minute time limit); this semantic fluency test is widely used in neuropsychological assessments to evaluate frontal lobe functions

Figure 9. Vocal tasks of the protocol (König et al., 2015).

The classifier developed by the authors showed an accuracy of 87% in discerning between HC and people with AD, 79% in discerning between HC and people with MCI, and 80% in discerning between people with MCI and people with AD, demonstrating its assessment utility (König et al., 2015).

The vocal tasks were completely recorded to extract specific vocal characteristics such as pause length, verbal reaction time, and silence.

Each diagnostic group's members performed differently on each voice challenge. Most of the time, these changes in vocal qualities are undetectable for a clinician's ear, but they were detected by the built speech analysis system.

According to Meilán et al. (2012), an increase in voiceless portions in a patient's speech is an indication that accounts for more than 34% of the variance in language and memory test scores. As a result, this rise could be linked to AD and, to a lesser extent, the cognitive impairments that come with it. They discovered that patients with AD had a higher proportion and quantity of voice breaks in their speech (Meilán et al., 2012).

Thus, these studies have shown that automatic speech processing technology can be a useful additional tool for physicians who are looking for more objective and automated methods to help them assess cognitive decline in the early stages.

There are lot of successful research for developing classifiers that analyze signals collected showing the changes in speech quality (Yeung et al., 2021). Figure 10 shows an overview of speech characteristics from the groups, persons with AD, MCI, and HC.

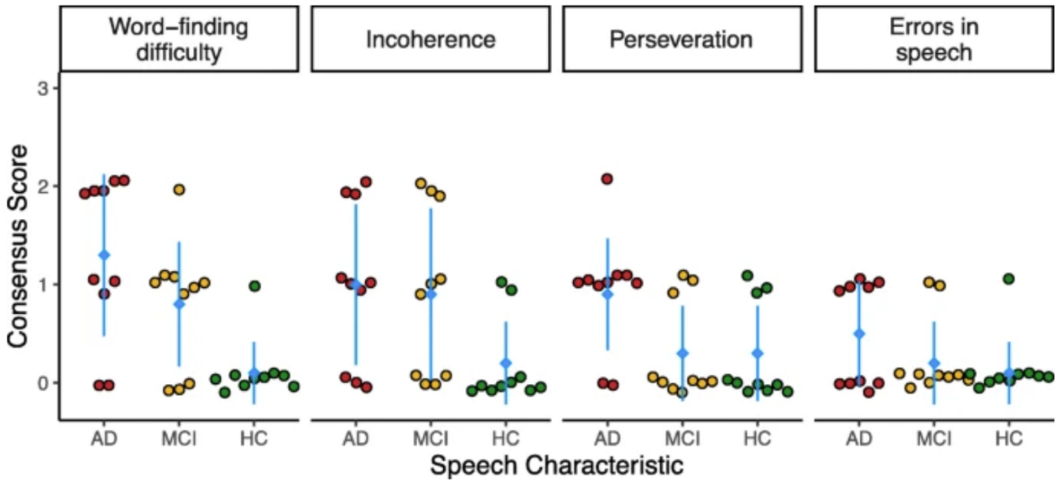


Figure 10. Speech characteristics of persons with AD, MCI, and HC (Yeung et al., 2021).

Another example is to study aging using voice technology in combination with MMSE (Section 3.1.1.4). The research attempted to create voice index training on 20 individuals who also completed the MMSE test (Tokuno, 2020). Figure 11 shows regression analysis calculated for 20 individuals that clearly illustrates differences between persons with dementia from the rest of the training set.

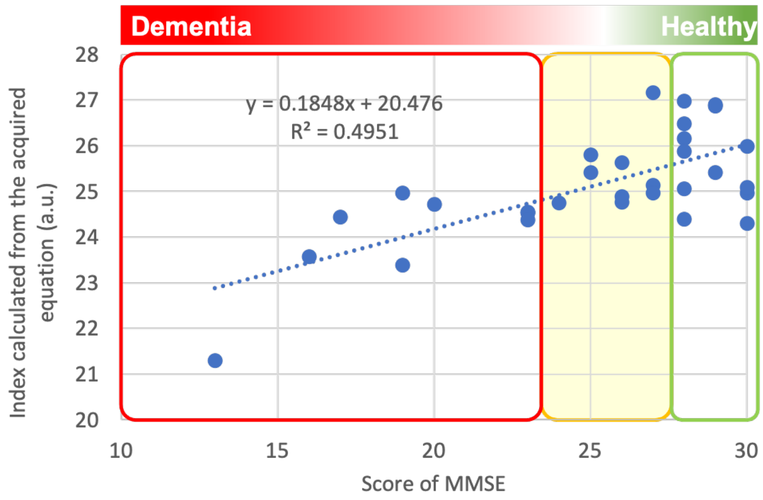


Figure 11. Presentation of voice index (Tokuno, 2020).

3.1.2.2 Event Monitoring System

König et al. (2015) investigated how to quantify autonomy in dementia patients using not only gait analysis but also participant performance on Instrumental Activities of Daily Living (IADL) that were automatically recognized by a video Event Monitoring System (EMS). While being recorded, three groups of participants (HC, MCI, and AD patients) were required to complete a standardized scenario that included physical tasks and multiple IADLs such as *"packing a pillbox"* or *"making a phone call"*. Following that, video sensor data was analyzed by the EMS that extracts kinematic properties of the individuals' gait and recognizes their activities. The participants' performance levels, referred to as autonomy, were then assessed using Artificial Intelligence (AI). Figure 12 shows the processing of information from the video input to setting diagnosis by a doctor.

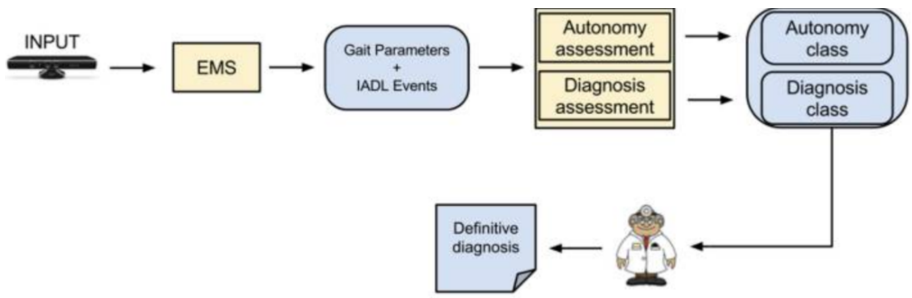


Figure 12. EMS architecture (König et al., 2015).

The assessment of autonomy was handled as a classification task utilizing AI methods that used the parameters retrieved by the EMS as input. The EMS was able to reliably identify activities with great precision. *"Prepare medication"* gave an accuracy of 93%, and *"using the phone"* gave an accuracy of 89%, and were the most correctly detected actions. When physical task studies were combined with IADL, the diagnostic group classifier had a precision of 73,46%. Further research found that when physical tasks and IADL were combined, the produced autonomy group classifier had a precision of 83,67%. The findings imply that IADL functioning may be quantitatively assessed with the help of an EMS and that the groups can be categorized with high accuracy based on the retrieved data. This suggests that the adoption of such technology could give clinicians diagnostically important information in real time, reducing observer biases and improving autonomy evaluation (König et al., 2015).

Detection, tracking, gait analysis, and event recognition are the four modules that make up the EMS, which leads to the accurate assessment based on automatically extracted video data. The major conclusion is based on the fusion of *"Gait Parameters"* and IADL, which are processed for autonomy and diagnosis assessment using a feature selection approach and a classifier (König et al., 2015). Figure 13 shows how a physical environment is being processed in terms based on activity zones.

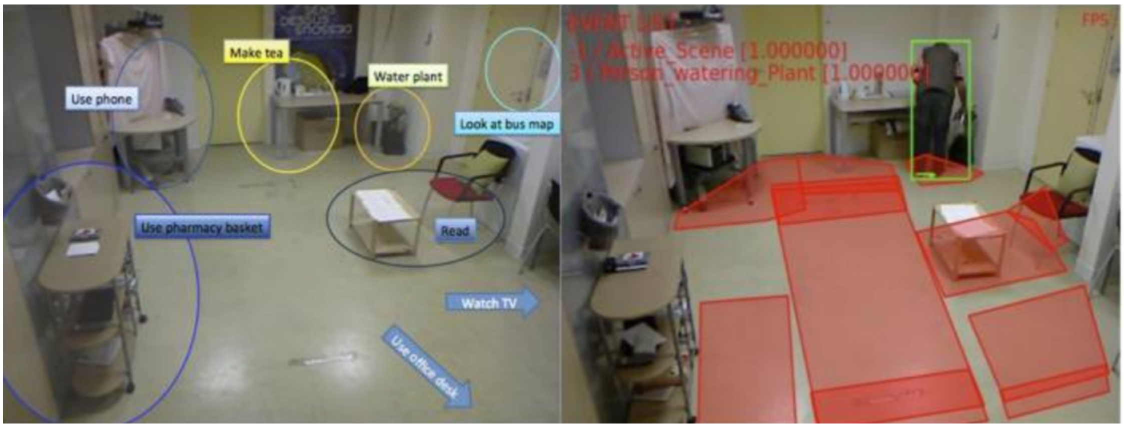


Figure 13. On the left, the contextual zones of the environment are utilized to explain the scene semantics. On the right, is an example of the automated video monitoring system's output (König et al., 2015).

The finding demonstrates that by using an EMS, it is possible to assess autonomy in IADL functioning and that different autonomy levels may be classified accurately merely based on the extracted video features. This is reflected in high accuracy regarding diagnosis (König et al., 2015).

3.1.2.3 HealthXAI

Khodabandehloo et al. (2021) presented an interesting article on sensors and a Health Explainable Artificial Intelligence (HealthXAI) system, which can be applied to a typical smart-home sensor infrastructure. The system is equipped with various types of sensors to detect the users´ position and interactions with furniture and appliances. These sensors could include Passive Infrared (PIR) motion sensors to track the users´ position or other sensors that identify a user´s location in the house. The design could suggest using e.g.:

- Contact sensors to track the interactions with the apartment's doors or the use of furniture, such as cabinets or the fridge door
- Motion sensors attached to certain objects to detect their usage
- Power sensors to detect the use of certain electric appliances

Khodabandehloo et al. (2021) discovered that there is a statistically significant link between HealthXAI's predictions and the experimental data-based diagnosis of the individuals' cognitive health state.

The architecture is based on a smart-home sensor infrastructure that integrates heterogeneous sensor data using a stream processing software platform and a semantic integration layer. Modules for monitoring the users´ activities and movements are included in the architecture. Both high-level behaviors such as *"cooking"* and fine-grained actions such as *"open fridge door"* are detected. The modules Detection of Behavioral Anomalies (DOBA) and Detection of Locomotion Anomalies (DOLA), examine activities and motion data to discover anomalies. To adjust the parameters of the DOBA module according to the context of the individual, a cloud-based collaborative data mining system oversees collecting anonymous data about the behaviors and actions witnessed in various houses. The knowledge-based anomaly refining module examines detected activity instances and anomalies to improve locomotion anomaly predictions by considering the context in which abnormalities are encountered.

The HealthXAI module examines the trained regression models to generate extensive natural language explanations of the predictions based on clinical markers. Predictions, explanations, and fine-grained abnormalities are sent to a remote healthcare center, where clinicians can examine the entire dataset using a user-friendly clinical dashboard.

Based on the findings of the trial, there is a statistically significant association between HealthXAI predictions and the diagnosis of participants' cognitive health status. When it comes to cognitively healthy people and people with disabilities, this link is especially clear.

When only people with MCI and cognitively healthy elderly were considered, they found a weak connection (Khodabandehloo et al., 2021).

3.1.2.4 Smart Environment

Schmitter-Edgecombe et al. (2013) presented a smart environment that can gather and apply information about residents and their physical surroundings, as well as use automated devices to enhance residents' experiences. Environmental or stationary gadgets that monitor a person in a specific place might be found in the home or elsewhere (Schmitter-Edgecombe et al., 2013).

Smart environments can help people maintain their independence by offering continuous and proactive assessments of their health and cognitive condition. The system functions by analyzing probable changes in functional performance and by tracking normal daily routine, as well as the time it takes to accomplish customary activities, and other everyday trends. Furthermore, if the person fails to get out of bed and cook breakfast as per her usual routine one morning, an alarm could be sent to check the well-being of the person. The smart home might also prompt to engage in health-related activities like exercise or socialization using activity-aware prompting, potentially reducing falls, and improving overall well-being (Schmitter-Edgecombe et al., 2013).

The intelligent software will be able to perform automated functional assessments and identify trends that are indicators and predictors of acute health changes as well as slower, more subtle progressive decline by tracking persons' daily behavior over time. By implementing activity-aware prompt-based interventions that support functional independence while also promoting healthy lifestyle behaviors, overall health and well-being can be improved while also altering the declining trajectory (Schmitter-Edgecombe et al., 2013).

There are also examples of systems that offer analysis of movement in an environment based on sensors, and speech dialog which is a part of care. Care providers can conduct a conversation with a person at home and in that way both monitor and help the person at home (Tamamizu et al., 2017).

3.1.3 Virtual Reality

VR is a 3D computer-simulated or imaged environment that allows users to feel as if they are in another physical location.

3.1.3.1 VR-Maze

Morganti and Riva (2014) discovered evidence indicating that a VR-Maze test (Figure 14) highlighted several aspects of the decrease of navigational ability in the elderly population that are normally undetectable by traditional spatial assessments. The VR-Maze test was produced using 3D Game Studio software, which allows users to design virtual versions of mazes. This program allows users to test their ability to identify the best route to a specific objective while immersed in an empty environment (Morganti and Riva, 2014).

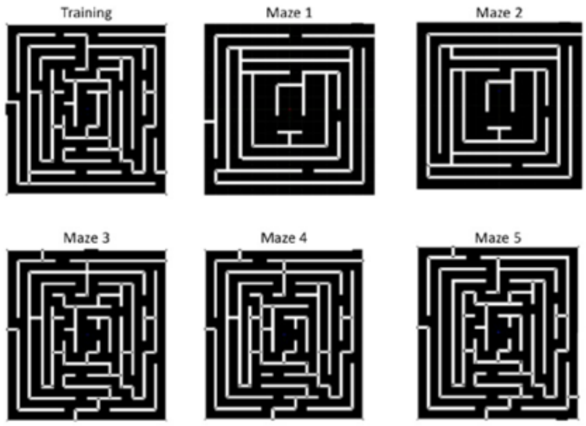


Figure 14. VR-Maze planimetry (Morganti & Riva, 2014).

To evaluate participant performance, all five mazes could track user spatial activity. Participants were requested to complete a Paper and Pencil (PP) version of the maze from beginning to end before moving on to the VR version of the maze. This was done to assess their ability to transform survey spatial information into a route one.

With increasing age, there is a considerable difference in performance when utilizing PP and VR, as can be seen in Diagram 1. The loss in wayfinding ability in the VR-Maze test is much higher in the participants of higher age when their cognitive level and memory functions drop, demonstrating that a decline in these areas goes hand in hand with a decline in wayfinding ability (Morganti and Riva, 2014).

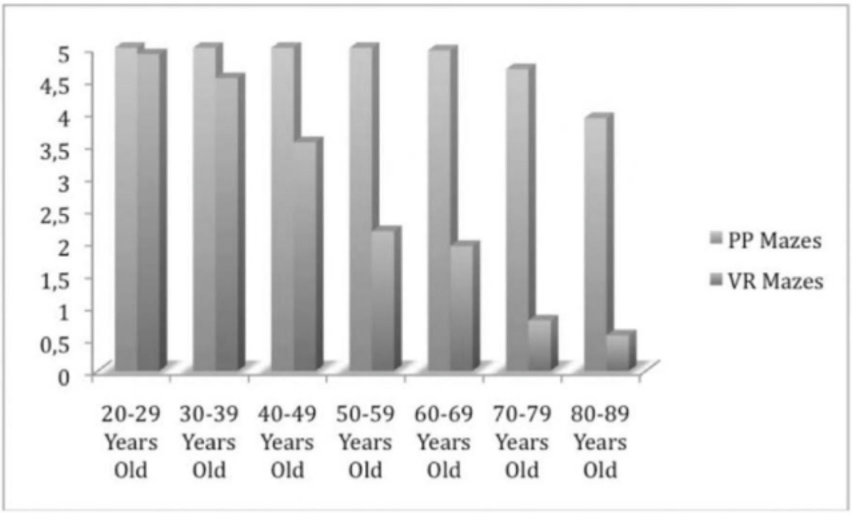


Diagram 1. Differences between the PP and VR mazes for various age groups (Morganti and Riva, 2014).

The study confirms the increased utility of VR activities as assessment tools for the aged population, particularly those involving spatial navigation skills (Morganti and Riva, 2014).

3.1.3.2 AI Meets VR

Cavedoni et al. (2020) write about how traditional neuropsychological assessments, which are based on a categorical model of diagnosis, could be combined with a dimensional assessment technique incorporating VR and AI. VR can be used to build highly environmentally controlled simulations that mimic daily life situations. Then, in conjunction with clinical and neuropsychological data, AI could use Machine Learning (ML) to analyze gathered data.

As a result, this new dimensional cognitive-behavioral evaluation would detect brain abnormalities and reduced cognitive skills in elderly persons, which are typical of MCI and dementia, even in the early stages, allowing for more timely interventions (Cavedoni et al. 2020).

Traditional neuropsychological testing does not provide this level of detail, but it can be used as a starting point for combining other data to detect a subclinical issue that would otherwise be undiagnosable using a category method (Cavedoni et al. 2020). To gain precise information measurements are set up to capture movement in a space with help of sensors and cameras as shown in Figure15.

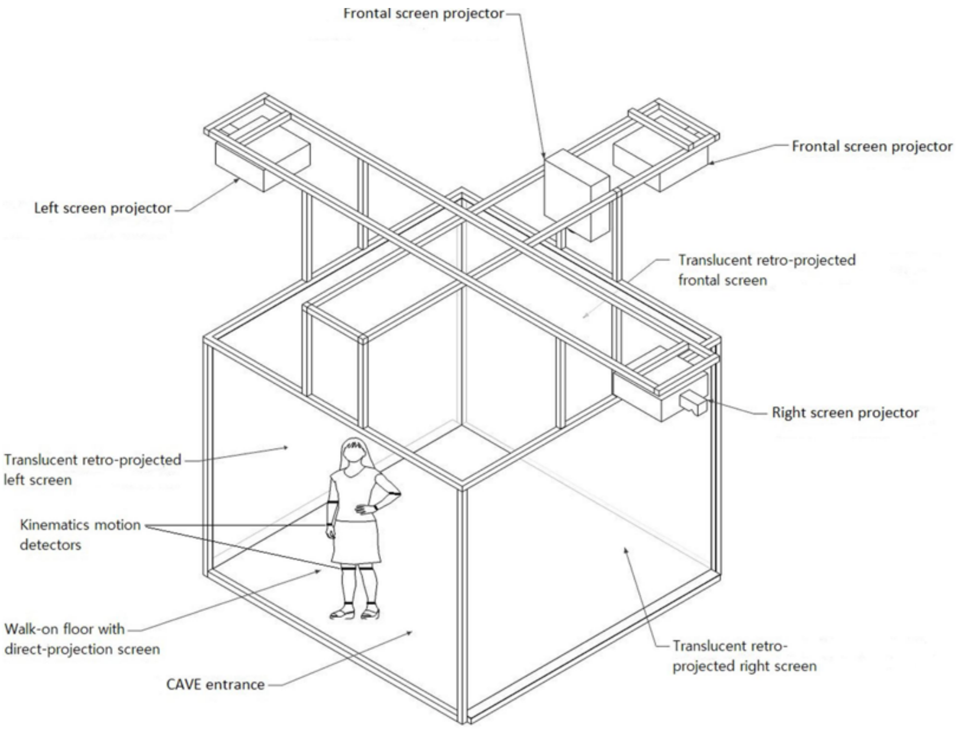


Figure 15. Movement measurements of participants were detected while conducting IADL in a VR environment to refine MCI assessment using a dimensional method (Cavedoni et al. 2020).

The ability of VR to detect both real-time behaviors and physiological indices is the most crucial aspect for this perspective. ML offers computational approaches and capacity as evidenced by prior studies that used this technique to distinguish between normal and pathological changes (Cavedoni et al. 2020). The researchers have suggested a combined model that can be seen in Figure 16.

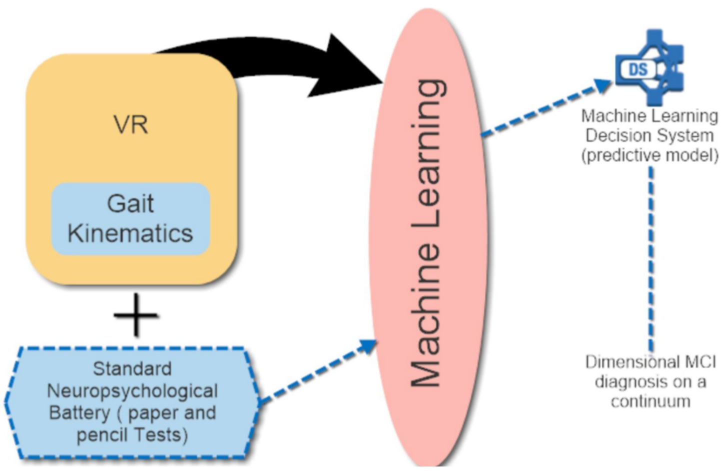


Figure 16. Schematic illustration of the innovative model proposed (Cavedoni et al. 2020).

3.1.3.3 Serious Games

In their study, Zucchella et al. (2014) present the development and usability testing of a 3D Serious Game (SG) that uses a virtual environment-based platform for the early detection and characterization of MCI. This SG can track a variety of metrics relating to the participants' cognitive condition, such as the number of correct actions, errors, incorrect recognitions, omissions, and the amount of time it takes to complete the task. Despite the authors' claims that SGs could be employed in the health domain, specifically in the assessment and rehabilitation of mental and neuropsychological diseases, this usability test highlights issues relating to task complexity (Zucchella et al., 2014).

A desktop personal computer with a sound card makes up the final VR system. A touch screen monitor is used to navigate and interact with the environment. There is no user-3D avatar because the application is based on a first-person perspective. The environment and the user's virtual position within it appear to be recorded from the front, and the navigation model allows users to move in the environment at a constant height to the floor and rotate the *head* within a limited range of angles. The 3D environment consists of a loft having the essential elements of a house with which one interacts. A kitchen area, a bedroom area, a living room area, and a bathroom area, are all contained in a limited space (Zucchella et al., 2014).

The platform's SG tasks are meant to engage participants in task-specific settings in which they are asked to undertake tasks that mimic daily activities. *Executive functioning* (reasoning and planning), *attention* (chosen and divided), *memory* (short- and long-term, prospective), and *visuospatial orientation* are among the five activities that have been created to assess different cognitive processes (Zucchella et al., 2014).

A performance-based evaluation index has been constructed for each task that was given and expected to be completed. The number of accurate actions, the number of errors, the number of false recognitions, the number of omissions, the time required to accomplish the work, and the distance traveled are all factors considered in this index (Zucchella et al., 2014).

3.1.4 Brain Imaging

Clinical practices use brain scans to detect important changes that happened due to diseases, aging, or dementia.

More precisely, early structural, and metabolic alterations in the hippocampus, entorhinal cortex, and gray matter regions in the Medial Temporal Lobe (MTL) are vital to investigate. It is always important to detect serious changes early, as timely detection is essential for initiating treatment.

DTI can be used to examine the microstructural integrity of white matter as shown in Figure 17. Subjects with white matter injury have higher mean diffusivity and lower fractional anisotropy. In individuals with AD, functional imaging studies using Positron Emission Tomography (PET) allow for the detection of amyloid plaques in the living brain (Yin et al., 2013). These are also connected with AD.

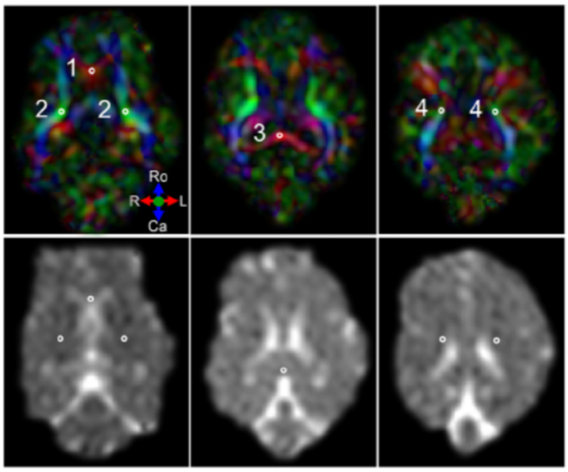


Figure 17. Processed DTI data visualizing white matter tracts in the brain (Lee et al., 2015).

If MCI symptoms are noticed in a patient, but their origin is not clear, it is advisable to do a brain scan to rule out other causes besides dementia. The most common types of scans used to diagnose dementia-like symptoms are CT scans, MRI scans, and Electroencephalogram (EEG) testing. However, as previously stated, there is no single definitive test for dementia (Taylor, 2022), so it is common to conduct several exams using different means to reliably establish a diagnosis.

Standard structural MRI scans can reveal physical abnormalities in grey and white matter brain form, as well as rule out other causes of cognitive decline such as tumors or hydrocephalus. It is obtained using T1-weighted, T2-weighted, and DTI sequences. Among those, T1-weighted MRI is considered an excellent tool for detecting localized decrease in grey matter volume, which is a common symptom of neurodegenerative dementias and is sometimes referred to as atrophy (Bonifacio and Zamboni, 2016).

The distribution of disease specific to various dementia types has been found to match the spatial pattern of grey matter atrophy indicated by T1-weighted MRI. E.g., in AD, atrophy is linked to the spread of neurofibrillary tangles in the brain. Furthermore, cognitive impairments are connected to the degree and rate of volume loss (Bonifacio and Zamboni, 2016).

T2-weighted MRI sequences with fluid-attenuated inversion recovery are the ideal modality for assessing white matter and periventricular lesions characterized by gliosis, ischemia, and oedema. As a result, they are particularly adept at detecting vascular damage, such as White Matter Hyperintensities (WMH) and lacunar infarcts, both of which are prominent in Vascular Dementia (VaD), as well as other white matter abnormalities seen in rare, rapidly progressing dementia syndromes. Microhemorrhages are common in hypertension-related VaD and cerebral amyloid angiopathy, and paramagnetic-sensitive MRI sequences such as T2-weighted Gradient-Recalled Echo (GRE) or susceptibility-weighted sequences are the best at detecting them. DTI identifies the random motion of water molecules, allowing inferences about the integrity of the white matter tract. It is currently exclusively used in research to determine the structural connections and axonal architecture of the brain (Bonifacio and Zamboni, 2016). Figure 18 shows sequences of structural MRI.

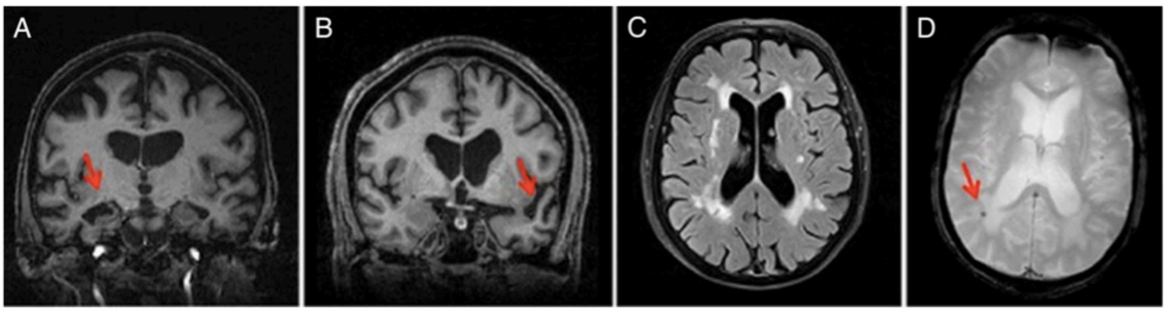


*Figure 18. (A) T1-weighted MRI picture of a patient with A*D*, with the right hippocampus atrophy indicated by the arrow. (B) T1-weighted MRI scan of a patient with dementia, with an arrow pointing to atrophy of the left temporal pole. (C) Fluid-attenuated inversion recovery picture of a patient with* VaD *and periventricular WMH, as well as symptoms of small vessel disease. (D) T2-weighted GRE picture of a patient with* VaD*, with an arrow pointing to a microbleed (Bonifacio* and *Zamboni, 2016).*

The number of hydrogen protons in the observed area is more important than the magnetic properties of the hydrogen nuclei in PD weighted pictures. They originate with the initial echo. When the contribution of both T1 and T2 contrast is minimized, PD weighted images result.

The functional state of the brain can be determined via functional MRI (fMRI). Activation maps that identify which parts of the brain are engaged when doing a task (task-related fMRI) or at rest (Blood Oxygen Level-Dependent (BOLD) fMRI) can be created (r-fMRI). The r-fMRI has recently been developed to study large-scale networks that are coactivated and functionally connected, referred to as resting state networks. It is simple to notice it even in people with severe cognitive impairment. Distinct dementia diagnoses have been shown to disrupt different networks in different ways, hinting that this technique could be beneficial in dementia differential diagnosis. Due to the high variability of BOLD responses between subjects, fMRI is still only used in research settings to compare groups of patients to HC and cannot yet be used to obtain clinical information from single patients, necessitating additional validation before becoming clinically exploitable (Bonifacio and Zamboni, 2016).

Functional imaging includes PET and Single Photon Emission CT (SPECT), which allow researchers to look at the metabolism and perfusion of the brain when it is at rest or executing a task. To function, they rely on the use of radioactive ligands. They provide patient-specific information that can aid in the differential diagnosis in clinical settings. Furthermore, they provide a better understanding of the disease's molecular and chemical etiology in research settings. PET imaging is thought to have superior specificity and sensitivity over SPECT imaging in the diagnosis of various dementia diseases. PET allows researchers to detect functional markers of neurodegeneration, specific neuropathological aggregates, and other factors that could influence the progression of various dementia disorders (Bonifacio and Zamboni, 2016).

Three brain scans are shown in figure 19, with the PET imaging technology being used to detect amyloid plaques in the brain by using a specific radioactive agent that binds to the plaques. PET scans are a significant advancement because they allow clinicians to improve their clinical evaluation by assessing direct biological changes in the brain caused by AD. As a result, it is a more accurate method of diagnosing AD (Rauf, 2019).

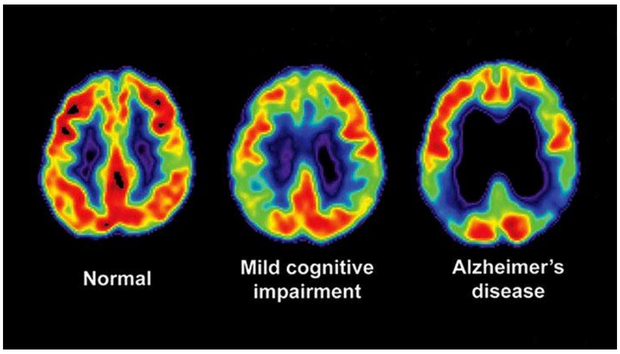


Figure 19. Picture of a normal, MCI and a brain with AD using a PET scan (Rauf, 2019).

It is of interest to understand in which way the disease might progress once the early signs are noticed. Structural MRI can help answer this question by detecting early localized atrophy in patients with MCI as compared to healthy patients, particularly in the MTL and areas outside of MTL, such as the lateral temporal lobes, medial parietal lobes, and lateral associative parietal areas.

Several longitudinal studies have demonstrated that structural MRI can distinguish patients with MCI who will progress to AD soon from patients with MCI who will remain stable (Bonifacio and Zamboni, 2016).

