Design, Prototypical Development and Usability Testing of a Visuospatial Neglect Training Application on a Touch Table

Master Thesis

For attainment of the academic degree of
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by

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Declaration

I hereby declare that

- I have written the work at hand on my own without help from others and I have used no other resources and tools than the ones acknowledged.
- I have complied with the Standards of good scientific practice in accordance with the St. Pölten UAS' Guidelines for Scientific Work when writing this work.
- I have neither published nor submitted the work at hand to another higher education institution for assessment or in any other form as examination work.

Regarding the use of generative artificial intelligence tools such as chatbots, image generators, programming applications, paraphrasing and translation tools, I declare that I have used generative artificial intelligence tools to proof-read this work.

Having read and understood the St. Pölten UAS‘ Guidelines for Scientific Work, I am aware of the consequences of a dishonest declaration.

Preface

Herewith I would like to thank all the people who have accompanied me on my way to get here. As an occupational therapist, working on a stroke unit is both challenging and rewarding. Studying Digital Healthcare helped me to look at the Austrian healthcare system from a different perspective and to recognize the combination of technology and medicine as an innovative opportunity for improvement. The possibilities for therapeutic purposes seem almost limitless. The idea of using a touch table to expand the neglect treatment in terms of client-centeredness is still of great interest to me until today.

I would like to take this opportunity to thank my parents for their emotional support and constant guidance. I wouldn't have got this far without you. Thanks, are also due to my fellow students for the unforgettable memories and the open exchange of knowledge. Furthermore, I would like to thank my supportive advisor and all the lecturers on the Digital Healthcare degree program, who were always open to questions and comments. Finally, I would like to thank myself for being motivated and persevering to write this thesis. The last few months have been characterized by enthusiasm, ambition and innovation and I am grateful to all those who have made this journey possible.

Abstract

Background: Approximately 12.2 million new strokes are documented worldwide every year. 30% of all these strokes are accompanied by symptoms of visuospatial neglect. Currently, assessment and therapy are largely performed using various paper and pencil tasks that are rarely stored or archived. The aim of this thesis is to assess the usability of a touch table prototype for the testing and training of neglect through usability testing.

Method: Usability testing was carried out in accordance with the user-centred design process. At the beginning of the project, an extensive literature review was carried out to evaluate current research findings. In addition, needs were identified through an interview with two experts. These findings were implemented in the development and design of such a prototype. The testing was carried out with five occupational therapists from the neurological field. A test scenario was performed, and three different user experience metrics were recorded. An interview was conducted with the test participants regarding user-friendliness as well as advantages and disadvantages of the prototype. The results were presented descriptively as well as by means of diagrams and correlation calculations.

Results: The importance of the ease of use of such an application, especially in neurological work, was demonstrated. It became clear that the placement of buttons may play a significant role with regard to deviations in the process. The testing showed that the device can be used independently in just a few minutes. Another requirement identified was the ability to customize the device. On the one hand, this includes the adaptability of the hardware (table height, tiltability of the table surface, storability). On the other hand, a variety of tools for the collection and training of neglect would facilitate its use in everyday clinical practice. The influences of the environment, such as incidence of light and noise interference, must be considered.

Conclusion: The integration of a touch table for neglect treatment in everyday clinical practice is recommended, particularly due to the large exploration area. Aspects of the adaptability of the table and the influence of external conditions must be taken into account.

Kurzfassung

Hintergrund: Jährlich werden etwa 12.2 Millionen neue Schlaganfälle weltweit dokumentiert. 30% all dieser Schlaganfälle gehen mit Symptomen eines visuospatialen Neglects einher. Das Assessment und die Therapie erfolgen derzeit weitgehend mithilfe unterschiedlicher Papier – Bleistiftaufgaben, welche kaum abgespeichert oder archiviert werden. Das Ziel dieser These ist es, die Benutzerfreundlichkeit eines Touch Table Prototypens für die Testung und das Training eines Neglects durch eine Usability Testung zur erheben.

Methode: Die Usability Testung wurde nach dem Schema des User – Centred – Design Prozesses durchgeführt. Zu Beginn des Projekts wurde eine ausführliche Literaturrecherche durchgeführt, um aktuelle Forschungserkenntnisse zu evaluieren. Zusätzlich wurden Bedürfnisse durch ein Interview mit zwei Expertinnen erhoben. Diese Erkenntnisse wurden in der Entwicklung sowie im Design eines solchen Prototypens umgesetzt. Die Testung wurde mit fünf Ergotherapeutinnen aus dem neurologischen Arbeitsfeld durchgeführt. Dabei wurde ein Testszenario durchgeführt und drei unterschiedliche User – Experience Metriken wurden aufgezeichnet. Ein Interview mit den Testteilnehmerinnen wurde bezüglich Benutzerfreundlichkeit sowie Vor- und Nachteile durchgeführt. Die Ergebnisse wurden deskriptiv sowie mittels Diagramme und Korrelationsberechnungen dargestellt.

Ergebnisse: Die Wichtigkeit der einfachen Handhabung einer solchen Anwendung vor allem in der Arbeit im neurologischen Bereich wurden aufgezeigt. Es wurde ersichtlich, dass die Platzierung von Buttons hinsichtlich Abweichungen im Prozess eine wesentliche Rolle spielen kann. Die Testung zeigte auf, dass der Umgang mit dem Gerät bereits in wenigen Minuten selbstständig erfolgen kann. Als weitere Anforderung wurde vor allem Anpassungsmöglichkeit des Geräts identifiziert. Hierzu zählt einerseits die Anpassung der Hardware (Tischhöhe, Kippbarkeit der Tischfläche, Möglichkeit zur Verstauung). Andererseits würde eine Vielfalt an Tools zur Erhebung sowie zum Training des Neglects den Einsatz im klinischen Alltag erleichtern. Die Einflüsse der Umgebung wie beispielsweise Lichteinfall und Geräuschstörungen müssen berücksichtigt werden.

Conclusio: Die Integration eines Touch Tables zur Neglectbehandlung in den klinischen Alltag ist vor allem auf Grund der großen Explorationsfläche zu empfehlen. Aspekte der Anpassungsfähigkeit des Tisches sowie der Einfluss externer Gegebenheiten müssen beachtet werden.

Table of Content

1 Introduction

Global statistics from 2022 show that approximately 12.2 million new strokes are reported worldwide each year. Of these, 47% occur in men, while 53% occur in women [1]. In Austria about 26 000 people suffered a stroke in the year of 2022 [2]. Another study has concluded that approximately 30% of all strokes, regardless of the location of the brain lesion or the intervention performed, lead to symptoms of spatial neglect. Spatial neglect represents a syndrome resulting from damage to the brain's neural network that impairs attention, especially to one side of the body, as well as important cognitive and motor functions. It is more commonly observed following right-sided brain damage (80%) than after left-sided brain damage (20%) [3]. A neglect tends to face multiple effects on the functional outcome after stroke rehabilitation, e.g., longer recovery duration, impaired activities of daily living as well as poorer functional outcome [4]. Therefore, an early and extensive diagnostic process is sought to be able to intervene earlier with essential measures. In most clinical settings in Austria paper-pencil tasks are chosen to evaluate neglect symptoms in stroke survivors. Current issues in the existing system relate to the extensive documentation and assessment process, which is often flawed by inaccuracy due to a lack of time. In addition, the poor transparency between different professional groups means that the severity of neglect is often misunderstood or underestimated by those not directly involved in the process of evaluation. Furthermore, storage and archiving of evaluation sheets or training progress is currently almost non-existent.

Given these problems, the need for technological intervention as a matter of urgency becomes clear. The integration of digital solutions offers a way to accurately quantify and assess the severity of neglect, providing a clear, data-driven understanding of the condition. By establishing a user-friendly touch-table interface, for the evaluation as well as the training of visuospatial neglect, a possible improvement in the effectiveness of therapeutic interventions, that will contribute to the overall well-being and recovery of stroke patients is examined. A usability testing as well as interviews with experts will therefore be conducted, to evaluate requirements and needs for the integration of a similar device into daily clinical practise.

1.1 Aim of the Thesis

The aim of this work is to develop and design a prototype for the evaluation and training of a visuospatial neglect. The prototype will be adapted to requirements, defined by practicing occupational therapists during an expert interview. Furthermore, the prototype will be tested and analysed for the usability in the means of different user-experience metrics. Thereby new perspectives on the digitalization of the evaluation methods of a neglect should be given and further research should be stimulated.

1.2 Research Questions

Based on the aforementioned issues, three different research questions were identified, which will be addressed in the course of this thesis.

RQ 1: What are requirements in detecting and quantifying visuospatial neglect in stroke patients identified by occupational therapists?

RQ 2: What functional and technical requirements are essential to develop a touch-based interface for a collaborative setting in occupational therapy with patients with visuospatial neglect?

RQ 3: What are the Task Completion Rate, the Time on Task and the User Error Rate as UX metrics testing a prototype for the evaluation of visuospatial neglect using a touch table application including occupational therapists?

1.3 User Centred Design Process

The usability testing as method was conducted by implementing the user centred design process. Therefore, quantitative as well as qualitative data could be gathered and analysed.

At the beginning of the study, a literature review was conducted, which covered theoretical content relating to neglect, differences in evaluation and training methods as well as technical framework conditions and the touch table. In addition, qualitative interviews were held with two experts in the area under investigation at the end of the analysis phase. During the interviews, requirements for the prototype were evaluated regarding useful items, practical design, and necessary tools. Those requirements were then synchronized and combined with the results of the literature research during the development of the prototype. With the help of phaser.js, the front end was developed featuring an assessment and a training tool. The goal was to implement the defined requirements as accurately as possible, to guarantee a user-friendly device. Once the design phase was completed, the evaluation phase started. This means, that the usability testing was carried out with five occupational therapists, whereby a test scenario was followed. The testing scenario included five different tasks that should have been completed as independent as possible. During the test three different user experience metrics were evaluated. Afterwards an interview with the participants was held to gather information about the user experience as well as advantages and disadvantages of the prototype. Last but not least, the results were structured and analysed to accurately present the findings of the process.

No application to the Austrian Ethics Committee was necessary.

2 Background and Related Work

This chapter first covers the medical basics of stroke and provides a comprehensive explanation of neglect syndrome. In addition, several diagnostic and training methods are analyzed and differentiated. Furthermore, the technical fundamentals of the prototype are outlined and previous projects in this area are highlighted.

2.1 Pathology, Diagnosis and Assessment of Neglect

2.1.1 Stroke

Stroke is a defined clinical syndrome of an acute, focal neurological impairment caused by a vascular damage affecting the central nervous system [5]. Records from the Global Stroke Sheet 2022 show that there are currently around 101 million people who have suffered a stroke in their lifetime. Every year approximately 12.2 million new strokes are reported globally and around 6.5 million people pass away annually due to a stroke, whereby 34% are younger and 66% are older than 70. Of all strokes 44% occur in men while 56% occur in women [1]. In Austria about 26 000 people suffered a stroke in the year of 2022 [2].

The term stroke includes ischemic brain- und spinal cord infarcts, intracerebral haemorrhage as well as subarachnoid haemorrhage [6]. An ischemic infarction is the most common form of stroke and occurs when a blood thrombus blocks a vessel supplying blood to the brain and causes a cerebral insufficiency in an affected area [7]. Those are often a result of large – artery atherosclerosis, cardioembolic events, small-vessel occlusion, or other causes. An ischemic stroke is primarily characterized by the sudden onset of various symptoms. These may include paralysis of one side of the body in the face, arm, or leg (hemiparesis), speech abnormalities, dizziness and feelings of weakness, headaches, and more [6]. Intracerebral haemorrhage is the second most common type of stroke and the one with the highest mortality rate. It is caused by the sudden rupture of a small cerebral artery within the brain parenchyma. Depending on the location, it can lead to motor and sensory impairments as well as cognitive deficits. In addition, centralized pain and attention deficits can manifest themselves. Above all, headaches are mentioned more frequently as a cardinal symptom of intracerebral haemorrhage compared to ischemic strokes [8]. Subarachnoid haemorrhage represents the rarest form of stroke, arising from an aneurysm or traumatic head injury, leading to bleeding between the arachnoid membrane and the pia mater. Abrupt-onset headaches, neck pain, nausea, and vomiting are common presenting symptoms.[9]

Alongside the term stroke, there is also the term TIA, standing for transient ischemic attack, which is frequently used in the literature. A TIA is defined as a short episode of focal neurological impairment that is not accompanied by a permanent cerebral infarction and lasts less than 24 hours [5]. This clinical condition is not discussed in the following paper.

Clinically visible symptoms alone are not enough to distinguish between an ischemic stroke, a cerebral haemorrhage or a TIA. After a stroke has occurred, patients should be treated on a multidisciplinary basis at a stroke unit [10]. The acute medical treatment depends on various factors. Therefore, it is essential to arrange a thorough examination with CT and MRI-based results in order to be able to intervene in a targeted approach. According to current guidelines, different methods of treating ischemic stroke are described depending on inclusion and exclusion criteria. These procedures include, for example, lysis therapy, in which fibrinolytic drugs are administered intravenously to dissolve the blood clot. Similarly, thrombectomy is also described for the mechanical loosening of blockages in large arteries supplying the brain by means of a catheter [11]. Intracerebral haemorrhage is also treated only after clarification of the inclusion and exclusion criteria. Guidelines describe the treatment with individually adjusted medication or targeted neurosurgical interventions to minimize bleeding [12]. Studies indicate that patients with intracerebral haemorrhage generally present with a less favourable initial condition upon hospital admission compared to those with ischemic stroke. Despite this initial disadvantage, individuals with intracerebral haemorrhage typically achieve a higher degree of functional independence and show less reliance on caregivers than patients with ischemic stroke [13]. In contrast to both intracerebral haemorrhage and ischemic stroke, the group with non-traumatic subarachnoid haemorrhage demonstrates a proportionally better rehabilitation trajectory. However, given that the initial state is often markedly poorer in this group, patients with subarachnoid haemorrhage usually do not attain the same level of recovery as observed in the other two groups [14].

When examining the risk factors for stroke, it is essential to differentiate between modifiable and non-modifiable factors. Non-modifiable risk factors include age, with the incidence doubling each decade after the age of 55. Additionally, premenopausal women face a higher risk due to factors such as pregnancy and oral contraception, while in later years, men are more prone to experiencing a stroke than women. Genetic predispositions, particularly related to various hereditary conditions or genetic variations, also elevate the risk of suffering a stroke. Among the modifiable risk factors, high blood pressure takes precedence. On average, half of all stroke patients, and even more in cases of intracerebral haemorrhage, have elevated blood pressure. Diabetes Mellitus contributes to 20% of all fatal strokes, and cardioembolic infarctions are frequently associated with ischemic strokes. Cigarette smoking doubles the risk of experiencing a stroke, while alcohol consumption shows a linear relationship with the risk of intracerebral haemorrhage. Elevated inflammatory markers are likewise associated with stroke and atherosclerosis [5]. Early interdisciplinary care at a stroke unit by nurses, occupational therapists, physiotherapists, speech therapists, social workers and neuropsychologists is central to the subsequent course of treatment. Following a stroke, approximately 75% of stroke survivors experience some level of physical, cognitive, or emotional change. This often leads to an ongoing need for care after the acute phase. Factors such as the severity of impairment, available support and response to rehabilitation determine the level of care required. Many may need help at home, while others may require care in a nursing home for more complex needs. Care after a stroke is diverse and individually adapted to each person's needs [10].