The availability of MRI in most Western countries, as well as its low cost and non-invasiveness, are obvious advantages. It is particularly important to detect localized atrophy on T1-weighted structural MRI to aid in the differential diagnosis of the many kinds of neurodegenerative dementia. The connection between atrophy and cognitive deterioration is undeniable as proven by the research (Bonifacio and Zamboni, 2016).

3.1.4.1 Standardization Efforts

Research is being conducted to standardize and validate structural imaging, specifically hippocampus volumetry, for it to be used for diagnosis and clinical trials. Nevertheless, structural MRI limitations account for the lack of specificity for the underlying pathology of dementing syndromes, as atrophy patterns might overlap across disorders. Furthermore, structural MRI takes a long time to alter and does not provide functional information like fMRI, limiting the ability to detect dynamic, short-term changes in response to prospective treatments. More research using sophisticated and innovative MRI techniques will likely reveal more pathology related to the various dementia illnesses (Bonifacio and Zamboni, 2016).

Figure 20 shows a CT scan and X-ray. A CT scan, combines a series of X-ray images collected from various angles around the body and utilizes computer processing to create cross-sectional images of the bones, blood arteries, and soft tissues within your body, is another often utilized exam (Mayo Clinic, n.d.).

Figure 20. CT scan and X-ray.

A CT scan can be used for a variety of purposes, but it's especially useful for quickly examining patients who may have internal injuries because of vehicle accidents or other sorts of trauma. A CT scan can visualize almost every region of the body and is used to diagnose sickness or injury as well as plan medical, surgical, or radiation treatment. CT scans have been utilized successfully in patients with dementia and probable deterioration. Because it is available in many hospitals and is quick to perform, thus it is used more frequently than MRI scans (Cleveland Clinic, 2020).

In addition, CT scans are cheaper to use than MRI scans. MRI scans can take months to get an appointment, so it is more practical with CT scans. For diagnostic purposes, CT scans are utilized with special software to capture and follow changes in brains using a dedicated software program (Health Images, n.d.).

A combined PET and CT exam utilize pictures from both PET and CT scans to provide information on the anatomy and function of organs and tissues from both scans. When combined, a PET and CT scan can help distinguish AD from other types of dementia (RadiologyInfo, 2022).

Another important exam is the EEG that is utilizing electrodes to precisely measure brain activity at multiple points on the head as shown in Figure 21.

A) *B)*

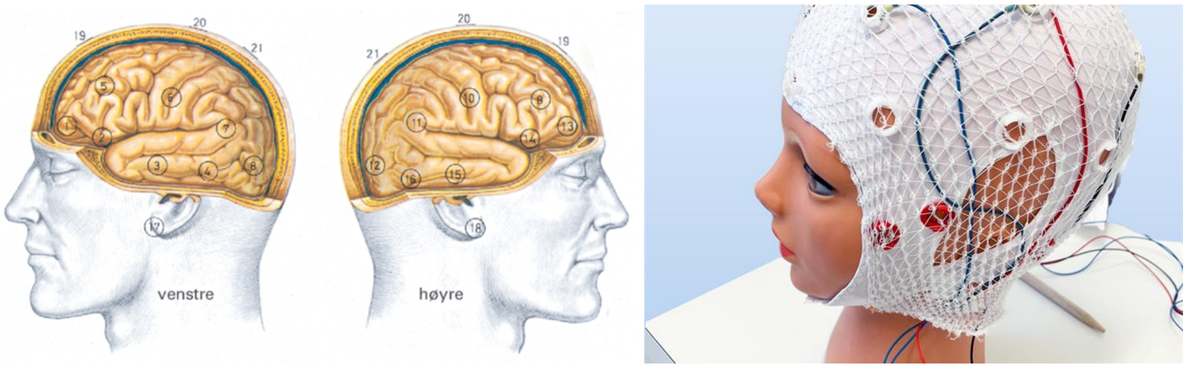


Figure 21. A) The EEG electrodes are placed in pairs symmetrically on the skull. The various derivatives are numbered according to an internationally determined system. The electrodes on the earlobe act as reference electrodes (Engstrøm and Jansen, 2019). B) A hood is placed on the persons head and wires are connected to it (Helse-Bergen, n.d.)

The points of activity that are interesting for analysis and the measurement equipment placed on the head, usually a hat is used in combination with electrodes. EEG testing is expected to detect electrical impulses that occur in the cerebral cortex (NHI, 2021).

3.1.5 Reflection on Methods

The information presented here is very detailed to show what level of sophistication is needed to capture an exact picture of brains. Either by imaging or measuring electric signals of the brain. Different techniques are capturing anatomical changes that impact the way the brain is functioning and with that how the whole person is functioning. Subtitle changes, like MCI, can be identified even using combined techniques and employing good expertise to interpret the results. The purpose is to provide as exact as possible diagnosis which will also influence the choice of treatment. However, ongoing efforts are required to standardize approaches and bring certainty into early diagnosing. Depending on the resources and available clinical practice there are always some methods that could be applied and combined.

3.2 IT Solutions for Treating Cognitive Decline

Depending on the severity of the decline the choice of treatment will vary. In milder forms, there are many non-invasive simple methods to imply which can engage persons who are affected by the condition. In more severe cases, where communication and abilities are limited, the treatment will make sense of soothing solutions that will provide comfort.

A systematic literature review was performed using keywords such as cognitive decline, treatment, therapy, information technology (IT), and dementia.

3.2.1 Virtual Reality

VR has been extensively used in medical and neuropsychological contexts as a diagnostic and rehabilitation tool for older persons suffering from the effects of traumatic brain injury, post-stroke patients, and spatial memory and balance, among other applications. Importantly, VR enables therapy to be personalized to each disease in a controlled manner, starting with a continual assessment of the persons behavior (Cavedoni, et al. 2020).

VR is a 3D computer-simulated or imaged environment that allows users to feel as if they are in another physical location. This technology has an interactive component and may include interactive computer-based cognitive training, which involves making decisions and learning in a virtual environment. This sort of virtual training for dementia patients usually entails the supervised practice of a set of standardized activities designed to exercise the brain across a variety of cognitive domains, such as processing speed, attention, and memory (D'Cunha et al., 2019). VR, in conjunction with smartphones, has the potential to make therapy more accessible. VR can be connected to a computer, but it can also refer to as Mobile-VR, which uses a smartphone with VR goggles to provide a unique experience. Because of its accessibility and affordability, Mobile-VR can be advantageous (Kloster and Babic, 2019).

D'Cunha et al. (2019) write how VR treatment has grown in popularity in recent years, and that it has been demonstrated to be pleasurable and increases a sense of control in patients with dementia (D'Cunha et al., 2019). Several research projects have investigated the impact of VR-based cognitive training on people with cognitive impairment.

An older study from 2005 by Giuseppe Riva concentrates on the thoughts and perspectives concerning psychotherapy and VR. Even back then, they knew that using VR in treatment could be advantageous and even beneficial. The authors demonstrated that employing VR in the therapy of phobias is advantageous, as it allows patients to be exposed to their concerns without having to face them in real life. They also demonstrated that VR might be utilized to treat Posttraumatic Stress Disorder (PTSD), eating problems, and body issues.
Two benefits were identified by the authors. Firstly, all approaches employed in routine treatments can be combined (cognitive, behavioral, and experimental). Secondly, VR causes a controlled sensory reorganization in the patient, which might alter physiological consciousness (Riva, 2005) (Kloster and Babic, 2019).

Hofmann et al. (2003) contrasted patients with AD to people with major depressive disorder and an age-matched HC group to see if the technology could improve cognitive functioning. IT was characterized in that study as interactive digital photos of the participants' genuine social and local environment that allowed a total of 120 decisions to be made within the interface. Participants were instructed to complete a variety of activities, including route navigation and a free recall task, using a sequence of photos showing a shopping journey on a computer touch screen. The study's findings revealed that participants in the AD group performed lower in all testing measures at baseline than the other groups. However, they exhibited a significant reduction in errors after 12 sessions of interactive cognitive training, whereas the other groups performed similarly, suggesting that interactive cognitive training could be suitable for people living with dementia. According to self-reported comments, participants in the AD group liked the training, and indicated that they could use it in real-life circumstances (Hofmann et al., 2003).

In a pilot study by Moyle et al. (2018), where the effects of a 15-minute interactive and immersive VR forest experience, measure the level of engagement, apathy, and emotional states of people living with dementia in two elderly care homes were investigated. Quantitative data on emotions, apathy, and engagement were collected using various scales and questionnaires, while semi-structured interviews with staff, dementia patients, and their families were undertaken to assess the entire experience. Residents reported higher joy and alertness than standard values for adults living with dementia in the Observed Emotion Rating Scale (OERS), shown in Table 6, which is an observational tool for rating two positive emotions; pleasure and general alertness (Phillips et al., 2010). The authors found that apathy was lower during the encounter, indicating that the participants were fully involved in the virtual world. Most of the participants liked the experience, but some experienced boredom and bewilderment, indicating that this type of intervention may not be suited for all dementia patients. Several limitations were highlighted in this study, including changes in setting between the two institutions´ *dark* vs. *bright* rooms and caregiver facilitation techniques *passive* vs. *active* participation (Moyle et al., 2018).

Emotional Rating Scale

5	out of control	
4	angry	
3	frustrated or anxious	
2	just okay	
1	happy	

Table 6. The OERS.

3.2.2 Games

From interviews with experts, it became clear that games were something they found to be very interesting for people with cognitive decline as *"games engage the patient"*. The content they state is not so important if it is made fun, patients are willing to spend time learning how the game works.

3.2.2.1 Videogames

Short action video game interventions have been shown in studies to improve a variety of perceptual and cognitive capacities (Boot et al., 2013).

Basak et al. (2008) spent hours training older people in a real-time strategy video game to strengthen their executive functions. The participants solved math problems, tasks that required them to judge whether a number was odd or even, upper and lower case letters appearing in different locations where the participant should press a key if the same letter appeared, color orientation, Raven´s Advanced Progressive Matrices where the goal is to find the missing piece to complete the pattern, stopping tasks, searching for a triangle among squares, identifying letters that had appeared, an indication of dots that had appeared on the screen and determining whether two shapes that were shown on the screen were the same. Before, during, and after video game training, cognitive tests, including executive control and visuospatial skills, were examined. In terms of game play, the trainees improved. In executive control functions like task switching, working memory, visual short-term memory, and reasoning, they improved much more than the control individuals. Improvements in task switching were linked to individual differences in game performance. One reason for the training group's improved performance in the transfer tasks could be that their priorities are constantly changing, albeit voluntarily, in which they may focus on building wonders, generating resources, maintaining multiple cities, attacking the enemy, or defending one's territories. Trainees could combine variable priority training into game training by emphasizing different parts of each game performance at different times. As a result, similar transfer effects could be detected for any video game, whether it prioritizes the learning and flexible deployment of complicated techniques or fast-paced responses to multimodal inputs, albeit this is unlikely given the specific transfer benefits that the authors saw. Examining the relationship between different forms of video games and the nature of transfer benefits is an essential future direction. It is worth studying whether video game training enhances performance on everyday cognitive abilities and real-world tasks, such as driving skills, working in a crowded workplace, or leisure hobbies and sports, in addition to laboratory-based tasks (Basak et al., 2008).

As a result, video game interventions could be an excellent way to address the multiple perceptual and cognitive deficits that come with age (Basak et al., 2008).

3.2.2.2 Serious games

SGs are games that have other purposes than just pure entertainment, e.g., storytelling and educational games (Muscio et al., 2015).

A study by Manera et al. (2017), which gives guidelines for using SGs with MCI patients as shown in Figure 22, covers computer-based assessment for people with MCI. According to the authors SGs were classified as either very adapted or completely adapted for patients with MCI. They state that SGs are also regarded to be better suitable for patients with early cognitive impairment than for those who are already losing autonomy in daily activities. Participants felt that SGs are well-suited for cognitive testing, as well as physical and cognitive training, promoting well-being, and teaching courses (Manera et al., 2017).

Are SG adapted to whom?

- SG are completely adapted to older people with MCI;
- Designing SG for people with dementia is challenging, but important.

What should be the SG target?

- Assessment, training and promoting wellbeing are good targets for people with MCI and dementia
- For MCI, SG for physical and cognitive stimulation are particularly suitable;
- SG choice should be personalized based on clinical assessment aiming at identifying training targets in different domains.

Where should SG be used, and with whom?

- SG can be employed both at home and in clinical facilities;
- SG are more effective when the patient is accompanied by a caregiver/clinician;
- some SG can be used alone;
- Home-based training is still challenging due to technical issues.

How often should SG be used?

- Training frequency between two and four times a week were rated as the most adapted; But
- Frequency of use for SG should be personalized based on the game features and the patient's clinical profile and motivation;
- Clinician follow up is crucial to keep the SG motivating (no loss of interest, no addiction).

Figure 22. Recommendations for the use of SGs with cognitively declined persons (Manera et al., 2017).

PhysioMate is an example of a SG about the effects of aging on the body and mind. The game's purpose is to encourage the player to become more physically active. The game can be used as a supplement to physiotherapist-assisted exercises, but it can also be utilized without the presence of the therapist. Users are coached through a series of activities using Microsoft Kinect and motion sensors (Madeira et al., 2014) (Kloster and Babic, 2019).

Dove and Astell (2019) write in their article that motion-based technologies can give meaningful and fun engagement in a wide range of activities, but for individuals with dementia to benefit from these devices, it is important to have a clear grasp of how to choose and deliver these activities. The goal of their study was to see how adults with dementia who attend adult day programs could use motion-based technology (Xbox Kinect) as a group activity. The qualitative study took place at an adult day program for older persons who were dealing with age-related issues. To obtain naturalistic data, participants were watched while playing a digital bowling game shown on Xbox Kinect (Figure 23), one hour per week for 20 weeks. Observation-based field notes were transcribed and analyzed to uncover emergent themes. The findings emphasized three main themes that highlight the potential of motion-based technology as a group activity for individuals with dementia who attend adult day programs: *the value of having a skilled trainer*, *learning vs mastery*, and *playing "independently together"*. Furthermore, using the technology in a group setting created a positive and supportive environment, which added to the enjoyment of the activity (Dove and Astell, 2019).

Figure 23. Bowling game using Xbox Kinect (Dove and Astell, 2019).

3.2.3 Tovertafel

Tovertafel is a game console made specifically for use in health care settings. Active Cues, a Dutch medical technology startup, debuted it in 2015. Interactive games are projected onto a table using high-quality projectors, infrared sensors, a loudspeaker, and a processor on the console. The console was created for people with cognitive disabilities in nursing homes, daycare centers, public libraries, and schools. There are many versions for different target groups, such as dementia patients, people with intellectual disabilities, and children with developmental disorders. It is designed to collect, engage, distribute happiness, activate, and be simple to use (Medema, n.d.) (Wikipedia, 2020).

Better physical activity in dementia patients, improved relationships between caregivers and residents, and higher satisfaction for caregivers, family members, and friends are some of the advantages of utilizing Tovertafel (Tover, 2021).

Several games can be played using the Tovertafel projector. They are arranged with one to five stars depending on the difficulty level. Effects like social, physical, sensory, and cognitive, are also included in the description of each game (Tover, n.d.). There are a lot of games that can be played using the Tovertafel, three of them are described in Table 7.

	Leisure Memo	Leaves	Football
Effect	Cognitive and Social	Physical and Sensory	Physical and Social
Level	5	2	4
Targets	Seniors	Seniors	Seniors
Description	Finding the two images that go together. Place the hand on a card and turn it over. This tough game entertains while stimulating the brain. Who will flip over the card, who will recognize the image, and who will know where the other is?	The table is covered in leaves. Rustling offers the impression of being outside. Participants rake the leaves into a pile and uncover three ladybirds beneath them. This encourages participants to make large arm and hand movements.	The participants aim to score as many goals as they can with the football. This game requires participants to significantly move and coordinate. If no one touches the ball, it will stop moving.
Picture			
Link	https://www.tover.care/game/leisure-memo	https://www.tover.care/game/leaves	https://www.tover.care/game/football

Table 7. Three games that can be played with the Tovertafel (Tover, n.d.).

3.2.4 Snoezelen

Snoezelen is a multi-sensory stimulation environment meant to provide a relaxing atmosphere with calming noises, enticing smells, tactile experiences, massage, vibration, vibrosonic sensations, and gradual movement (Snoezelen, n.d.). A picture of the environment can be seen in Figure 24. The stimulating scenario established inside a Snoezelen is not considered an attempt to teach some specific abilities. Therapeutic effects and learning may occur through the Snoezelen activities or a base simply for promoting relaxation and quietness. It is offered as an opportunity to foster a broad sense of restoration and rejuvenation, which can be obtained by engaging in delightful and stimulating activities that are free of stress and may be fully appreciated (Lancioni et al., 2009). Solutions are tailored for a specific user group and are meant to always provide a rewarding sensory experience (Snoezelen, n.d.).

Figure 24. Snoezelen multi-sensory environment (Snoezelen, n.d.).

3.2.5 Websites

After performing a search in Google Play for applications on cognitive decline, additional applications were found. A screenshot is presented in Figure 25. There is however limited information about their performance and scope, but it is obvious that there is a lot of interest in providing IT solutions using applications.

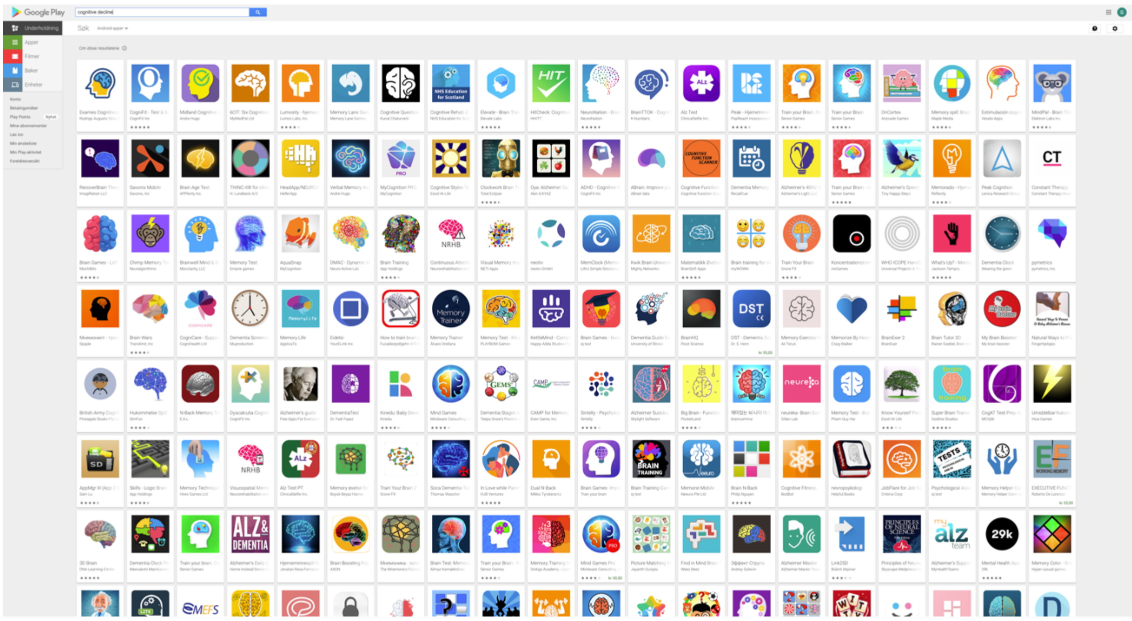


Figure 25. Result of a Google Play search for cognitive decline applications.

3.2.5.1 Hva kan hjelpe

Hvakanhjelpe.no is a Norwegian website that provides information, recommendations, and sound advice on a variety of solutions, aids, and welfare technology for individuals who want to live more independently.

The website was part of a larger effort aimed at reaching out to the public with simple instructions on how to use *"every day"* technology. The website can provide an overview of what the user needs to remember during the day, as well as resources for remembering it. E.g., the user may need to call family and friends, remember to take prescriptions, engage in physical exercise, or listen to music. Hvakanhjelpe.no is a website that provides examples of tools that can be utilized in this procedure (Hvakanhjelpe, n.d.). Figure 26 displays a screenshot of the website.

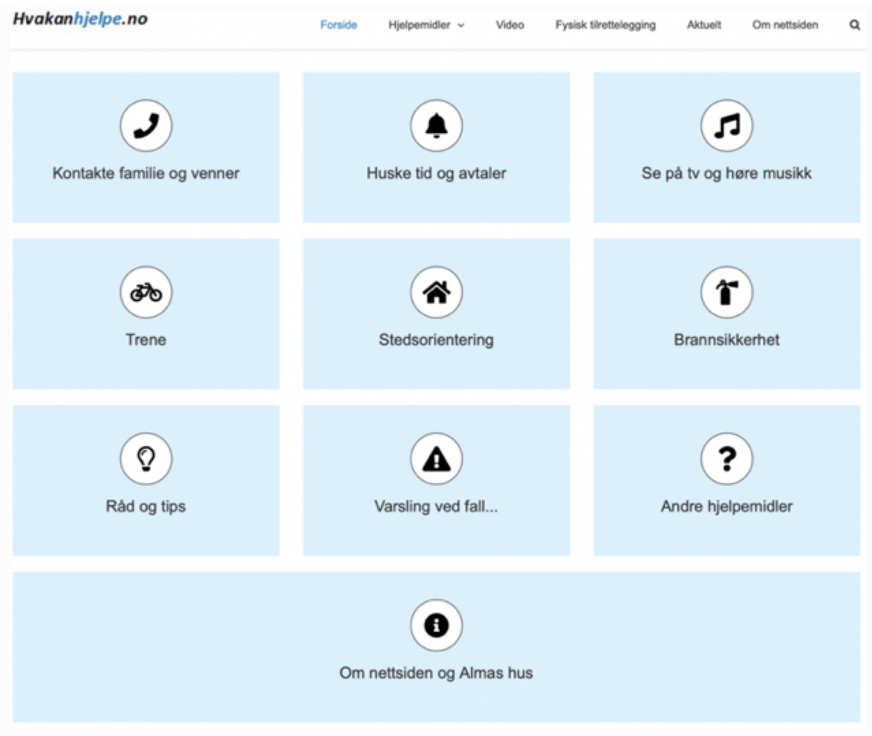


Figure 26. Screenshot of the hvakanhjelpe website (Hvakanhjelpe, n.d.).

3.2.5.2 Televindu

Televindu is an audiovisual sensory stimulation technique that helps to build security, inspire interest, increase appetite, and reduce restlessness and anxiety. This can improve quality of life while also making life easier for colleagues and family members.

Targeted sensory inputs have been shown to have the following effects:

- Invigorating and socializing effect

- Preventing and reducing challenging behavior
- Reduction in the use of force and sedatives
- Better working environment and reduced need for care
- Increased appetite

It can be utilized as an alternative to traditional environmental therapy and stimulation. Video is used as an activity in Televindu. A video is a form of entertainment that elicits memories and dialogues. The user can choose from 250 videos customized for persons with dementia using the television window. This portal also allows users to contribute their videos, such as those from local cultural events (VilMer, n.d.).

All health facilities can use Televindu to create their video platform. They can share videos between institutions, build playlists specific to the institution, and control who has access to the videos and playlists they submit. This facilitates knowledge sharing. Televindu focuses on videos from places and activities with which the elderly has a special bond. This offers a conducive environment for intimate discussions on shared memories and upcoming events, and a sense of self-assurance and independence, which can help with recollection therapy (VilMer, n.d.). Figure 27 shows how to interact with Televindu through three screens. Firstly, the person can explore content based on interests and stimulus levels, then connect the tablet or computer to a TV with a HDMI cable, and finally, enjoy the memorable video.

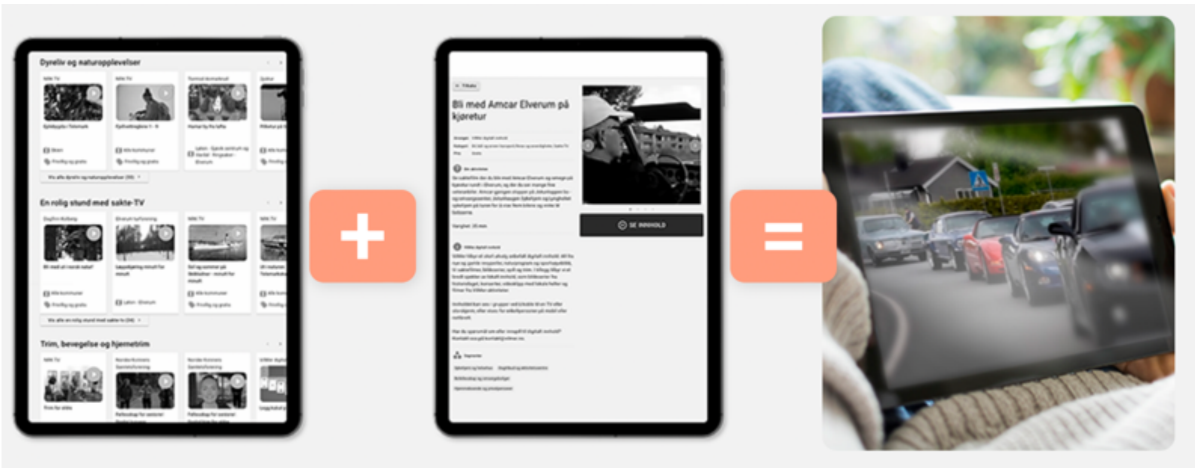


Figure 27. Televindu (VilMer, n.d.).

3.2.5.3 Memory Notebook

Schmitter-Edgecombe et al., (2013) has been trying to help people with MCI and their caregivers become more proactive in adopting efficient memory and problem-solving skills into their daily lives. Their goal is to help individuals with MCI keep their independence, reduce caregiver stress, improve quality of life, and engage in healthy lifestyle activities linked to a lower risk of dementia. Simple technologies, such as a memory notebook or a Personal Digital Assistant (PDA), has been widely utilized to aid cognitive compensation and can also be used to improve health and well-being. While some people with cognitive impairment may have trouble learning to use a memory notebook, PDAs, which allow for the establishment of reminder prompts, may help people use their aids more often. An intelligent smart home reminder might prompt a person to write in the memory notebook based on tracking of a person's activity level and location, as well as a knowledge of the persons routine. Furthermore, such an intelligent system might give a person prompts not only to commence activities but also to perform difficult everyday tasks precisely and entirely (Schmitter-Edgecombe et al., 2013).

3.2.6 Virtual User Model

The study by Segkouli et al. (2015) is an investigation of the utilization of PC-based technology. The researchers created and tested a Virtual User Model (VUM), shown in Diagram 2, to imitate an individual with MCI doing a cognitive task. The goal of the VUM was to identify and address typical interface accessibility difficulties that may arise when people with MCI utilize PC-based cognitive stimulation technologies. A four-step trial was proposed by the authors. MCIs and controls were assessed using standard neuropsychological tests and a computer-based battery in the first phase. The suggested VUM was then taught using real user performances in the second phase. The authors improved the VUM and the Virtual User Interface (VUI) in the third phase. The authors used the optimized VUI to examine differences between real and virtual MCIs in the final phase (Segkouli et al., 2015)

The result suggests that over 90% of all frequent interface accessibility concerns were addressed by the authors' new system (Segkouli et al., 2015). In addition, they introduced a screening test named Boston Naming Test (BNT) (Figure 28) in which participants need to name animals

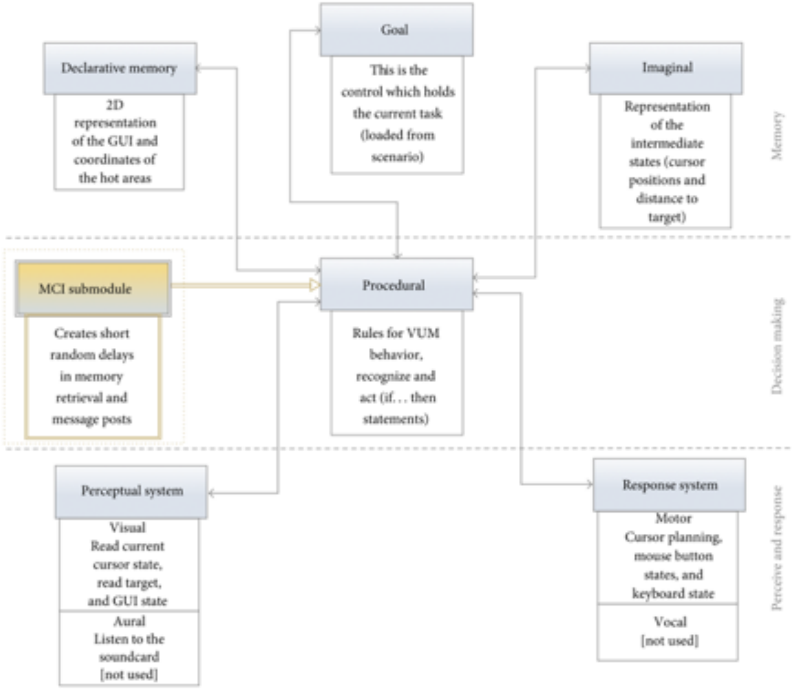


Diagram 2. The cognitive model of the VUM (Segkouli et al., 2015).

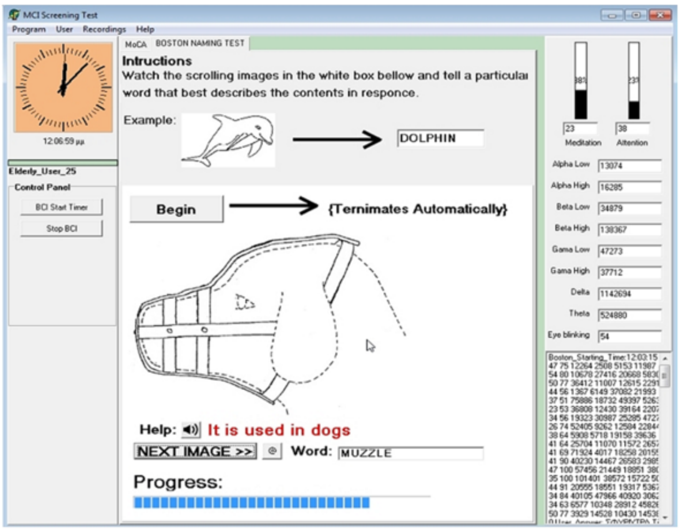


Figure 28. The computer-based BNT interface (Segkouli et al., 2015).

3.2.7 e-Health platform

The research by Kyriazakos et al. (2017) is a comprehensive investigation of MCI cognitive stimulation using personal gadgets. The authors demonstrated an eHealth platform for MCI that connects multiple personal devices, as well as ambient and wearable sensors, via a cloud environment. The eHealth system includes cognitive games, such as memory games and testing, attention games, and executive function games, among its applications. Figure 29 shows an example of what an application could look like. This approach tries to preserve cognitive capabilities in healthy people and MCI people. Aside from improving cognition, this form of intervention should aid MCI patients in maintaining a high quality of life. This study has this far addressed only design and is still in the planning phase (Kyriazakos et al., 2017).

Figure 29. Example of application on the platform (Kyriazakos et al., 2017).

3.2.8 Sensors

3.2.8.1 SmartWalk System

The SmartWalk System intends to test sustained auditory attention while the subject walks and stimulates the sustained attention domain (Bastos et al., 2029). The architecture of the system is shown in Figure 30.

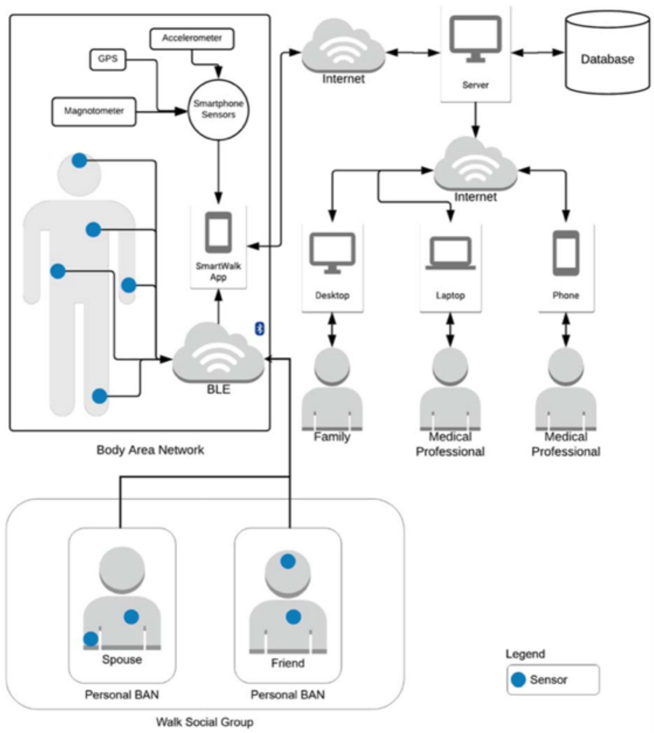


Figure 30. The architecture of the SmartWalk System (Bastos et al., 2020).

The SmartWalk System's goal is to promote city walks to encourage people to be more physically active. Body Area Networks (BAN) are used to collect data from various types of sensors and broadcast it to a server to help carers make educated decisions when organizing physical activities for patients. The SmartWalk System performs well in terms of battery usage, data upload, ability to recover from connectivity failures, and body area network wireless coverage. A SmartWalk App links to the external sensors of the BAN using Bluetooth Low Energy and makes use of numerous sensors already present in a standard smartphone. All the data collected by the SmartWalk App is sent to the SmartWalk Server, which is responsible for storage (Bastos et al., 2020).

Figure 31 shows a screenshot from the smartphone application developed for older adults that allows users to see the planned routes and the actual routes walked (blue being the planned route, and red being the actual route walked). Heart rates, blood oxygen levels, distance walked and how long they had been walking could also be accessed. The SmartWalk System enables caregivers to create fitness regimes for the user by scheduling walks for them. This makes it possible for the caregiver to analyze the users´ performance. Since there is already stored information about the user, and the SmartWalk App can gather more data about the user to complement clinical information, it allows for the caregiver to make well thought-out decisions when planning routes for the user to walk, and maybe notice performance deterioration (Bastos et al., 2020).

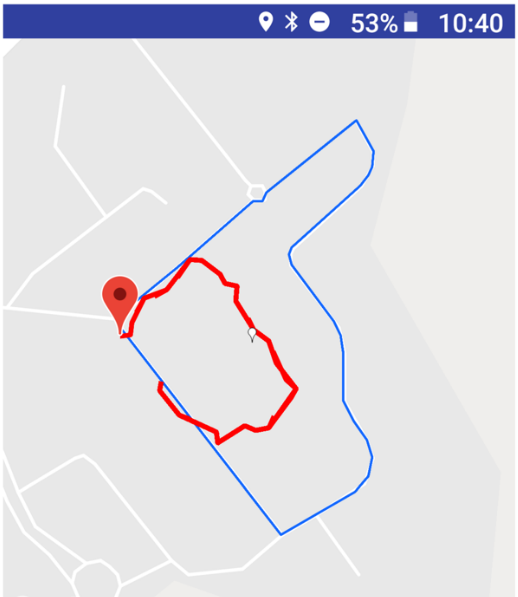


Figure 31. Showing the route screen. The picture indicates the limited space used by the patient (Bastos et al., 2020).

3.2.9 Robots

In nursing, robots can help with physical and mental care. Studies show that workers with physical assistance are less likely to suffer from injuries. Similarly, those with mental issues benefit from assistance. It has been shown that early intervention with robots can prevent disease to further develop, which is also the case with dementia. Both prevention and care put demands on nursing and society at large. Japan as an ageing society has felt the burden of many elderlies including those with dementia. One of the strategies they use is the development and usage of robots in care which makes them unique and worth studying. Western society has already adopted some solutions from Japan but not by far as extended. This chapter investigates the possibility of using robots in care for both patients with mild and severe stages of cognitive loss (Kolstad and Babic, 2019) (Goda et al., 2020) (Kolstad et al., 2020).

In the paper "*Robots in therapy for dementia patients* ", Martín et al. (2013) discuss the use of humanoid robots in the treatment of dementia patients. They planned and carried out three different types of sessions: music therapy, physiotherapy, and logic-language therapy. During music sessions, the robot plays songs from the patients' childhood to elicit positive emotions. During physiotherapy sessions, the robot performs a series of physical exercises that the patients are expected to repeat. Logic-language therapy uses a series of short questions to promote the patient's cognitive responses. The preliminary medical results on genuine individuals with moderate dementia are promising, according to the researchers. Their neuropsychiatric problems seem to improve when compared to patients who receive traditional therapy, but further research is needed. It seems that elderly persons are drawn to robots due to their human-like appearance as well as confusing them with pets or children (Kolstad et al., 2020). Their motion and musical ability are also appealing (Martín et al., 2013). Robots were also helpful to introverted patients. Additional positive effects comprised the increased interest of groups and grandchildren to visit nursing homes and learn more about robots (Kolstad et al., 2020).

Several commercially available humanoid robots are used as therapeutic tools. Japan is strategically allocating resources to buy and further develop and promote robots in health care facilities. Depending on the patient´s status and cognitive abilities different robots can provide support and comfort. Those who have more preserved cognitive capacity will find more interactive robots interesting while those with severe cognitive decline prefer robots with minimal interaction to comfort them (Kolstad and Babic, 2019). Table 8 provides an overview of available humanoid robots for therapy.

 	**PEPPER – Social human robot** Price: *ca. 84 000 NOK* Size: *Height 120 cm* Weight: *28 kg* Pepper, a social humanoid robot from SoftBank. Unveiled in 2014 and is available for purchase. https://www.softbankrobotics.com/emea/en/pepper https://www.softbank.jp/robot/pepper/consumer/
	**PALRO – Conversational humanoid care robot** Price: *ca. 29 000 NOK* Size: *Height 40 cm* Weight: *1,8 kg* Fuji Soft Inc. is the company behind Palro. Palro is a little robot that can communicate, walk, connect to the Internet, and learn. https://palro.jp/en/feature/spec.html
 	**ROBOHON – Human-like robot-phone hybrid** Price: *ca. 6500 NOK* Size: *Height 19 cm* Weight: *390 g* RoBoHoN is a human-like robot-phone hybrid created by CEO Takahashi of Robo Garage Co. Ltd. in partnership with Sharp. https://cocorostore.sharp.co.jp/robohon/body/sr-05m-set
	**PARO – Seal-type therapeutic robot** Price: *ca. 30 000 NOK* Size: *Length 57 cm* Weight: *2,7 kg* AIST developed Paro, available for purchase since 2004/2005. In February 2002, Paro was certified as the most therapeutic robot and joined the Guinness Book of World Records in 2003. https://www.daiwahouse.co.jp/robot/paro/products/about.html https://www.aist.go.jp/aist_e/list/latest_research/2004/20041208_2/20041208_2.html

	**SMIBI – Healing baby robot** Price: *ca. 5600 NOK* Size: *Height 44 cm* Weight: *1,2 kg* Togo Seisakusyo Corporation created Smibi, which has been on the market since 2016. http://www.togoh.co.jp/products/care-smiby.html
	**QOOBO – Therapeutic robotic cat pillow** Price: *ca. 3000 NOK* Size: *Diameter 32 cm* Weight: *1 kg* Qoobo was created by Yukai Engineering Co., Ltd., a Tokyo-based corporation. https://www.robot-advance.com/EN/actualite-the-new-qoobo-cat-robot-150.htm https://qoobo.info/index-en/
	**MyBom1 – Home service robot** Size: *Height 48 cm* Weight: *1,5 kg* World´s first AI-based dementia care robot developed by the Korea Institute of Science and Technology (KIST). http://www.koreabiomed.com/news/articleView.html?idxno=5721 https://www.roaigen.com/en/html/product/product01.php

Table 8. Overview of robots.

3.2.9.1 Pepper

According to the official website[2], *"Pepper was optimized for human contact and is able to communicate with people through speech and his touch screen".* This humanoid robot has a social personality that can be seen as a child and/or staff member. Pepper is capable of entertaining and accompanying the elderly to improve their mental health (SoftBank Robotics, n.d.).

Pepper's application for geriatric care and rehabilitation was investigated in a 2018 study. Observation, actigraphy, and Heart Rate Variability (HRV) demonstrated that patients with dementia showed favorable connections between sympathetic nerve activity level and actigraphy activity count in a wakeful state, according to the findings. This shows that Pepper

[2] https://www.softbankrobotics.com/emea/en/pepper

may be able to help elderly individuals enhance their quality of life. Although the study does not specify the number of participants, the presence and participation of Pepper have been shown to have positive benefits (Tanioka, 2019) (Kolstad and Babic, 2019). The presentation of a digital game via a humanoid robot appears to successfully encourage MCI patients to commit to their training for the duration of it. According to Manca et al. (2021), users were positive toward Pepper and willing to interact with it. This demonstrates that using robots at an older age is still possible. Moreover, despite having no prior experience engaging with robots, all the participants were able to interact with Pepper separately and finish the training without difficulty. This form of equipment and training game can be considered a viable and usable option for stimulating MCI elderly people, as well as providing some emotional support, which is something that elderly people value. In terms of task completion timeframes, Pepper adds greater empathic/emotional input (via body movements and lighting) to better emphasize and reinforce the outcomes (Manca et al., 2021). There were examples of using Pepper for Taio, the daily Japanese stretching (Kolstad et al., 2020)

Results suggest that the robot's emotional feedback did not distract participants from their primary task. Technologies have increasingly been conceptualized as a support for patients, their caregivers, and physicians in the context of interventions for minimizing cognitive decline in the elderly population (Manca et al., 2021).

3.2.9.2 Palro

Palro is a little robot that can communicate, walk, connect to the Internet, and learn (Fuji Soft, n.d.).

Palro is sold to elderly facilities, nursing homes, and home care to extend life expectancy and prevent healthy people from getting sick. Palro can be used to communicate and watch the elderly living in remote areas. The use of Palro in society can be extended to patients with disabilities, the elderly, and for education. Palro can replace the role of a phone and thus support communication between elderly people and their families through a more natural interface. For nursing care facilities, Palro´s original function was to have daily conversations with users, so Palro can be a talking partner. Palro can also provide recreation, typically for 20-30 minutes (Kolstad and Babic, 2019).

Studies have shown positive effects of using Palro, e.g., Palro has encouraged persons with dementia to interact with others (Inoue et al., 2014).

3.2.9.3 RoBoHoN

RoBoHoN is a human-like robot-phone hybrid robot. It can be customized through apps for a specific purpose like childcare, elderly care, or handicapped people, but the hardware itself is the same for everybody. RoBoHoN is designed to talk like a kid so that people do not get high expectations when interacting with it since people tend to be satisfied if robots meet their expectations. Robots are generally designed not to be superior to their intended target user group (Lawson, n.d.) (Kolstad and Babic, 2019).

Results have shown that the elderly were more interested in performing tasks when robots were present. Talking to robots has stimulated interest and activity (Tamai et al., 2019).

3.2.9.4 Paro

Shibata and Wada (2011) presented a review on robot therapy as a new strategy for the mental healthcare of the elderly, with Shibata being the founder of Paro. According to Shibata and Wada (2010) *"Interaction with animals has long been known to be emotionally helpful to people"*. The effects of animals on humans have been studied and proven scientifically in recent years. Animal-Assisted Treatment and Activities (AAT and AAA) are thought to have three effects: *"Psychological effect (e.g., relaxation, motivation), physiological effect (e.g., improvement of vital signs); and social effect (e.g., promotion of conversation among inpatients and carers)"*. Due to Japan's ban on the use of live animals in nursing homes, Shibata and Wada have devised plans to develop a seal-a-like robot (Shibata and Wada, 2010). Therefore, Paro was developed as a therapeutic robot and as a substitute for animals. It helps develop tactile sensations, autonomous behavior, and animal-like responses which are all elements that must be present in robots. The baby harp seal was ecologically researched, and genuine baby seal calls were sampled and utilized to replicate the liveliness and sweetness of a young harp seal in Paro (Shibata and Wada, 2011).

A clinical trial has shown positive effects of using robots in care in terms of improving mood, social interaction, and communication (Yu et al., 2015).

A randomized controlled experiment found that taking Paro can minimize the use of psychotropic drugs for anxiety by 30%. In addition, the Paro effect lasted two hours longer than the drug (Financial Times, 2016).

3.2.9.5 Smibi

Kanoh, the designer of Smibi released a paper titled *"A Robot as 'Receiver of Care' in Symbiosis with People"* in 2015 (Kanoh, 2015). The idea is that by taking care of a baby robot elderly would be taking care of themselves. It would give them purpose, interaction, a positive response from the robot, and often even a reminder of how they took care of their own kids. Therefore, therapeutic robots must have an interaction-oriented design that strongly appeals to a person's feelings. The interaction must be reciprocal for both the robot and the human to process the data received from the other (Kanoh, 2015).

Smibis resemblance to a human baby enables one-way exchanges, as well as serving as a sign of a care recipient and a simple manner of communicating information through expressions and noises. Smibis goal is to relieve the psychological tension of elderly people and patients needing long-term care by having them take care of it, contrary to what one might expect to hear from parents of small children. As a result, the robot's look, and perceived lack of features, such as no legs and short arms, have been influenced by the concept of helplessness (Kanoh, 2015) (Kolstad and Babic, 2019).

In an experiment in a healthcare center, the robot was tested in terms of acceptance and rejection by five elderly female participants with no cognitive impairment according to an MMSE. Smibi was rated positively by four out of five participants, with one participant suspecting that the one unfavorable review was due to the experimental settings rather than the robot. The experience was described as *"therapeutic"* and *"fun",* with interactions with Smibi including singing to the robot, watching television together, and expressing personal thoughts, among other things. Results suggest that Smibi has the potential as a therapeutic robot (Kanoh, 2015) (Kolstad and Babic, 2019).

3.2.9.6 Qoobo

Qoobo is a circular fuzzy-tailed cushion that was designed for older persons who live in facilities that do not allow pets. It responds to nonverbal activities such as touching and petting. It even wags the tail to say hello. It is reassuring communication that, like in animals, is heart-warming (Yukai Engineering Co., n.d.) (Robot-Advance, n.d.). Caregivers have expectations that Qoobo would become a regular assistant in therapy (Lehmann et al., 2021).

One study has shown that Qoobo was mostly utilized by a patient who disliked connecting with others. The robot had a calming impact on the patient and could make the patient happy, something that the human carers had difficulty accomplishing (Kolstad and Babic, 2019).

3.2.9.7 MyBom1

MyBom1 is the world´s first AI-based dementia care robot. It was developed by the Korean Institute of Science and Technology (KIST). For mild cognitive declined patients MyBom1 will give alarms for illegal outings, medication and meal reminders, and an adaptable service that matches patient characteristics (Han-soo, 2019). MyBom1 has a camera for the detection and recognition of human faces and expressions, and for detecting objects and obstacles (Roaigen, n.d.).

KIST expects the robot to be able to care for dementia patients at home for at least two hours in the early stages of commercialization (Han-soo, 2019).

3.2.10 Reflection of Methods

Treatment procedures presented here are very detailed and show the variety of technologies on the market today. The methods capture technologies for both mild and severe declined patients. Different techniques are trying to help patients slower the development of the disease. Robots can e.g., be used for communication, games for interactions and fun, and sensors for physical activity. Similarly, robots demanding minimal interaction could be used by severely affected persons since their goal is to provide comfort.

Chapter 4

4 Methodologies and Methods

This chapter presents research methodologies and methods used in this research project. This includes the Design Science research framework, data collection, and the design and evaluation of the prototype.

4.1 Design Science

According to Hevner et al. (2004), Design Science aims to expand the boundaries of human and organizational capabilities by designing new and inventive products. It is a problem-solving discipline that aims to develop and assess IT artifacts that address recognized organizational issues. In Design Science, the design process is an iterative process that includes a variety of tasks for the continual design and evaluation of a new product. The artifact evaluation gives feedback and a deeper knowledge of the problem, which can help to enhance the product's quality and the design process itself (Hevner et al., 2004).

When designing an artifact there are three different cycles to take into consideration according to Design Science: *relevance cycle, design cycle,* and *rigor cycle* (Figure 32) (Hevner, 2007).

The relevance cycle, which is concerned with the environment surrounding the desired item, is the first cycle that is exhibited. It is critical to comprehend the target user groups, their specific requirements, and their expectations from an artifact. The design cycle, which iterates between design options and their evaluation to deliver an artifact, is the second cycle. The third cycle is the rigor cycle, which employs prior information relevant to artifact design as well as scientific methodologies for design development. The rigor cycle's methods ensure that the research is valid (Hevner, 2007).

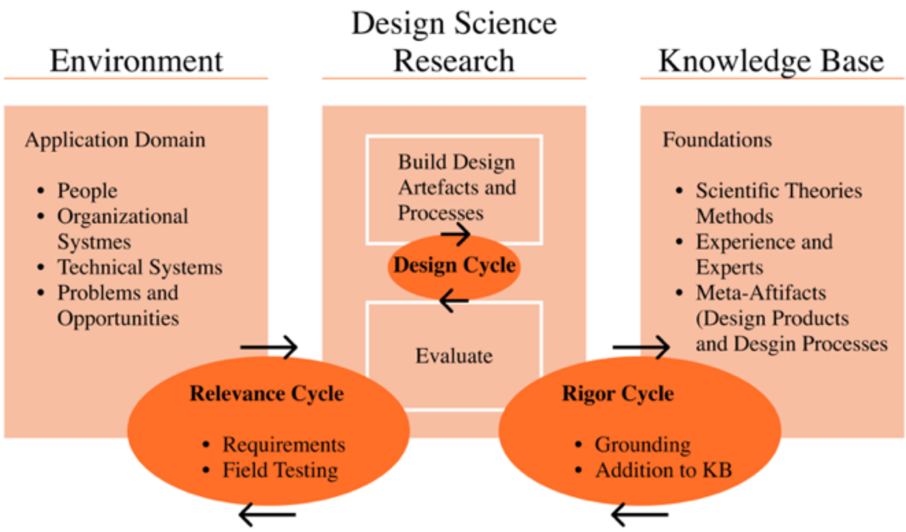


Figure 32. Design Science Research Cycles (Hevner, 2007).

A set of seven guidelines for doing and evaluating Design Science research has been created by Hevner et al. (2004). These recommendations should assist in ensuring that the design problem is understood during the development of the artifact. Each of the recommendations should be considered while adopting the Design Science approach, according to Hevner et al. (2004), but in a creative way that is appropriate for the unique research subject. In Table 9 the guidelines are presented as well as a short description of how they relate to this research project:

Guideline	Description	How this research meets the description criteria
Guideline 1: Design as an Artifact	*Design Science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.*	Two kinds of artifacts were planned. The first one would present a structured knowledge regarding IT used in cognitive decline. The other one, a website created as low and mid-fidelity prototypes to present knowledge about cognitive decline to a broader audience.
Guideline 2: Problem Relevance	*The objective of Design Science research is to develop technology-based solutions to important and relevant business problems.*	The artifact of this research project had the intention to structure the knowledge and present it to several possible user groups (relatives of people with cognitive decline, health care personnel, and even people with Mild Cognitive Decline).

Guideline 3: Design Evaluation	*The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.*	Frist, it was important to derive a competent and comprehensive representation of knowledge. Then, it was important to design and test the artifact that could communicate this knowledge to different user groups.
Guideline 4: Research Contributions	*Effective Design Science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.*	The goal of the research was to make the knowledge transparent and exposit it to the public in both a scientific way (an article and as an artifact dedicated to a general audience). The latter should also be evaluated according to the Design Science that assumes potential user groups, IT usability experts, as well as field experts.
Guideline 5: Research Rigor	*Design Science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.*	The research was designed to follow the Design Science framework and apply methods that were suitable for different iterations. E.g., open coding was used to analyze interviews, and design methodology was used to deliver an artifact. These methods were well-documented in the literature.
Guideline 6: Design as a Search Process	*The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.*	Several iterations are to be carried out. Firstly, to structure the knowledge, and secondly to develop an artifact that could communicate that knowledge. During iterations, the input of experts and potential user groups is to be considered to evaluate the current state of the artifact and suggest changes. Each iteration ends up with things that need to be done in the next iteration.
Guideline 7: Communication of Research	*Design Science research must be presented effectively both to technology-oriented as well as management-oriented audiences.*	Artifacts coming out of this research should be understandable to the scientific audience as well as to a wider audience looking for the information on diagnosing and treatment of cognitive decline. A scientific article was planned and comprehensive evaluation to

		make sure that the artifact and results are well understood.

Table 9. Overview of the seven Design Science guidelines with description, and how they relate to this research project (Hevner et al., 2004).

4.1.1 Design as an Artifact

Constructions, models, procedures, and instantiations are all examples of IT artifacts. This research project focuses on the latter, which includes system design, prototype, implementation, and evaluation. Instancing denotes that a system's structures, models, or techniques can be implemented. They show the feasibility and give actual assessments of an artifact's potential to achieve its intended aim (Hevner et al., 2004). A prototype intended for people with cognitive decline, relatives, and caregivers is to be created following the guidelines of Design Science through several design iterations.

4.1.2 Problem Relevance

This guideline should describe the current condition of the problem and how the artifact might be used to solve it (Hevner et al., 2004). The system would be the communication of cognitive decline between the communicator and the receiver, as this research project is more of a human perspective than a business perspective. The goal is to make the knowledge about cognitive decline first structured, and then more accessible.

4.1.3 Design Evaluation

According to Hevner et al. (2004), evaluation is an important aspect of the research process in design science, with the artifact requirements serving as a starting point for evaluation. Functionality, completeness, consistency, accuracy, performance, stability, usability, and other relevant quality measures can all be tested on the artifact (Hevner et al., 2004).

Three iterations were required for prototype development, which must take principles and aims into account. During these iterations, user and IT usability expert evaluations were conducted to ensure the high quality of academic content of the solution. The prototype adheres to a set of design principles as well as usability objectives. When building prototypes, these principles offer the best User Experience (UX) to the target groups´ optimum usability (Hevner et al., 2004).

When creating the prototype this study follows five design principles. These principles aid in the development of the prototype, ensuring the optimum design for a better UX (Rekhi, 2017).

Visibility is when a user should be able to see all the numerous alternatives available to them. Because the User Interface (UI) should be intuitive, nothing should be hidden from the user. UI is the interaction and communication between human and computer in a device. However, if everything is displayed, the interface becomes cluttered, so striking a balance is critical (Rekhi, 2017).

Feedback is for the user to recognize that the action they performed was successful. The user should never have to guess what the outcome of their actions will be. Although feedback can take many forms, it is common in interface design to use visual, tactile, and aural feedback (Rekhi, 2017).

Constraints make it more difficult for a user to commit a mistake. It will limit the user's range of interaction possibilities because too many options can lead to confusion about which is the best option (Rekhi, 2017).

Consistency when generating an item is crucial. There should be no surprises in the design, which means that for similar jobs, the same processes and elements should be employed (Rekhi, 2017).

Affordance is about employing symbols that people are already familiar with for them to grasp what the action is, such as a house representing the home page. To afford is to convey a hint, therefore an artifact with high affordance makes it obvious how to use it (Rekhi, 2017).

4.1.4 Research Contributions

The study´s key contribution would be understanding how IT solutions can be used to diagnose and treat cognitive decline. This knowledge is developed from literature reviews and interviews with field experts in the early stages of the establishment of requirements. More information and feedback were obtained during the evaluation with users in the target group. A contribution was made in a form of the working prototype.

4.1.5 Research Rigor

This research project used a variety of evaluation methods to assess the artifact's design. Semi-structured interviews were used for data gathering with field experts. An iterative flexible development methodology was used during the development process of the prototype. A combination of relevant tools was used for design and development. Participatory observations, SUS, and Nielsen´s heuristics were used during testing with users in the target group and usability experts for evaluation of the final prototype.

4.1.6 Design as a Search Process

Interviews with health care professionals, evaluation of iterations, evaluation of the finished prototype, as well as tools and frameworks used, have all contributed to the results of the research project.

4.1.7 Communication of Research

According to Hevner et al. (2004) Design Science must be able to be communicated to both a technology-oriented and an administrative target group. Technology-oriented recipients need sufficient details to be able to implement the current artifact within an appropriate organizational context (Hevner et al., 2004). To provide these target groups with sufficient information, requirements were established for the solution. They are described in detail in Chapter 5, while the steps for how the solution is implemented are described in detail in Chapter 6. In addition, an academic article was created and excepted for presentation at an international conference (Appendix C1).

4.2 Methods

4.2.1 User-Centered Design

User-Centered Design (UCD) is a design method in which the intended user and their needs are prioritized throughout the process. Content is only one aspect of good design. Users expect to be presented with systems that are well-functioning and simple to use, therefore having a decent UI is important. To meet user needs, UCD must go through four phases. Figure 33 depicts the steps of the process, which mirrors the Design Science research cycles in some ways but is more focused on the design itself. The first step is to understand the usage context. The second phase is to define functional and non-functional needs. The third phase is to create design solutions. The design is evaluated in the fourth stage (however it is not always the last). Each design iteration should be tested and evaluated to ensure that the result is satisfactory for the intended user. Unless the users' needs are addressed, the procedure will be repeated (Interaction Design Foundation, n.d.).

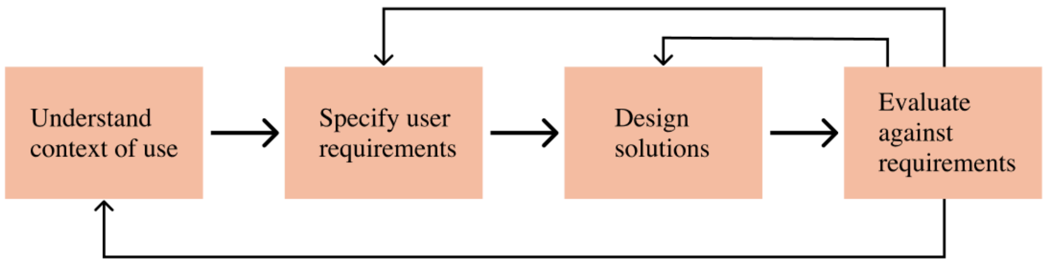


Figure 33. UCD process (Interaction Design Foundation, n.d.).

4.2.1.1 Conceptual Design

Conceptual design is a framework for establishing the fundamental idea behind a design and a plan for how it will be expressed visually (Levanier, 2021). A conceptual model depicts the application's major features and how users can interact with it. It is an outline that shows what a product can perform and what is required to engage with it. There is no right or wrong method to employ conceptual design, but there are certain general guidelines to follow. In the early stages of development, a conceptual model can be extremely useful (Sharp, Rogers, and Preece, 2019, 71-77, 434-444). Table 10 shows the key principles of conceptual design.

Keep an open mind, but never forget users and their context.	Discuss ideas with other design team members.
Prototype with users to get rapid feedback.	Iterate.

Table 10. Conceptual design key principles (Sharp, Rogers, and Preece, 2019, 434-435).

4.2.1.2 Prototyping

A prototype is a physical representation of a design that allows users to engage with it and evaluate its applicability. It can be anything from a hand-drawn prototype to a complex system. A prototype is the temporary version of the product, and there are three stages of prototypes: *low-fidelity*, *mid-fidelity,* and *high-fidelity*. The low-fidelity prototype is a straightforward design that needs little time and money to create. It could be a paper sketch of various frames from an app. The mid-fidelity prototype offers more interaction than the low-fidelity prototype for the user to experience the interaction itself. The high-fidelity prototype is interactive and has a lot of the same features as the finished product. It allows testing functionality and appears and feels like the final product. This makes it as close to a final product as possible without having to make the entire product (Sharp, Rogers, and Preece, 2019, 422-434). The product in this research project is aimed at the mid-fidelity level.

4.2.2 Data gathering

Data gathering in this research project was done utilizing several methods. Qualitative data was gathered through literature review, semi-structured interviews, and observations of university professors, health care staff, university students, and field experts. Even though the method might be time-consuming, it was utilized for gathering unexpected data (Ivan, 2021).

4.2.2.1 Literature Review

A literature review is a process of looking for, collecting, and reviewing previously published literature on a given topic. This strategy typically entails searching online libraries for papers, books, or other related documents using keywords. It can also aid in establishing requirements for developing an artifact.

4.2.2.2 Open Coding based on Literature

The Grounded Theory method of analyzing qualitative data includes steps such as open coding, axial coding, and selective coding (Figure 34). In contrast to other methods, which start with established theories and determine whether newly collected data corresponds to them, Grounded Theory allows researchers to derive new theories and concepts based on evidence (Sharp, Rogers, and Preece, 2019, 334-335).

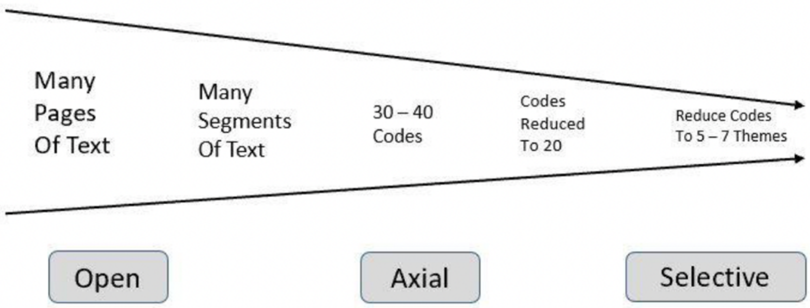


Figure 34. Overview of the coding process: Open, Axial and Selective Coding (Williams & Moser, 2019).

The open, axial, and selective coding strategy allows for an iterative and evolving data loop in which the researcher interacts, compares data, and applies data reduction and consolidation procedures regularly. As the coding process develops, its dynamic function and nonlinear directionality allow essential themes to be recognized, coded, and interpreted in support of a research study's emphasis, while also contributing to the literature. This iterative process is both an art and a science, requiring the researcher to have a thorough understanding of the data by reading and rereading the acquired data regularly for theory to emerge (Williams and Moser, 2019).

The initial level of coding is open coding. The researcher uses open coding to find separate concepts and themes for categorization. The first level of data organization is accomplished by establishing broad subject domains for data collection. The goal of open coding is to express data and phenomena as concepts. Classifying expressions into meaningful units to attach annotations and concepts. The concept-indicator model was the name given to this technique in open coding. In summary, the concept-indicator model in this project concentrated on comparing regularly occurring textual material and used the constant comparison of indicators. This technique was complemented by the ongoing coding of themes as indicators of a notion, which was always compared to previously coded indications (Williams and Moser, 2019).

The scope of this project was to identify all important open codes and connect them in a meaningful and practical way. That is why the whole concept focused on two main categories, namely diagnosing and treatment. No further theory was considered because of the diversity of approaches, and number of different indicators (from mild to severe cognitive loss). IT was also important to keep the theory building transparent and allow the prototype to focus on these two functional areas. Certain coding was also done around the severity of the condition resulting in two domain concepts (Graphs 2 and 3 Section 6.3.2).

This research made no attempt to present the whole process diagnosing of cognitive decline and how these different stages are treated within a healthcare system. To attempt to build such relationships and theories would take yet another line of research that would involve healthcare professionals on a larger scale. Moreover, loss of cognitive capacity is quite hard to detect, and it often depends on the relatives or environment to notice it and to initiate contact with health care staff.