In the remaining part of the thesis, the main subject is visuospatial neglect as an effect of a stroke.

2.1.2 Pathophysiology of Neglect Syndrome

Spatial neglect syndrome, otherwise known as unilateral or hemineglect syndrome, is an attention disorder characterized by the unilateral disregard of the contra lesional side following damage to the brain's neural network. This impairment extends beyond sensory and motor functions and may also affect perceptual, visuospatial, representational, and various behavioural components. Usually, neglect syndrome is accompanied by a lack of awareness of own impairments, which is referred to as anosognosia [15].

In addressing such a complex topic, various theoretical principles require explanation and discussion. The most common theory is based on hemispheric asymmetry. Neurological impairments cause different symptoms depending on the localization of the damage. Already a few decades ago, scientific findings made hemispheric asymmetry responsible, meaning that the two hemispheres of the brain do not necessarily control the same functions. It can be assumed that both hemispheres of the brain have attentional functions. However, it should be noted that the attentional function of the right hemisphere relates to both sides and those of the left hemisphere only relates to the contralateral right side. A neglect to the left side following damage to the right hemisphere is therefore more common than a neglect to the right side following left-lesional damage [16], [17]. Further theoretical groundwork is provided by the understanding of attentional systems of the brain. Dorsal and ventral areas of the brain in particular are examined in more detail. In the published literature, the exact classification is controversial. Several studies assume that the general clinical manifestation is actually a disruption of the dorsal attention system, as those affected show a unilateral reduction in exploratory behaviour and attention to the contra lesional side [18]. Despite this finding, other trials show that in clinical practice a neglect occurs more frequently after structural damage to areas of the ventral than of the dorsal system [19]. This discrepancy indicates that neglect is not only a matter of damage to a specific area of the brain, but rather a complex interaction between different systems of the brain [20]. Interhemispheric interaction is as well discussed in the literature. According to this, communication between the two brain hemispheres may also play an important role in the development and recovery of neglect syndromes [19], [21], [22]. Studies indicate that there is a multi-network-like dysfunction of interhemispheric interaction in affected individuals during the subacute phase after a stroke. This implies that a disturbance of communication between the two hemispheres results in an impairment of several functions, including attention [19]. Furthermore, in the recovery of a neglect, this points to the possibility that a normalization of communication is also accompanied by an improvement in symptoms [23]. Alongside these theoretical principles, certain areas of the brain have emerged as being affected in most cases of neglect symptoms. A neglect syndrome that occurs due to damage in the right hemisphere is usually caused by lesions that affect the upper and middle temporal lobe, the inferior parietal cortex, or the inferior frontal cortex. Additionally, subcortical lesions in the region of the thalamus or the basal ganglia in the right hemisphere can also cause left-sided neglect [24]. Neglect symptoms affecting the right side are caused by damage to the left cerebral hemisphere. Lesions in the left parietal and frontal lobes in particular, as well as in the connections between them, especially in the superior longitudinal fasciculus, can increase the prevalence of neglect [25].

Anyway, anatomical fundamentals are indeed good indicators of a neglect, but in daily clinical practice they do not provide any information about the actual occurrence, specific symptoms, and severity. Understanding the clinical appearance and common signs as well as less noticeable effects is crucial for recognition and classification. In the acute onset of neglect symptoms, the eyes and the head of the affected person are usually tilted to the ipsilesional side. If the affected person searches for objects in their environment, exploration typically takes place exclusively on the ipsilesional side. The contra lesional side is not sought, meaning that objects, people, or obstacles are not perceived. This is referred to as abandonment and reduced exploration towards the affected side. [24]. A common scenario is eating only one half of their meal. Some neglect sufferers do not even bother to eat the left side of their dish and claim to have finished eating after consuming the right side. Figure 1 shows an illustration of this example.

Figure 1 Half meal plate as an exemplary illustration of a neglect patient from own recording

Studies indicate that when affected individuals explore the neglected field of vision, it is particularly difficult to redirect attention from an expected event (e.g. a conversation with a person) to an unexpected event (e.g. a glass falling to the floor). In other words, they are, for example aware of the conversation, but are uncaring about the falling glass. Similarly, those affected are easily distracted by stimuli in the ipsilesional field of vision and reorientation to the contra lesional area becomes more difficult [18]. Those symptoms become relevant when people affected must act independently in their everyday lives. Several studies have shown that accurately recognizing the position of an object and estimating its size, speed or direction of movement is essential for many activities, such as walking through a room or grasping a glass. The symptoms of neglect syndrome restrict this ability, which significantly reduces independence in everyday life [26]. In addition, object-centred neglect occurs. At the visual level of neglect (visuospatial), a distinction is made between two different categories. The main distinction here is between egocentric and allocentric neglect [24]. Egocentric neglect is distinguished by impaired attention to stimuli presented on the contra lesional side of the own body. In allocentric neglect, on the other hand, elements on the contra lesional side of an individual object are not perceived [27]. According to findings from a 2011 study, patients affected by allocentric neglect are more severely restricted in their daily activities than individuals affected by egocentric neglect [28].

2.1.3 Diagnostic and Assessment of Visuospatial Neglect

In the following chapter, conventional neglect assessments in paper-and-pencil format and afterwards also digital versions are described and then analysed regarding their objective and quality. It is important to emphasise that in addition to these evaluation methods, other approaches are also applied in everyday clinical practice. These include assessments with actual everyday material, reading as well as observation when performing everyday activities. These methods are not relevant for the further paper.

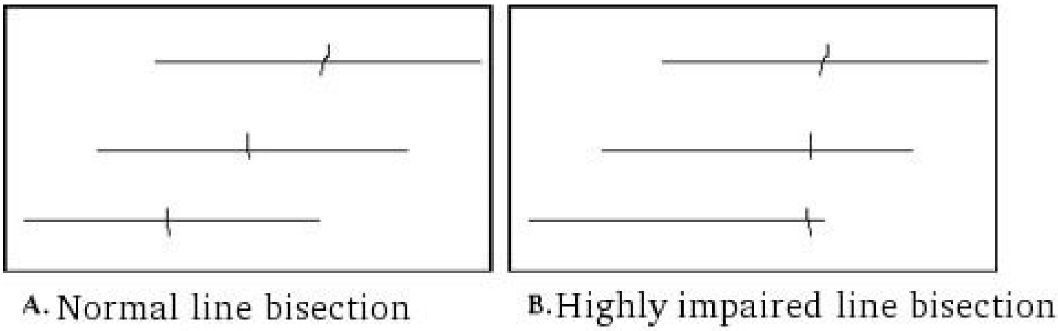

Figure 2 Line Bisection Test: Test without (on the left) and with (on the right) neglect syndrome [29]

Since there are numerous methods for measuring neglect, only assessments based on current German guidelines are listed and discussed in more detail below. These include, for example, the Line Bisection Test [24]. The test, as presented in Figure 2 is widely applied to diagnose neglect symptoms. The person concerned is asked to accurately mark the centre of a presented line. A deviation of the actual centre point indicates a neglect to the opposite side. It was assumed that the average of the deviation reflects the perceived centre point of the affected person and thus also indicates asymmetrical perception [29]. Due to the frequent incorrect implementation and calculation, the Line Bisection Test is often criticized in the literature. An additional evaluation method is provided by various search and cross-out tasks. These include, for example, the Bells Test as well as the Star

Cancellation Test. [24]. In both tests, various symbols are displayed several times on a piece of paper. The person concerned must find all the identical symbols from a previously defined one. The approach, also known as search strategy, processing speed and visual perception are assessed. The number and distribution of omissions can be used to more precisely standardize the severity of a neglect [30]. Figure 3 illustrates an example of the Star Cancellation Test. There are several letters, words as well as large and small stars. The person is asked to put a mark on all the small stars on the sheet. The person being tested highlights a total of 7 out of 34 possible stimuli and these are located exclusively on the right, ipsilesional side. There is no indication of any exploration to the contra lesional side.

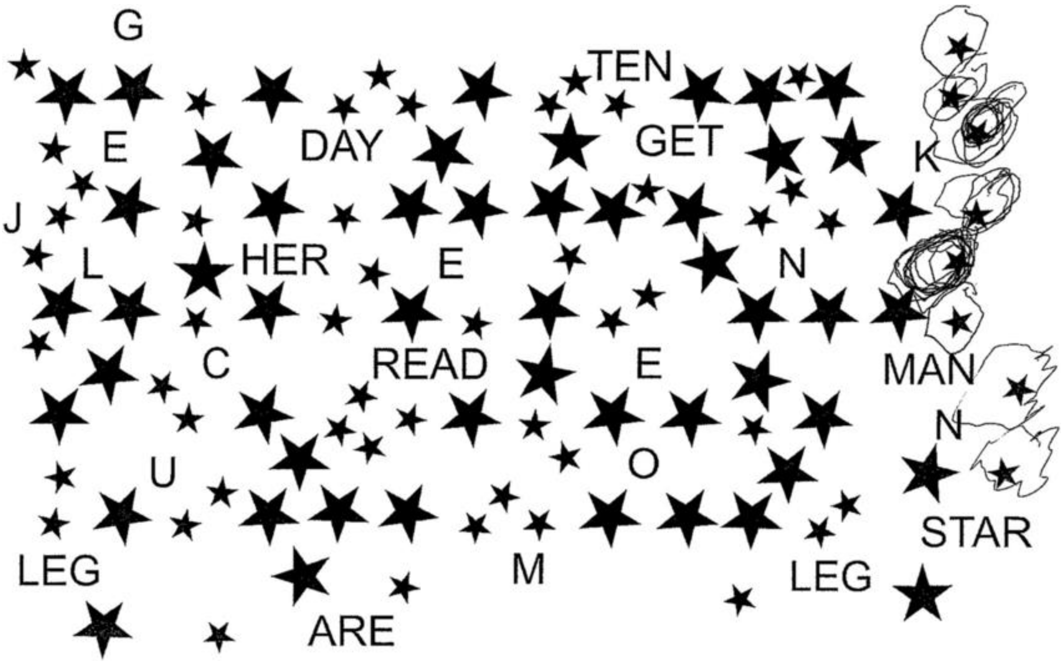

Figure 3 Star Cancellation Test: person with neglect syndrome finds target only on the ipsilesional side [31]

Further search and cross-out tasks distinguish, among other things, by neglect in the surrounding area of the person affected, egocentric neglect, and by neglect in relation to an object, allocentric neglect. These include, for example, the Sensitive Neglect Test or the Apples Test [24]. The Apples Test contains a total of 150 apple-shaped items, which are presented pseudo-randomly on an A4 sheet of paper in landscape format. All apples are oriented towards the top. Two thirds of the apples are used exclusively for distraction and are therefore incomplete on one side each (50% have an opening on the right side, 50% an opening on the left side). The reason for this was that processing each of the stimuli would lead to an increased exploration and therefore reduce the direct relation of the test to the standardization. The Apples Test is divided into five columns and two rows for better evaluation, but these are not visible to the person being tested. Each of these fields contains a total of 15 apples (three large and twelve small). Depending on the omission, it allows to determine whether the neglect is more pronounced on the left or right, as well as the upper or lower side. The person being tested has the task of marking all complete apples and ignoring all incomplete apples. Before starting the test, a trial session is carried out to ensure that the task has been understood. If most of the items are marked correctly, but only on the ipsilesional side, and there are some omissions on the contra lesional side, egocentric neglect can be assumed. If, in addition to the correct items, many distractors are also marked, an allocentric neglect can be assumed [28]. The main difference between these two forms of neglect is illustrated in Figure 4.

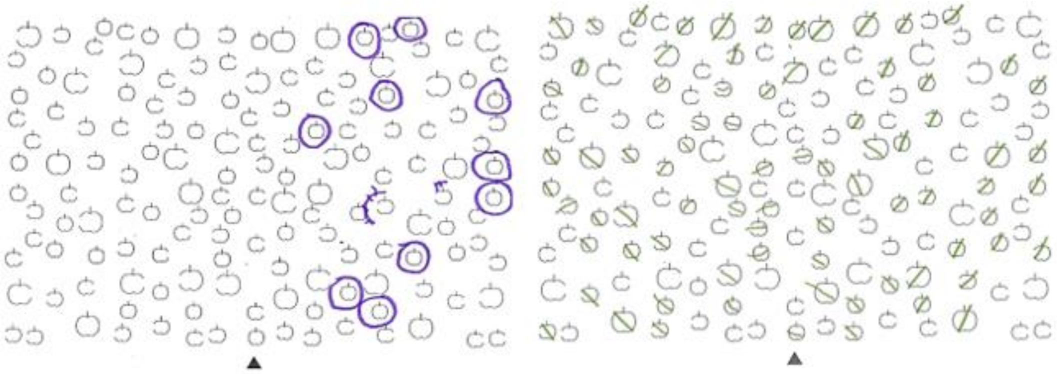

Figure 4 Apples Test: Egocentric Neglect (left) vs. Allocentric Neglect (right) [32]

In addition to the tests described previously, the person concerned is regularly asked to copy representational illustrations (e.g. house, flower, bicycle) or to draw something freehand as can be seen in Figure 5. In comparison to the search and cross-out tasks, these tools usually place higher requirements on the person concerned. This for example also includes the clock drawing test [24]. Depending on the instructions, the affected person is requested to draw a clock in a freehand manner or in a predetermined circular shape and then fill in a specific time. The evaluation of the clock test varies to some extent between operators, which affects its validity and interpretation. Current studies indicate that individuals with hemineglect tend to make smaller circles, as they usually draw too far from the centre of the page, leaving little space for the rest of the drawing. Similarly, there is often a distortion of the circular shape towards an ellipse, which indicates a disturbance in spatial abilities. The correct allocation of the numbers in the four quadrants of the clock is commonly significantly deficient in affected people, as can be seen in the picture.

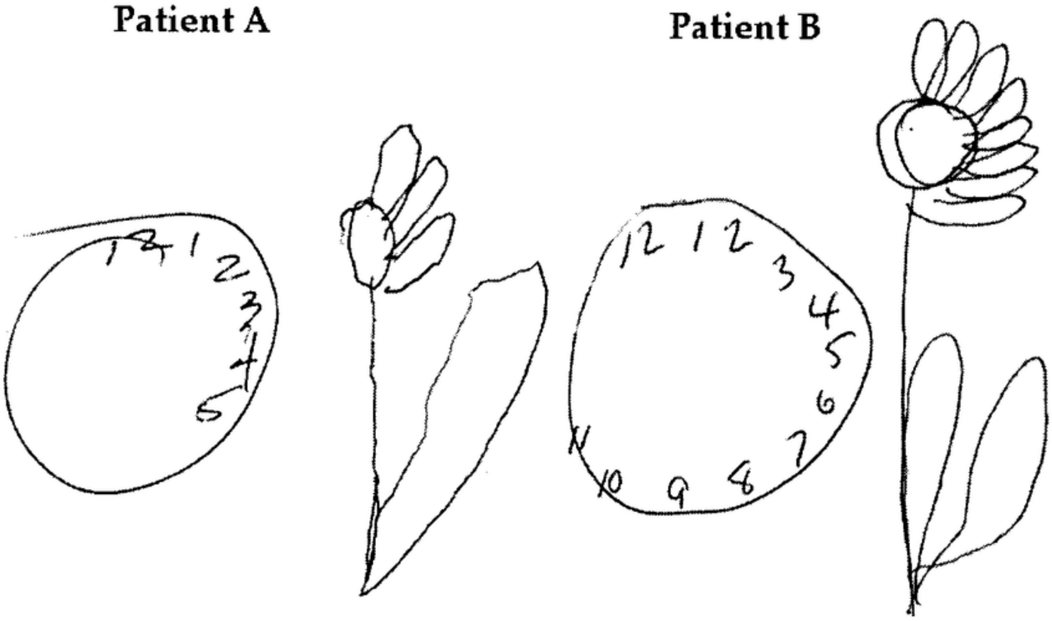

Figure 5 Example of a Hemineglect towards the left by means of copying a figure (flower) and Clock Drawing Tests [33]

Computer and touchscreen-based tasks for evaluating a neglect have been developed since the late 1990s to provide more detailed information gathering. Technologies have both advantages and disadvantages [34]. One advantage of these technologies is that the execution time as well as performance speed can be collected and recorded in greater detail [35]. The distribution of omissions and therefore the centring and severity of the neglect can be captured more accurately. In terms of search strategy, a computer can better adapt follow-up training sessions to the individual by specifically mapping the stimuli [36]. This therefore reduces the probability of a learning effect adjusted to the test. Similarly, there are always options for further measurements and recordings such as eye tracking or screen recording [37]. A significant disadvantage of digitalised evaluation methods is the high purchase expense, which many clinics are unwilling to invest in. In addition, problems with technical errors and the time required for maintenance work are an additional problem [34]. Reviews in the current literature show that computer- and touchscreen-based programmes are predominantly based on already existing paper and pencil tasks. As an example, the line bisection test is displayed on a computer screen or a touch tablet. Cancellation tests as described above are also used [34] [38]. In addition, current guidelines also recommend the use of virtual reality, as 3D scenarios can be used to carry out measurements not only in the peri personal area but also in the extra personal area [24].