4.2.2.3 Semi-Structures Interview

Semi-structured interviews combine characteristics of structured and unstructured interviews (Pollock, n.d.). In semi-structured interviews, a set of pre-defined questions are used to frame the interview where the goal is to get as much as possible information about a specific theme. Questions are asked and are open for the interviewee to respond freely, debate, and contribute with knowledge (Sharp, Rogers, and Preece, 2019, 269-271).

This method was used in the second iteration to gather information from field experts. Appendix B1 contains the informed consent authorized and accepted by Norwegian Centre for Research Data (NSD) (Appendix A1). To gather knowledge on IT solutions for cognitive decline semi-structured interviews were conducted with field experts, the interview guide can be found in Appendix B2.

4.2.2.4 Observations

Observations were used to collect data that could help measure usability. This includes information on task completion time, body language, and remarks on artifacts coming out of interaction with the researcher conducting the evaluation (Sharp, Rogers, and Preece, 2019, 287-288). This research observation yielded useful information on how users rated the artifact and what questions they had regarding using the artifact. During the evaluation, participants were given their own time and freedom to explore the artifact, but they could also ask questions along the way if they felt for it.

4.2.3 Likert Scale

Likert scales are well-known tools for measuring user satisfaction with products and are used to gauge views, attitudes, and perceptions (Sharp, Rogers, and Preece, 2019, 280-281). The interviewee is supplied with a statement regarding a product using a Likert scale, such as the user's opinion about colors on a web page. The interviewee is offered five possible responses to the statement (i.e., strongly agree, partly agree, neutral, partly disagree, strongly disagree, or expressed as numbers 5, 4, 3, 2, 1) as shown in Table 11. This strategy was utilized multiple times throughout the research, including when establishing specifications and evaluating the artifact using SUS and Nielsen´s heuristics (Section 7.1.4, 7.1.6, and 7.1.7).

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Table 11. The Likert scale.

4.2.4 Evaluation

Quantitative data was gathered through the evaluation of the prototype with IT usability experts and users. SUS was used to grade the usability of the prototype, and a heuristic evaluation was done on the final mid-fidelity prototype. All comments from the evaluation sessions were noted down and participants were observed to make notes of more difficult questions.

4.2.4.1 Usability Testing

Usability testing is done to evaluate users' responses to the prototype and to gather feedback which provides often points of improvement which are addressed during the iterative development. Often one iteration finishes with evaluation and the feedback is the entry to the next design iteration (Sharp, Rogers, and Preece, 2019, 524). Tools used in this process are two-fold, first, a set of tasks is created that is given to all evaluators, and then a standardized tool such as SUS is given to the evaluators to complete. Calculating the SUS score helps to compare the current state of the prototype to any other prototype since values of 68 and more stand for a good and expectable prototype (Smyk, 2020) (Thomas, n.d). Remarks from the evaluation could also be taken if they concern some of the features and users' requirements. Usability testing was done in the third and last iteration of this research project.

4.2.4.2 System Usability Scale

SUS consists of ten questions with five different options, using the Likert scale (Section 4.2.3) to measure from *strongly agree (5)* to *strongly disagree (1).* The value of one question on its own has no value, and the usability can only be tested in correlation with each other. One question is usually affirmative while the following is providing a contrary statement. The SUS is quick and easy for measuring usability, as one can get accurate results by having a few people test it and tell if the system is usable or not (Usability, 2020).

Following are the ten questions used in SUS (Usability, 2020):

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

SUS was an efficient method to use to measure the usability of the prototype, but since it is not possible for the user to comment during the evaluation it is considered a more general feedback method. Figure 35 shows the range of the SUS score. When calculating the score, odd numbers will subtract 5 from the total value, while even ones will subtract the total score from 25. After adding the final score, multiply the result by 2.5 to get the SUS score out of 100. According to an empirical study, the average SUS score is 68. Scores below 68 suggest that there are design flaws that need to be investigated and rectified, while scores above 68 indicate that modest design modifications are required. Excellent scores are scores above 85 (Smyk, 2020) (Thomas, n.d).

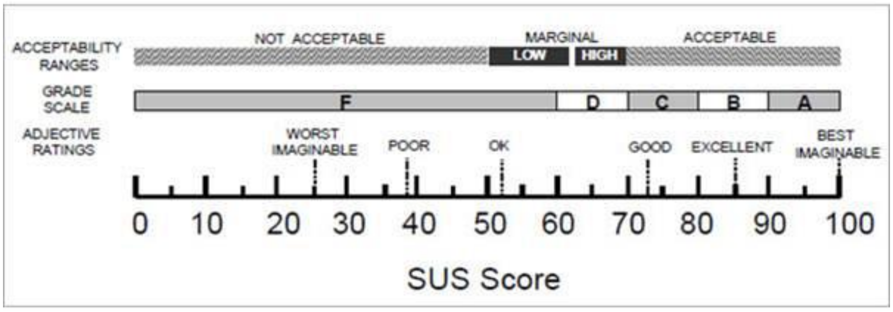
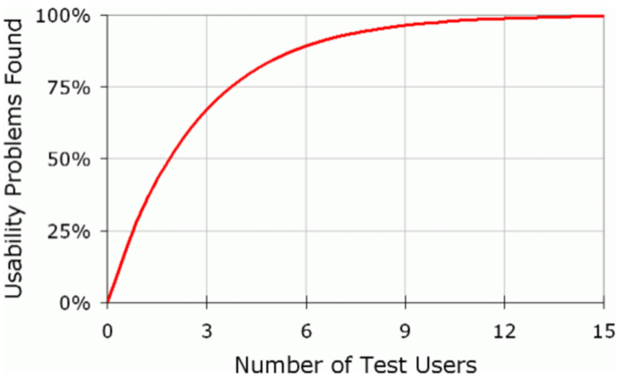


Figure 35. SUS score ranging (Bangor et al., 2009).

4.2.4.3 Heuristic Evaluation

Jakob Nielsen (1994) presented a type of usability testing for finding problems with usability in UI design that can be addressed as part of an iterative design process. A small group of evaluators examines the interface and judges its conformity with accepted usability standards using heuristic evaluation. It is hard for a single person to uncover all the usability issues in an interface, which makes heuristic evaluation impossible. Fortunately, experience from a variety of projects has revealed that different users have distinct usability issues. By involving multiple users, it is feasible to improve the method's performance (Nielsen, 1994). Graph 1 shows that three to four evaluators have empirically proven to be capable to address 75% of issues (Nielsen, 2000).



Graph 1. Number of test users and percentage of problems found (Nielsen, 2000).

Table 12 shows Jakob Nielsen´s 10 heuristics to follow for a good UI. Since the principles are not specific usability guidelines, they are called heuristics (Nielsen, 1994).

Visibility of system status	*The design should always keep users informed about what is going on, through appropriate feedback within a reasonable amount of time.*
Match between system and the real world	*The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon. Follow real-world conventions, making information appear in a natural and logical order.*
User control and freedom	*Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process.*
Consistency and standards	*Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.*
Error prevention	*Good error messages are important, but the best designs carefully prevent problems from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.*
Recognition rather than recall	*Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design should be visible or easily retrievable when needed.*
Flexibility and efficiency of use	*Shortcuts — hidden from novice users — may speed up the interaction for the expert user such that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.*
Aesthetic and minimalist design	*Interfaces should not contain information which is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility.*
Help users recognize, diagnose, and recover from errors	*Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.*
Help and documentation	*It's best if the system doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks.*

Table 12. Nielsen´s 10 heuristics

Chapter 5

5 Requirements

In this chapter ethical considerations and the approval from NSD are presented. Presented are also the target group, research participants, usability, and field experts, as well as functional and non-functional requirements for the prototype.

5.1 Ethical Considerations

The Norwegian Centre for Research Data (NSD) has approved this study. The NSD approval can be found in Appendix A1, and the informed consent and interview guides in Appendix B1, B2, and B3. The participants in the study signed an informed consent before the interviews, testing, and evaluations. The participants were also informed about the right to remove themselves from this research at any point, and with no questions asked about it. They were also informed their privacy would be secured and preserved by anonymization and proper storage of their informed consents.

5.2 Target Group

The target group in the study has been cognitive decline patients, their relatives, and health care professionals. The IT requirements for the target group are focused on easy access to knowledge about IT techniques used in diagnosing and treatment of cognitive decline. In this case, the target group often includes more relatives than the primary target group due to the often advanced stage of decline. In all cases, it is also important that health care providers can advise on where to find information on cognitive decline and what is available for its treatment. That makes the health care group important to include in the evaluation of the prototype.

5.3 Research Participants

The research participants consisted of two field experts on cognitive decline, three users (two from the target group, a relative and a health care provider, and a potential user), and six IT usability experts.

5.3.1 Field Experts

Both field experts were recruited through connections from the university. They took part in semi-structured interviews through Zoom separately (Section 6.4.5). Their expertise field is different. One is into studies of cognitive decline and developing prevention tools. The other one is a researcher in the field of biomedical engineering whose interest is to collect technical information and analyze it with ML methods. Both fields of expertise provide the basis of IT solutions.

5.3.2 Users

Three users were interviewed to test the mid-fidelity prototype. Two of them are representatives of two main user groups. One is a relative whose the parent has severe cognitive decline, and the other one is representative of the health care givers who were coordinating the care of persons with cognitive decline. The third one is a potential user. All three were in the position to search for information to learn about the condition and make care decisions. The third target group, persons with cognitive decline, were interviewed in this case because no medical researcher was involved to assist in selecting proper candidates.

Three usability tasks were created for the testing, and SUS was calculated from all users (Section 7.1.3 and 7.1.4). In addition, the evaluators were asked to give their remarks and opinion about what they would like more of in the prototype.

5.3.3 IT Usability Experts

In this research, we define usability experts as people who studied information science or similar subjects since they have both theoretical and practical knowledge of information system development. Since the artifact was indented for a broad public, anybody searching for IT solutions for cognitive decline, this enables to include usability experts of slightly different backgrounds and work experience. The advantage of using experts is that they can give competent feedback in a short time and suggest improvements based on their expertise (Hall, 2017). A total of six experts participated and evaluated the prototype. Their background is in front-end, IT consultant, and biomedical engineering.

All evaluators completed a SUS evaluation and Nielsen´s heuristic after accomplishing the test tasks (Section 7.1.5, 7.1.6 and 7.1.7).

5.4 Establishing Requirements

A requirement specifies what a particular product should do or how it should perform. The requirements should be as specific, unambiguous, and clear as possible. It is important to understand who the users are, what should be implemented, and how it should be implemented. There are two types of requirements: functional and non-functional. Functional requirements record what the product should perform and do in practice, while non-functional requirements address the system and development constraints (Sharp, Rogers, and Preece, 2019, 387-398).

During the first iteration, the literature served the two main applications of IT, one was in diagnosing and the other in treatment. This conditioned that knowledge would be structured around these terms as well as the future prototype provided to the public. These requirements are following clinical practice in which people are first diagnosed and then treated. The prototype developed in this research had a goal to structure, organize and present the main IT approaches and techniques to anybody interested in the subject. Information gathered in the literature was very comprehensive detailed, and mainly scientific, and therefore could be difficult for everybody to read through. Consequently, the prototype had to be designed to provide easy-to-read and understandable content that could be easily navigated.

5.4.1 Functional Requirements

Sharp, Rogers, and Preece (2019) define functional requirements as *"what the product will do"* (Sharp, Rogers, and Preece, 2019, 390). It is important to understand the user needs and what the system should contain when defining functional requirements.

The following functional requirements were created and updated based on the identified user needs according to the literature and usability testing:

- Present information about cognitive decline
- Show diagrams of IT solutions
- Present information about the IT solutions
- Split between diagnosis and treatment
- Provide links to websites containing videos and relevant information
- Provide pictures and illustrations for the aesthetics
- Search button for easy navigation
- Home button to easily get to the landing page
- Information must be easy and understandable for everybody to read
- Use contrast colors that are suitable for cognitive decline persons

5.4.2 Non-functional Requirements

Sharp, Rogers, and Preece (2019) define non-functional requirements as *"the characteristics of the product"* (Sharp, Rogers, and Preece, 2019, 390). The non-functional requirements concern the technical and development aspects of designing the prototype.
The following non-functional requirements were created:

- Must be appealing to look at
- Provide clean design
- Must be easy to learn and navigate
- Quick response time
- Must be created for all age groups
- Must be locally adjusted to local health care providers when possible
- Must do what the users expect of it
- Must allow user-friendly print-out of the content

5.4.3 Personas

According to Sharp, Rogers, and Preece (2019) personas are extensively used and have proven to be an effective tool for developers to see the traits of different people and communicate goals to designers and developers. The two main goals for a persona are to *"help the designer make design decisions",* and *"to remind the team that real people will be using the product"* (Sharp, Rogers, and Preece, 2019, 404).

Instead of only looking at different user requirements, personas were created to help understand what potential user groups should be considered. The movie *"Vær her"* by Ragnhild Nøst Bergrem (Figure 36) presents the painful changes that cognitive decline brings into the lives of those who suffer from it, and their relatives. Within this research, we had no resources or possibilities to interact with persons with cognitive decline. However, the recent Norwegian movie *"Vær her"* outlined and inspired the four potential users as personas, relevant for this research project. One person could still live at home, but with difficulty (Figure 38). Another person also lived at home but needed help from relatives (Figure 39). The other two persons were a nurse (Figure 37) and a relative (Figure 40), both interested and expected to learn more about cognitive decline and dementia. The movie is also presenting one severe case, a person who lives at a nursing home who would not be able to use IT, therefore this persona was not included.

Figure 36. Picture of the front page of the movie "Vær her" (Bergrem, 2020).

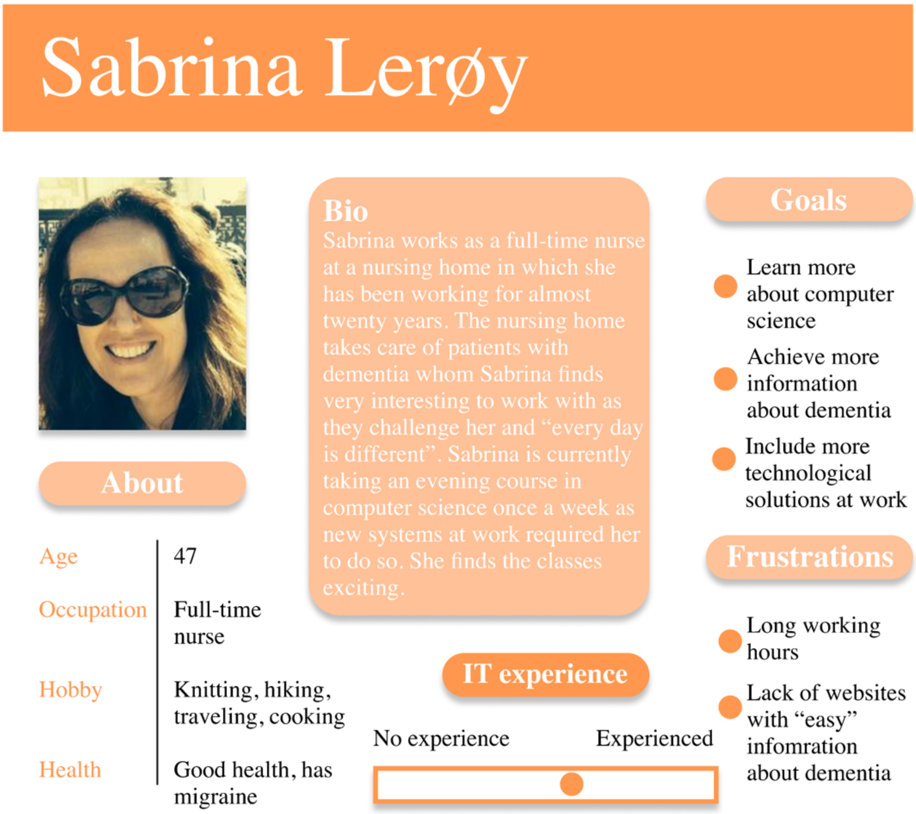


Figure 37. Persona 1 – full-time nurse.

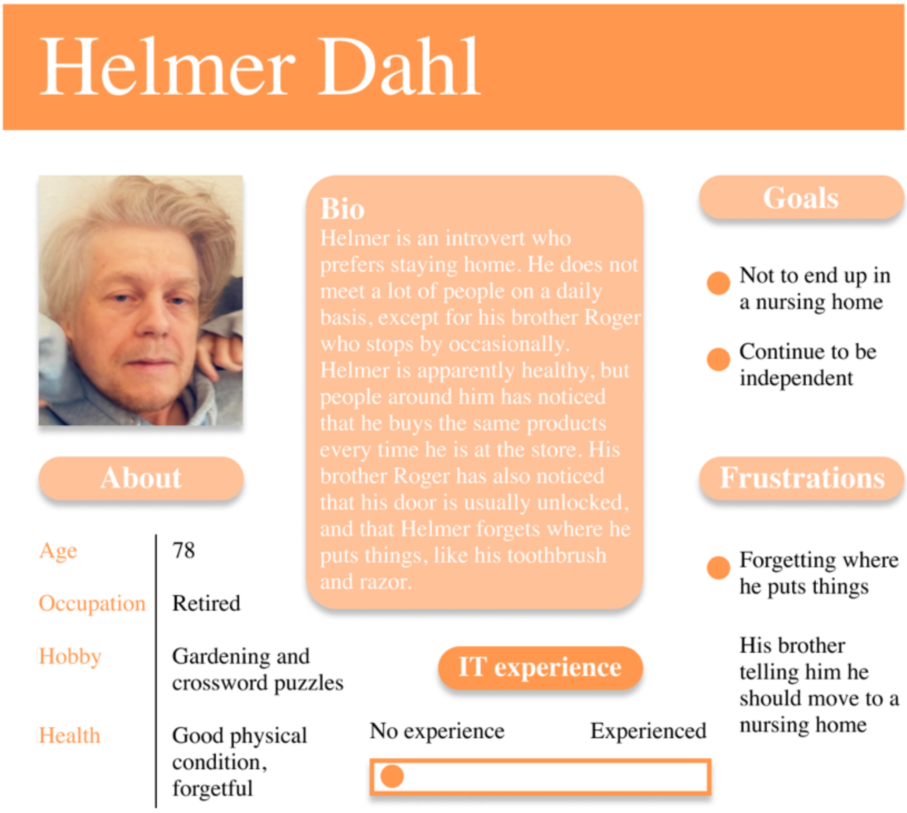


Figure 38. Persona 2 – elderly man with mild form of cognitive decline.

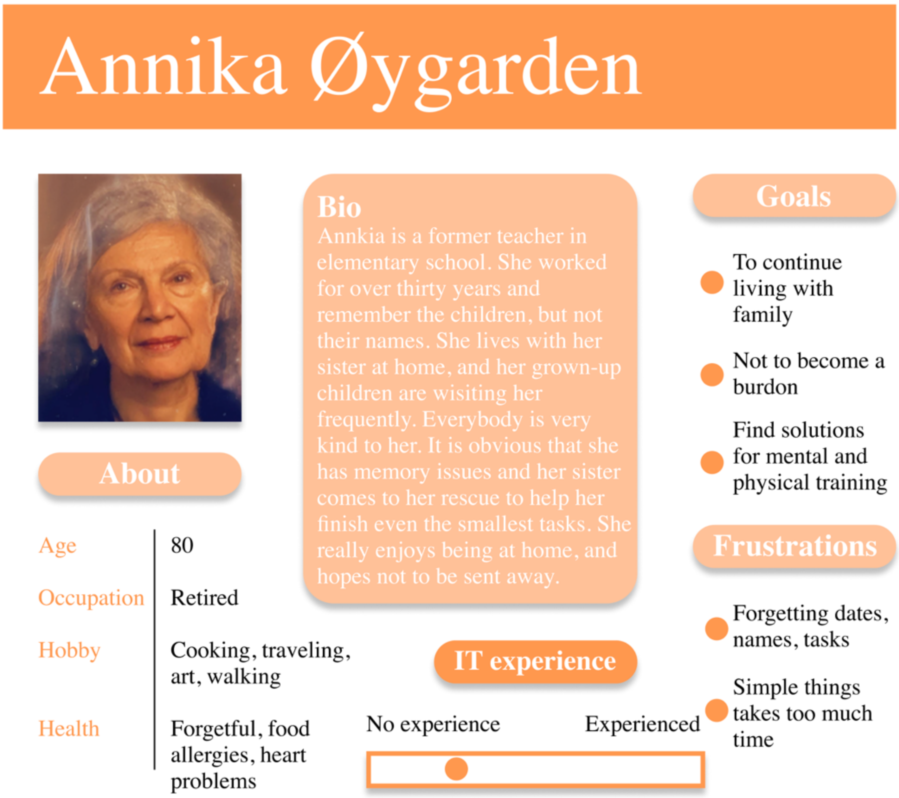


Figure 39. Persona 3 – elderly woman with more severe form of cognitive decline.

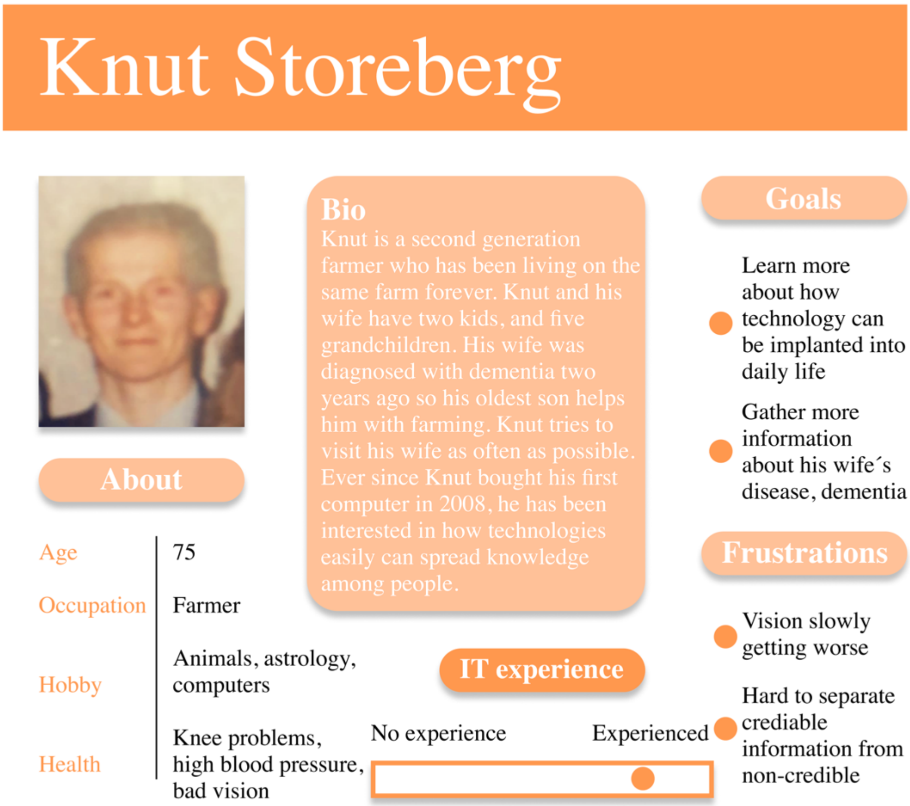


Figure 40. Persona 4 – relative (husband) curious to learn more about cognitive decline.

Chapter 6

6 Prototype Development

This chapter presents the tools used for development, the establishment of requirements, different versions of the prototype, and interviews with experts and potential users. It will also give an overview of all iterations and strategies used in prototyping the artifact. The artifact is based on the literature review from Chapter 3 focusing on IT solutions for diagnosis and treatment of cognitive decline. The prototype was indented to be generic, not customized to mobile phones or the web, but designed in a way that it could be included on both mobile devices and websites.

The main goal of the prototype was to share knowledge that is not easy to gather in one place, and for somebody who is presented with a cognitive decline challenge. It is usually health care staff and relatives that meet and figure out what information and solutions are most appropriate for the given case. That is why Figma is used as a development tool since it allows code to be imported into different systems used by different kinds of users.

The overview of the literature results suggests that there are many IT solutions, so the prototype presents these approaches in a user-friendly way. This implies that the content is presented more comprehensively and in an easy-to-read form. Illustrations and figures are added to provide additional information and complement the textual information.

6.1 Development Tools

This section presents the development tools used in the process of designing and creating the prototype.

6.1.1 Figma

Figma is a design tool that can be run in the browser or downloaded as a desktop application. Figma offers functionality for designing prototypes for both web applications and mobile applications (Mbaabu, 2021). The low-fidelity wireframe (Figure 43 Section 6.3.6.2), mid-fidelity prototypes (Figure 44 Section 6.4.3 and Figures 46, 47, and 48 Section 7.1.1), personas (Figures 37, 38, 39 and 40 Section 5.4.3), and the User-Centered Process (Figure 33 Section 4.2.1) in this research project were developed using Figma. The advantage is that components created in Figma could be reused (Figma, n.d.).

6.1.2 Kanban

Kanban is a workflow management strategy for establishing, managing, and optimizing knowledge work services. It assists in visualizing work, maximizing productivity, and continuously improving. Kanban boards represent work in terms of what needs to be done, what is in process, and what has been done. This allows to maximize job delivery across many teams and manage even the most complicated projects in one place. Kanban was in this research project used for prioritizing tasks and to enable good workflow (Kanbanize, n.d.).

6.1.3 Adobe Photoshop

Adobe Photoshop is a graphics editor that allows to easily create and edit images, drawings, and 3D artwork (Adobe, n.d.). Adobe Photoshop was used to make a logo for the artifact (Figure 45 Section 6.4.4) and graphs based on literature (Graphs 2 and 3 Section 6.3.2).

6.1.4 Draw.io

Draw.io is a free online diagram editor that helps design flowcharts, Unified Modeling Language (UML) diagrams, entity relationship diagrams, network diagrams, mock-ups, and more. In this research project, Draw.io was used to make a tree-like presentation of knowledge based on literature (Diagrams 3 and 4 Section 6.3.2) and the conceptual model (Figure 41 Section 6.3.5) (draw.io, n.d.).

6.2 The Iteration Overview

A summary of the design iterations during the study can be seen in Table 13. UCD was followed throughout the development.

Iteration	1	2	3
Define/Redefine	Define the scope of the literature overview. Conduct literature overview using indexed databases and other relevant sources.	Redefine information structure after feedback obtained in the first iteration based on literature and open coding.	Redefine information and upgrade artifact after feedback from field expert interviews and evaluations.
Fidelity	Low (paper sketches and wireframes).	Low/Mid. Colors were added to distinguish diagnosis from treatment.	Mid. Illustrations and updated content were added.
Method	Literature review. Open coding to structure results according to the two main categories; diagnosis and treatment.	Two expert interviews. Further modeling.	User (from target user groups) and IT expert usability testing.
Evaluate	Presented at the poster session, and feedback was taken.	Feedback from field experts.	Tasks and SUS with users. Tasks, SUS and Nielsen's heuristics with IT usability experts.

Table 13. Design iteration overview.

Low fidelity prototype was made in the first iteration along with the literature review. This gave the basis for the second iteration where the prototype was further developed into a mid-fidelity prototype and interviews with field experts were conducted. In the third and last iteration, the prototype was even further developed, and users and IT usability experts conducted testing of the prototype along with SUS evaluation and Nielsen´s heuristics.

6.3 First Iteration

The first design iteration describes the work process from conceptual design to implementation of the first version of the prototype. In the first iteration, a broad literature review was done, and a very simple low-fidelity website prototype was sketched on paper.

6.3.1 Open Coding

Open coding was used to separate concepts and themes, and categorize them. It allowed for deriving new theories and concepts based on existing evidence. It was used as the initial step for analyzing qualitative data. As mentioned in Section 4.2.2.2 this research did not attempt to make new theories about diagnosis and treatment, but rather to provide a transparent structure for organizing both knowledge and the artifact on cognitive decline. Some dept was achieved structuring the IT techniques around the concept of severity (Diagrams 3 and 4 Section 6.3.2).

6.3.2 Literature Review Results

Literature results have been summarized in two forms. In the form of a tree-like structure based on diagnosis and treatment options, and as graphs introducing the severity of the decline.

One of the main topics for this study was to find IT solutions for diagnosing someone with cognitive decline. Diagram 3 shows the currently available solutions found in the literature.

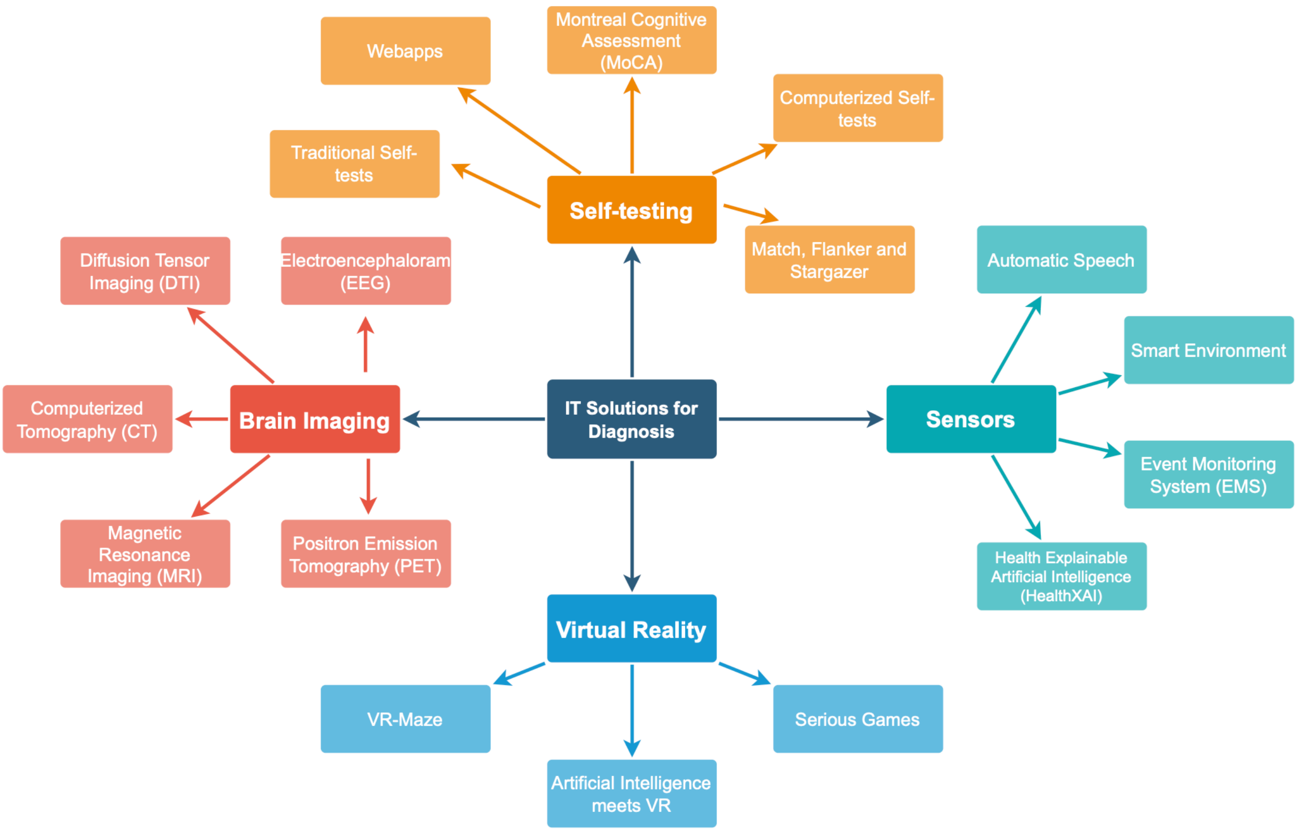


Diagram 3. Data category – IT solutions for diagnosis.

The other major topic in the structure of IT knowledge is for the treatment of cognitive decline. Diagram 4 shows the treatment solutions.

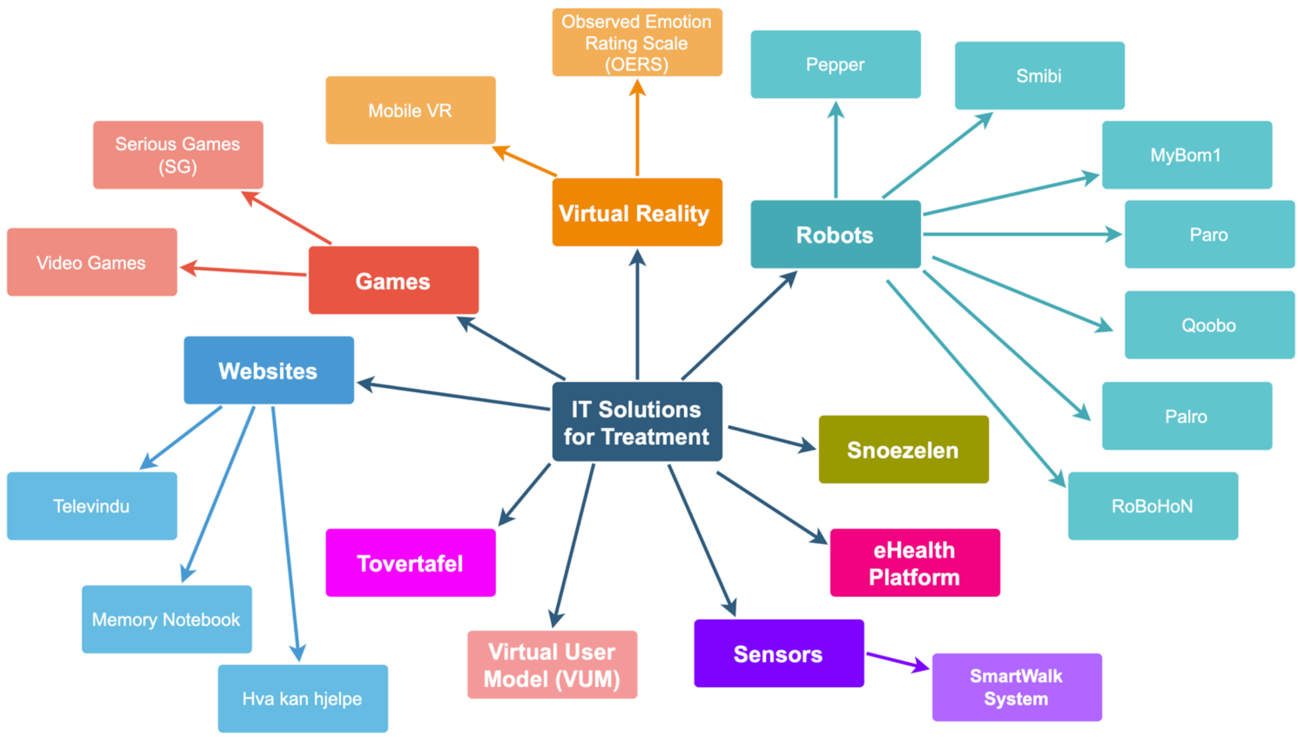
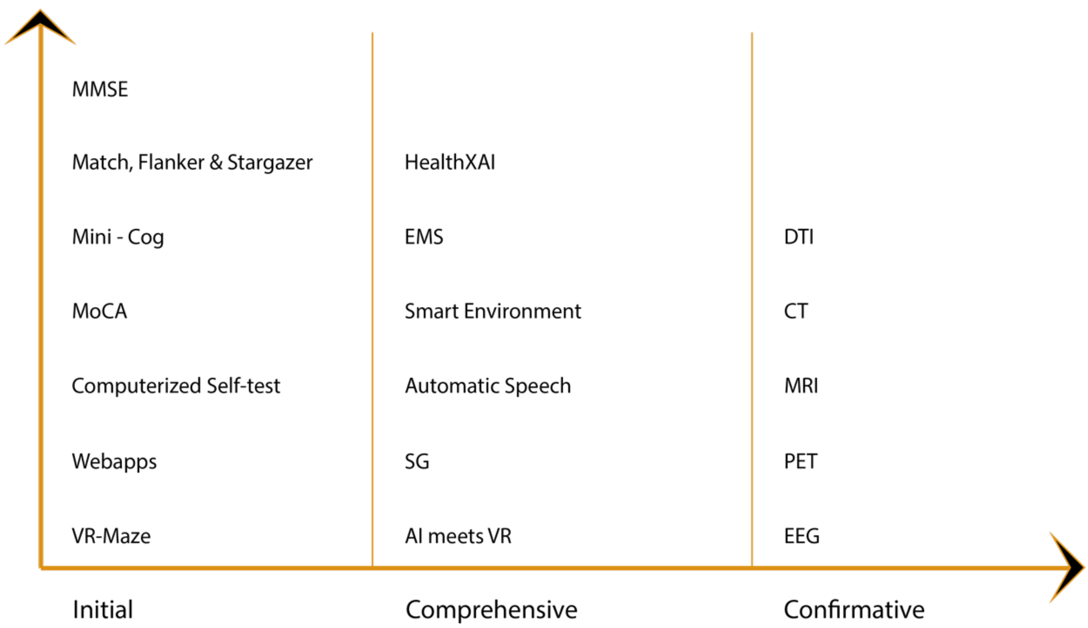
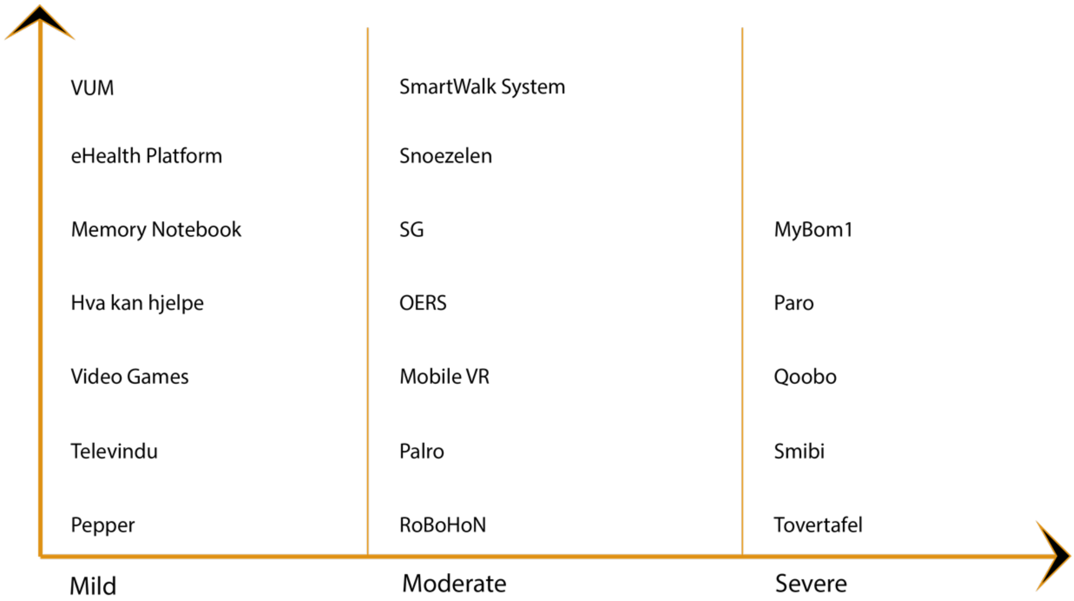


Diagram 4. Data category – IT solutions for treatment.

The graphs below show how the severity of the condition influences the choice of IT. Graph 2 is showing grading of IT solutions starting with initial, simple to perform tests, to more sophisticated comprehensive IT, and moving on to confirmative, highly specialized medical equipment. Graph 3 shows the breakdown of IT used for treatment based on severity.



Graph 2. Grading of IT solutions for diagnosis.



Graph 3. Severity of IT solutions for treatment.

6.3.3 Low-Fidelity Prototype Requirements

The landing page for the prototype should include three buttons, one for cognitive decline, one for diagnosis, and one for treatment illustrated as a tree-like structure. Introducing too many buttons and options on the landing page could be confusing.

The button for cognitive decline should have two arrows. One pointing at the diagnosis button, and one pointing at the treatment button, symbolizing that they are connected to the same medical field, but offering different options. The button for cognitive decline should lead you to an information page about what cognitive decline is, while the diagnosis and treatment buttons should lead you to new pages with a tree-alike map including IT solutions for both. Clicking on one of the solutions should open the page for further description and details about what the IT solution provides.

There should be a home button so that the user can easily go back to the landing page and a search button. The website should have a logo and pictures. A dedicated logo helps the identity of the page and makes it recognizable for returning users who want to keep reading (TaylorBrands, n.d.).

To support the usability requirements, the design was made simple with no unnecessary information or buttons. Because the prototype's purpose was to educate people about how IT solutions can be used for the diagnosis and treatment of cognitive decline, having a non-distracting interface design was critical to the prototype's success. Since one of the target groups is people with cognitive decline, making the interface simple would help with learnability and make it easier to utilize the content. The users must be able to easily get from one point of the website and quickly to another, and thus navigation through the UI is important (Polyuk, 2019).

The low-fidelity prototype and the wireframe, which served as the iteration's final output, concentrated on implementing numerous design suggestions and simple forms of interaction that demonstrated the concept. The prototype was designed as a MacBook 14” screen as older adults prefer big screen sizes. A smartphone can be challenging for some to look at due to its size (Polyuk, 2019).

6.3.4 Structure of the Prototype

The initial requirements were modified after interviews with field experts and potential users. Personas (Section 5.4.3) also helped in modifying the requirements as well. The interviews gave a wide insight into user needs and therefore requirements were updated.

A literature review is designed to give the researcher and the audience a picture of what is known about the subject at hand. A thorough literature evaluation helps guarantee that a legitimate research topic has been posted and that the appropriate theoretical framework and/or research methodology has been selected (The Writing Center, n.d.).

After conducting the literature review it was clear that there was a lot of information on both diagnosis and treatment. Several papers were reviewed, and the most relevant ones became the basis of the study and the prototype. The data gathering process consisted of reviewing multiple articles. The most relevant articles were collected resulting in the mid-fidelity prototype as shown in Figures 46, 47, and 48.

6.3.5 Conceptual Model

A conceptual model is a high-level explanation of the artifacts outline, as well as what a user may do with it and what concepts and know-how are required to engage with it (Sharp, Rogers, and Preece, 2019, 74-77). Figure 41 depicts the artifact´s principles, including its structure and interaction points. When designing the artifact, it is necessary to employ identifiable icons and methods, such as a magnifying glass to use for searching, or a house for the home button.

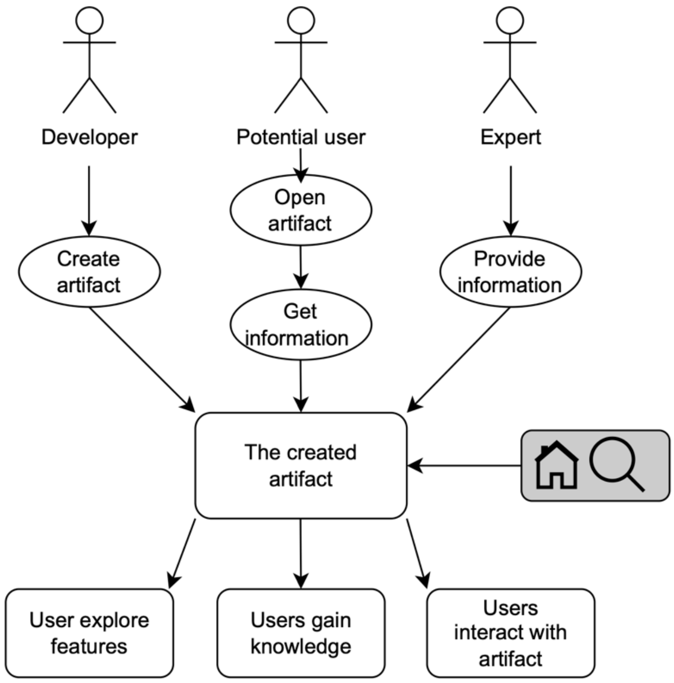


Figure 41. The conceptual model.

6.3.6 Low-fidelity Prototype

The low-fidelity prototype concentrated on implementing numerous design suggestions and simple forms of interaction that demonstrated the concept. The prototype's review yielded input on the concept, user-friendliness, and learning content, all of which were included in the next iteration.

Paper sketches can be used to generate low-fidelity prototypes that can be utilized to concretize conceptual design principles (Table 10 Section 4.2.1.1) and demonstrate the idea (Sharp, Rogers, and Preece, 2019, 427).

The low-fidelity prototypes, the early versions of the application, were made on paper and in Figma. To test alternative layout options, numerous variations were created on paper. The key functionality included in the sketch was the main features and the navigation between them.

6.3.6.1 Paper Sketches

Figure 42 depicts the elements and screenshot that the website should include to concretize the conceptual model (Figure 41 Section 6.3.5) that was created. The relationship between the scenes is displayed by arrows.

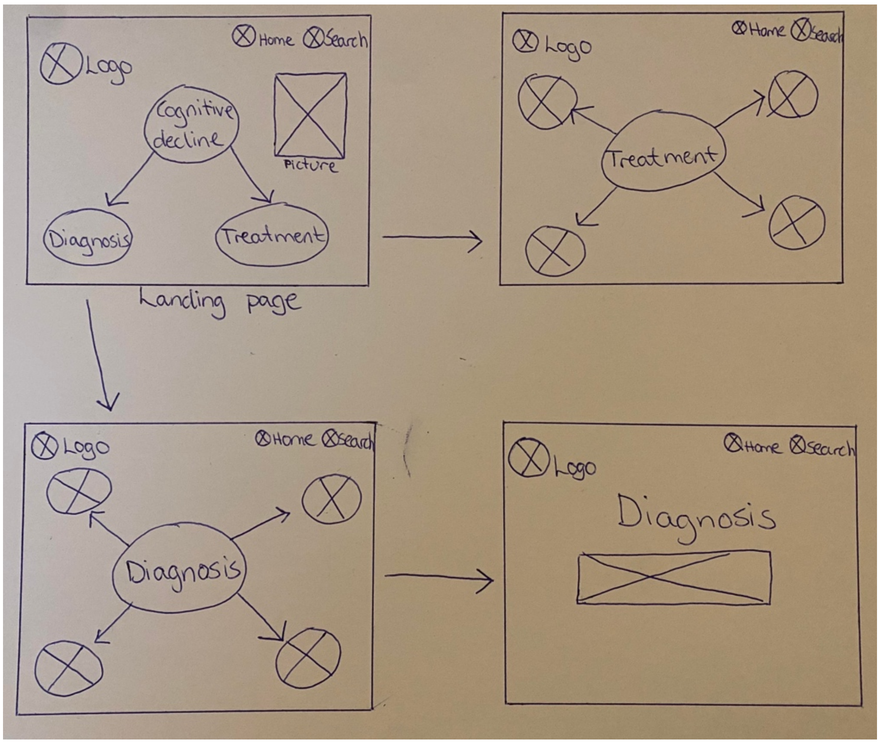


Figure 42. Low-fidelity prototype paper sketches.

6.3.6.2 Wireframes

Wireframes, which are a collection of documents that show the structure, content, and controls of a product, can be used to visualize a conceptual model (Figure 41 Section 6.3.5). Wireframes can be built with varying degrees of abstraction to display portions of the product or a complete overview (Sharp, Rogers, and Preece, 2019, 445). Here wireframes were used to detail content.

Figure 43 below shows the wireframes made in Figma.

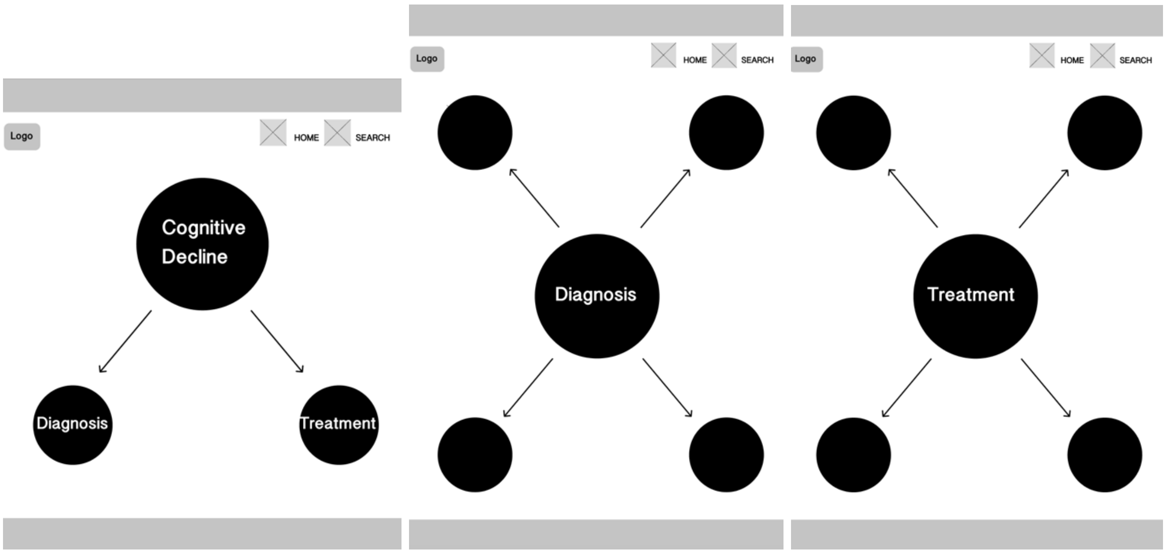


Figure 43. Wireframes.

6.4 Second Iteration

In the second iteration, the main goal was to conduct interviews with experts in the field of cognitive decline and continue the work with the prototype aiming into making it a mid-fidelity prototype using Figma.

As a part of acquiring knowledge for the solution, two field experts were interviewed. One expert was into cognitive decline research from a clinical point, and the development of preventative methods. The other was a biomedical engineering researcher who is interested in collecting brain wave signal data and analyzing it using ML approaches. Both competencies are essential for building IT solutions.

The interviews were semi-structured (Section 4.2.2.3), and both the participants gave their informed consent (Appendix B1) before the interview. Personal information and other relevant information could be published if the participants agreed to so. Otherwise, their personal data was anonymized.

6.4.1 Redefining the Prototype

It is common to take feedback from the first iteration into the second to both improve and further build the prototype of the first iteration. The low-fidelity prototype is upgraded to a mid-fidelity prototype based on the feedback during the poster session and further readings on the topic.

6.4.2 Reviewing Design Principles

Five design principles (Section 4.1.3) were reviewed to create a better mid-fidelity prototype. This was to make sure that all the principles were integrated into the current design. Examples of design features that were implemented to create good UX are described below.

Visibility was achieved by adding text on the buttons and next to them to ensure that users knew what they were pressing, and what kind of information to expect.

Feedback was accomplished by giving information to the user to orient themselves regarding where in the artifact they were currently. E.g., if they pressed the *"Diagnosis"* button, they would be directed to the diagnosis site where all information about the diagnosis could be found. Similarly, they could navigate to the next more detailed information on different diagnosis approaches.

Constraints were implemented to make it harder for the user to make mistakes. E.g., a home button was added so that the user easily could go back to the landing page. A search button was also implemented so that the users easily could search for information without going through multiple pages.

Consistency of the design of the application was implemented by using the same colors, icons, and font throughout the application.

Affordance was achieved by using common icons and a consistent layout throughout the whole artifact. Choice of color and contrast colors were done concerning the literature on cognitive decline.

6.4.3 Mid-fidelity Prototype

The goal here was to work on the tasks identified in the first iteration and illustrated in the low-fidelity prototype. There were a few details to be worked out, such as website navigation, visuals, information hierarchy, layouts, and flow, as well as making it more user-friendly.

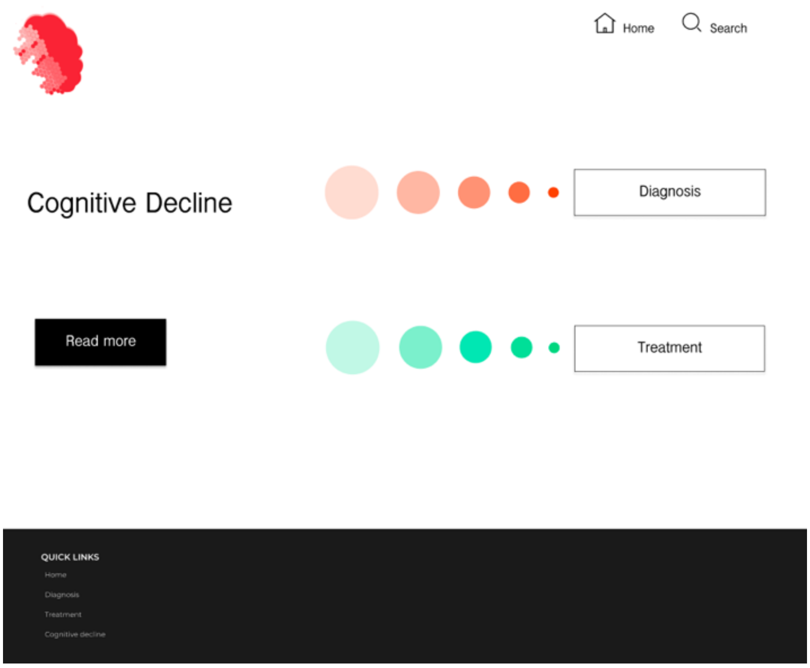
The user-centered goal was to make the website as simple and user-friendly as possible to use. The search button and home have been made clearer. The home button was included for easy navigation serving as a safe point on the interface (Polyuk, 2019). This will make it easier for the user to search and navigate through the website and explore the information.

Clickable buttons have been labeled with text to make them clear for everybody. The button and text sizes are made large for visual accessibility (Polyuk, 2019). The logo and some texts were implemented.

The gestures in the prototype are made with minimal complexity to make it possible for the elderly to explore the content. The user should always feel that they know their position and how to get back to the landing page (Maserati et al., 2019).

Figure 44 below illustrates examples from the mid-fidelity prototype showing both diagnostics and treatment technologies with an example (*Sensors*). Each technology got its page with information regarding it.

A)



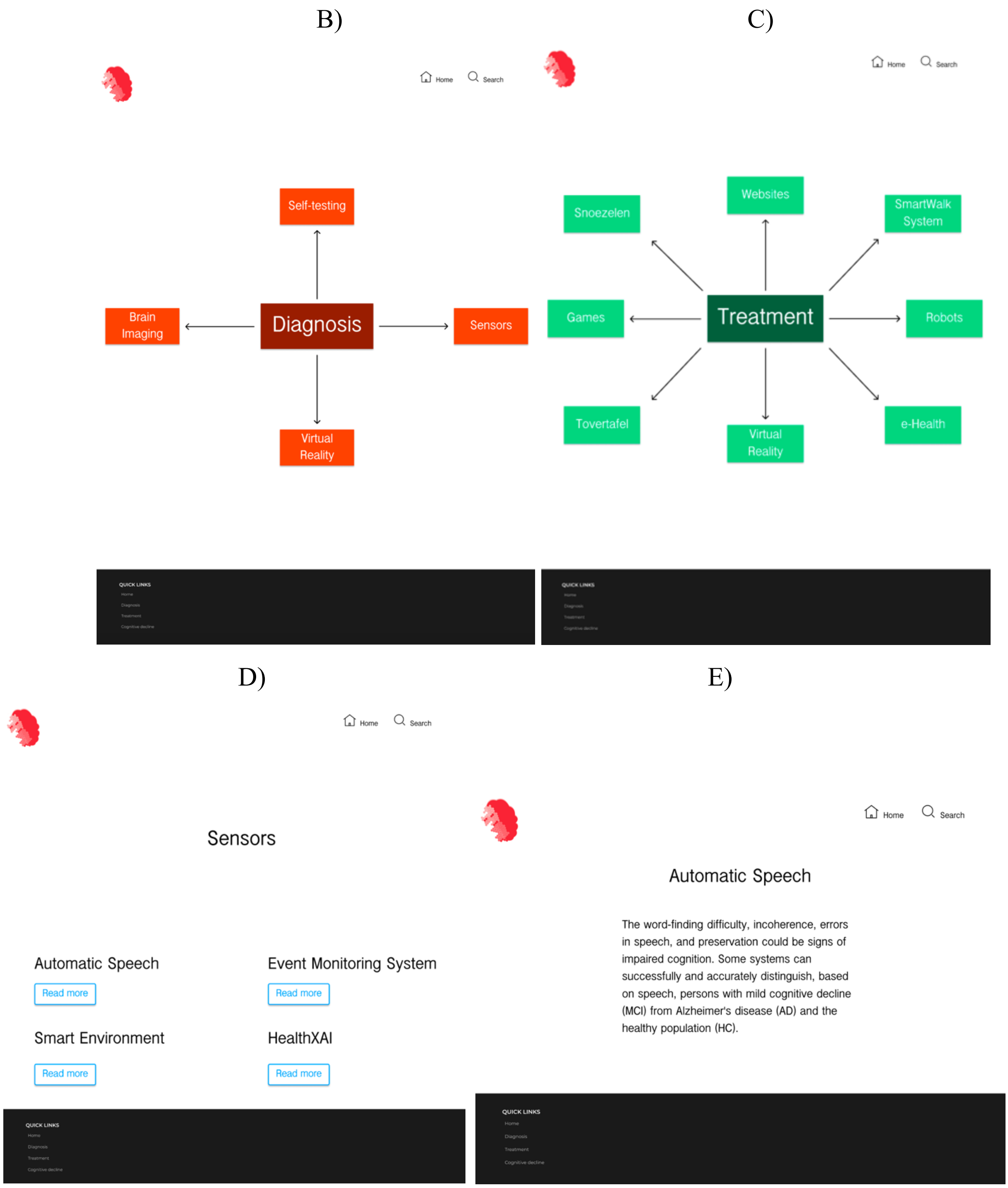


Figure 44. Screenshots from the first mid-fidelity prototype. A) Illustrates landing page. B) and C) illustrates the diagrams shown when the "Diagnosis" or "Treatment" buttons are pushed on the landing page. D) Show examples of technologies for diagnosis if the "Sensor" button is pushed. E) Gives detailed information about a technology.

6.4.3.1 Color Choices

When it comes to color preferences for individuals with dementia, red, blue, and green are appreciated colors. Blue is giving a calming effect and using blue in a physical environment has been shown by researchers to lower blood pressure (The Advocate, 2016). The red color can increase brain wave activity. To get attention from a person suffering from dementia, red is a good color to use. Green is the most restful color of the three. It can help people stay calm and reduce central nervous system activity. For dementia patients, the green color is effective for visual attention (The Advocate, 2016). All three colors are used in the mid-fidelity prototype. Red and green appear more often than blue since they help keep attention, while contrast colors such as black and white make reading easier (The Advocate, 2016) (Polyuk, 2019. Even though blue is a good color for dementia patients, when it comes to light shades of blue the color can look faded to them. Therefore, blue was not used as frequently (The Advocate, 2016) (Polyuk, 2019). The red and green fading and decreasing bobbles on the landing page represent cognitive decline.

6.4.3.2 Font Choice

The font chosen for the mid-fidelity prototype is "InaiMathi" as it was found to be clear and easy to read.

InaiMathi

This is the font used in the prototype.

Illustration 1. The font used in the prototype.

6.4.3.3 Icons

Icons are from Ikonate (Ikonate, n.d.) which provides free vector icons. These are easily implemented into Figma.

Illustration 2. Icons used in the prototype (Ikonate, n.d.).

6.4.4 Logo Design

The logo (Figure 45) was developed to suggest the content of the artifact. The logo is representing a brain in which half of the brain is disappearing, just as it is with cognitive decline in patients. The colors are chosen based on the literature on preferred colors for dementia patients (Section 6.4.3.1). The red color has been shown to increase brain wave activity, which makes it a suitable choice when patients are expected to pay attention and engage (The Advocate, 2016) (Polyuk, 2019). The logo was not implemented as a feature into the artifact until the second iteration.

Figure 45. The logo design.

6.4.5 Expert Interviews

Two field experts were interviewed and afterward, the interview transcriptions were analyzed paying attention to the main topics following pre-defined questions that can be found in the interview guide (Appendix B2). The questions referred to several priorities that the experts found relevant for them and the kind of research they were doing. They were also asked to reflect on the future and possible development in their respective fields.

Both experts gave broad insights into IT solutions and provided a lot of relevant information. They have been working in their fields for a long time and could provide new information that was not so transparent from the literature review. It became obvious that having clearly defined standards for the target group was critical. One of the field experts later conducted a usability testing of the mid-fidelity prototype, together with IT experts, in the third iteration using a SUS evaluation and Nielsen´s heuristics.

Chapter 7

7 Evaluation

This chapter presents the third iteration of this research project with feedback from users and IT usability expert evaluations.

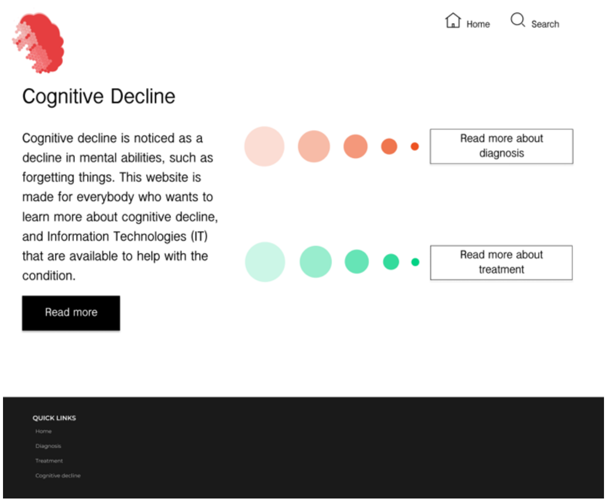
7.1 Third Iteration

This iteration summarizes results and suggestions from users and IT usability experts and updated mid-fidelity prototype based on feedback from the second iteration, SUS - and heuristic evaluation findings.

7.1.1 Redefining after Feedback from Field Experts

The field experts gave a lot of interesting information about the topic in the second iteration. This helped in redefining and updating the information in the new prototype. The mid-fidelity prototype was further developed. Lots of content was added regarding different approaches to diagnosing and treatment. Illustrations were also added to help understand and relate to the content. Language in the prototype was made as clear as possible so that most people would be able to read and learn. YouTube links were included in the more detailed description to make it easier for people who have a hard time reading and understanding the subject. Several pages with information about different technologies were made. Figure 46 shows a selection of pages that illustrates different parts of the artifact. Figures 47 and 48 illustrates more technologies.