In the interview with specialists in the specific field, meaning occupational therapists in an acute neurological setting, a variety of programs were identified and discussed. The "CogPack" program was highlighted by both occupational therapists. This software features a range of cognitive training programs and, alongside other items, also includes neglect assessments preferred by the interviewees, such as line bisection or circle segmentation. As shown in the free demo version, deviations to the middle point are calculated in percentage values and the average amount of deviations is displayed in the analysis. CogPack also measures the deviations in the first half of the test and the second half in order to identify possible deficits in cognitive endurance. One advantage of the CogPack program seems to be its simplicity of use. Since user profiles do not necessarily have to be generated, evaluation and training sessions can be started quickly. A disadvantage is the overall design of the software. It appears outdated and not very appealing in general. One interviewee noted a lack of colourful and playful design. In the existing literature, CogPack is largely associated with disorders such as schizophrenia or addiction. No specific studies on neglect diagnostics were found.

One of the interviewees mentioned “Neurovitalis” as a survey tool for neglect. Basically, the target group of the Neurovitalis screening tool are geriatric clients. Nevertheless, the screening tool includes an item designed to assess visuospatial neglect. Once the screening reveals a neglect, the subsequent training with the same program is adapted to suit the treated client. The occupational therapist describes the design as an advantage of the software. The layout is friendly and includes several illustrations. The software also provides some auditory stimuli, which significantly increases accessibility. Due to the individual patient profile, the training can be easily tracked and recorded. One disadvantage is the time factor. It is described that logging in and out of the program can be time-consuming in the daily work routine and the structure of the website is sometimes misleading. In the current literature, Neurovitalis is predominantly tested on patients with Parkinson's disease or older patients with mild cognitive impairment. The study results in this regard are promising [39]. An additional program that was mentioned during the interviews is “Neurotrax”. Internet research led to this program as well. Neurotrax provides a test battery for assessing cognitive deficits, with a test unit that measures visuospatial functions. Intensive research has also been carried out here over the last few years, although the focus is primarily on multiple sclerosis sufferers and not on patients with neglect. As the interviewee has not yet tested the program personally and no further information is available, it is not possible to consider advantages and disadvantages.

2.1.4 Aspects of Standardization in the Transformation from Paper Pencil to Technology

The transformation of paper-and-pencil-based assessments for neglect identification to procedures with a digital component therefore raises concerns about standardization and interpretation. Since standardized tools such as the Star Cancellation Test (see above) have been validated for certain sizes and formats, it cannot be assumed that these tests can be adopted without doubt. It cannot be completely excluded that the results have the same significance under other circumstances.

A study from 2022 focused specifically on this aspect regarding cancelation tests. Two components of the test procedures were examined. One of the aspects analysed was whether there is a difference between paper-pencil tasks and a digitalization of these tasks in the same size. Furthermore, it was investigated whether the size of the presentation in terms of screen dimensions has an impact on the results. For this purpose, screen sizes of tablet size (small), A4 size (medium) and a 27-inch touchscreen (large) were compared. It was found that there was no significant difference between the scores of the paper and pencil-based tests compared to the digital based ones. Similarly, no significant difference was found between the three screen sizes in terms of centre of cancellation, search speed and search strategy. However, it was mentioned that a larger presentation of the individual stimuli enables a faster speed of search, which means that the patient being tested exhausts less quickly. The results of the study clearly show that cancellation tests provide meaningful information regardless of the presentation size. In this regard, it should also be noted that the conditions and requirements should be as similar as possible to the already known scheme. This includes, for example, the horizontal positioning of the screen. In the study described above, the screen has been placed flat on the same table surface that was used for the paper and pencil test. It is important to ensure that all stimuli can still be easily reached with the unaffected arm. An additional interesting idea is to carry out the test with a touch pen in order to approach the conditions as accurately as possible [40].

2.1.5 Therapy and Training of Visuospatial Neglect

In addressing the topic of neglect rehabilitation, a distinction between two different approaches is often used. These are known as the "bottom-up" or "top-down" approach. The bottom-up approach describes predominantly passive interventions that are intended to trigger an automatic change in behaviour. The top-down approach describes interventions in which affected persons actively adopt new behaviours and search strategies. The bottom-up approach includes interventions such as caloric or vestibular stimulation, contra lesional limb activation, trunk rotation, neck muscle vibration, optokinetic stimulation or prism adaptation [41].

The potential of caloric vestibular stimulation (CVS) was first demonstrated by Rubens in 1985. During the procedure, cold water is applied to the contra lesional ear or warm water to the ipsilesional of the affected person. This causes vestibular-induced changes in the direction of gaze. The effect of this is a reduction in neglect during and shortly after the treatment (for about ten to fifteen minutes), making it easier to perform certain tasks [42]. Further studies confirm this short-term effect of CVS [43], however, there are no significant results regarding long-term outcomes [44]. According to Karnath et al in 1993, the centreline of the trunk might contribute significantly to neglect treatment. If the perceived midline of the body is shifted to the contra lesional area, it may lead to an improvement in neglect symptoms. It has further been observed that rotating the upper body to the contra lesional side while keeping the head and eyes looking straight ahead significantly improves the perception of stimuli on the neglect side [45], [46]. A further well-known "bottom-up" approach is the neck muscle vibration (NMV). This method involves stimulating the trapezius muscles on the contra lesional side with a vibration device at a frequency of around 80 - 100 Hz. This triggers a proprioceptive illusion which causes the midline of the body as well as the surrounding area to be perceived as if it was shifting to the stimulated side [47]. Additional studies show that this method, in combination with other "top-down" approaches such as scanning training, strengthens further therapeutic effects [48]. An application of just 5 minutes in order to prepare for subsequent therapeutic interventions has already been shown to improve the symptoms [49].

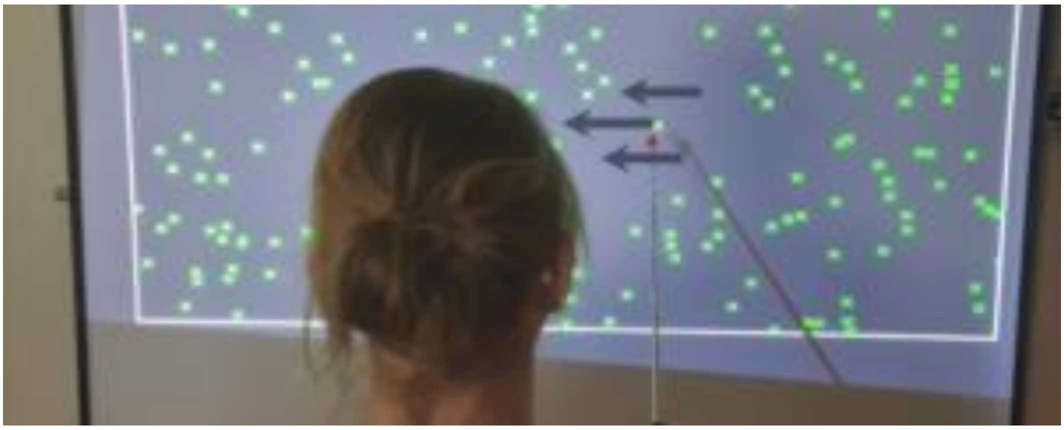

Figure 6 Optokinetic stimulation: The dots are displayed on a wall using a projector and move from right to left (neglect side) [52]

Optokinetic stimulation, as seen in Figure 6, is another approach that has been described as effective in the published literature. Using this method, affected persons observe small dots moving from the ipsilesional side towards the contra lesional side on a screen. These can be displayed on small screens as well as on large projectors. It promotes optokinetic nystagmus with the pursuit phase from one side to the other and fast eye movement to the neglected side. The evidence base for this method is extensive and shows significant positive effects on visuospatial neglect and subsequently on the implementation of activities of daily living.

A further bottom-up method is called prism adaptation. This procedure involves the use of visuomotor-adapted prism glasses that are worn for about 20 minutes, which is intended to adapt the spatial orientation [50]. Rossetti was among the first to find this technique, with the adaptation of the glasses accounting for about 10° of horizontal alignment. The same study found an improvement in neglect symptoms shortly after the glasses were removed and the effect was even more apparent two hours after treatment [51]. Several other studies also show an improvement in visual exploration to the neglect side, better somatosensory perception and an improvement in reading, writing and performance of activities of daily living [52]. Top-down approaches for example include visual scanning therapy. Several studies describe difficulties with top-down approaches, as a high level of attention is required from the patient and anosognosia tends to block this [53]. Current guidelines recommend, for instance, active exploration training, also known as visual scanning therapy. This was further developed by Pizzamiglio and aims to improve visual search behaviour and the active perception of stimuli on the contra lesional side. In the original training protocol, four standardized training modules were conducted. These included computerized digit detection projected on a large screen, copying a figure, picture scanning as well as reading and writing tasks. During active training, exploration to the affected side is encouraged through operant conditioning techniques and the development of compensation strategies. This includes reinforcing correct scanning movements and systematically practicing various search strategies [54]. During the interviews with the experts, the software "Headapp", "Optokin" and the program "RehaCom" were found to be digital training tools that both interviewees either already use or are familiar with. The "Headapp" software cooperates with the "NeuroVitalis" software described above. On the one hand, it offers exercises to improve visual scanning attention and response in a general sense. In Figure 7[1] it can be seen, for example, that the affected patient has the task of connecting letters in the correct order. If the patient does not find a letter on the ipsilesional side, the motivation to explore the contra

[1] Figure of “MatchIt” module in HeadApp: https://www.headapp.com/de/produkt/matchit/

lesional side is increased. The same application also provides optokinetic stimulation, which one of the interviewees described as particularly valuable.

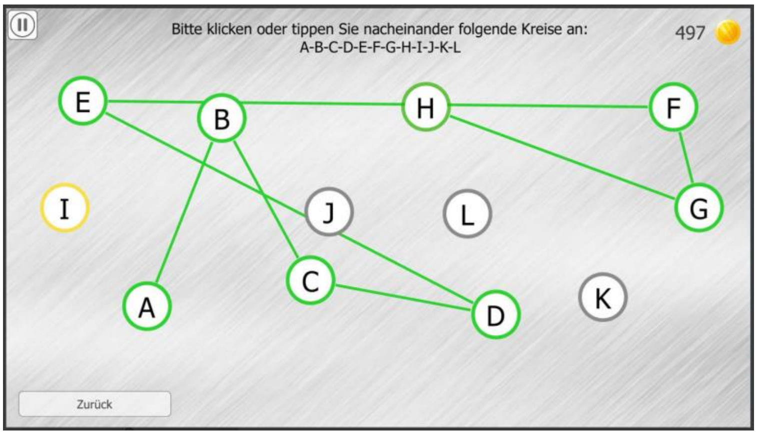

Figure 7 Visual Scanning within the software "HeadApp"

The "RehaCom" program was also highlighted by both interviewees. The "Visual Exploration" module in particular was described as effective and useful in everyday practice. This module of RehaCom provides two additional training items in which a gaze strategy is to be trained. In some parts, exercises can also be combined with optokinetic stimulation, whereby both bottom-up and top-down approaches are pursued. This is illustrated, for example, in Figure 8, where the patient has to recognize a certain number on the screen while optokinetic stimulation occurs in the background. The software is described as ideal for recording and analysing the training. As a personal profile is generated for each user, training progress is automatically documented and visualized in graphs. One disadvantage of the programme is the high cost of acquisition, as each module is licensed separately for larger companies such as hospitals and must be paid for extra. This contrasts with the "Optokin" program, which is significantly cheaper. Optokin offers a gamified version of optokinetic stimulation whereby certain factors can be individually adapted and designed. Specifically, the stimuli in the foreground, which were described above as "dots", can be altered into a range of images such as numbers, fish, or colourful shapes. The background can likewise be adapted in a variety of colours or patterns. The direction and speed of movement can be customized to suit the individual patient. There is no time data or analysis of progress [55].

Since intrinsic motivation plays an essential role, especially in patients with neglect symptoms, the current literature addresses the factors and possibilities of gamification [56] The term gamification describes the implication of playful design elements in a normally non-game context in order to generate desired behaviour by means of intrinsic motivation. Some research has already been conducted on this area in combination with virtual reality. There are differences between non-immersive virtual reality, where the desired image is displayed on a monitor, and immersive virtual reality, where virtual reality glasses are worn [57] There are significant results between traditional, non-digital therapy and non-immersive virtual reality therapy, particularly when performing cancellation tests [58]. Studies on immersive virtual reality therapy also revealed significant effects in terms of cancellation assessments and increased motivation [59]. It is therefore important to know motivational factors and to incorporate these in the treatment. Research was conducted in which reward systems were examined to encourage intrinsic motivation in neglect rehabilitation. It was shown that an expected reward can influence the level of attention positively. Neglect therapy should therefore be designed in a playful way with a certain incentive for rewards in order to achieve better results [60].

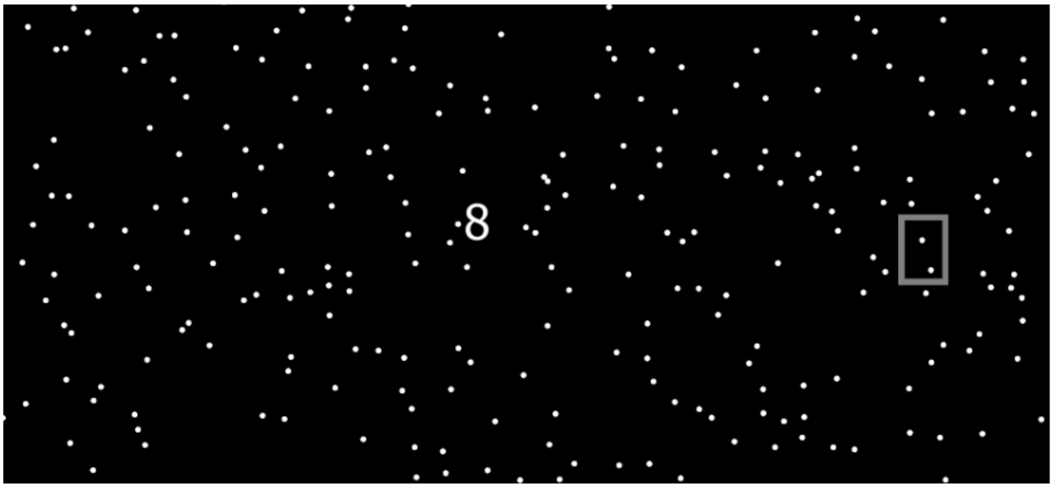

Figure 8 RehaCom module "Visual Exploration" in combination with optokinetic stimulation[2]

2.2 Touch Tables in Therapy: Use Cases and Related Work

A multi-touch table is used as the technical platform for the prototype to display the application on the screen. Multi-touch refers to the ability of the screen to simultaneously recognize and process more than one touch. This technology enables users to operate with both hands or with multiple fingers, for instance. This possibility makes it easier to configure user interfaces and interactions with digital objects, along with other things [61].

[2] Figure of RehaCom handbook of module “Visual Exploration”: https://hasomed.de/wp-content/uploads/2020/02/VISE.pdf

The multi-touch table hardware consists out of a type of table and a touchscreen technology. In the literature, this is referred to as Frustrated Total Internal Reflection (FTIR) for the optical recognition. In this process, an infrared light is projected towards an acrylic board. When touching the surface, the infrared light is then frustrated, and a reflection is created. This reflection is captured by sensors or an infrared-sensitive camera [62]. A significant advantage of touch-table technologies is that they are usually individually adaptable, as illustrated in Figure 9[3]. In addition to components that are already pre-selected, such as the screen size, other details are often variable. This includes, for example, the orientation of the screen. Some touch table devices can be tilted from 0° to 90°, allowing the table to be adapted to different areas as well as individual users. The height of the table itself can likewise be adjusted. In terms of therapy for stroke survivors, this may be particularly relevant for people sitting in wheelchairs. The Austrian company "WeTouch", for example, offers a good overview of current options[4].

Figure 9 Example of a multi touch table device which can be adapted in inclination and height

Touch tables have been tested in different environments in the past few years and have therefore also been applied in a variety of areas. In Tübingen, Germany, a project team developed a prototype for a patient record system running on a multi-touch table with the intention of simplifying the process of making a diagnosis. The advantages and disadvantages of the multi-touch table were also highlighted. One advantage concerns the support of cognitive processes. The ability to arrange documents in a free and simultaneous manner on the same screen allows information to be located and compared more efficiently. The ease of usability was also emphasized in the course of the project, as touch-based commands can be used to simplify the workflow. The possibility of displaying analyses on a larger surface also eases the process of filtering important information. A disadvantage is the difficulty of learning how to use the touch table. Since the technology may not be familiar to some users, it is essential that they are trained and use it regularly. In addition, some applications may have more complex touch functions

[3] Ideum Multitouch Tables, Touch Displays & Open Frame Monitors’: https://ideum.com/products

[4] Company WeTouch with overview of current touch tables: https://wetouch.at/

integrated (for example to zoom or rotate objects), which not every user is aware of [63].

Furthermore, the effects of touch tables on the respective users should not be overlooked. In the relevant literature, projects with children and young people in particular are described. One of the projects tested touch tables with regard to the learning effect on children. A customized game was developed to make it easier for children to learn programming. A control group with a standard touch computer and an intervention group with an interactive touch table were examined, whereby attention was paid to several factors such as touches per minute or verbal interaction per minute. The results show that the multi-touch table led children to learn the content more easily due to its highly stimulating nature [64]. Another project analysed the implementation of a multi-touch table as an interactive learning tool at the University of Bridgeport. The project focused on improving learning outcomes, promoting collaborative working, and increasing student engagement. It proved to be an advantage that students showed a longer attention span while using the touch table and were more engaged in the learning experience as a result of the interactive features. The high costs were described as a disadvantage. A lack of financial resources is frequently discussed in the context of touch tables [65]. However, it is assumed that the elderly in particular are not familiar with touch technologies and therefore using them within the healthcare sector may be challenging. In 2021, researchers investigated how touchscreen-based devices may affect the social behaviour and emotional regulation of people with dementia. The results show that the acceptance of technology varies depending on the individual person. For some of the elderly, the usage of touchscreen-based devices elicited a positive response, while others showed a certain scepticism and reluctance towards the technology. Nevertheless, the results of the study show that participation in activities can be increased with the device and that the general use of the devices can have a positive effect on mood and quality of life [66].

Touch tables have also been used repeatedly in therapeutic and nursing settings. Some companies, for example, already offer touch tables especially for care homes. These devices are mainly equipped with various apps for overall activation. Examples include programs such as drawing, strategy games, sensory apps, puzzles, and so on. Companies such as "Life Size Touch" also provide apps for making phone calls via Skype or Zoom as well as streaming programs with old films and documentaries [5]. Furthermore, there are projects for collaborative games

[5] Company Life Size Touch: https://lifesizetouch.com

on a touch table in care homes to promote social behaviour and maintain mental health. There is also a case study on this topic by the company "Newcare Projects". In this project, the aim was to mentally stimulate the residents of a care home and motivate them to engage in activities. Five different touch tables were installed and equipped with games for cognitive training as well as board games. It was found that the use of these tables quickly became part of everyday activities and the older people were able to initiate games on their own [6].

A further randomized controlled trial from the year of 2023 investigated the effects of cognitive training using a touch table compared to conventional non-digital exercises. Both of these interventions involved sessions of cognitive therapy over a time period of four weeks. The intervention group performed interactive multi - touch games on a touch table. The control group performed paper - pencil exercises. In both groups, the main focus lay on the fields of attention, memory and executive functions. The findings of the study revealed that both groups showed improvements in the cognitive aspect. However, the intervention group performed better in the area of memory performance, which indicates that interactive multi-touch games could be more effective in the area of memory support with older people. While both groups also improved in the area of executive functions, only the intervention group made significant progress. These improvements were particularly evident in cognitive flexibility. Overall, the results of the study indicate that cognitive training in combination with a touch table could achieve significant results and that further research is needed in this area [67].

[6] Touchscreen Tables for NewCare Homes, Project of Midshire: https://midshire.co.uk/case-studies/touchscreen-tables-innovate-newcare/

3 Methods and User Centred Design

The objective of this project was the development as well as the design of a prototype for evaluating and training neglect using a touch table and testing it with occupational therapists. This was a matter of concern from the very start, as a digital version of neglect treatment only appears to be useful if the target group embraces and integrates the system into everyday clinical practice.

In order to achieve this in the best possible way, the process of user-centred design (UCD) was followed. UCD refers to the entire process, including all techniques, methods, and procedures, of developing and designing a product or system to make it simple for the end user to work with. This approach proved to be useful in this instance, as it follows principles that were feasible to implement in this context and that pursue the objective of the project with solid quality. These include early interaction with potential end users, testing of the product and iterative adjustments [68]. The traditional UCD process is based on five different phases, as can be seen in Figure 10, of which the first three were followed during this project. Prior to the start of the process, a goal and overall vision for the finished end product were defined. These goals were adjusted to the end users and the current state of knowledge during the project.

3.1 Phase 1: Literature Research and Interview with Experts

The initial phase therefore involved analysing the needs and expectations of end users. An intensive literature research was conducted in order to determine these needs in a substantiated and targeted approach in subsequent interviews. In particular, the PubMed, OTSeeker, GoogleScholar, IEEE and ACM databases were used for the research. In January and February 2024, studies were sought that described stroke, neglect symptoms, occupational therapy assessment and treatment as well as relevant projects. Depending on the topic and focus, different inclusion and exclusion criteria were applied. Basic medical knowledge on stroke and neglect was identified from both current specialist literature and basic studies. As older studies were also referred to in the current study situation, no annual data were defined as exclusion criteria. For the remaining topics, an attempt was made to select literature from 2015 onwards.

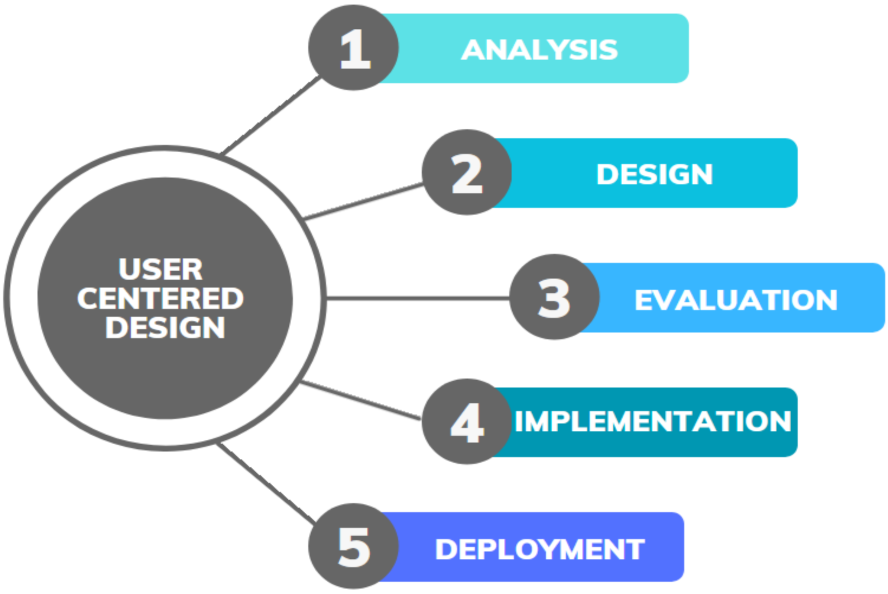

Figure 10 User - Centred Design Process represented by own illustration

The selected literature was initially sorted and analysed exclusively for the purpose of explanation and introduction to the subject area. A structured interview guide with three introductory questions, six main questions and four possible intermediate questions was created for this purpose. The questions were openly formulated to allow qualitative information to be identified. Among the topics covered by the questions were state of the art evaluation as well as training methods and determining which of these methods are most practicable in everyday clinical practice. In addition, already known digital applications were highlighted and the advantages and disadvantages of the digital tools were compared to conventional methods. As a concluding but comprehensive question, the needs for technical solutions and possible requirements for a prototype were identified. A total of two interviews were intended for this purpose and these were also carried out. The aim was to find individuals who had not only been working as occupational therapists for at least six months, but who also worked at least part-time in an acute neurological setting. These conditions were verified on the basis of the health professional registry ("Gesundheitsberuferegister" of Austria). Both interview participants had a knowledge of German above B2 level, which ensured the absence of any language barriers. These inclusion and exclusion criteria were determined in order to achieve a certain level of professional experience and therefore knowledge of the subject matter. One of the two interviewees had nine months and the other two years and eight months of professional experience, and both work full-time in an acute healthcare setting. The interview partners were contacted by personal request as well as e-mail and were asked for an interview. The interviews were carried out voluntarily and without financial or material compensation. However, before the interviews were conducted, a form with a voluntary declaration of consent and information on the protection of personal data was provided and signed. The interviews were performed on 4th and 6th of March, towards the end of the literature research. Both interviews were held during daytime and lasted approximately 15 - 20 minutes in each case. Only the individual interviewee together with the project lead were present during the interviews in a one-to-one meeting. Before the start of the actual interview, the experts received information about the topic of the project and the envisioned prototype. The procedure for the interview and the further processing of the collected data itself was likewise discussed. Both interviews were recorded with an audio recorder for further processing after consent had been given. The audio recordings were next transcribed in the form of written notes. The transcripts were then read through several times and relevant sections of text were assigned with codes. These codes referred to previously defined key areas, meaning that deductive coding was carried out. This resulted in a categorization and combination of the subject areas and revealed intersections between the two interview results. Information from the interview findings was subsequently used on the one hand to complete the theoretical background. On the other hand, the detailed outcomes were also used to answer the first research question and were further processed in chapter 4.1 using a qualitative content analysis and a tabular visualization.

The limitations of the project here already became evident during the interview, as some preferences could not yet be integrated into the prototype as part of the project due to a lack of time resources. These include, for example, the creation of patient profiles, several evaluation tools for assessing neglect and different training modules. For further information on the limitations of the project see chapter 5.2.

3.2 Phase 2: Design and Structure of the Prototype

The analysis was followed by the second phase whereby a prototype was developed and designed. This first involved creating a fundamental structure along with the first rough version. The tools for evaluation and training were customized as best as possible to the current evidence on neglect treatment. Once the technical basis was set, the requirements of the experts identified in the interview were integrated directly to the prototype. These included requirements for the therapeutic tools on the one hand and requirements for the touch table as a device and its integration into everyday clinical practice on the other.

The application was programmed for .html with the phaser framework features an evaluation tool alongside a training module with three different levels of difficulty. After an intensive internet survey, phaser was chosen because it is considered a popular open-source framework for developing interactive html5 programs and is apparently simple to understand. The development of the prototype was started by designing the evaluation interface using Phaser2DEditor. This is a software by phaser that enables simple design of the user interface using a drag and drop approach. It enabled a simplified division of the stimuli into the corresponding areas and quadrants, see Figure 14 for a detailed explanation of the defined areas. The code for this was written in typescript, which was retained for the rest of the prototype and appears to be usual for phaser. Basically, thirteen different scenes were developed and linked together to form a program using an index.ts file. In this instance, the scenes refer to each additional interface, such as each level, each level explanation, the evaluation, and so on. As can be seen in Figure 11, all scenes are merged in this index.ts file by importing them from the respective file path with “import”.

```
import Phaser from "phaser";
import evaluation from "./scenes/evaluation";
import mainmenu from "./scenes/mainmenu";
import DataCollection from "./scenes/dataCollection";
import preevaluation from "./scenes/preevaluation";
import postevaluation from "./scenes/postevaluation";
import pretraining from "./scenes/pretraining";
import pretrainingone from "./scenes/pretrainingone";
import pretrainingtwo from "./scenes/pretrainingtwo";
import pretrainingthree from "./scenes/pretrainingthree";
import levelOne from "./scenes/levelone";
import levelTwo from "./scenes/leveltwo";
import levelThree from "./scenes/levelthree";
import posttraining from "./scenes/posttraining";
```

Figure 11 Code from index.ts file to import all scenes used in the prototype

An event listener has also been inserted in the same file, which on the one hand ensures that the configuration options regarding the width and height of the screen, alignment and screen colour are set and on the other hand ensures that the main menu is started after loading the page. Since a complete presentation of the code would go beyond the scope of this thesis, only an exemplary excerpt of the evaluation scene is provided below. The structure of the user interface and consequently the evaluation scene is described in more detail in the text below. The following code illustrates both the process of marking a target stimulus and the differentiation between target stimuli touched in the left and right halves of the screen. The division and differentiation are essential for the evaluation by occupational therapists, making this function an important part of the prototypes. Looking closer at the code in Figure 12, you can see the function parameter "index," which indicates which of the targets was clicked. First, an if statement checks whether the timer has already been activated and is still running. If this condition is met, touching the target stimuli is possible. If such a stimulus is then touched, "this.targetsClicked[index]" checks whether the individual stimulus has been touched before or not. If the target has not been touched yet, the score is incremented by one point, and the target stimulus is crossed out horizontally with a red line. "this.timer.destroy()" in this context means that the timer is stopped once all target stimuli have been found. The if statement "if (target.x < this.cameras.main.width / 2)" checks whether the found stimuli are located to the left or right of the screen's center line. Accordingly, the respective arrays "targetsOnLeft" or "targetsOnRight" are incremented by one point each. This allows for an appropriate breakdown of the distribution between the right and left halves of the screen.

```
onTargetClick(index: number) {
    // Check whether the timer is running
    if (this.timer && !this.timer.paused && this.timer.getElapsedSeconds() < this.timeElapsed) {
        // Check whether the target has not yet been clicked
        if (!this.targetsClicked[index]) {
            this.playerScore++;
            this.targetsClicked[index] = true;
            // Update score
            this.updateScoreText();
            // Crossing out the clicked stimulus
            this.drawStrikeThrough(this.targets[index]);
        }
        if (this.playerScore === this.targets.length) {
            // Stop timer when all targets have been found
            this.timer.destroy();
        }
        const target = this.targets[index];
        // Check whether the target was touched on the left or right
        if (target.x < this.cameras.main.width / 2) {
        // The target was touched on the left
        this.targetsOnLeft.push(index);
        } else {
        // The target was touched on the right
        this.targetsOnRight.push(index);
        }
    }
}
```

Figure 12 Code for processing pressed target stimuli: Detecting, crossing out, updating score, and distributing on the screen.