A)



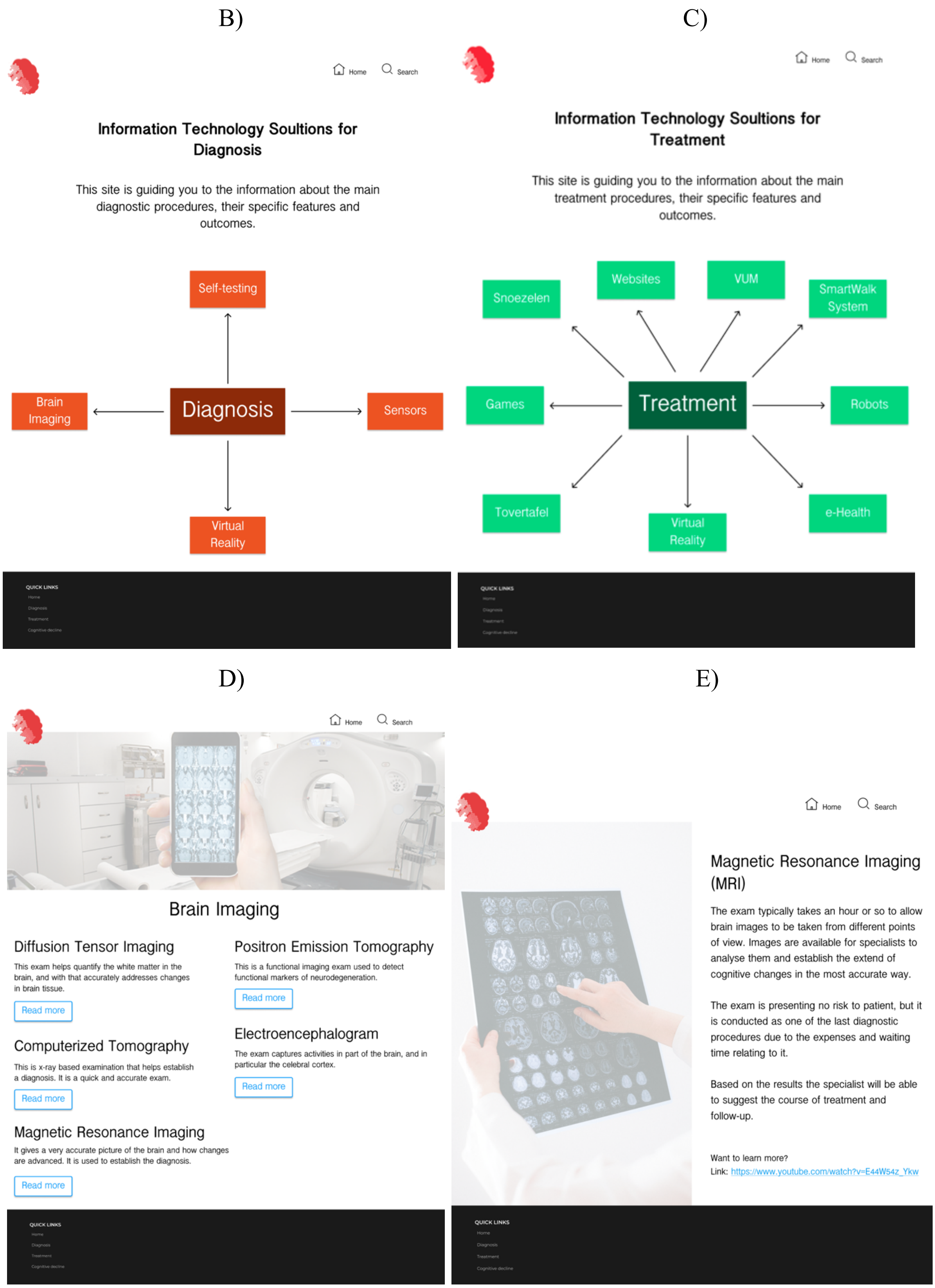


Figure 46. The mid-fidelity prototype used for testing. A) Illustrates landing page. B) and C) illustrates the diagrams shown when the "Read more about diagnosis" or "Read more about treatment" buttons are pushed on the landing page. D) Show examples of technologies for diagnosis if the "Brain Imaging" button is pushed. E) Gives detailed information about a technology.

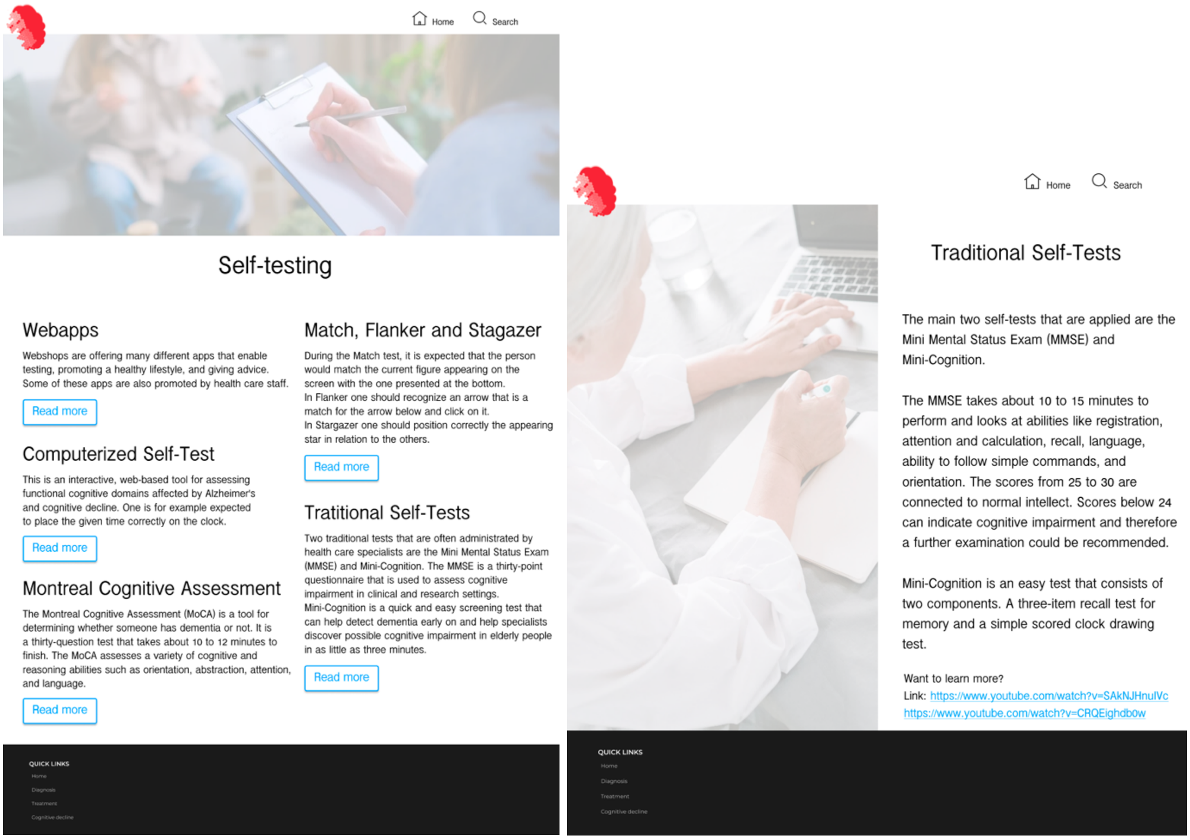


Figure 47. Mid-fidelity prototype – Self-testing.

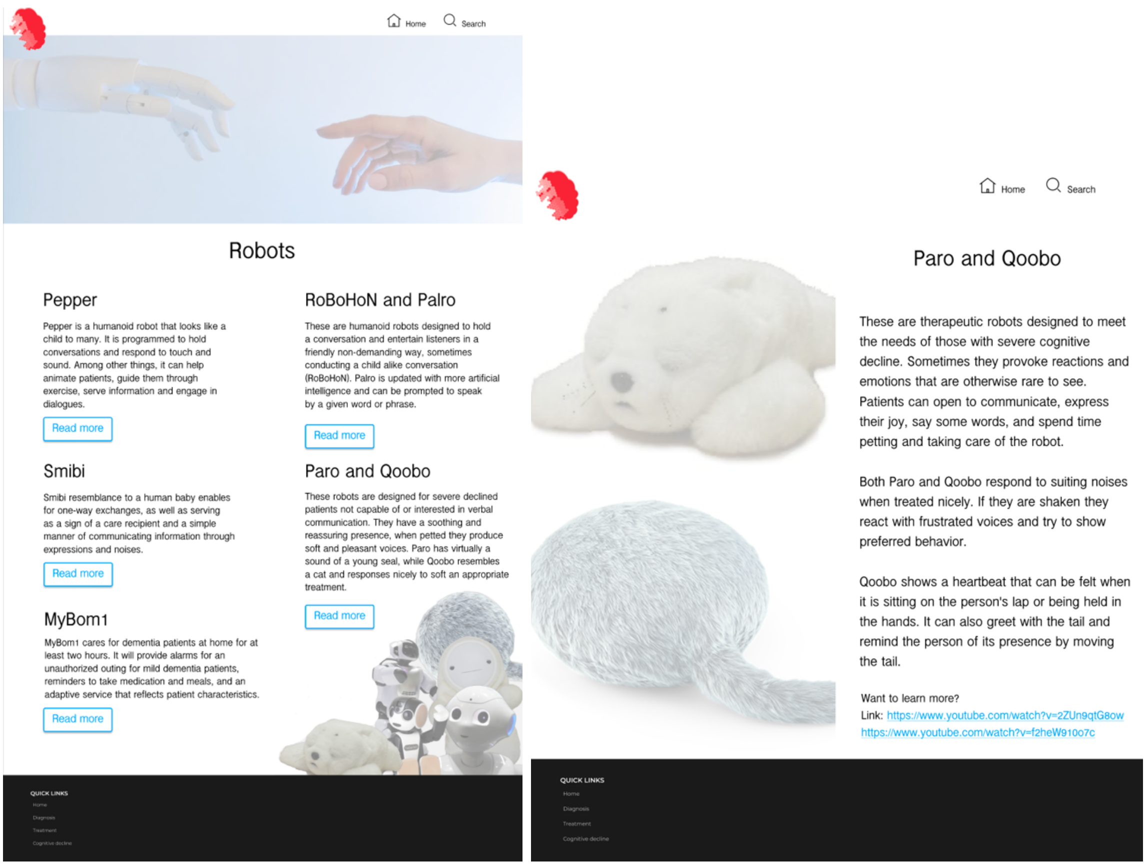


Figure 48. Mid-fidelity prototype - Robots.

7.1.2 Evaluators

To get more varied feedback on the prototype, two different usability testing groups participated in the evaluation. The purpose was to get feedback on functionality and design from different viewpoints, as well as feedback on whether they liked the idea presented by the artifact. According to Sharp, Rogers, and Preece (2019, 500) usability testing is a *"fundamental, essential Human-Computer Interaction (HCI) process"*.

The first group comprised three users that could represent the target group and real potential users. The second group consisted of six IT usability experts. A total of nine evaluators were used to provide a good baseline for evaluating novel designs and to detect as many usability issues as possible (Six and Macefield, 2016).

7.1.3 Usability Testing with Users

The three users participated in the usability testing first. One was a nurse working in the field for many years, one was a relative (son) to a person with severe decline and one was a potential user not from the target group but interested in the field (Table 14). The testing was done over Zoom by sharing the screen on three separate occasions. In turn, this should help the users express their opinions freely and explore the content at their own pace.

	User 1	User 2	User 3
Age	59	58	57
Gender	Male	Female	Male
Target group	Relative (son)	Health care worker (nurse)	Potential user (not from target group, but generally interested)

Table 14. User demographics.

A set of three different tasks were defined for the users to complete. Those were presented prior to testing giving the possibility for the researcher to answer any question the user might have. The researcher conducting the research project observed the users while performing the tasks to see how they reacted to tasks and how they navigated. Because the mid-fidelity prototype was created in Figma (Figma, n.d.), it was not possible to get all the intricacies, animations, and micro-interactions in place which could be expected in a high-fidelity prototype. The researcher was neutral but helped with managing the prototype since the testing was done on Zoom.

Task 1: *Find information about VR treatment.*
Users 1 and 2 struggled with this task as they were not yet familiar with the setup of the prototype. User 1 was confused on the site with the diagram for treatments, not understanding that only one of the buttons (the button for VR) was the correct one. For User 3 this task went very well.

Task 2: *What information and solutions are there for diagnosis using brain imaging?*
This task went easier than the first as the users now were more familiar with the setup. Although User 1 got confused when entering the site for all diagnosis options for brain imaging, not understanding that all diagnosis provided on the site was dedicated to brain imaging. However, this task went well for all the users, and they found the setup to be logical.

Before giving the users the last task some short background information was given on robots and how they are used for the treatment of different stages of cognitive loss. This introduction was given since robots are mainly used in Japan, although increasing many countries are seeing the potential of using robots in nursing homes. Japanese society has made a strategic investment in developing robots for nursing purposes due to the proportion of the aging population. Although not mentioned and explained to the users, the two robots for the most severe patients (Paro and Qoobo) can be purchased and are used in Norway (Picomed, n.d.) (Ledelse og teknikk, n.d.).

Task 3: *What robot(s) would you recommend to the patients with the most severe cognitive decline?*
This task was experienced as easiest by the two users who were familiar with cognitive decline, as they have either worked with those patients or have relatives affected by it. Both knew that cognitively declined persons do not tend to talk too much and therefore the robots Qoobo and Paro are the preferred robots for those patients. They found the description of the robots clear and understandable. They could easily distinguish which robots would suit the

most severe patients. For User 3 this task went very well even though the user had little experience with cognitively declined persons.

After completing the third task, all three users had a good understanding of the content, and how to navigate through the prototype. They mentioned the logo which they liked a lot and said that the half-brain logo was well suited. All the users enjoyed the artifact and stated that it was a good idea.

As a part of the evaluation the users were asked two easy questions and performed a SUS evaluation (Section 4.2.4.2) to fill in to provide a more objective evaluation two additional questions were asked:

Would you recommend this website?

Are there other functions you would like to see?

All of them said that they would recommend the website as they enjoyed it a lot and that they enjoyed completing the tasks. User 1 stated that since people google a lot and there is a lot of misinformation out there, a website like this could provide users with credible information. Moreover, presented in a user-friendly way, it was easier to understand the content than by reading a research article alone. User 3 had some comments on the functionality, saying that he enjoyed the easy design and language, but he missed easier navigation to the technologies on the landing page as he now had to go through several steps to read about them. User 2 felt that it might still be difficult for someone with cognitive decline to navigate the site and read and understand the provided information. Based on what User 2 had seen on cognitive decline she felt that the site would be more appealing to relatives and health care personnel than to somebody who is already experiencing severe forms of decline.

The benefit of this form of evaluation is that it provided detailed feedback on specific aspects of the artifact and its functionality. The ability for users to provide direct input and for us to ask users questions about various aspects was beneficial in forming a larger and more thorough picture of what needs to be improved (Sharp, Rogers, and Preece, 2019, 500-503).

Nielsen´s heuristics evaluation was not done with users as they are not usability experts.

7.1.4 SUS Evaluation with Users

After solving the three tasks the users completed the SUS evaluation form. They found the prototype to be clear and understandable with credible information, but a bit difficult at the beginning since the prototype does not look exactly like a common website.

The score from each user is shown in Table 15. The Likert scale (Section 4.2.3) was used to rate the answers. Using a scale starting with *strongly disagree (1) to strongly agree (5).* Afterward, the scores were calculated as described in Section 4.2.4.2.

	User 1	User 2	User 3
Question 1. I think that I would like to use this system frequently.	4	4	5
Question 2. I found the system unnecessarily complex.	2	2	1
Question 3. I thought the system was easy to use.	4	5	5
Question 4. I think that I would need the support of a technical person to be able to use this system.	1	2	1
Question 5. I found the various functions in this system were well integrated.	5	4	5
Question 6. I thought there was too much inconsistency in this system.	1	2	1
Question 7. I would imagine that most people would learn to use this system very quickly.	4	4	4
Question 8. I found the system very cumbersome to use.	2	2	1
Question 9. I felt very confident using the system.	4	4	5
Question 10. I needed to learn a lot of things before I could get going with this system.	2	2	1
Total SUS score	**82,5**	**77,5**	**97,5**

Table 15. Results from SUS evaluation with users.

All scores were above acceptable (above 68), thus reaching between good and excellent scores according to Bangor et al., 2009.

7.1.5 Usability Testing with IT Usability Experts

A total of six IT usability experts participated in the evaluation. All of them have a background and knowledge about how to evaluate prototypes as they have been working or studying information science, user design, interaction design, etc. Table 16 shows an overview of the participants and their backgrounds based on answers from the interview guide (Appendix B3).

	Background
Expert 1	Master's degree in information science, specializing in UX design. Currently working as a full stack developer.
Expert 2	Master's degree in information science. Currently working as a full stack developer.
Expert 3	Master's degree in information science. Currently working as a UX designer.
Expert 4	Master's degree in information science. Currently working as a full stack developer.
Expert 5	Associate professor and researcher in the field of ML, AI, and biomedical engineering.
Expert 6	Master's degree in information science focusing om data mining on knee arthroplasty.

Table 16. The IT usability experts.

The IT usability experts were asked the same three tasks and got the same background information about robots as the three users, and the same mid-fidelity prototype was used. After completing the tasks, the experts conducted a SUS evaluation (Table 17), Nielsen´s heuristics (Table 18) and answered a few pre-prepared questions from the interview guide (Appendix B3). All evaluations were done on Zoom.

Task 1: *Find information about VR treatment.*

There was some confusion as to whether they should press the *"Read more"* or *"Read more about treatment"* button. Some of the experts did not understand that the last one was a clickable button since they found the *"Read more"* button to be more dominant. Although navigation went well and all experts finished the task quickly, there was some confusion about whether buttons were clickable or not. Expert 4 found the buttons to not be well enough defined, and that there was no definition of how to navigate further. The user would prefer more information about the buttons and diagrams.

Task 2: *What information and solutions are there for diagnosis using brain imaging?*
This task went very well for all experts. Expert 5 missed a technology for brain imaging technologies (fMRI) so this should be implemented.

Task 3: *What robot(s) would you recommend to the patients with the most severe cognitive decline?*
Again, navigation went very well. All experts found that Qoobo and Paro, as well as MyBom1, were the best suitable robots for the most severe patients indicating that the language in the prototype was understandable. None of them had any deeper knowledge of the robots in care. Experts 1, 2, and 6 stated that keywords under each robot could be beneficial for quicker and easier navigating, especially for cognitively declined users. Some of the experts mentioned that they missed more pictures and illustrations as this may help in understanding where in the artifact one is.

When enquired about the logo all experts seemed to have liked it and the meaning behind it.

7.1.6 SUS Evaluation with IT Usability Experts

All IT expert evaluators provided feedback in this third iteration through a SUS evaluation. This was done during the Zoom session after tasks were executed and they got familiar with the navigation.

SUS scores were based on the Likert scale (Section 4.2.3), *strongly disagree (1) to strongly agree (5)*. Afterward, the scores were calculated as described in Section 4.2.4.2 and can be seen in Table 17.

According to Bangor et al., 2009 a score above 68 is acceptable and considered good to excellent. All scores from the SUS evaluation with experts were above acceptable (Bangor et al., 2009).

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
Question 1. I think that I would like to use this system frequently.	5	5	4	4	4	5
Question 2. I found the system unnecessarily complex.	1	1	1	4	1	1
Question 3. I thought the system was easy to use.	4	3	5	4	5	4
Question 4. I think that I would need the support of a technical person to be able to use this system.	1	1	1	1	2	1
Question 5. I found the various functions in this system were well integrated.	4	5	5	5	5	5
Question 6. I thought there was too much inconsistency in this system.	1	2	1	1	1	2
Question 7. I would imagine that most people would learn to use this system very quickly.	4	4	4	5	3	5
1Question 8. I found the system very cumbersome to use.	2	1	1	5	1	1
Question 9. I felt very confident using the system.	4	4	5	5	4	4
Question 10. I needed to learn a lot of things before I could get going with this system.	1	1	1	1	2	1
Total SUS score	**87,5**	**87,5**	**95**	**77,5**	**85**	**92,5**

Table 17. Results from SUS evaluation with IT usability experts.

7.1.7 Heuristics with IT Usability Experts

The final part of the expert evaluation was to fill out a Nielsen´s heuristics form described in Table 12 Section 4.2.4.3. The grading was based on the Likert scale (Section 4.2.3), *strongly disagree (1) to strongly agree (5).* Afterward, the scores were calculated as described in

Section 4.2.4.2 and can be seen in Table 18. All the six experts that conducted the SUS evaluation also conducted Nielsen´s heuristics evaluation on the same mid-fidelity prototype.

The ninth heuristic (*"Help users recognize, diagnose, and recover from errors*") was not evaluated since this functionality was not implemented in the current version of the artifact.

	Expert 1	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**	**Expert 6**
Visibility of system status	5	4	4	3	4	5
Match between system and the real world	5	5	5	3	5	4
User control and freedom	4	5	5	2	3	5
Consistency and standards	4	4	5	5	5	4
Error prevention	4	4	5	5	3	5
Recognition rather than recall	5	5	4	4	4	5
Flexibility and efficiency of use	3	4	5	4	5	5
Aesthetic and minimalist design	4	5	4	5	5	5
Help users recognize, diagnose, and recover from errors	-	-	-	-	-	-
Help and documentation	1	3	5	2	5	5
Average Nielsen´s score	**3,89**	**4,33**	**4,67**	**3,67**	**4,33**	**4,78**

Table 18. Results from Nielsen´s heuristics with IT usability experts.

Scores are calculated as average values. Since question nine was not included, the score was divided by nine instead of ten. The evaluators gave feedback and recommendations for each heuristic as follows.

Visibility of system status – The experts felt that the artifact did not give enough feedback within a reasonable time and that it gives too little information about what is going on. Suggestions here were to include breadcrumbs for easier navigation and help users position themselves. A drop-down window was also recommended to implement on the landing page as this would be beneficial for easier navigation through the prototype.

Match between system and the real world – The experts felt that the language was easily understandable and suitable for a page like this, however, they felt that there was a lack in including icons and information about buttons in the artifact. They also found the buttons to be too different from each other, which could confuse users. Several experts stated they were not sure whether the diagrams were clickable or not.

User control and freedom – The experts were satisfied with the home button. No more information was provided.

Consistency and standards – The experts found that some of the buttons might be hard to understand, especially whether they were clickable. This was the case with the landing page where several experts wondered if the *"Read more"* button was the only clickable button. They also found the diagrams a bit hard to manage.

Error prevention – The experts found that there is a lack of buttons in the prototype. They would like to see a button for both *"diagnosis"* and *"treatment"* on the *"Read more about cognitive decline"* page. They found it difficult to understand what kind of information is on the *"read more"* page on cognitive decline. The *"Read more about cognitive decline"* button they found to be too dominant compared to the other two buttons on the landing page. This caused some confusion.

Recognition rather than recall – According to the experts the landing page of the artifact needs some more attention, such as clearer buttons, breadcrumbs, and a drop-down menu. User 5 suggested that having a read-aloud button would be a great help to users.

Flexibility and efficiency of use – The users found the *"Quick links"* to be a good thing about the artifact. However, they did not like the position of being at the bottom of the page. They mentioned again that they missed breadcrumbs. Regardless, they found the artifact to be suitable for both experienced and inexperienced users.

Aesthetic and minimalist design – The experts would like to see keywords underneath each technology presented. This would make it easier for people that do not have a lot of background information to quickly navigate and gather information. They found it to be too much text for the most severe patients. However, they still found the design to be simple and clean.

Help users recognize, diagnose, and recover from errors – The functionality was not implemented in the artifact, and therefore could not be evaluated. The work is planned for the high-fidelity prototype.

Help and documentation – Some of the experts missed this heuristic and said the artifact needs an *"about us"* or *"help"* site. Others thought that there was enough clarity from the design as it is.

7.1.8 Concluding Remarks

A comprehensive evaluation is conducted in this iteration concerning usability and user friendliness.

From the practical point of view, the buttons need some work regardless of their function. Equally presentation of knowledge based on the literature could still be more demanding for common readers.

This was the last iteration of this prototype. All the results from the evaluation could be used during the next iteration or implementation. Features developed in Figma could be reused in the next design iteration or become a part of a hospital website or any other health care dedicated application.

Chapter 8

8 Discussion

This chapter discusses the methodologies and methods used, the research questions that were stated in the initial chapter, and the limitations of design and development.

8.1 Research Methodologies and Methods

8.1.1 Design Science

To integrate the methods used, the Design Science framework was applied throughout the project. Seven guidelines are developed within Design Science to ensure that research is conducted effectively. The use of the methodology is outlined in Section 4.1, and demonstrates that all the procedures necessary to produce the artifact were followed. The framework is recommended for research that requires a variety of expertise and approaches.

All three design cycles were taken into consideration when designing the artifact. That meant that methods were chosen carefully to suit the research problems and the user's environment. The design was informed by paying attention to both theory and user expectations.

8.1.1.1 Design Principles

The artifact´s usability was ensured using the five design principles. They prioritize design over content, which seems to contrast with content that is central to this project. However, all five principles were used to create an intuitive UI as they improve the design of the artifact and help communicate knowledge (Section 4.1.3 and Section 6.4.2).
The design concepts were critical for ensuring continuity and orderly development, which benefitted the project.

8.1.2 User-Centered Design

UCD relies on feedback from intended users and was therefore considered necessary in the development of this artifact, which must be improved iteratively. User requirements and preferences are prioritized in UCD, and therefore evaluation with users is essential. However, users are not necessarily present in each iteration but are certainly invited to evaluate an artifact of mid-fidelity. In this project, this was possible in the third iteration when three tasks were created for users to accomplish and thereafter provide their feedback and evaluation scores (Sections 7.1.3 – 7.1.7).

8.1.2.1 Conceptual Design

Throughout this project, four guidelines from the conceptual design approach (Table 10 Section 4.2.1.1) functioned well with the other design principles and methods. All four guidelines were applied and used regularly, and it was necessary to keep an open mind while considering new user and usability requirements.

Users and experts provided the most valuable information especially in the third iteration when they could reflect on the conceptual design model and provide feedback in addition to SUS and Nielsen's heuristic scores.

8.1.2.2 Design Prototyping

Although prototyping takes time, the result is quite rewarding. Users must interact to understand what they are receiving and how the design might be improved in the future. Because low-fidelity prototypes were quick and easy to update, numerous versions were created and discussed together with the supervisor before moving on to mid-fidelity prototyping. User and expert feedback were quite helpful and could be used in future prototype versions such as high-fidelity and final products.

8.1.3 Data Gathering

8.1.3.1 Literature Review

As a part of the first iteration, a broad literature review (Chapter 3) was conducted to gather information about IT solutions for cognitive decline. The primary source of information was the literature and all other content such as websites of the hospitals and the industries delivering technologies for cognitive decline. Keywords like cognitive decline, diagnosis, treatment, information technology (IT), and dementia secured a body of 81 references. The articles were further studied and summarized using the qualitative method that is described in the following chapter.

8.1.3.2 Open Coding

To identify and segregate information from the literature review, open coding was employed (Sections 4.2.2.2 and 6.3.1). It enabled the development of new hypotheses and notions based on current data. It was utilized as the first step in qualitative data analysis. The distinguishing categories are diagnosing, treatment, severity, and prevalence.

8.1.3.3 Semi-Structured Interview

Semi-structured interviews were conducted to collect qualitative data throughout the design iterations (Section 4.2.2.3 and 6.4.5). The method proved effective in gathering information and domain knowledge that would have been difficult to comprehend or collect using other methods. E.g., an interview with an expert could give important insights, thoughts on the current issues, and important research ideas that are not yet published.

Interviews with specialists in the field of cognitive decline offered additional insight into the area and helped to clarify the needs and constraints of the target group. This information was useful in determining requirements and establishing scope and content frameworks. The IT usability experts' comments on expected functionality and proposed improvements led to new visions of the prototype.

Semi-structured interview with field experts has revealed an interesting observation which one of the experts saw as a limitation. Regardless of years of research, focus seems to be on measuring and understanding cognitive loss. Undoubtedly, this will result in better knowledge about the condition. However, it seems as if very little of this knowledge is transitioned into daily life. One of the experts would have liked to see a more positive impact and improvement for persons with cognitive loss, e.g., getting better at daily tasks not only working memory tasks. More engaging games with positive measurable impact would be appreciated.

8.1.3.4 Observation

Observation (Section 4.2.2.4) was used to acquire qualitative and quantitative data on the actual use of the prototype during testing (Sections 7.1.3 - 7.1.7) with users and IT usability experts. The strategy produced high-quality qualitative and quantitative data that supplemented information gained through user interviews. Observations made during user testing helped to explain a variety of factors that may have influenced how the activities were completed. The observations gave important input on the interaction design, as well as indicators of the prototype´s user-friendliness and UX.

8.1.3.5 Data Validity

Several data collection strategies were used during the investigation. Standardized data collection methods were also implemented, with interviews conducted using interview guides to ensure consistency in the data acquired throughout all interviews. The data includes both qualitative and quantitative information, resulting in a high level of validity.

8.1.4 Evaluation

8.1.4.1 Likert Scale

A Likert scale (Section 4.2.3) was used to obtain information on users' preferences for the functionality and design of the artifact in a SUS and Nielsen´s evaluation. The process provided clear answers to what users and IT usability experts desired in the artifact during the third iteration.

8.1.4.2 Usability Testing

The usability testing revealed whether the UI was intuitive. Participants were given tasks to perform that they all completed without assistance (Sections 7.1.3 and 7.1.5), implying that the interface was simple to grasp. Having three users and six IT usability experts test the artifact provides valuable information (Section 7.1.2). Observing the users throughout the usability test is also crucial since it helps uncover flaws that would not be apparent otherwise because they are hard to predict.

8.1.4.3 System Usability Scale

SUS is a simple and quick method of evaluating most systems and artifacts. A good SUS score will reflect a design-specific method with a focus on users' ability to use the artifact. In the third design iteration, users and IT usability experts conducted a SUS evaluation (Sections 7.1.4 and 7.1.6) to identify some usability concerns regarding the artifact.

8.1.4.4 Nielsen´s Heuristics

Six IT usability experts evaluated the artifact in the third iteration (Section 7.1.7) using Nielsen´s heuristic. Since this is a cheap way of evaluation and does not require lots of planning, it was easy to get multiple experts to evaluate. Here it was expected to get more critical feedback and reassurance of ideas. When evaluating Nielsen´s heuristics the experts did discover several aspects that could be improved throughout further iterations. However, the experts found the artifact to be good and satisfactory in its current for both experienced and inexperienced users.
A total of six evaluators were engaged following the theory that clarifies how 80-90% of all usability issues could be addressed by six evaluators (Graph 1 Section 4.2.4.3).

Disclaimer: during current development, the ninth heuristic *"Help users recognize, diagnose, and recover from errors"* was not implemented. This should be done in the final high-fidelity prototype once the other development is finalized. To compensate for the lack of this functionality during the evaluation participants were given instructions when needed.

8.2 Prototype Development

The use of low and mid-fidelity prototypes (Figure 42 Section 6.3.6.1, Figure 44 Section 6.4.3, and Figures 46, 47, and 48 Section 7.1.1) in the design helped to visualize the functionality. When getting feedback and suggestions, having prototypes for users and IT usability experts to interact with was critical.

The prototype development process included only three primary design iterations in theory, but there were many smaller iterations in between that led to the prototype's continuous improvement. Smaller design iterations were useful for tracking progress and achieving usability objectives. Figma was used to create the design for the mid-fidelity prototype.

8.3 Limitations

There were some limitations to the research project. Most limitations were related to time constraints and the availability of persons with cognitive decline who could be participants in the research project. However, relatives and a health care giver have been engaged.

It would have been beneficial for the artifact to evaluate with persons who have some cognitive loss. The prototype has been designed with them in mind, e.g., color choice and easily readable content were made to suit them. The fourth iteration artifact should be planned with this target group.

Another limitation was that a high-fidelity prototype was not made during any of the iteration processes. This work is to be completed in future iterations.

More functionalities should be added to the artifact, but due to mainly time constraints, they must be done in the future. E.g., voice and breadcrumbs could be added.

8.4 Research Question Answers

These are the Research Questions (RQ) formulated for this research project:

RQ1: *How to structure concepts and scopes of the current IT solutions used in the assessment and treatment of cognitive decline?*

The most credible information could be found in the literature and especially in scientific publications that present results of the studies, drive questions regarding the development of methods and their improvements, and address issues such as the severity of cognitive loss, methods for diagnosis and treatment, and even discuss how to diagnose cognitive loss early enough. To summarize findings from the literature review a tree-like presentation of the knowledge was developed (Diagrams 3 and 4 Section 6.3.2).

Interestingly, persons with decline in cognitive loss gradually lose perspective on the severity of their condition which usually makes family, friends, and health staff look for answers in the literature on the websites and in personal contact with health care systems. This was the reason we also developed an artifact that could present the main findings on diagnosing and treatment in a way that could be understandable to a broader public (Figures 46, 47, and 48 Section 7.1.1).

The two research directions we have taken are not the only ones. One possibility would be to investigate the clinical aspects and how the group of people with cognitive decline would process the information and knowledge regarding cognitive loss. Both clinical and patient perspectives were not within the scope of this research project, but some researchers are working on these questions. The scope listed was to focus on IT and how technologies are utilized for different purposes such as diagnosing and treatment.

RQ2: *What are the IT solutions that could be offered to support establishing diagnosis and treatment of people in whom the decline is objectively confirmed?*

There are numerous methods supported by IT that combined can help establish a diagnosis. Webapps and self-testing are the easiest available, and then some methods combining high-level signal processing such as MRI and CT (Section 3.1).

Concerning treatment there are several methods supported by IT. Starting with games, VR, and Tovertafel to robots, specially developed and used in Japan for this purpose (Section 3.2).

Here again, the research has not explored all the possibilities for a person to obtain a diagnosis and treatment, since this is dependent on how health care systems are organized. It seems to be clear that one could start with self-testing and take a long road to a final diagnosis established using highly sophisticated medical equipment supported by IT solutions such as imaging (Graphs 2 and 3 Section 6.3.2).

RQ3: *How are degrees of cognitive decline influencing the design of the IT solutions?*

Depending on the degree of cognitive decline, different methods are utilized. E.g., persons with milder forms of decline will utilize video games, websites, Tovertafel (Section 3.2), and even robots such as Pepper that can occupy them in a conversation or make them exercise (Section 3.2.9.1). For those who have already experienced more severe degrees of cognitive decline, IT provides mainly comfort and keeps them calm. In this group, there are e.g., robots reminding them to take medication (Section 3.2.9.7) or being used to play with them and sit on their knees (Section 3.2.9).

In this research project we have not explored how efficient all these approaches are, but the results of the literature would suggest positive and encouraging outcomes. Here again, one could gain some understanding of what different health systems are offering. In some chronic diseases like diabetes (Section 2.2) the persons affected by the condition are still fully functioning and can make their own way and choices. On the other hand, persons with cognitive decline become dependent on relatives and others to help them. For this reason, evaluation of the artifact developed in this research project was conducted with three representatives of user groups that have seen a decline but have not experienced it. This is valid for one relative to a person with cognitive decline, and another who is a health care professional in the field (Section 5.3.2). The third user was interested in the field for private reasons (Section 5.3.2).

RQ4: *What is the clinical staff´s perspective on the usage of the IT solutions?*

Given the results of the literature review, there are many people interested in the field of cognitive decline. Within this research, we have interviewed two experts that are working with clinical data. Additionally, one user is working in a clinical setting as a nurse and have very good understanding of the severity of cognitive decline (Section 5.3.2). She appreciated the fact that there were good IT approaches to help the patients, even for the most severe cases.

One of the field experts was a clinical psychologist that believed in using games and working with a healthy lifestyle which she believed could significantly slow down the cognitive decline process. The second expert worked in the field of biomedical engineering and believed that by applying ML methods could accurately learn from signal analysis when cognitive decline becomes more obvious (Section 6.4.5). Such early diagnosing is very beneficial for early intervention that could slow down the decline.

In short, there was a positive attitude towards the usage of IT solutions.

RQ5: *Is there any user-friendly way to inform potential users about the available IT technology?*

There is information available in several places, but it seems to be quite professional and probably hard to grasp. Even self-testing is usually done in a non-interactive way with the help of a physician or a clinical psychologist (Section 3.1.1). There is a possibility to develop more tools for persons with milder forms of cognitive decline that could potentially be more user-friendly.

We have not explored any artifacts, such as tools, for persons with cognitive decline. But we have developed an artifact that presents all currently available IT-supported methods found in the literature review (Chapter 3). We have tested the usability of this artifact on a group of nine persons and described the results in Chapter 7.

The results suggest the artifact is user-friendly but would still need more work to meet the needs of persons with cognitive decline.

Chapter 9

9 Conclusion

The goal of this research was to identify, understand and structure the role of IT in the field of cognitive decline. This is a very demanding field of research in which results are expected to prevent and treat the disease.

The work started with the literature review and moved toward the development of the artifact that could communicate gathered knowledge to all interested parties and a broad public. The Design Science research methodology was used throughout the project to ensure relevance, rigor, quality, and design of the artifact providing information about cognitive decline.

The artifact has been developed in three different design iterations, with two field experts, three representatives of potential user groups, and six IT usability experts. Based on evaluations from users and experts, the results could be considered novel, significant, and a contribution to the base of knowledge.

One of the main contributions of this research project was a broad literature review that first resulted in the structure of the knowledge, focusing on two major clinical areas: diagnosis and treatment. This knowledge was the basis for the artifact. According to the Design Science methodology artifact was developed further considering potential users and IT experts. An approval from the NSD was obtained to ensure the privacy of the data.

From the conceptual model, based on the literature, first, a low-fidelity prototype was developed by prototyping and sketching on paper, and then the mid-fidelity prototype with valuable input from field experts (Section 7.1.1). The mid-fidelity prototype implemented in Figma enabled interaction and a comprehensive evaluation with users and IT usability experts.

Two medical field experts in cognitive decline provided insight into medical information regarding cognitive decline that could be implemented into the artifact.

The potential users tested the artifact first. They conducted three usability tasks and afterward completed a SUS evaluation. The IT usability experts conducted the same three tasks, as well as a SUS evaluation. In addition, they performed Nielsen´s heuristics to establish how intuitive the UI was. The average SUS score of the user group (Table 15 Section 7.1.4) was 85,83, and for the IT usability experts (Table 17 Section 7.1.6) was 87,5, respectively. The average Nielsen´s score for the IT usability experts (Table 18 Section 7.1.7) was 4,28. In addition to encouraging comments that the artifact was a good idea, and useful, both the SUS and Nielsen´s score indicates that the artifact has the potential to communicate knowledge and serve as a useful tool for those who search for information on cognitive decline.

The results from the literature review and the first design ideas of the artifact were accepted for publication as a paper at the 20th International Conference on Informatics, Management and Technology in Healthcare 2022 (Appendix C1).

Future work will be driven by clinical development and the needs of persons with cognitive decline, which is to be supported by IT. As mentioned at the beginning of the research project (Section 2.5) the motivation for early diagnosis of cognitive loss is to introduce intervention and prevent the disease from fully developing and slow down the process. This research has pointed to several methods that are dedicated to these goals, which will demand continued research.

Chapter 10

10 Future Work

The literature work is a continuous process, and it is expected to see new developments that will have an impact, among other things, on the artifact developed within this project. The immediate steps should be to improve the current version of the artifact with the feedback from the third iteration (Section 7.1). A high-fidelity prototype should be made including breadcrumbs, the text being read aloud, information about fMRI, clearer labeling, and more information regarding buttons.

With appropriate ethical approvals and close cooperation with health care staff, the user group should be extended to include persons with cognitive decline. The current design includes color choice, presentation of the content, and illustrations that were made according to the literature and should be suitable for them. However, this must be tested.

Requirement analysis should also be carried out in cooperation with persons experiencing cognitive decline since they might have needs that were not captured by the literature. There is limited research regarding restraints that comes with the condition and have an impact on HCI.

The current prototype is a stand-alone, but it needs to be seen whether it could be included on the pages of health care providers, and interest groups dealing with cognitive loss, or whether it should be made into a functional application. Regardless of the choice of platform, the content will need credible staff to maintain it.

Bibliography

Adobe. (n.d.). “Adobe”. URL: https://www.adobe.com/products/photoshop.html . Found: 05.12.21

Albert, M. S. (2011). “Changes in cognition”. URL: https://www.sciencedirect.com/science/article/pii/S0197458011003472. Found: 22.10.21

Allan, C. L., Behrman, S., Ebmeier, K. P., and Valkanova, V. (2017). “Diagnosing early cognitive decline—when, how and for whom?”. *Maturitas*, *96*, 103-108. URL: https://www.sciencedirect.com/science/article/pii/S0378512216303826#bib0010 . Found: 10.11.21

Alzheimer´s Association. (n.d.). “Mild Cognitive Impairment (MCI)”. URL: https://www.alz.org/alzheimers-dementia/what-is-dementia/related_conditions/mild-cognitive-impairment . Found: 15.10.21

Alzheimer´s Society. (n.d.). “Risk factors: Who gets Alzheimer´s disease?”. URL: https://www.alzheimers.org.uk/about-dementia/types-dementia/who-gets-alzheimers-disease . Found: 21.02.22

Bangor, A., Kortum, P.T. and Miller, J.T. (2009). “Journal of Usability Studies”, 4(3), 114-123. URL: https://www.researchgate.net/figure/Grade-rankings-of-SUS-scores-from-Determining-What-Individual-SUS-Scores-Mean-Adding-an_fig1_285811057 . Found: 19.03.22

Basak, C., Boot, W. R., Voss, M. W., and Kramer, A. F. (2008). “Can training in a real-time strategy video game attenuate cognitive decline in older adults?”. *Psychology and aging*, *23*(4), 765. URL: https://psycnet.apa.org/fulltext/2008-19072-010.pdf . Found: 18.11.21

Bastos, D., Ribeiro, J., Silva, F., Rodrigues, M., Silva, A. G., Queirós, A., ... and Pereira, A. (2020). “SmartWalk BAN: using body area networks to encourage older adults to perform physical activity”. *Electronics*, *10*(1), 56. URL: https://www.mdpi.com/2079-9292/10/1/56/htm . Found: 23.01.22

Bergrem, M. (2020). “Vær her”. URL: https://www.filmweb.no/film/EUF20190080#27.05.2022 . Found: 24.03.22

Bonifacio, G., and Zamboni, G. (2016). “Brain imaging in dementia”. *Postgraduate medical journal*, *92*(1088), 333-340. URL: https://pmj.bmj.com/content/postgradmedj/92/1088/333.full.pdf . Found: 12.10.21

Boot, W. R., Champion, M., Blakely, D. P., Wright, T., Souders, D., and Charness, N. (2013). “Video games as a means to reduce age-related cognitive decline: attitudes, compliance, and effectiveness". *Frontiers in psychology*, *4*, 31. URL: https://www.frontiersin.org/articles/10.3389/fpsyg.2013.00031/full . Found: 15.11.21

Botha, M., Botha, A., and Herselman, M. (2014, December). "The Benefits and Challenges of e-Health Applications: A Content Analysis of the South African context". In *International Conference on Computer Science, Computer Engineering, and Social Media*. URL: https://www.researchgate.net/publication/269401037_The_Benefits_and_Challenges_of_e-Health_Applications_A_Content_Analysis_of_the_South_African_context . Found: 28.04.22

Cafasso, J. (2020). "Is It Mild Cognitive Impairment or Something Else?". URL: https://www.healthline.com/health/is-it-mild-cognitive-impairment-or-something-else#MCI-vs.-dementia-vs.-healthy-aging . Found: 24.03.22

Cavedoni, S., Chirico, A., Pedroli, E., Cipresso, P., and Riva, G. (2020). "Digital biomarkers for the early detection of mild cognitive impairment: artificial intelligence meets virtual reality". *Frontiers in Human Neuroscience*, *14*, 245. URL: https://www.frontiersin.org/articles/10.3389/fnhum.2020.00245/full#B2 . Found: 22.01.22

Centers for Disease Control and Prevention. (2019). "Subjective cognitive decline—a public health issue". URL: https://www.cdc.gov/aging/aginginfo/subjective-cognitive-decline-brief.html . Found: 22.10.21

Charalambous, A. P., Pye, A., Yeung, W. K., Leroi, I., Neil, M., Thodi, C., and Dawes, P. (2020). "Tools for app-and web-based self-testing of cognitive impairment: systematic search and evaluation". *Journal of medical Internet research*, *22*(1), e14551. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6996724/ . Found: 15.12.21

Cleveland Clinic. (2020). "CT (Computed Tomography) Scan". URL: https://my.clevelandclinic.org/health/diagnostics/4808-ct-computed-tomography-scan . Found: 17.01.22

D´Cunha, N. M., Nguyen, D., Naumovski, N., McKune, A. J., Kellett, J., Georgousopoulou, E. N., ... and Isbel, S. (2019). "A mini-review of virtual reality-based interventions to promote well-being for people living with dementia and mild cognitive impairment". *Gerontology*, *65*(4), 430-440. URL: https://www.karger.com/Article/FullText/500040 . Found: 20.01.22

Delve. (n.d.). "How To Do Open, Axial and Selective Coding in Grounded Theory". URL: https://delvetool.com/blog/openaxialselective . Found: 29.01.22

Demenskartet. (n.d.). "Hvor mange i Norge har demens? ". URL: https://demenskartet.no/?doing_wp_cron=1632818536.6927649974822998046875 . Found: 15.12.21

Dougherty Jr, J. H., Cannon, R. L., Nicholas, C. R., Hall, L., Hare, F., Carr, E., ... and Arunthamakun, J. (2010). “The computerized self test (CST): an interactive, internet accessible cognitive screening test for dementia”. *Journal of Alzheimer's Disease*, *20*(1), 185-195. URL: https://content.iospress.com/download/journal-of-alzheimers-disease/jad01354?id=journal-of-alzheimers-disease%2Fjad01354 . Found: 01.11.21

Dove, E., and Astell, A. (2019). “The Kinect Project: group motion-based gaming for people living with dementia”. *Dementia*, *18*(6), 2189-2205. URL: https://journals.sagepub.com/doi/full/10.1177/1471301217743575 . Found: 10.01.22

Draw.io. (n.d.). URL: https://app.diagrams.net . Found: 22.02.22

Engstrøm, M. and Jansen, J. (2019). “Elektroencefalografi”. URL: https://sml.snl.no/elektroencefalografi . Found: 02.11.21

FHI. (2021). “Demens”. URL: https://www.fhi.no/nettpub/hin/ikke-smittsomme/demens/ . Found: 22.02.22

Figma. (n.d.). “Create components to reuse in designs”. URL: https://help.figma.com/hc/en-us/articles/360038663154-Create-components-to-reuse-in-designs . Found: 12.12.22

Financial Times. (2016). “The soft side of robots: elderly care”. URL: https://www.youtube.com/watch?v=ppPLDEi82lg . Found: 15.11.21

Forbes-McKay, K., Shanks, M. F., and Venneri, A. (2013). “Profiling spontaneous speech decline in Alzheimer's disease: a longitudinal study”. *Acta Neuropsychiatrica*, *25*(6), 320-327. URL: https://www.cambridge.org/core/journals/acta-neuropsychiatrica/article/abs/profiling-spontaneous-speech-decline-in-alzheimers-disease-a-longitudinal-study/A7E6279AC4D6272BA042B045681DC2AB . Found: 29.01.22

Fuji Soft. (n.d.). “What is PALRO?”. URL: https://palro.jp/en/feature/spec.html . Found: 22.11.21

Gjøra, L., Kjelvik, G. , Strand, B.H., Kvello-Alme, M. and Selbæk G. (2020). “Forekomst av demens i Norge. Rapport Aldring og helse”. URL: https://butikk.aldringoghelse.no/file/sync-files/rapport-forekomst-av-demens-a4_2020_web.pdf . Found: 05.12.21

Goda, A., Shimura, T., Murata, S., Kodama, T., Nakano, H., and Ohsugi, H. (2020). “Psychological and Neurophysiological Effects of Robot Assisted Activity in Elderly People With Cognitive Decline”. *Gerontology and Geriatric Medicine*, *6*, 2333721420969601. URL:https://journals.sagepub.com/doi/full/10.1177/2333721420969601 . Found: 01.02.22

Hall, T. (2017). “When to Do an Expert Evaluation, and How to Make It Stick”. URL: https://uxplanet.org/when-to-do-an-expert-evaluation-and-how-to-make-it-stick-8e53fc34682f . Found: 23.03.22

Han-soo, L. (2019). “KIST develops world´s 1st AI-based dementia care robot”. URL: http://www.koreabiomed.com/news/articleView.html?idxno=5721 . Found: 22.05.22

Health Images. (n.d.). “MRI vs. CT Scan”. URL: https://www.healthimages.com/mri-vs-ct-scan/ . Found: 20.01.22

Helse Bergen. (n.d.). “EEG-undersøking – Bildeserie for barn Klinisk nevrofysiologi”. URL: https://helse-bergen.no/behandlinger/eeg-bildeserie-for-barn?sted=-klinisk-nevrofysiologi . Found: 02.11.21

Helsedirektoratet. (2022). “1. Om demens”. URL: https://www.helsedirektoratet.no/retningslinjer/demens/om-demens . Found: 22.11.21

Hevner, A. (2007). “A Three Cycle View of Design Science Research”. URL: https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1017&context=sjis . Found: 17.03.22

Hevner, A., March, S., Park, J. and Ram, S. (2004). “Design Science in Information System Research”. URL: https://www.jstor.org/stable/25148625?seq=6 . Found: 22.01.2

Hicks, T. (2022). “Human Brain Doesn´t Slow Down Until After Age of 60”. URL: https://www.healthline.com/health-news/human-brain-doesnt-slow-down-until-after-age-of-60 . Found: 24.05.22

Hofmann, M., Rösler, A., Schwarz, W., Müller-Spahn, F., Kräuchi, K., Hock, C., and Seifritz, E. (2003). “Interactive computer-training as a therapeutic tool in Alzheimer’s disease”. *Comprehensive psychiatry*, *44*(3), 213-219. URL: https://www.sciencedirect.com/science/article/pii/S0010440X03000063 . Found: 18.01.22

Hvakanhjelpe. (n.d.). “Velkommen til hvakanhjelpe”. URL: https://hvakanhjelpe.no . Found: 24.11.21

Ikonate. (n.d.). URL: https://ikonate.com . Found: 22.03.22

Inoue, K., Sakuma, N., Okada, M., Sasaki, C., Nakamura, M., & Wada, K. (2014, July). “Effective application of PALRO: A humanoid type robot for people with dementia”. In *International Conference on Computers for Handicapped Persons* (pp. 451-454). Springer, Cham. URL: https://link.springer.com/chapter/10.1007/978-3-319-08596-8_70 . Found: 05.05.22

Internet World Stats. (2022). “Internet Usage Statistics”. URL: https://www.internetworldstats.com/stats.htm . Found: 05.03.22

Jack, C. R., Shiung, M. M., Weigand, S. D., O'brien, P. C., Gunter, J. L., Boeve, B. F., ... and Petersen, R. C. (2005). "Brain atrophy rates predict subsequent clinical conversion in normal elderly and amnestic MCI". *Neurology*, *65*(8), 1227-1231. URL: https://n.neurology.org/content/neurology/65/8/1227.full.pdf . Found: 04.11.21

Kanbanize. (n.d.). "What is Kanban? Explained for Beginners". URL: https://kanbanize.com/kanban-resources/getting-started/what-is-kanban . Found: 11.11.21

Kanoh, M. (2015). "A Robot as "Receiver of Care" in Symbiosis with People". *Journal of Japan Society for Fuzzy Theory and Intelligent Informatics*, *27*(6), 193-201. URL: https://www.jstage.jst.go.jp/article/jsoft/27/6/27_193/_pdf/-char/ja . Found: 16.11.21

Khodabandehloo, E., Riboni, D., and Alimohammadi, A. (2021). "HealthXAI: Collaborative and explainable AI for supporting early diagnosis of cognitive decline". *Future Generation Computer Systems*, *116*, 168-189. URL: https://www.sciencedirect.com/science/article/pii/S0167739X20330144 . Found: 14.10.21

Kloster, M. and Babic, A. (2019). "Leveraging virtual reality technology in developing neck exercise applications". URL: https://bora.uib.no/bora-xmlui/bitstream/handle/1956/20818/Master-thesis_Mads-Kloster.pdf?sequence=1&isAllowed=y . Found: 22.02.22

Kolstad, M. and Babic, A. (2019). "Robots in Service and Nursing Care". URL: https://bora.uib.no/bora-xmlui/bitstream/handle/1956/21273/Master-Thesis-Markus-Kolstad---Robots-in-Service-and-Nursing-Care.pdf?sequence=1&isAllowed=y . Found: 03.10.21

Kolstad, M., Yamaguchi, N., Babic, A., and Nishihara, Y. (2020). "Integrating Socially Assistive Robots into Japanese Nursing Care". URL: https://bora.uib.no/bora-xmlui/bitstream/handle/11250/2738807/Kolstad%2Bet%2Bal%2BICIMTH2020.pdf?sequence=1&isAllowed=y . Found: 22.01.22

König, A., Crispim-Junior, C. F., Covella, A. G. U., Bremond, F., Derreumaux, A., Bensadoun, G., ... and Robert, P. (2015). "Ecological assessment of autonomy in instrumental activities of daily living in dementia patients by the means of an automatic video monitoring system". *Frontiers in aging neuroscience*, *7*, 98. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4451587/ . Found: 19.10.21

König, A., Satt, A., Sorin, A., Hoory, R., Toledo-Ronen, O., Derreumaux, A., ... and David, R. (2015). "Automatic speech analysis for the assessment of patients with predementia and Alzheimer's disease". *Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring*, *1*(1), 112-124. URL: https://www.sciencedirect.com/science/article/pii/S2352872915000160 . Found: 19.10.21

Kvello-Alme, M., Bråthen, G., White, L. R., and Sando, S. B. (2019). “The prevalence and subtypes of young onset dementia in central Norway: A population-based study”. *Journal of Alzheimer's Disease*, *69*(2), 479-487. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6598022/ . Found: 03.10.21

Kyriazakos, S., Prasad, R., Mihovska, A., Pnevmatikakis, A., Hermens, H., Barone, P., ... and Atanasovski, V. (2017). “eWALL: An open-source cloud-based eHealth platform for creating home caring environments for older adults living with chronic diseases or frailty”. *Wireless Personal Communications*, *97*(2), 1835-1875. URL: https://link.springer.com/article/10.1007/s11277-017-4656-7 . Found: 21.10.21

Lancioni, G. E., Cuvo, A. J., and O'reilly, M. F. (2002). “Snoezelen: an overview of research with people with developmental disabilities and dementia”. *Disability and rehabilitation*, *24*(4), 175-184. URL: https://www.tandfonline.com/doi/abs/10.1080/09638280110074911 . Found: 08.05.2

Lawson, K. (n.d.). “RoBoHoN: An Adventure in Robotics. What You Need to Know”. URL: https://www.sharp.co.uk/cps/rde/xchg/gb/hs.xsl/-/html/robohon-an-adventure-in-robotics-what-you-need-to-know.htm . Found: 05.11.21

Lecturio Medical. (2017). “Cognitive Disorders: Assessment and Testing – Psychiatry | Lecturio”. URL: https://www.youtube.com/watch?v=ItjstlkgCUM . Found: 23.09.21

Ledelse og Teknikk. (2020). “Kosedyrhodepute”. URL: https://emag-ledelseogteknikk.lomedia.no/kosedyrhodepute-6.511.676108.809fc086b1 . Found: 16.05.2

Lee, W., Lee, S. D., Park, M. Y., Foley, L., Purcell-Estabrook, E., Kim, H., and Yoo, S. S. (2015). “Functional and diffusion tensor magnetic resonance imaging of the sheep brain”. *BMC veterinary research*, *11*(1), 1-8. URL: https://www.researchgate.net/publication/283951738_Functional_and_diffusion_tensor_magnetic_resonance_imaging_of_the_sheep_brain . Found: 07.11.21

Lehmann, S., Ruf, E., & Misoch, S. (2021, July). “Using a Socially Assistive Robot in a Nursing Home: Caregivers’ Expectations and Concerns”. In *International Conference on Human-Computer Interaction* (pp. 148-155). Springer, Cham. URL: https://link.springer.com/chapter/10.1007/978-3-030-78642-7_20 . Found: 22.04.22

Levanier, J. (2019). “What is conceptual design? And how to wrap your mind around iteration”. URL: https://99designs.no/blog/tips/conceptual-design/ . Found: 05.05.22

Lim, K. B., Kim, J., Lee, H. J., Yoo, J., You, E. C., and Kang, J. (2018). “Correlation between montreal cognitive assessment and functional outcome in subacute stroke patients with cognitive dysfunction”. *Annals of rehabilitation medicine*, *42*(1), 26. URL:

https://www.researchgate.net/publication/323748592_Correlation_Between_Montreal_Cognitive_Assessment_and_Functional_Outcome_in_Subacute_Stroke_Patients_With_Cognitive_Dysfunction . Found: 27.02.22

Lin, Y., Shan, P. Y., Jiang, W. J., Sheng, C., and Ma, L. (2019). "Subjective cognitive decline: preclinical manifestation of Alzheimer's disease". *Neurological Sciences*, *40*(1), 41-49. URL: https://link.springer.com/article/10.1007/s10072-018-3620-y . Found: 23.01.22

Madeira, R. N., Costa, L., and Postolache, O. (2014, October). "PhysioMate-Pervasive physical rehabilitation based on NUI and gamification". In *2014 International Conference and Exposition on Electrical and Power Engineering (EPE)* (pp. 612-616). IEEE. URL: https://www.researchgate.net/publication/289777871_PhysioMate-Pervasive_physical_rehabilitation_based_on_NUI_and_gamification . Found: 15.01.22

Manca, M., Paternò, F., Santoro, C., Zedda, E., Braschi, C., Franco, R., and Sale, A. (2021). "The impact of serious games with humanoid robots on mild cognitive impairment older adults". *International Journal of Human-Computer Studies*, *145*, 102509. URL: https://www.sciencedirect.com/science/article/pii/S1071581920301117 . Found: 23.01.22

Mancioppi, G., Fiorini, L., Timpano Sportiello, M., and Cavallo, F. (2019). "Novel technological solutions for assessment, treatment, and assistance in mild cognitive impairment". *Frontiers in Neuroinformatics*, 58. URL: https://www.frontiersin.org/articles/10.3389/fninf.2019.00058/full . Found: 28.11.21

Manera, V., Ben-Sadoun, G., Aalbers, T., Agopyan, H., Askenazy, F., Benoit, M., ... and Robert, P. (2017). "Recommendations for the use of serious games in neurodegenerative disorders: 2016 Delphi Panel". *Frontiers in psychology*, *8*, 1243. URL: https://www.frontiersin.org/articles/10.3389/fpsyg.2017.01243/full . Found: 04.10.21

Martín, F., Agüero, C., Cañas, J. M., Abella, G., Benítez, R., Rivero, S., ... and Martínez-Martín, P. (2013). "Robots in therapy for dementia patients". URL: https://www.researchgate.net/publication/304231155_Robots_in_therapy_for_dementia_patients . Found: 18.11.21

Mayo Clinic. (n.d.). "CT Scan". URL: https://www.mayoclinic.org/tests-procedures/ct-scan/about/pac-20393675 . Found: 19.01.22

Mayo Clinic. (2020). "Mild Cognitive Impairment (MCI)". URL: https://www.mayoclinic.org/diseases-conditions/mild-cognitive-impairment/diagnosis-treatment/drc-20354583 . Found: 15.10.21

Mbaabu, O. (2021). "Figma for Web Design – A Beginner´s Guide". URL: https://www.section.io/engineering-education/using-figma-for-web-design/ . Found: 07.04.22

Medema. (n.d.). "Tovertafel 2 Original". URL: https://medema.no/produkter/velferdsteknologi/tovertafel/ . Found: 10.10.21

Meilán, J. J., Martínez-Sánchez, F., Carro, J., Sánchez, J. A., and Pérez, E. (2012). "Acoustic markers associated with impairment in language processing in Alzheimer's disease". *The Spanish journal of psychology*, *15*(2), 487-494. URL: https://www.cambridge.org/core/journals/spanish-journal-of-psychology/article/abs/acoustic-markers-associated-with-impairment-in-language-processing-in-alzheimers-disease/D4F070DCB4F46E200A99554C384A9F61 . Found: 07.03.22

Mini-Cog. (n.d.). "Standardized Mini-Cog Instrument". URL: https://mini-cog.com/mini-cog-instrument/standardized-mini-cog-instrument/ . Found: 06.11.21

Mini-Cog. (n.d.). "Using the Mini-Cog". URL: https://mini-cog.com/about/using-the-mini-cog/ . Found: 06.11.21

MoCA. (2022). "MoCA Talk #4". URL: https://www.mocatest.org . Found: 07.05.22

MOCIA. (2022). "MOCIA". URL: https://mocia.nl/scientific/ . Found: 08.04.22

Morganti, F., and Riva, G. (2014). "Virtual reality as allocentric/egocentric technology for the assessment of cognitive decline in the elderly". URL: https://books.google.no/books?hl=no&lr=&id=u2znAgAAQBAJ&oi=fnd&pg=PA278&dq=it+technology+for+cognitive+decline&ots=ZyYUo3iUc_&sig=OEZ76eAR-hEExNj_W0zRV0gI-yI&redir_esc=y#v=onepage&q=it%20technology%20for%20cognitive%20decline&f=false . Found: 15.10.21

Moyle, W., Jones, C., Dwan, T., and Petrovich, T. (2018). "Effectiveness of a virtual reality forest on people with dementia: A mixed methods pilot study". *The Gerontologist*, *58*(3), 478-487. URL: https://academic.oup.com/gerontologist/article/58/3/478/3072156 . Found: 18.01.22

Muscio, C., Tiraboschi, P., Guerra, U. P., Defanti, C. A., and Frisoni, G. B. (2015). "Clinical trial design of serious gaming in mild cognitive impairment". *Frontiers in aging neuroscience*, *7*, 26. URL: https://www.frontiersin.org/articles/10.3389/fnagi.2015.00026/full . Found: 03.11.21

NASEM Health and Medicine Division. (2017). "Preventing Cognitive Decline and Dementia: A Way Forward". URL:https://www.youtube.com/watch?v=NcFdAVrYfns . Found: 22.09.21

National Institute of Aging. (2017). "What Happens to the Brain in Alzheimer´s Disease?". URL: https://www.nia.nih.gov/health/what-happens-brain-alzheimers-disease . Found: 10.12.21

NHI. (n.d.). "EEG". URL: https://nhi.no/sykdommer/barn/undersokelser/eeg/ . Found: 17.11.21

NHI. (2022). “MMSE – NR3 (MMSE – norsk revisjon)”. URL: https://nhi.no/skjema-og-kalkulatorer/skjema/geriatripleie/mmse-nr2-mms-norsk-revisjon/ . Found: 23.01.22

Nielsen, J. (1994). “Enhancing the Explanatory Power of Usability Heuristics”. URL: https://static.aminer.org/pdf/PDF/000/089/679/enhancing_the_explanatory_power_of_usability_heuristics.pdf . Found: 06.02.22

Nielsen, J. (1994). “How to Conduct a Heuristic Evaluation”. URL: https://www.nngroup.com/articles/how-to-conduct-a-heuristic-evaluation/ . Found: 13.03.22

Nielsen, J. (2020). “10 Usability Heuristics for User Interface Design”. URL: https://www.nngroup.com/articles/ten-usability-heuristics/ . Found: 13.03.22

Nielsen, J. (2000). “Why You Only Need to Test with 5 Users”. URL: https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/ . Found: 14.05.22

O´Bryant, S. E., Humphreys, J. D., Smith, G. E., Ivnik, R. J., Graff-Radford, N. R., Petersen, R. C., and Lucas, J. A. (2008). “Detecting dementia with the mini-mental state examination in highly educated individuals”. *Archives of neurology*, *65*(7), 963-967. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2587038/ . Found: 01.12.21

Oxford Medical Education. (n.d.). “Mini-Mental State Examination”. URL: https://oxfordmedicaleducation.com/geriatrics/mini-mental-state-examination-mmse/ . Found: 20.05.22

Phillips, L. J., Reid-Arndt, S. A., and Pak, Y. (2010). “Effects of a creative expression intervention on emotions, communication, and quality of life in persons with dementia”. *Nursing research*, *59*(6), 417. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3010410/ . Found: 20.01.22

Picomed. (n.d.). “Robotselen PARO”. URL: https://picomed.no/produkt/robotselenparo/ . Found: 16.05.22

Pollock, T. (n.d.). “The Difference Between Structured, Unstructured & Semi-Structured Interviews”. URL: https://www.oliverparks.com/blog-news/the-difference-between-structured-unstructured-amp-semi-structured-interviews . Found: 23.03.22

Polyuk, S. (2019). “Age Before Beauty – A Guide to Interface Design for Older Adults”. URL: https://www.toptal.com/designers/ui/ui-design-for-older-adults . Found: 09.02.22

RadiologyInfo. (2022). “Alzheimer´s Disease”. URL: https://www.radiologyinfo.org/en/info/alzheimers . Found: 12.05.22

Rauf, D. (2019). “Amyloid PET scans May Drastically Change Alzheimer´s Diagnosis and Care, Study Finds”. URL: https://www.everydayhealth.com/alzheimers-disease/amyloid-pet-scans-may-drastically-change-alzheimers-diagnosis-care-study-finds/ . Found: 24.11.21

Rekhi, S. (2017). “Don Norman´s Principles of Interaction Design”. URL: https://medium.com/@sachinrekhi/don-normans-principles-of-interaction-design-51025a2c0f33 . Found: 12.03.22

Riva, G. (2005). “Virtual reality in psychotherapy”. *Cyberpsychology & behavior*, *8*(3), 220-230. URL: https://www.liebertpub.com/doi/10.1089/cpb.2005.8.220 . Found: 05.10.21

Roaigen. (n.d.). “MyBom1”. URL: https://www.roaigen.com/en/html/product/product01.php . Found: 15.05.22

Robot-Advance. (n.d.). “The Qoobo cat robot”. URL: https://www.robot-advance.com/EN/actualite-the-new-qoobo-cat-robot-150.htm . Found 02.02.22

Rosenzweig, A. (2022). “Montreal Cognitive Assessment (MoCA) Test for Dementia”. URL: https://www.verywellhealth.com/alzheimers-and-montreal-cognitive-assessment-moca-98617 . Found: 04.05.22

Schmitter-Edgecombe, M., Seelye, A., and Cook, D. J. (2013). “Technologies for health assessment, promotion, and assistance: Focus on gerontechnology”. In *Positive Neuropsychology* (pp. 143-160). Springer, New York, NY. URL: https://link.springer.com/chapter/10.1007/978-1-4614-6605-5_8 . Found: 22.01.22

Segkouli, S., Paliokas, I., Tzovaras, D., Tsakiris, T., Tsolaki, M., and Karagiannidis, C. (2015). “Novel virtual user models of mild cognitive impairment for simulating dementia”. *Computational and Mathematical Methods in Medicine*, *2015*. URL: https://www.hindawi.com/journals/cmmm/2015/358638/ . Found: 19.10.21

Sharp, H., Rogers, Y. and Preece, J. (2019). “Interaction Design I beyond Human- Computer Interaction”. 5th ed. John Wiley & Sons, Inc., Indianapolis, Indiana.