Due to the language skills of the test participants, the entire software is written in German. Starting the software will display the main page. It shows a broad heading with the words "NeglectCare" and includes three different buttons, "Evaluation", "Training" and "Auswertung" as can be seen in Figure 13.

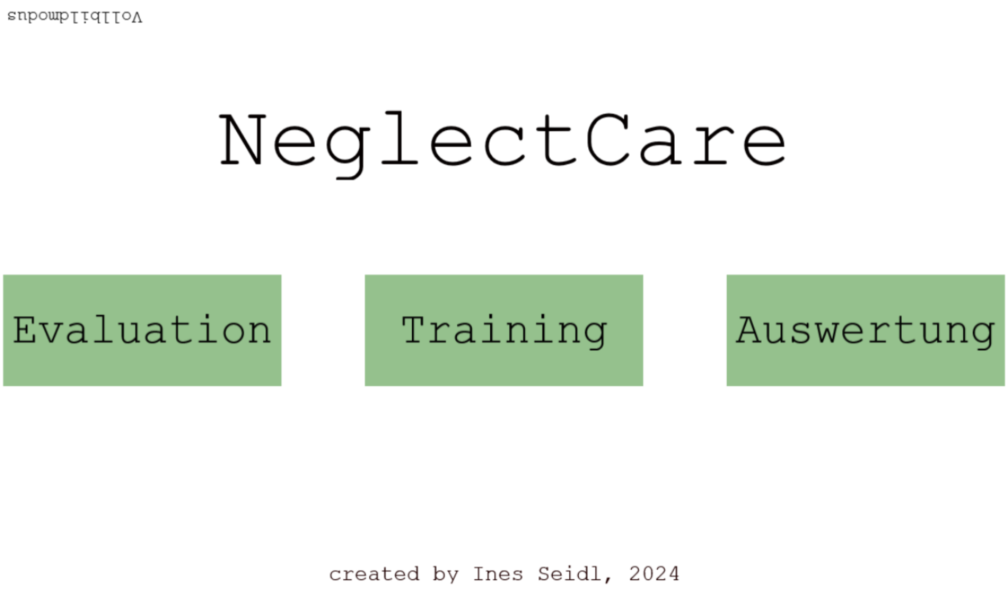

Figure 13 Home page of the developed software: three different buttons along with a twisted toolbar for the therapist

Touching the "Evaluation" button reveals instructions describing the subsequent test and displaying an illustration of the stimulus that is being searched for. An animated image was chosen to clarify the task. The therapist responsible for carrying out the test is then able to access the test and start the time measurement by pressing the start button. A screen with 120 similar-looking images appears. Forty of these images represent the target stimuli. The remaining eighty images represent four different distraction symbols. An attempt was made to divide the symbols into twenty areas to enable a more specific analysis. Five of these areas are in each of the four quadrants, i.e. top and bottom left as well as top and bottom right. There are two target stimuli in each area. Distraction stimuli were not considered. Bickerton et al also carried out a similar subdivision when creating the Apple test [28]. The auxiliary lines as shown in Figure 14 are not visible when the evaluation tool is used. The dark blue lines in the figure show the subdivision of the four quadrants, while the light blue lines indicate a rough subdivision of the individual areas. The illustrations are reminiscent of existing paper and pencil tools that are used to differentiate between allocentric and egocentric neglect. The patient to be tested now faces the task of searching and touching all target stimuli. By touching an image, both target and distraction stimuli, the illustration is crossed out by the appearance of a horizontal line. This is intended to symbolize to the patient that this visual stimulus has already been touched. The time measurement can be paused or stopped completely by pressing the buttons seen on the right upper corner in Figure 14. If, for instance, a disruptive event occurs in the meantime (such as distractions in the room, various needs of the patient, and so on), the time measurement can be interrupted by pressing the pause button. The timer can be continued at any time by pressing the start button. As soon as the patient has found all the target stimuli, the time measuring as well as the presentation of the test stop automatically. If the patient verbally indicates that they think that all target stimuli have been found, the therapist can press the stop button. At the end of the test, a screen appears in which the patient is positively encouraged regarding the completion of the evaluation before the main screen appears again.

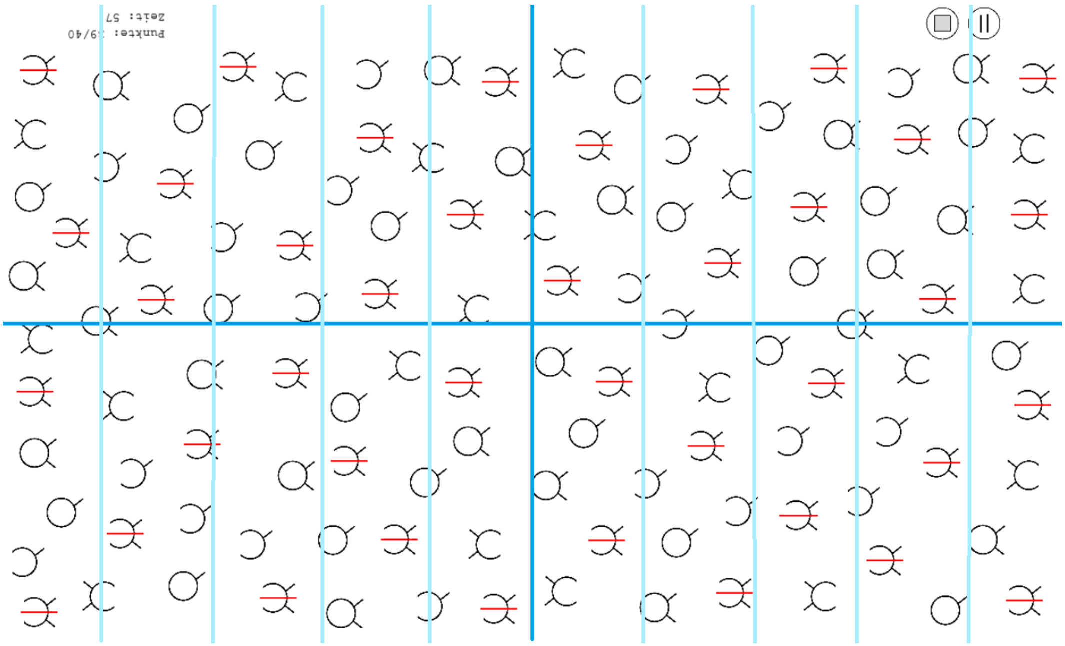

Figure 14 Evaluation tool with visualization of the broad subdivision into different areas for more specific analysis

As soon as the "Training" button is touched, a selection of three different levels is offered. Once a level has been chosen, an instruction for the respective exercise is displayed. As with the testing tool, the therapist can also use the start, pause, and stop buttons to influence the execution as well as the time measurement. All levels are based on the concept of optokinetic stimulation, which has the highest level of evidence in current research for the treatment of neglect. The basic task here is to steer a coloured ball that moves from right to left into a field of the same colour. The ball appears on the right-hand side of the screen and moves at a steady pace towards the left-hand side of the screen. Each time it reappears, it changes to a different colour. On the left side of the screen there are colourful bars that correspond to the colours of the ball. On the right side of the screen a vertical grey bar allows moving the ball up and down by touching the screen. If the ball is moved into the correct field, the score increases by one point. Otherwise, the patient receives no points. The therapist has the option of varying the speed of the ball using two different buttons. "Level 1" corresponds to the lowest skill level. In this case, the ball only changes between two different colours (red and blue) as can be seen in Figure 15.

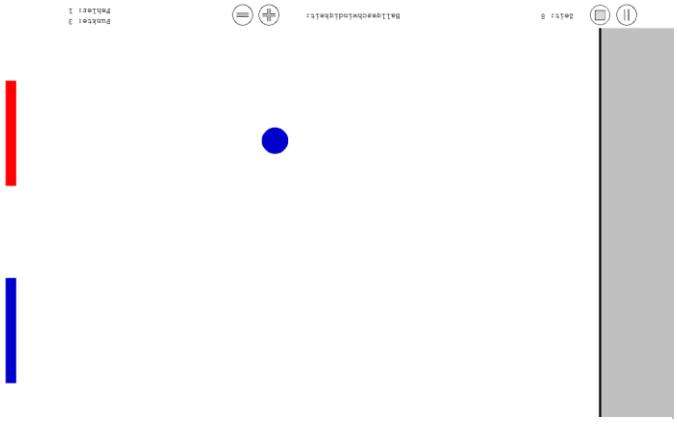

Figure 15 Visualization of the first level where the toolbar with points, time and control buttons as well as the grey steering bar are shown

"Level 2", as shown in Figure 16, corresponds to a medium level of difficulty. At this level, the ball changes between five colours (red, blue, yellow, green, and purple), making the coloured bars on the left-hand side of the screen smaller and therefore more difficult to hit. Level 3 is very similar to level 2, but in the background there can be seen other, grey-coloured symbols moving from right to left, which serve as a distraction, see Figure 17. After completing the exercise by pressing the stop button, a short sentence appears to give the patient positive reinforcement.

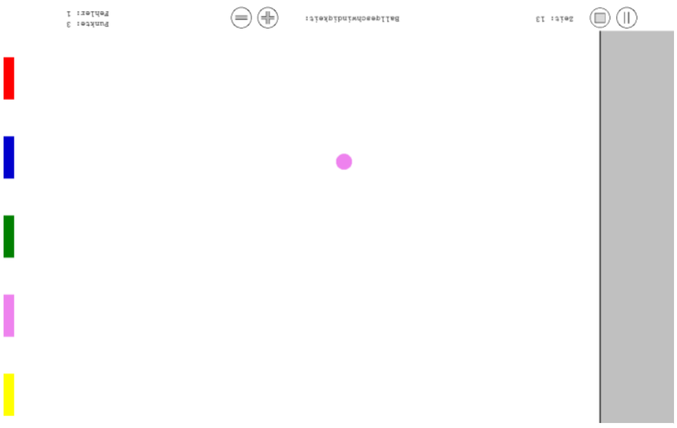

Figure 16 Visualization of the second level with more coloured bars and smaller ball size

Test and training results can be accessed via the "Auswertung" button. The test results include the date, time, the number of identified target stimuli with an additional specification of how many of these stimuli were found in the right half of the screen and how many in the left half, errors and time taken to complete the test. In addition to this list, a button has also been integrated that enables downloading a picture of the completed test. The training results include the specification of the level,

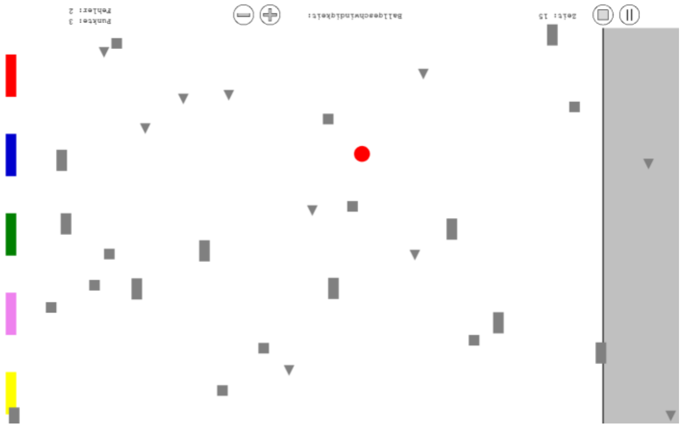

Figure 17 Representation of the third level with distracting elements in the background

date, time, number of correctly hit fields as well as the total number of balls shown and the overall execution time. The representation of the evaluation table is shown in Figure 18.

Auswertung Evaluation

Datum	Uhrzeit	Punkte Gesamt	Punkte Links	Punkte Rechts	Fehler	Gesamtzeit	Download
14.05.2024	17:03:52	20 / 40	5 / 20	15 / 20	3	00:18	Test speichern:

Auswertung Training

Level	Datum	Startzeit	Punkteanzahl	Gesamtzeit
Level 3	14.05.2024	17:04:52	2/6 korrekt	00:17
Level 2	14.05.2024	17:04:29	4/7 korrekt	00:16
Level 1	14.05.2024	17:04:08	5/6 korrekt	00:11

Hauptmenü

Figure 18 Presentation of the evaluation table, with exemplary data

In terms of usability, it is important to mention that the buttons for the therapist are located at the top of the screen and have been rotated by 180°. This makes the software easy to use, as the therapist usually sits opposite the patient in everyday clinical practice. As a result, the content can be read and controlled more conveniently.

3.3 Phase 3: Evaluation and Setting of the Usability Testing

Phase three involved already the evaluation of the prototype. Prior to testing the prototype directly with potential end users, it was discussed and modified in consultation with the project advisor and two further colleagues within the field. As a result, fine adjustments could already be made in order to focus specifically on the research questions within the actual testing unit. This usability test aimed to determine whether the prototype may be relevant for everyday use in clinical practice. For this purpose, five test subjects were approached by email and given information about the context of the project. Prerequisites for participation in the usability testing were at least six months of occupational therapy work experience in an acute neurological setting, working at least 15 hours a day, as well as German language skills of at least level B2. These inclusion and exclusion criteria were checked based on a review of the Austrian register of healthcare professionals ("Gesundheitsberuferegister"). The inclusion and exclusion criteria were tailored to the available time constraints and resources by the project lead as best as possible. Participants were required to be proficient in the German language to use the prototype and understand the interview questions. Rubin et al generally recommends a large number of test subjects to ensure a more comprehensive understanding [68]. However, due to time limitations, this recommendation, as well as the criterion for professional experience, could not be followed.

In total, five female participants participated in the usability test. A total of two different departments were approached for this purpose. There were no male occupational therapists in either of the workplaces, which implies that a limitation can be assumed here. Additionally, it is important to mention, that only about 6.13% of all occupational therapist in Austria are male [69]. The target group therefore consists mainly of female therapists. Four of these test participants are employed in the same workplace and provide treatment to neurological patients in acute and early rehabilitation settings as well as in a stroke unit. This means that they care for patients in rehabilitation phases A - C. One participant works predominantly in phases A and C. As can be seen in Table 1, both young as well as very experienced participants were included. This enables a comprehensive survey of different expectations and needs of the prototypes.

The usability testing was conducted on 14.04.2024 and on 16.04.2024. The first testing therefore was conducted on a Sunday and, because the test person requested it, was held at their home. The other testing sessions were conducted during the working hours of the participants at their workplace, as can be seen in Figure 19. The testing was conducted in a one-to-one setting between the participant and the project manager. The followed interview was held in a one-to-one setting between the participant and a project assistant.

The participant was greeted, and a description of the project was provided both in writing and verbally. The procedure for the upcoming test was then discussed and any unanswered questions were clarified. The declaration of consent can be viewed in the appendix. It has been adapted to the language of the participants and was therefore written in German. The participants received both a written description of the project objective and the research question as well as clarification of further verbal questions before the start. The declaration of consent also includes permission to record audio and video material, which was only made available to the project lead. In addition, the participants voluntarily agreed to the data protection regulation and the testing. All participants gave their consent to allow both the testing and the subsequent interview to be recorded with video and audio.

User ID	**Age in years**	**Gender**	**Experience overall**	**Experience in neurologic field**
A	23	female	10 months	10 months
B	32	female	9 years	9 years
C	38	female	16 years	15 years
D	56	female	33 years	29 years
E	43	female	19 years	19 years

Table 1 Specification of the participants

Once the organizational issues had been dealt with, all participants received brief instructions for the touch table along with an overview of the software. A description of the test scenario was first provided. On this scenario, there were several different tasks that the participants had to accomplish independently. The test scenario can also be viewed in the appendix. The individual tasks were listed in the German language as follows:

- Open the neglect evaluation tool and perform one test: find at least ten stimuli on the left half of the screen, find at least fifteen stimuli on the right half of the screen, trigger at least two errors
- Open the training tool and perform level one for one minute: adapt the ball speed at least twice, trigger at least two errors
- Open the training tool and perform level two for one minute: adapt the ball speed at least twice, trigger at least two errors
- Open the training tool and perform level three for one minute: adapt the ball speed at least twice, trigger at least two errors
- Open analysis: Enter information manually in spreadsheet, download image file of the evaluation tool

Figure 19 Representation of the two testing environments. On the right, the first test conducted in the home environment of test participant A during the execution of Level 1 can be observed.

The participants performed the test scenario at their own individual pace, and it was recorded by a video camera as well as a screen recording for further processing of the data collected. Each of the participants was able to master the required tasks. During the second test, connection issues occurred with the Internet of the participant's workplace. It was no longer possible to run the software, although a solution to the problem was found after about two minutes. As a result, the test had to be restarted after about 45 consecutive seconds. Up until then, no tasks had been carried out and the participant had to restart from the beginning.

During the last test, the touch table showed signs of overheating. The screen had already warmed up considerably and no action could be performed anymore on two occasions during the test. The computer therefore had to be restarted twice. Thanks to the video recording, however, the test runs could still be analysed precisely, meaning that the technical difficulties had no influence on the test results. For the results three different user experience metrics have been recorded during the testing. These firstly include the task completion rate. It measures the success of the individual tasks by means of a scoring system. Each sub-step which was completed correctly and without any assistance was awarded with two points. In case the participant requested verbal support and then completed the task correctly, the sub-step was awarded with one point. If the task could not be completed, zero points were awarded. Furthermore, the time on task was also measured. This indicates that the time for each individual sub-step was recorded individually. The intermediate reading of the test scenarios was not considered. Finally, the user error rate was as well analysed. All unintentional deviations from the task were counted and documented. These user experience metrics were identified and evaluated both through a screen recording and a detailed analysis of the video material.

Once the scenario had been completed, an interview was then conducted based on an interview guide. As already mentioned, the interview was conducted by a project assistant who was not known to the test participants beforehand. This was to prevent any possible bias on the part of the participants in order to be able to generate the most objective opinion and estimation of the prototype possible. The touch table as the executing device and the prototypical software were reflected and analysed along with the test participants. The interview guide consisted of a total of three introductory questions relating to the training, professional experience and everyday tasks of the individual test subjects. This was followed by a total eight main questions. The questions addressed the individual sub-steps as well as the advantages and disadvantages of the different tools and the prototype as a whole. The potential relevance of the prototype for everyday clinical practice and how it might be integrated into a work process were considered. Likewise, suggestions for improvement and wishes regarding user-friendliness, design and functionality were discussed. The findings of the interview following the usability testing can be found in chapter 4.2. A straightforward usability test as well as a qualitative survey of experts' professional opinions were therefore carried out here. This methodology was chosen in order to achieve a meaningful result that is underpinned by precise numbers on the one hand and by statements from the relevant professional group on the other. The qualitative survey not only enabled a more targeted analysis, but also defined guidance for future projects.

3.4 Phase 4: Analysis of Results

The fourth phase of the user-centred design process would incorporate the implementation of the results. An actual implementation and subsequent deployment represent a limitation for the current stage of the project due to a shortage of time resources. Nevertheless, the collected results and data were then sorted, analysed, and finally interpreted.

First, both the video and screen recordings were analysed with regard to the three user experience metrics described above which were then compiled in tables. When capturing the time on task metric, attention was paid to ensuring that times spent reading through the task or times caused by technical problems were subtracted from the actual execution time. The task completion rate as well as the user error rate were also precisely documented via video analysis. The subsequent interview was then transcribed and coded. Key aspects and suggestions for modification were examined in greater detail. The evaluation and analysis of the data took around ten days from the time of testing.

After the results were analysed, they were scientifically documented in chapter 4. The results were presented using various bar charts as well as descriptive statistics. The contents, both positive aspects as well as problems and suggestions for solutions, were then discussed and compared with other relevant studies and projects in chapter 5.

4 Results

The research questions are answered gradually, taking into account the interview data and user experience metrics. For a better overview, the results relating to the research questions were divided into three chapters.

4.1 Requirements for Detecting and Quantifying Visuospatial Neglect Defined by Occupational Therapists

Research question one, as described in the introduction, deals with the requirements that are defined by occupational therapists to recognize and quantify a neglect. The results of the two expert interviews were analysed to answer this question and presented descriptively.

During the interview, both experts mentioned similar methods for identifying a neglect, which predominantly involved conventional paper-and-pencil tasks. As in the literature, both experts referred to the star cancellation test, the line bisection test, the line crossing test as well as the clock test. In addition, one of the experts also mentioned reading tests, the E&R test, the bells test, and assessments with haptic materials. The star cancellation test is most frequently used for evaluation by both experts and is justified on the grounds that it demonstrates the severity of a neglect symptom quite accurately. However, both experts also emphasized that a variety of assessments are usually used to gain a comprehensive impression. Digital diagnostic methods are rather unknown to both experts, although the RehaCom program as well as the CogPack program were mentioned. The disadvantage of current digital assessments appears to be the lack of standardization and the need to switch from paper format to computer. The experts identified the sustainability aspect, the ability to archive the data directly, the detailed data gathering and the possibility of variation as potential advantages.

In contrast to the evaluation of a visuospatial neglect, digital programs are already being used more commonly for the training. Conventional methods include, for example, daily training in everyday situations, describing pictures, exploring memory cards as well as reaching targeted stimuli. When training with digital methods, both experts stated previous experience with different programs. Both experts mentioned the CogPack program, optokinetic stimulation with Optokin3 and Neurovitalis, among others. In addition, one expert each mentioned RehaCom, Headapp and NeuroTrack. The disadvantages of these training methods were the lack of a haptic component and the questionable added value for the patient's actual everyday life. The advantages mentioned were the size of the work surface for exercises with a projector, the flexibility and the playful design of the programs.

Requirements for detecting and quantifying a visuospatial neglect	**Expert A**	**Expert B**
Possibility of obtaining comparable values	mentioned	mentioned
Archiving of the test	not mentioned	mentioned
Adaptation of the image size	mentioned	not mentioned
Variety of testing material	mentioned	not mentioned
Patient-oriented explanation	not mentioned	mentioned
Standardization	not mentioned	mentioned

Table 2 Requirements for detecting and quantifying a visuospatial neglect

Considering the advantages and disadvantages mentioned above, there are already some requirements that a prototype for neglect detection and quantification must fulfil. In addition, the experts also expressed wishes and needs for such a prototype as also can be seen in Table 2.

1. Possibility of obtaining comparable values: As an important requirement the possibility of being able to make comparisons between the test and training data collected over several therapy sessions was stated. The desire to obtain statistical evaluations such as the mean and deviations from the norm was also expressed.
2. Archiving of the test: Direct storage or archiving of the assessment is seen as essential, as this also makes it possible to demonstrate the respective progress to the patient.
3. Adaptation of the image size: It was stated that assessments should be adaptable to possible visual impairments in order to improve the validity of the results.
4. Variety of testing material: In order to obtain a comprehensive picture of neglect symptoms through multiple data, a variety of testing material should be available.
5. Patient-oriented explanation: The explanation of various assessments is sometimes difficult for patients and simpler methods are needed in this regard.

6. Standardization: The standardization of assessments is essential for their validity and for communication within the interdisciplinary team.

4.2 Functional and Technical Requirements for Developing a Touch-Based Interface for Neglect Care

The second research question aims to identify the functional and technical requirements for a prototype that is used in occupational therapy for neglect treatment. In order to answer this question, an interview was conducted after a usability test had been carried out on the prototype.

In the following context, the functional requirements relate to the software that was developed for the purpose of assessing, training, and evaluating neglect. The technical requirements relate to the touch table as a representation device. During the interview, both advantages and disadvantages of the software were identified, resulting in clear requirements and wishes. The software has already been described in chapter 3.2. The following aspects were described by the participants in relation to the functional requirements:

1. User-friendliness: Every participant described the user friendliness as an advantage of the prototype. The buttons and switches were easy to understand, and the targeted tasks could be performed intuitive.
2. High degree of exploration: The size of the representation and the wide-ranging distribution of the stimuli were described as an advantage and added value compared to other programs.
3. Clarity of the results: The listing and presentation of the results was confusing for some of the participants. The breakdown of the results was described as misleading and also had an impact on the user error rate in the user experience metrics. A clearer listing is described as a requirement.
4. Significance of the results: Test subjects perceive the variety of the results, meaning the exact execution time, points and errors and the division between left and right recognized stimuli as an advantage of the software. The results were described as highly informative.
5. Understandability of the descriptions: Some of the test subjects found the descriptions of the individual tools to be detailed and comprehensible. Nevertheless, there was an increased error rate in some cases, which would imply an even more precise and simpler explanation.

6. Possibility to adjust difficulty: The evaluation tool in particular was described as highly demanding for severely affected neglect patients or for those with spatial deficits. A possibility for gradation and individual adaptation is necessary.
7. Variety of tools: Test persons would prefer a larger selection of evaluation as well as training tools. For an actual purchase, the software would have to have more options to choose from.
8. Patient register: Saving and backing up data and results was also mentioned by some participants. Creating a patient-specific file would make follow-up checks much easier in the long term and improve monitoring of the process.

Table 3 lists, how often each of these functional requirements were mentioned and if they were described as a useful advantage of the prototype or if the participants missed those details. Therefore a "p" shows which requirements were mentioned as well as described as a positive advantage in this prototype. The "n" shows which requirements were mentioned but were described as a negative detail in the prototype. Empty spaces indicate which requirements weren't mentioned by the individual user at all.

Functional requirements for developing a touch–based interface for neglect care	**User ID**				
	A	**B**	**C**	**D**	**E**
User-friendliness	p	p	p	p	p
High degree of exploration	p	p		p	
Clarity of the results		p	n	p	p
Significance of the results	p			p	
Understandability of the descriptions	p				n
Possibility to adjust difficulty	p		n		n
Variety of tools	n			n	n
Patient register	n			n	

Table 3 *Functional requirements:* "p" shows which requirements were mentioned as a positive advantage. "n" shows which requirements were described as a negative. Empty spaces indicate which requirements weren't mentioned.

As already mentioned, the technical requirements for the prototype focus on the touch table as a representative device. None of the participants had any previous experience with this type of device, which means that a similar starting point can be assumed. Here as well, the participants discussed both advantages and disadvantages in the subsequent interview. From this, basic requirements for the device were identified that are crucial for integration into everyday therapy.

1. High level of encouragement: Some participants recognize the device as an appealing tool that can be used in a variety of ways for neglect treatment.
2. Large representation area: The size of the screen for therapy was described as a clear advantage and added value compared to conventional screens. According to one participant, this means that more subtle neglect symptoms may also be detected.
3. Storage of the table: Some of the participants described a lack of storage space at their workplace. Small therapy rooms do not allow a permanent place for the touch table. The device must be easy to stow away, for example with a removable or folding screen.
4. Height-adjustable table: The table height posed a significant problem for one of the participants, as the screen surface reflected in the light due to her shorter body height. The table needs to be adjustable, especially for wheelchair users.
5. Transportation of the device: The table can be used optimally for therapy if, for example, it is equipped with wheels for easy transportation. This allows therapy to take place directly in the patient's room.
6. Short set-up process: During the test, the participants recognized technical problems in terms of long starting times as well as overheating. Switching on the table and starting the program must proceed more quickly.
7. Reactivity of the touchscreen: When touching some buttons or surfaces, for example in the training module of the software, the inputs were not always taken over adequately. This can lead to incorrect evaluations. Precise and fast touchscreen responsiveness is essential for effective use.

Table 4 lists, how often each of these technical requirements were mentioned and if they were described as a useful advantage of the prototype or if the participants missed those details. Therefore a “p” shows which requirements were mentioned as well as described as a positive advantage in this prototype. The “n” shows which requirements were mentioned but were described as a negative detail in the prototype. Empty spaces indicate which requirements weren’t mentioned by the individual user at all.

Technical requirements for developing a touch–based interface for neglect care	**User ID**				
	A	**B**	**C**	**D**	**E**
High level of encouragement	p		p	p	p
Large representation area	p	p		p	p
Storage of the table		n	n	n	n
Height-adjustable table	n				n
Transportation of the device	n	n			
Short set-up process		n	n		
Reactivity of the touchscreen			n	n	

Table 4 *Technical requirements:* "p" shows which requirements were mentioned as a positive advantage. "n" shows which requirements were described as a negative. Empty spaces indicate which requirements weren't mentioned.

In addition to the requirements mentioned above, the participants also expressed concerns regarding integration options in everyday clinical practice. On the one hand, the purchase of the device was discussed. It must therefore be possible to justify the high cost of the device by offering a wide range of services. The participants questioned whether the company would finance such a device for the representation of one software. Some consideration should be given to the environment where the table would be located. It was mentioned that other conversations or background distractions in the room are already perceived as disturbing for people without neglect. A quiet room must be provided in order to achieve a high level of concentration and attention. Two of the participants expressed problems with the lighting conditions in the room, whereby the images on the screen were no longer sufficiently recognizable. It must be possible to darken the room in order to enable adequate evaluation and effective training. One participant with a slight visual deficit described the horizontal alignment of the tabletop as inconvenient. An angled alignment would enable patients with visual impairments to have a better user experience.

4.3 User Experience Tested for a Touch Table Application by Occupational Therapists

The third research question deals with the three different user experience metrics that were collected during the usability testing of the discussed prototype. Each of the user experience metrics was collected individually for the five different tasks.

The tasks and the test setting were described in chapter 3.3. In Table 11 all tasks are briefly mentioned again and related to the respective mean values of the user experience metrics.