Shibata, T., and Wada, K. (2011). “Robot therapy: a new approach for mental healthcare of the elderly–a mini-review”. *Gerontology*, *57*(4), 378-386. URL: https://www.karger.com/Article/Pdf/319015 . Found: 23.11.21

Six, J. M., and Macefield, R. (2016). “How to Determine the Right Number of Participants for Usability Studies”. URL: https://www.uxmatters.com/mt/archives/2016/01/how-to-determine-the-right-number-of-participants-for-usability-studies.php . Found: 12.05.22

Smyk, A. (2020). "The System Usability Scale & How It´s Used in UX". URL: https://xd.adobe.com/ideas/process/user-testing/sus-system-usability-scale-ux/ . Found: 24.04.22

Snoezelen. (2022). "Benefits & Applications". URL: https://www.snoezelen.info/benefits-and-applications/ . Found: 16.04.22

SoftBank Robotics. (n.d.). "Pepper". URL: https://www.softbankrobotics.com/emea/en/pepper . Found: 06.11.21

Strand, B. H. (2021). "Demens". URL: https://www.fhi.no/nettpub/hin/ikke-smittsomme/demens/ . Found: 28.11.21

Tamai, T., Majima, Y., Masuda, S., Nakamura, Y., Koizumi, A., & Sakata, N. (2019, July). "Development and Practical Evaluation of Dementia Prevention Program by Communication Robot". In *2019 8th International Congress on Advanced Applied Informatics (IIAI-AAI)* (pp. 146-151). IEEE. URL: https://ieeexplore.ieee.org/abstract/document/8992752 . Found: 25.01.22

Tamamizu, K., Sakakibara, S., Saiki, S., Nakamura, M., and Yasuda, K. (2017, July). "Capturing activities of daily living for elderly at home based on environment change and speech dialog". In *International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management* (pp. 183-194). Springer, Cham. URL: https://link.springer.com/chapter/10.1007/978-3-319-58466-9_18#Fig2 . Found: 03.12.21

Tanioka, T. (2019). "Nursing and rehabilitative care of the elderly using humanoid robots". *The Journal of Medical Investigation*, *66*(1.2), 19-23. URL: https://www.jstage.jst.go.jp/article/jmi/66/1.2/66_19/_pdf/-char/ja . Found: 16.11.21

Taylor, D. (2022). "Dementia Symptoms, Causes, Types, Stages, and Treatments". URL: https://www.medicinenet.com/dementia/article.htm . Found: 14.05.22

Taylorbrands. (n.d.). "7 Reasons Why a Logo is Important". URL: https://www.tailorbrands.com/logo-maker/why-a-logo-is-important . Found: 12.05.22

The Advocate. (2016). "Can different colors influence a person with dementia? Here´s what to know". URL: https://www.theadvocate.com/baton_rouge/entertainment_life/health_fitness/article_922b136a-84d5-11e6-8c00-fbc8ac72b472.html . Found: 09.03.22

The Writing Center. (n.d.). "Literature Reviews". URL: https://writingcenter.unc.edu/tips-and-tools/literature-reviews/ . Found: 08.05.22

Thomas, N. (n.d.). "How To Use The System Usability Scale (SUS) To Evaluate The Usability Of Your Website". URL: https://usabilitygeek.com/how-to-use-the-system-usability-scale-sus-to-evaluate-the-usability-of-your-website/ . Found: 12.02.22

Tokuno, S. (2020). “Aeging: Detection of cognitive impairment using voice analysis technology”. URL: https://www.openaccessgovernment.org/detection-of-cognitive-impairment-voice-analysis/84069/ . Found: 04.04.22

Tover. (n.d.). “Games for seniors”. URL: https://www.tover.care/games-for-seniors . Found: 13.12.21

Tover. (2021). “Care and enjoyment for people with cognitive challenges”. URL: https://www.tover.care/games . Found: 24.11.21

Tsoy, E., Possin, K. L., Thompson, N., Patel, K., Garrigues, S. K., Maravilla, I., ... and Ritchie, C. S. (2020). “Self-administered cognitive testing by older adults at-risk for cognitive decline”. *The journal of prevention of Alzheimer's disease*, *7*(4), 283-287. URL: https://link.springer.com/article/10.14283/jpad.2020.25 . Found: 12.10.21

Usability. (n.d.). “System Usability Scale (SUS)”. URL: https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html . Found: 24.04.22

U.S. Department of Health & Human Services. (2019). “Subjective Cognitive Decline – A Public Health Issue”. URL: https://www.cdc.gov/aging/data/subjective-cognitive-decline-brief.html . Found: 04.12.21

VilMer. (n.d.). “Televindu”. URL: https://vilmer.no/produkter/televindu . Found: 01.02.22

Wexner Medical Center. (n.d.). “SAGE: A Test to Detect Signs of Alzheimer´s and Dementia”. URL: https://wexnermedical.osu.edu/brain-spine-neuro/memory-disorders/sage . Found: 09.03.22

WHO. (2021). “Dementia”. URL: https://www.who.int/news-room/fact-sheets/detail/dementia . Found: 28.11.21

Wikipedia. (2020). “Tovertafel”. URL: https://en.wikipedia.org/wiki/Tovertafel . Found: 24.11.21

Wikipedia. (2022). “Mini – Mental State Examination”. URL: https://en.wikipedia.org/wiki/Mini–Mental_State_Examination . Found: 03.12.21

Yeung, A., Iaboni, A., Rochon, E., Lavoie, M., Santiago, C., Yancheva, M., ... and Mostafa, F. (2021). “Correlating natural language processing and automated speech analysis with clinician assessment to quantify speech-language changes in mild cognitive impairment and Alzheimer’s dementia”. *Alzheimer's research & therapy*, *13*(1), 1-10. URL: https://alzres.biomedcentral.com/articles/10.1186/s13195-021-00848-x . Found: 30.03.22

Yin, C., Li, S., Zhao, W., and Feng, J. (2013). “Brain imaging of mild cognitive impairment and Alzheimer's disease”. *Neural regeneration research*, *8*(5), 435. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4146132/ . Found: 08.11.21

Yu, R., Hui, E., Lee, J., Poon, D., Ng, A., Sit, K., ... & Woo, J. (2015). “Use of a therapeutic, socially assistive pet robot (PARO) in improving mood and stimulating social interaction and communication for people with dementia: Study protocol for a randomized controlled trial”. *JMIR research protocols*, *4*(2), e4189. URL: https://www.researchprotocols.org/2015/2/e45/ . Found: 23.02.22

Yukai Engineering Co. (n.d.). “Qoobo”. URL: https://qoobo.info/index-en/ . Found: 02.02.22

Zucchella, C., Sinforiani, E., Tassorelli, C., Cavallini, E., Tost-Pardell, D., Grau, S., ... and Nappi, G. (2014). “Serious games for screening pre-dementia conditions: from virtuality to reality? A pilot project”. *Functional neurology*, *29*(3), 153. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4264781/ . Found: 09.03.22

Appendix A

A1 – Approval from NSD.

NSD MELDESKJEMA FOR BEHANDLING AV PERSONOPPLYSNINGER Norsk Gina Farsirotos

Meldeskjema / IT solutions for cognitive decline / Vurdering

Vurdering

01.03.2022 Skriv ut

Referansenummer
372285

Prosjekttittel
IT solutions for cognitive decline

Behandlingsansvarlig institusjon
Universitetet i Bergen / Det samfunnsvitenskapelige fakultet / Institutt for informasjons- og medievitenskap

Prosjektperiode
01.04.2022 - 01.06.2022

Meldeskjema

Dato	**Type**
01.03.2022	Standard

Kommentar
Data Protection Services has carried out an assessment of the processing of personal data in this project. Our assessment is that the processing will comply with data protection legislation, so long as it is carried out in accordance with what is documented in the Notification Form and attachments, dated 01.03.2022, as well as in our message correspondence.

TYPE OF DATA AND DURATION
The project will process general categories of personal data until 20.05.2022.

LEGAL BASIS
The project will gain consent from data subjects to process their personal data. We find that consent will meet the necessary requirements under art. 4 (11) and 7, in that it will be a freely given, specific, informed and unambiguous statement or action, which will be documented and can be withdrawn.

The legal basis for processing general categories of personal data is therefore consent given by the data subject, cf. the General Data Protection Regulation art. 6.1 a).

PRINCIPLES RELATING TO PROCESSING PERSONAL DATA
We find that the planned processing of personal data will be in accordance with the principles under the General Data Protection Regulation regarding:
• lawfulness, fairness and transparency (art. 5.1 a), in that data subjects will receive sufficient information about the processing and will give their consent
• purpose limitation (art. 5.1 b), in that personal data will be collected for specified, explicit and legitimate purposes, and will not be processed for new, incompatible purposes
• data minimisation (art. 5.1 c), in that only personal data which are adequate, relevant and necessary for the purpose of the project will be processed
• storage limitation (art. 5.1 e), in that personal data will not be stored for longer than is necessary to fulfil the project's purpose

THE RIGHTS OF DATA SUBJECTS
We find that the information that will be given to data subjects about the processing of their personal data will meet the legal requirements for form and content, cf. art. 12.1 and art. 13.

Data subjects will have the following rights in this project: access (art. 15), rectification (art. 16), erasure (art. 17), restriction of processing (art. 18), notification (art. 19) and data portability (art. 20). These rights apply so long as the data subject can be identified in the collected data.

We remind you that if a data subject contacts you about their rights, the data controller has a duty to reply within a month.

FOLLOW YOUR INSTITUTION'S GUIDELINES
Our assessment presupposes that the project will meet the requirements of accuracy (art. 5.1 d), integrity and confidentiality (art. 5.1 f) and security (art. 32) when processing personal data.

To ensure that these requirements are met you must follow your institution's internal guidelines and/or consult with your institution (i.e. the institution responsible for the project).

NOTIFY CHANGES
If you intend to make changes to the processing of personal data in this project it may be necessary to notify us. This is done by updating the information registered in the Notification Form. On our website we explain which changes must be notified. Wait until you receive an answer from us before you carry out the changes.

FOLLOW-UP OF THE PROJECT
We will follow up the progress of the project at the planned end date in order to determine whether the processing of personal data has been concluded.

Good luck with the project!
Contact person: Henning Levold

b19329f23

Chat med oss på hverdager fra 12-14

Appendix B

B1 – Informed Consent Form.

Are you interested in taking part in the research project *"Information technology in cognitive decline"*?

This is an inquiry about participation in a research project where the main purpose is to gain understanding of all information technologies used for diagnostics and treatment of cognitive decline. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

This research project is part of a master's study at the Department of Information and Media Science at the University of Bergen. The purpose of this study is to gain understanding of all information technologies used for diagnostics and treatment of cognitive decline.

To gain understanding of all information technologies (IT) used for diagnostics and treatment of cognitive decline.
Besides creating knowledge about this area, we want to create an artifact in form of a web-based system that will offer information to both experts, patients, and their relatives. That is why we find it necessary to get expert feedback on the content and their experience dealing with the cognitive decline.
Feedback from IT experts is important for designing a user-friendly system that will be easy to use and appealing to a possibly broad audience.

Who is responsible for the research project?

The department of Information and Media Science at the University of Bergen is the institution responsible for the project.

Why are you being asked to participate?

We want to know the general knowledge about the field, and how you work with these technologies. We would also like to know if you were looking for information since it was of interest of you personally or somebody related to you. If you are a care provider or a researcher in the field of cognitive decline, we would like to know if you were asked to recommend some therapies or tests, and whether you were comfortable giving information to patients or their relatives. Regardless of your role, we would like to know how easy or difficult it was to find and communicate information regarding usage of information technology in cognitive decline.

What does participation involve for you?

One participation group will be participating in an interview asked about their knowledge on cognitive decline, and the other participating group will be trying out the finished prototype and then answering a few simple questions to find out what the participant thinks about the prototype. The interviews will be recorded on audio tape and written notes might be taken along the way. The interviews will take approx. 30-45 minutes.

Participation is voluntary

Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

All personal information will be treated confidentially. Only the student and supervisor of the project have access to personal information. Personal information (both in writing and in the form of audio recordings) is not stored directly by name, names will be replaced with a reference number. Name list with the connection key will be stored on external storage device. On this device, the task itself or other material using these reference numbers will not be stored.
No participants in the study will be recognized in the publication.

What will happen to your personal data at the end of the research project?

The project is scheduled to end on June 1st 2022. Your data will be deleted after June 1st 2022 when study will be completed. Your data will be stored one month after the project has finished.
At the end of the project, all files with personal information will be deleted. Name list/link key will be deleted and all audio recordings as well as notes kept during interviews will be deleted and shredded.

Your rights

So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent.

Based on an agreement with Institution of Information Science and Media Studies. Data Protection Services has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:

- Institution of Information Science and Media Studies via supervisor *Ankica Babic, email:* *ankica.babic@uib.no* *, telephone: +47 55 58 91 39.* Student *Gina Farsirotos, email:* *gpr005@uib.no* *, telephone: +47 90 18 60 01*
- Our Data Protection Officer: *Janecke Helene Veim, email: janecke.veim@uib.no , telephone: +47 55 58 20 29*
- Data Protection Services, by email: *personvernombud@uib.no* or by telephone: +47 55 58 20 29.

Yours sincerely,

Ankica Babic Gina Farsirotos
(Researcher/supervisor)

Consent form

Consent can be given in writing (including electronically) or orally. NB! You must be able to document/demonstrate that you have given information and gained consent from project participants i.e. from the people whose personal data you will be processing (data subjects). As a rule, we recommend written information and written consent.

- *For written consent on paper you can use this template*
- *For written consent which is collected electronically, you must chose a procedure that will allow you to demonstrate that you have gained explicit consent (read more on our website)*
- *If the context dictates that you should give oral information and gain oral consent (e.g. for research in oral cultures or with people who are illiterate) we recommend that you make a sound recording of the information and consent.*

If a parent/guardian will give consent on behalf of their child or someone without the capacity to consent, you must adjust this information accordingly. Remember that the name of the participant must be included.

Adjust the checkboxes in accordance with participation in your project. It is possible to use bullet points instead of checkboxes. However, if you intend to process special categories of personal data (sensitive personal data) and/or one of the last four points in the list below is applicable to your project, we recommend that you use checkboxes. This because of the requirement of explicit consent.

I have received and understood information about the project *Information Technologies for Cognitive Decline* and have been given the opportunity to ask questions. I give consent:

☐ to participate in *(insert method, e.g. an interview)*
☐ to participate in *(insert other methods, e.g. an online survey) – if applicable*
☐ *for my/my child's teacher to give information about me/my child to this project (include the type of information)– if applicable*
☐ *for my personal data to be processed outside the EU – if applicable*
☐ *for information about me/myself to be published in a way that I can be recognised (describe in more detail)– if applicable*
☐ *for my personal data to be stored after the end of the project for (insert purpose of storage e.g. follow-up studies) – if applicable*

I give consent for my personal data to be processed until the end date of the project, approx. *July 1st 2022*

(Signed by participant, date)

B2 – Interview Guide for Field Experts.

INTERVIEW GUIDE – FIELD EXPERTS

“IT solutions for cognitive decline”

This is an interview guide for this project about IT solutions for cognitive decline. The focus will be to gather as much information possible in the field.

Information from this project will be handled anonymously, unless the participant wants otherwise. The interview will be recorded.

This is a simplified guide to how the interview might look like:

- Short presentation about what has been gathered through literature review (approx. 5 min.)
- Questions on the topic (approx. 30 min.)

This is semi-structured interview with the following questions:

1. What is your professional background?
2. How long have you been working in the field?
3. Are you working both with patients and research?
4. What information technology (IT) have you used in your work?
5. What are your expectations regarding existing IT tools, and what would you like to see in the future?
6. What are you recommending to your patients as a therapy?
7. Are there any IT tools you are also recommending?
8. Are there any specific IT tools you liked and found to be useful?
9. Have you participated in developing IT tools yourself, if yes, which ones?
10. Would you be willing to participate in development of new IT tools (if you have not done so by now)?
11. Can you comment on the results of the master thesis once the results are summarized and presented?

B3 – Interview Guide for IT Usability Experts and Users.

INTERVIEW GUIDE – USER AND EXPERT EVALUATORS

"IT solutions for cognitive decline"

This is an interview guide for this project about IT solutions for cognitive decline. The focus will be to gather as much information possible concerning the prototype. Participants will be given three tasks to perform and two tests to assess the mid-fidelity prototype. Those are System Usability Scale (SUS) and Nielsen´s heuristics. Upon the completion they will be given several questions.

Information from this project will be handled anonymously, unless the participant wants otherwise. The interview will be recorded.

This is a simplified guide to how the interview might look like:

- Short presentation about what has been gathered through literature review (approx. 5 min.)
- Tasks and evaluations of the prototype (approx. 25 min.)
- Pre-made questions (approx. 10 min)

This is semi-structured interview with the following questions:

1. What is your professional background?
2. How long have you been working in the field?
3. Have you been working with health care informatics?
4. Can you comment on the SUS test that has been completed?
5. Can you comment on the Nielsen´s heuristics results?
6. Do you have any comment and/or recommendations?

Appendix C

C1 – Related Publications.

Full paper –

20th International Conference on Informatics, Management and Technology in Healthcare.

Conference date and location: 1st – 3rd July, Athens, Greece.

A full paper was accepted and will be indexed in PubMed.

Information technologies for cognitive decline

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Abstract. Information technology (IT) is used to establish diagnosis and provide treatments for people with cognitive decline. The condition affects many before it becomes clear that more permanent changes, like dementia, could be noticed. Those who search for information are exposed to lots of information and different technologies which they need to make sense of and eventually use to help themselves. In this research, we have systematically analyzed the literature and information available on the Internet to systematically present methods used in diagnosing and treatment. We have also developed an artifact to help users obtain information with help of illustrations and text. The final user groups are all those for whom the cognitive decline is of concern. Medical professionals could be interested to direct their patients to use the artifact to gain information and keep learning at their own pace.

Keywords. Cognitive decline, information technology (IT), diagnosis, treatment

1. Introduction

Cognitive decline is difficult to understand. Initial signs are memory lapses that can be attributed to exhaustion or stress alone. They are frequently linked to more serious brain abnormalities that can escalate into permanent disorders. Early diagnosis of illness progression is the focus of clinical research. The difficulty lies in detecting the problem and connecting many tests to establish a diagnosis as early as possible [1] [2].
Clinical tests provide an objective way of documenting symptoms, but there are other tests used by doctors and psychologists. Most of them appear to be done on paper and during medical consultations. There are numerous strategies and procedures used in clinical practice when it comes to therapy of dementia, but it is less clear how to identify cognitive decline and understand its severity as well as keeping it under control. The questions that both health care professionals and patients face are choices of appropriate methods for diagnosing and treatment. IT provides many tools, but it is not always clear what would be the most appropriate for cases at hand. Even medical experts are commonly asked about possibilities based on IT to help patients monitor their condition and treat it. To that end there are many IT solutions designed for patients including games [3], virtual reality (VR) [4][5], and personalized service robots [6]. In this research we aimed at formulating what user demands could IT solutions address, and how [1]. The goal of this study is to assess various IT approaches to recognize cognitive decline and to prevent its development into diseases such as dementia.

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2. Method

In this research, we have combined two methods, first the comprehensive literature review to obtain the knowledge structure. In addition, the artifact was designed to provide users the possibility to search for and explore different IT solutions used in cognitive decline.

2.1. Literature review

Keywords used were *cognitive decline, information technology (IT), diagnosis* and *treatment*. A total of 39 papers were analyzed in detail. In addition, the Internet was searched for information on websites which included clinical information, patient information, and games available for people with cognitive decline. YouTube was searched for information on the decline instructions, clinical testing, instructions for those interested in a healthy lifestyle, and understanding symptoms and signs of decline.

2.2. Prototype development

A prototype was developed through two iterations, low-fidelity, and mid-fidelity. The latter was implemented in Figma [7], which allows modeling with intended user groups and enabling user-centered design. The code can be imported into the final product [7].

3. Results

3.1 Literature review

Figure 1 shows the division of the IT solutions according to their applications. Clinically relevant is the severity of the condition.

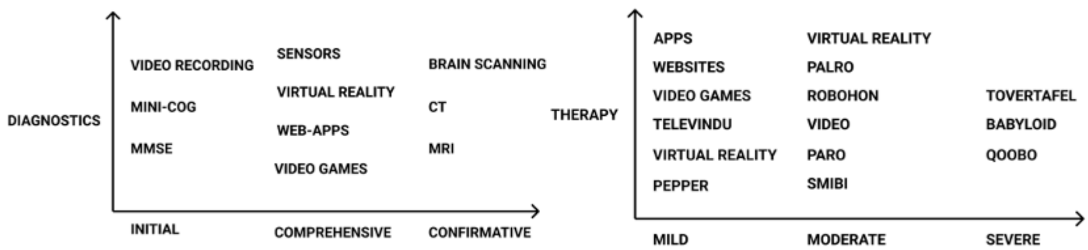

Figure 1. Division of the IT solutions according to their clinical applications.

Some of the technologies are in form of information systems, while the others are including sophisticated medical equipment such as computed tomography (CT) and magnetic resonance imaging (MRI). They are considered reliable tools for establishing an exact diagnosis. However, due to the cost of such medical examination, many other pure IT solutions are appealing and are developed intensively to meet users' needs.

Figure 2 is a graph containing the main technologies used in cognitive decline. The tree like structure was designed to make a search for information easier. Here a user can see for example techniques used for diagnosing such as self-testing (mini mental status exam), sensors, brain imaging, and VR. For treatment often used are robots, games, websites, and VR. The design is intuitive and navigated by clicking on the nodes to get more detailed information. Some techniques are suitable for both diagnosing and treatment which could be further explained under the nodes.

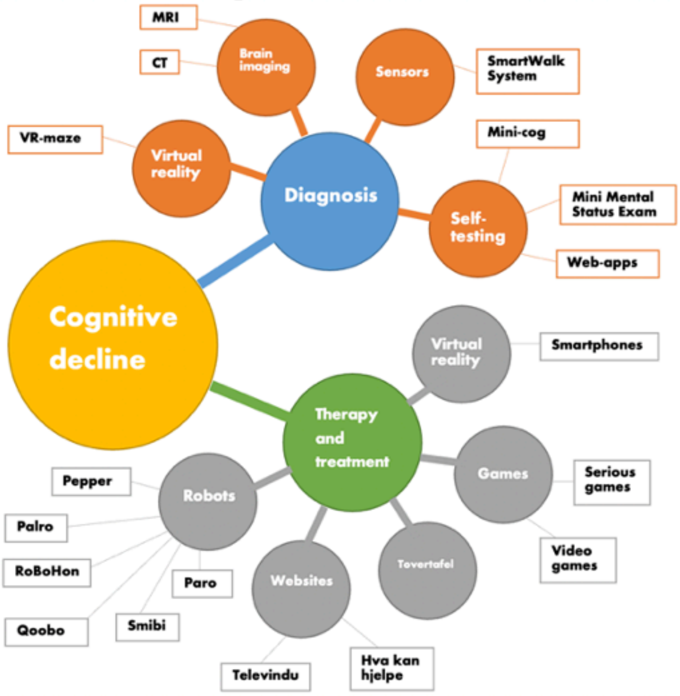

Figure 2. Overview of IT solutions for diagnosis and treatment of cognitive decline.

3.2 Prototype

The prototype is designed for a broad user group searching for information and knowledge on cognitive decline. It is intended for medical professionals, but also as a tool they could recommend to their patients. It was required that information should be easy to read and that there would be a good overview of all technologies available. The goal is that the system could be implemented within different kinds of websites by importing code in Figma. Figure 3 illustrates a mid-fidelity prototype. The colors are chosen according to the recommendations [8]. Preferred are strong colors like red against a neutral background and contrasting colors like black and white for technical details [9].

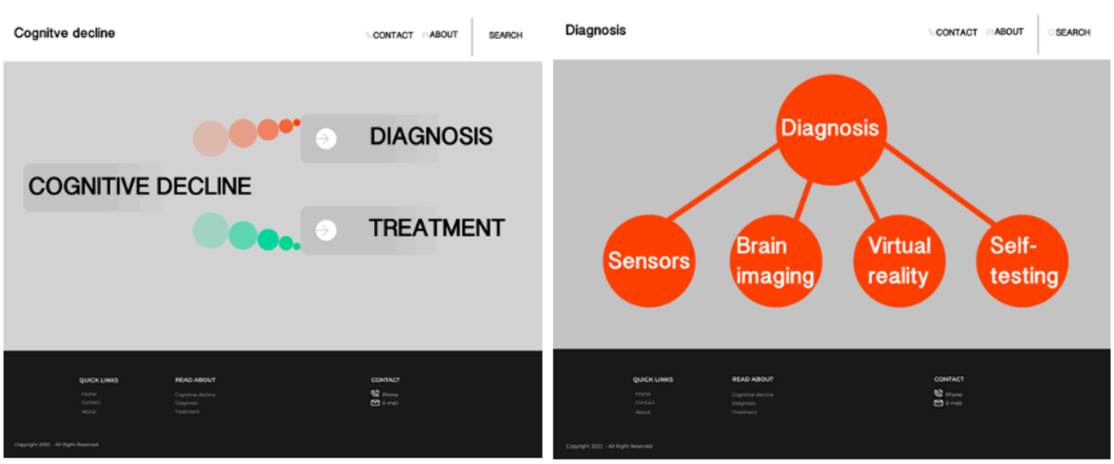

Figure 3: Mid-fidelity prototype for MacBook 14′ with landing and the diagnosis page.

4. Discussion

There is a lot of information on cognitive decline, but it takes time and effort to structure knowledge and understand applications, benefits, and impact for a person with cognitive decline [1][2]. The clinical picture is also complex since it is not clear when the decline has begun, how severe it is, and what can be done to prevent the decline [1]. We aimed at structuring all the information in a user-friendly way to make it available to the public. For that it was necessary to perform a comprehensive analysis of the results and develop a user-friendly prototype that would allow users to read and process all the information successively and their own pace [9]. The starting point was clinical using the literature since it was difficult to approach all intended users. A set of requirements could vary for different user groups, and especially those in whom cognitive decline has already started. This group would be different from people with diabetes who have a clear picture of their situation [2]. Our intention was however to make all the information accessible and easy. The prototype was implemented to enable user experience and provide feedback. It is essential for implementing the prototype to include health care and medical field professionals. The knowledge on the decline is evolving, so the prototype should be regularly updated with new facts. The current design allows for that due to its modular structure. The development is multidisciplinary and concerns both clinical and IT aspects. The study limitation relates to the use of literature only, hence missing clinical input.

5. Conclusion

Depending on the severity of the condition several tools are usually available for cognitive decline. Resulting of this research is knowledge structure and a mid-fidelity prototype that enables users to interact and follow their inquiries to learn through both illustration and text. The future work entails evaluation by IT and medical experts to refine design and address the clinical complexity.

References

[1] Lin Y, Shan PY, Jiang WJ, Sheng C, Ma L. Subjective cognitive decline: preclinical manifestation of Alzheimer´s disease. Neurological Sciences. 2019; 40(1):41-49.

[2] Allan CL, Behrman S, Ebmeier KP, Valkanova V. Diagnosing early cognitive decline – when, how and for whom? Maturitas. 2017; 96:103-108.

[3] Manera V. et. al. Recommendations for the use of serious games in neurodegenerative disorders. Frontiers in psychology. 2017; 8:1243.

[4] D'Cunha NM. et. al. A mini-review of virtual reality-based interventions to promote well-being for people living with dementia and mild cognitive impairment. Gerontology. 2019; 65.4:430-440.

[5] Morganti F, Riva G. Virtual reality as allocentric/egocentric technology for the assessment of cognitive decline in the elderly. MMVR; 2014. p.278-284.

[6] Goda A, Shimura T, Murata S, Kodama T, Nakano H, Ohsugi H. Psychological and Neurophysiological Effects of Robot Assisted Activity in Elderly People With Cognitive Decline. Gerontology and Geriatric Medicine. 2020; 6:2333721420969601.

[7] Figma. (n.d). https://www.figma.com (accessed January 10, 2022).

[8] The Advocate. Can different colors influence a person with dementia? Here´s what to know. 2016. https://www.theadvocate.com/baton_rouge/entertainment_life/health_fitness/article_922b136a-84d5-11e6-8c00-fbc8ac72b472.html (accessed February 2, 2022).

[9] Polyuk S. Age Before Beauty – A Guide to Interface Design for Older Adults. 2019 Jun. https://www.toptal.com/designers/ui/ui-design-for-older-adults (accessed March 4, 2022)