The time on task metrics provide an overview of the time required for individual tools, but also the progression of ease of use. Times between individual tasks (e.g. for reading the task) were not considered. Table 5 shows that the average time required to complete the first task, in other words the evaluation tool, lasted for an average of one minute and 51 seconds. Two of the users performed below the average while three participants performed above this average. The consideration of tasks two to four here was interesting as the tasks were very similar. These tasks focus on the performance of levels one to three. It can be observed that learning, understanding and performing the first level still took an average of two minutes, while understanding and performing the third level was already more than 25% faster with an average time of one minute and 27 seconds. Task number four was therefore completed the fastest on average. The fifth task required the most time. This task was completed in an average time of two minutes and 27 seconds, although there was a significant outlier in this regard. User D took exactly twice as long with a time of four minutes and 16 seconds as the next fastest user B with two minutes and eight seconds.

	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Total**
User A	01:39	02:32	01:52	01:59	02:00	10:02
User B	01:20	01:48	01:30	01:24	02:08	08:10
User C	01:53	01:40	01:18	01:09	02:01	08:01
User D	02:18	01:53	01:50	01:29	04:16	11:46
User E	02:06	02:08	01:23	01:18	01:50	08:45
Mean	**01:51**	**02:00**	**01:34**	**01:27**	**02:27**	**09:20**

Table 5 *Time on Task*: The table provides insight to the duration of individual tools and the progression of ease of use. Notably, tasks two to four showed increased efficiency, while task five exhibited the longest duration, with User D as a significant outlier.

Overall, it can be concluded that it takes approximately nine minutes and 20 seconds to complete all tasks. Based on the results of chapter 4.2 and this mean score, it can be assumed that the device and software require a maximum of twelve minutes to learn how to use. With the exception of one outlier, no task took more than three minutes, even though the reading of the tool explanation and a test session had been completed. This finding is in line with the generally positive statement on user-friendliness identified in the interviews. Table 6 visualizes the individual execution times of a single user in contrast to the time required by other users. The colored bars represent the particular tasks and the length of the bars indicates the time required to complete them. A comparison of the individual users shows that user C needed the least time to complete the task, at eight minutes and one second. User D needed the most time to complete the individual tasks, with a total of eleven minutes and 46 seconds. User B was the only user who was faster than average in all tasks.

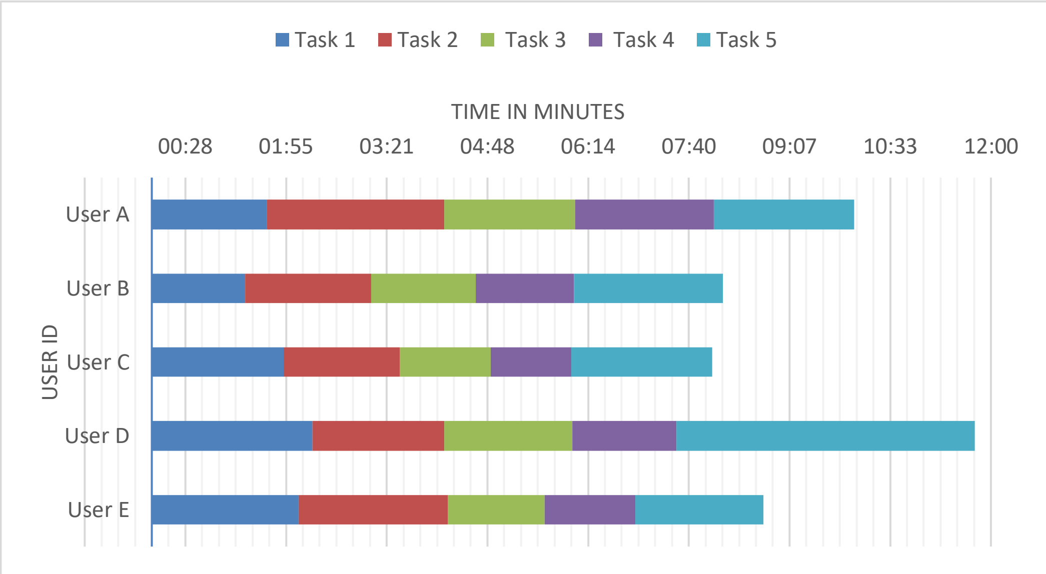

Table 6 *Time on Task:* The table illustrates the individual execution times of one user compared to others. The coloured bars represent the specific tasks, with the length indicating the time required to complete them. The average time for all tasks is approximately nine minutes and 20 seconds, suggesting that the device and software can be learned within a maximum of twelve minutes.

The user error rate describes the average number of errors that are measured during the execution of the individual tasks. Table 7 shows the error rate for each task and each user. In this case, the coloured bars represent the individual users. The height of the bars provides information on how many errors were made by each user. The red line in between represents the mean value of the user error rate per task. In general, it can be observed that only during the execution of the first task every user made at least one error and that there were no errors in the fourth task. Therefore, the first task also has the highest user error rate with a total of nine errors. This was followed by tasks two and five, each with five errors made by four users. In task three, only user D generated an error and task four was completed correctly by all users. The first task mainly identified the handling of the individual buttons as an error. As it is necessary to press the start button after the explanation first and then press the play button again to start the time and the tool, there is a dual start requirement. This was not clear to a total of four out of five test subjects at the beginning. The error was not repeated after the first task but it lead to minor time delays anyway. Furthermore, two users missed the start button at the beginning and tried to start the program by pressing the target stimulus image. One of the users forgot the target symbol after pressing the start button and therefore needed additional help. Another user forgot to read the task and needed brief assistance to navigate back to the main menu. Another user also requested assistance to exit the tool, as the function of the stop button seemed to be unclear.

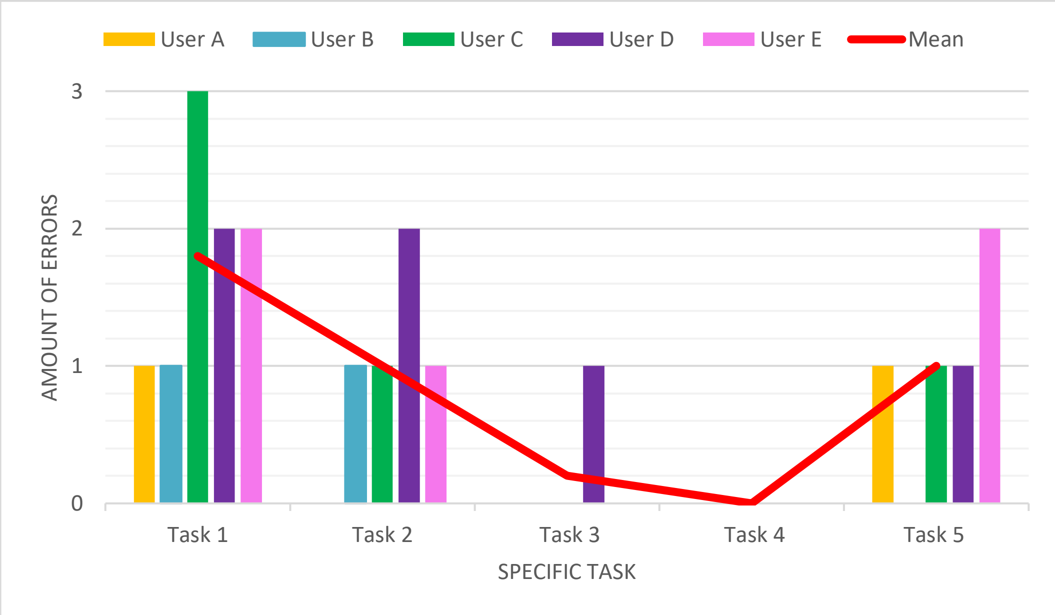

Table 7 *User Error Rate*: Visualisation for each task, with coloured bars indicating individual users and the red line denoting the mean error rate per task. Notably, the first task exhibited the highest error rate while task four showed no errors across all users.

Two errors were noted for the second task, as two users did not touch the grey bar directly to control the ball and therefore the object hardly moved at all. Instead, one of the two users touched the white area next to it, while the other user tried to control the ball along the black line between the grey bar and the white area. Two further errors were detected, as two users did not change the speed at all or only changed it once, contrary to the task instructions. The fifth error for this task was caused by one user not touching the screen but attempting to navigate about five centimetres above the screen using hand movements. The error in the third task was caused by user D opening a different level at the beginning. The most common error in the fifth task is related to downloading the image of the evaluation tool. Two of the users did not download the image at all, while one user downloaded the image five times. This can be attributed to the fact that there is no visual feedback as soon as the download button is pressed. One user expressed the wish for a visual change as soon as the image was saved. Two further errors are related to the incorrect transcription of the data collected. The arrangement and listing of the results were not consistent for both users, although only one user mentioned this in the interview.

Looking at the correlation between the time on task metric and the user error rate metric, the value calculated is 0.33. This value indicates a tendency for a change in the time on task to be accompanied by a change in the user error rate. However, the correlation value also shows that there is no strong connection between the two values. Table 8 illustrates that users A and B had a similar time expenditure, shown here by the orange line, as the other users despite a low error rate, visualized by the blue bars. For users C, D and E, the relationship between the values appears to be more pronounced. Therefore, it can be assumed that the identified errors are due to ambiguities of the user interface, unclear instructions, or misleading tools. A hasty execution therefore should not influence the error rate and the time schedule must not be extended.

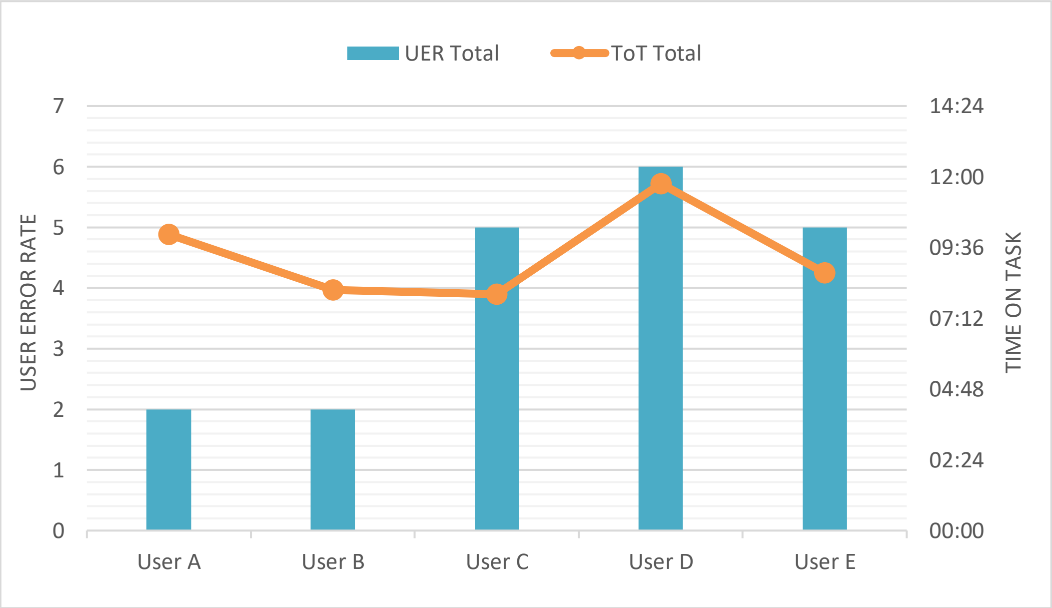

Table 8 *Correlation between time on task and user error rate*: Indications of a moderate relationship (0.33) are shown. Users A and B exhibit similar time expenditure despite low error rates, contrasting with users C, D, and E, where the relationship between time spent and error rate is more pronounced.

Another connection that should be considered is the relationship established by the user error rate and the age of the person performing the task. It is assumed that the average younger person learns to operate technical devices more easily and more quickly compared to the average older person. Table 9 illustrates that the two variables have a similar graph. Given a correlation value of 0.89, it can be assumed that there is indeed a relationship between the age of the therapist and the tendency for errors. The positive correlation value indicates that the error rate increases with age. In this instance, User D, as the oldest participant at 56 years of age, made the highest number of errors with a total of six incorrect attempts. The two youngest test participants, aged 23 and 32, made the fewest errors with a total of two mistakes. This circumstance may be based on possible previous experiences or qualifications in dealing with technical media as well as personal preferences regarding media consumption. A further statistical comparison of the relationship between the time on task metrics and the age of the participant shows a correlation value of 0.48. This indicates that there is a moderate but not a strong relationship between the time on task and the age. Knowledge of this fact should be relevant for future projects, as it clearly shows that the needs of different age groups vary and that prototypes should be tested on several groups of people.

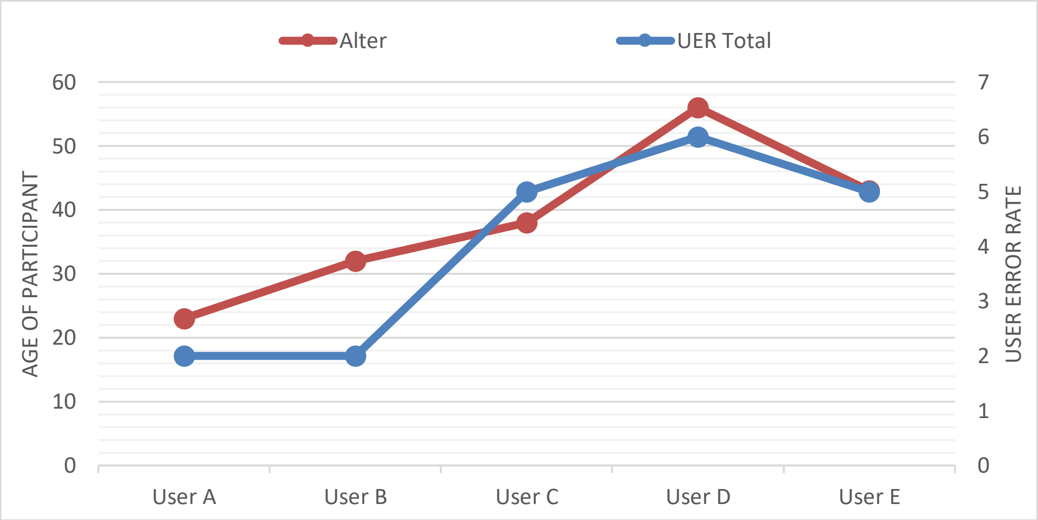

Table 9 *Correlation between user error rate and age of the participant:* A strong positive correlation (0.89) is evident, with User D, the oldest participant, making the most errors, while the youngest participants made the fewest.

Last but not least, the task completion rate was also measured. The individual tasks were analysed with regard to the need for external verbal support. Table 10 visualizes the results of this metric by showing each bar representing a task and the coloured subdivisions indicate the respective user. The height of the bars provides information about the Task Completion Rate score. It is important to note that a high score means that the test subjects were able to act independently. A low score indicates that assistance was required more frequently. It can be seen that every participant was able to carry out and complete all tasks since no task was scored with zero points. It is also evident that all participants required verbal support to complete task one. While two of the participants required only a single hint, the other three participants needed assistance three times each. The questions in this context mainly related to the start buttons or forgetting symbols or tasks. In the second task, two out of three users were able to complete the instructions without assistance. The other three participants required assistance with finding the speed control, timing, and the precise use of the grey navigation panel. In the third task, four of the participants were able to act independently. User D needed assistance to navigate back to the level preselection after choosing the wrong level. Task number four was the only task that could be completed by all participants without assistance. This indicates that the handling of the training module was quickly learned after just a few repetitions. User A was the only participant to require assistance when completing task number five. The question here related to the sequence of the results. Overall, it can be seen that user C needed the least support to complete the task with nine out of ten possible points, while user D needed the most support with seven out of ten possible points.

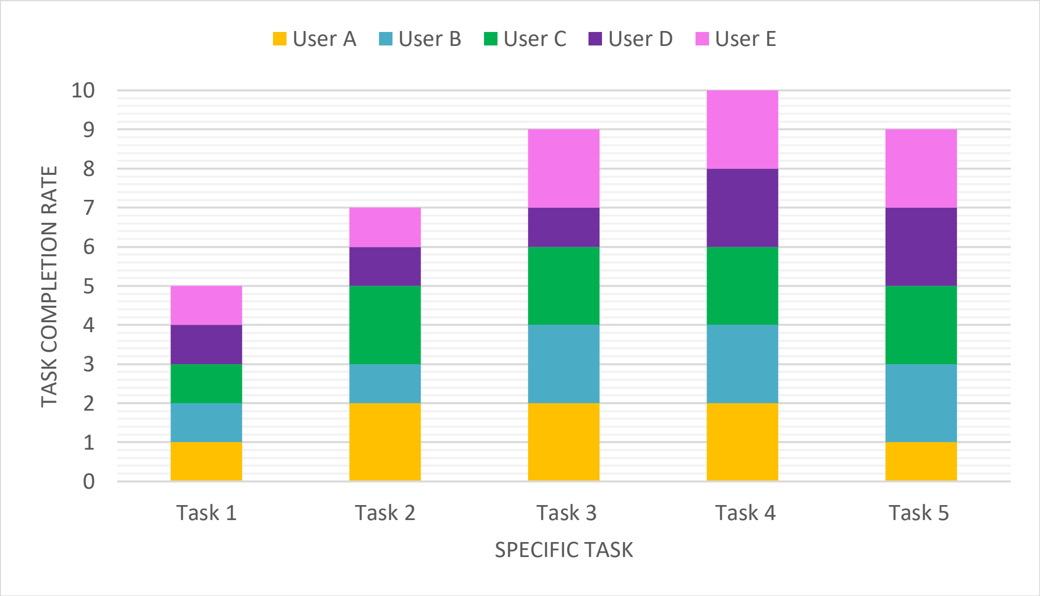

Table 10 *Task Completion Rate*: Each bar represents a task, with coloured subdivisions indicating users. The height of the bars reflects the Task Completion Rate score. Notably, all participants successfully completed all tasks, although with varying degrees of support.

It is interesting to note that user C with the highest task completion rate also had the fastest execution time, while user D with the lowest task completion rate needed the longest amount of time. The correlation value between the task completion rate and the time on task metrics is -0.84, which indicates a negative correlation. The faster the tasks can be completed, the less help appears to be necessary.

Table 11 summarizes all the mean values of the individual user experience metrics for each task. The time on task was abbreviated as ToT, user error rate as UER and task completion rate as TCR in the table shown. Overall, the metrics indicate that the testing unit was carried out successfully. This can be seen from a low error rate as well as a high degree of independent execution. It can also be concluded that the operation with the prototype can be learnt quickly.

Tasks	**Mean of user experience**		
	ToT	**UER**	**TCR**
Open neglect evaluation tool, perform the test	01:51	1,8	1
Open training tool, perform level one	02:00	1	1,4
Open training tool, perform level two	01:34	0,2	1,8
Open training tool, perform level three	01:27	0	2
Open analysis and enter information	02:27	1	1,8
Total	**09:20**	**4**	**8/10**

Table 11 Overview of all user experience metrics means

5 Discussion

The following chapter interprets and compares the most important results of the usability testing and critically examines the chosen method and objectives in order to draw important implications for future research projects.

5.1 Analysis and Interpretation of the Findings

The first finding, which was investigated by all the three research questions, was user-friendliness. During the interviews after the usability testing, user-friendliness was mentioned by all of the participants and was identified as an advantage of the given prototype. Detailed explanations regarding specific factors were not actively pursued. It is assumed that a simple user interface is even more important and significant when working with patients suffering from spatial deficits. This might be, for example, the simplicity of the buttons, rather fewer stimuli, and visual effects than too many, good contrast between the colours as well as a logical process. In this case, a simple layout was chosen, featuring only three possible buttons on the homepage for selection. The contrast of the buttons with the background colour is moderately strong, but this wasn't specifically addressed by the test participants. Additionally, the control bar for therapists wasn't directly mentioned in the interviews. However, during the testing, three out of five participants made positive comments about the inverted bar. A scoping review from the year 2021 examined tablets in relation to patients with dementia. The results indicate that user-friendliness also plays an important role in this context. Parallels can be seen particularly in the fact that both of these target groups have neurological cognitive deficits and the handling of a touchscreen-based tool was analysed [66]. The results of the user experience metrics also demonstrate a high degree of user-friendliness. The time on task metric, for example, shows that the test participants became increasingly faster when performing a level task and the user error rate also indicates that there were no deviations from the expected process at the third level. This suggests that there was a clear learning effect even after only a few minutes. Features that still require further improvements can be identified in the simplicity of the buttons in the prototype. Due to the repeated need to press the start button, some errors were recorded during the testing. The entire set-up process was another disadvantage of the prototype identified during the interviews.

However, this is mainly due to the initial setup of the device in the new environment, which required an electricity connection to be found using an extension cable as well as an active internet connection. Other weaknesses of the prototype can additionally be identified. These include, for example, the evaluation tool, the reactivity of the touchscreen and the external conditions of the prototype's hardware. The results evaluation of the test and training values were described as confusing by the majority of the participants. In particular, the listing of the results was a hindrance. This situation also shows a link with the metrics gathered. Of all five tasks, this one required the most time on average. Four out of five participants make at least one mistake during this task, although only one person asked for assistance. A possible reason for such an error rate could be related to the fact that the most recent result was always displayed at the top of the list. Therefore, when entering the final results in the spreadsheet, the first level was displayed at the bottom and the third level at the top. However, it is questionable whether the time consumed is partly due to the fact that the participants had to enter the results in the spreadsheet by hand. Each person writes at a different speed and orientates themselves in tables for different lengths of time. During the survey conducted by the two expert interviews, hardly any parameters for quantifying neglect tests were mentioned. Nevertheless, the Star Cancellation Test was perceived to be the favourite among the assessments. The widespread use of the Star Cancellation is probably due to the fact that it has been used for neglect diagnostics since 1987. However, as the study by Bickerton et al, which was already mentioned in chapter 2.1.3, shows, other assessments such as the Apples Test can assess neglect symptoms more accurately and in a more differentiated way [28]. The spread of these tests is probably not as advanced due to the later year of publication. Despite these statements, the neglect test in the prototype was based on the Apple test in order to integrate the latest findings, such as those of Bickerton, into the prototype. This was considered an advantage in the usability test as well as a potential for significant results.

Another finding regarding the user experience is the reactivity of the touchscreen. Two participants identified the reactivity as a disadvantage of the prototype during the interviews. According to the participants, there were sometimes difficulties during testing, as the touchscreen did not react immediately when executing levels or pressing certain buttons. However, it was also observed that the handling of the control mechanism seemed to be confusing. The prototype was programmed in such a way that the balls can be moved one-to-one in the different levels, meaning that the ball moves at exactly the same height as the person touching the screen. It was observed that people intuitively tried to push the ball upwards, which resulted in them repeatedly touching the bottom and the ball bouncing down again. This poses a difficulty in terms of handling and therefore an adaptation of this function should be considered. The finding could also indicate that more targeted instruction for the occupational therapists would be needed for smoother implementation. Despite these challenges, the large representation surface of the table was identified as a further important key point. In the expert interview, the requirement was expressed to be able to adapt the size of the test format or stimuli to the respective patient. This is indeed a parameter that is relevant for the identification of visuospatial neglect, especially for patients with visual impairment. As mentioned in chapter 2.1.4, a study from 2022 showed that increasing the size of the entire test leads to a faster search speed when searching for letters. No difference was found with regard to search speed when the Bells test was scaled up overall. Rosenzopf et al. attribute this to the fact that automated letter finding is superior to object finding [40]. Another consideration regarding the magnification of stimuli only and not of the total size is standardization. Since test results appear to remain the same despite a change in format, it should be considered that changing only the stimulus sizes and not the format will change the relations and distances between the stimuli. If the result of the test is to remain meaningful, this is therefore not advisable. However, the input could certainly be considered for training tools. The opportunity to adjust the size was therefore not implemented in the prototype. Despite this, the size of the screen was anyway identified as a clear advantage compared to conventional methods or normal screens, as it may also be possible to identify minor manifestations of neglect symptoms. The study by Rosenzopf et al described above also clearly states that the search strategy for assessments is more precise and efficient on larger formats than on small formats [40]. One disadvantage of the size is that severe forms of neglect may not yet derive any added value from this application, as it could be too complex. It must be recognized at this point that not every therapeutic tool is suitable for every patient at all times. It is the responsibility of the treating therapist to adapt the choice the therapeutic method. An additional finding that is important in this context is the variety of tools. This was mentioned in one of the two expert interviews and later also described in the usability tests. An exact number of testing and training materials that would be important for the purchase and use of a device was not mentioned. According to one participant in the expert interview, a large number of tools would provide a comprehensive picture of the symptoms. Similarly, current guidelines from 2023 point to the use of several tests and assessments, whereby the use of computer-based assessments is recommended here primarily for the evaluation of mild neglect symptoms [24]. Should more tools be implemented, the use of a patient register is also worth considering. This was already mentioned by both participants in the expert interview in order to draw possible conclusions and comparisons between individual training units. It should be determined whether only the results in numbers or also files of the tests carried out should be implemented. The long-term archiving of tests and results also describes less a parameter for recognition and more a framework condition for quality assurance. The extent to which paper and pencil assessments or images of digital surveys may or even must be archived in accordance with the European General Data Protection Regulation must also be questioned. During the usability tests, this issue was also raised by two participants and suggested as a possible improvement to the prototype.

In relation to the actual use of the prototype, conclusions can be drawn from various correlations made. If we look at the calculated correlations between the individual user experience metrics, the correlation between age and user error rate in particular represents a significant value. The correlation could be attributed to the fact that younger people may have grown up with technical devices and therefore use them more naturally, whereas elderly people may have hardly learned how to use them intuitively. On the other hand, it may also be explained by the fact that the people selected pursue different interests and have perhaps already gained more experience through training and leisure activities. The results from the correlation between user error rate and age should also be considered in relation to the findings from the interview. For instance, the oldest participant also had the highest number of errors. In the interview, this person in turn stated that they had experienced difficulties due to a visual impairment. This can also occur with users in the younger age group, which means that the result must be viewed critically. In this context, hardware settings and any environmental factors must also be taken into account. The ability to tilt the screen would represent significant added benefit for the treatment. Adapting the angle could improve the usability, especially in the case of unchangeable lighting conditions or when providing therapy directly at the patient's bedside. The extent to which the significance of the neglect test would be the same with a tilted surface should be considered in this case. In this context, the concluding final test would have to be adapted to the circumstances of the initial test which would also offer potential for further studies in this area. The possibility of easily stowing the touch table was mentioned as a requirement by four of the participants. The ability to tilt the table surface would likewise contribute to being able to store the device in small rooms or close to a wall. In addition, a table with castors for easier transportation to a possible storage area would be an advantage. It is important to consider which table model could fulfil the requirements required in this context. An additional aspect that was frequently highlighted during the interviews was the adjustability of the height of the table. The only way to adjust the height of the prototype in this instance was with a screwdriver, which was not only difficult but also very time-consuming.

Especially for patients whose height deviates from the average, the table height needs to be easily and quickly adjustable in order to ensure effective therapy. e precise adaptation by means of a handle or a similar mechanism, for example, could provide great added value for both therapists and patients. Nevertheless, environmental factors were also pointed out during the usability tests, which may have influenced the different results of the user experience metrics. The aforementioned study from 2021, which looked at the use of tablets for people suffering from dementia, also addressed the issue of light. Some of the people tested in this study had clear difficulties with the reflection of light on the screen. Therefore, the content can hardly or no longer be seen or recognized [66]. This outcome also coincides with the findings of two interviewees in the usability test. A study from 2021 investigated the influence of different room lighting in combination with monitor screen work. Seven different lighting settings were tested on fifteen people. It was found that very warm room lighting of 1500 lux and 3000 K would be optimal to counteract visual fatigue as well as cognitive strain and generally improve overall comfort. However, the extent to which these settings can also be transferred to an acute hospital setting remains questionable. Another issue that addresses environmental aspects concerns the background noise in a room. During the interviews, it was noted that simultaneous conversations in the same room, such as other interviews, were a significant distraction factor when carrying out the tasks. This should therefore also be taken into account when conducting actual therapy. A study from 2019 investigated the influence of noise on the concentration and mood of participants. A total of 37 participants were therefore tested under three different noise exposures. The results suggest that background noise can have an adverse effect on concentration, verbal learning as well as visuospatial memory skills, while music showed no significant influence. n this context, however, it is important to note that the effects of sounds and music on cognitive performance can depend on various factors such as the nature of the task, the volume and individual differences. Therefore, it is always recommended to make the initial situation as comfortable as possible for the patient in order to guarantee optimal performance in therapy. The extent to which a reduction in noise pollution can be implemented in everyday clinical practice remains questionable.

5.2 Methodical Setup and Limitations Overview

The methodology of usability testing was chosen to collect both quantitative data as well as qualitative data. Whereas the quantitative results were obtained by gathering three different user experienced metrics, two separated interview guidelines were also performed with a total of six different interview participants. The richness of the results provided a broad understanding of the user perspective. Another reason for selecting the usability testing method was that the user-oriented design process could be implemented most effectively by applying the usability testing method. It involved testing in the most realistic usage scenario possible, allowing potential problems to be assessed realistically by the final users. It is worth considering whether a heuristic evaluation, think-aloud tests or cognitive walkthroughs would also have served to answer the research questions. However, it should be mentioned here that each of the methods listed would lack either qualitative or quantitative components, which would mean that the advantage of a comprehensive approach would be thereby lost. This simultaneously describes another advantage of this method, namely the close connection to expert opinion. The participants for the two expert interviews at the end of the literature review were recruited through personal contacts. Care was taken to ensure that they had more than six months' professional experience and were employed in an acute neurological setting for at least fifteen hours per week. Two young female occupational therapists were included in the interviews. It should be noted that the research question could probably have been answered more comprehensively if the range of participants had been more diverse. In retrospect, at least one expert with more than five years of professional experience should have been recruited for this initial evaluation in order to gather different perspectives. The number of two experts was sufficient for the purpose of the interview in the context of this project, as it was concerned with an early evaluation of potential needs. Five participants with the same inclusion and exclusion criteria were then selected for the actual usability testing. One of the participants was first also interviewed as an expert. The distribution of age and professional experience among the test participants is reasonable, which means that different points of views can be assumed. However, it should be noted that four of the participants work in the same institution, which means that the current level of knowledge could possibly be very similar. All of the participants are women. The chosen quantity of the participants corresponded with the time schedule criteria, but in retrospect it should be noted that multiple participants would have positively influenced the validity of the results. Participants of different genders and from different institutions would likewise have added value to the usability testing. The latest report by the Vienna Employment Association on the personnel forecast for medical-technical services in Austria shows the gender distribution of all active occupational therapists in Austria. It shows that out of 3881 occupational therapists working in 2020, only 238 of them were male. This indicates that approximately 6.13% of occupational therapists in Austria on average are male and therefore only represent a small proportion of the target group [69]. Nevertheless, a larger number of test participants and different genders would be desirable for a more comprehensive result. In addition to the choice of participants, the choice of testing locations should also be evaluated. A silent room without any distractions such as noise or other conversations was selected for conducting the two expert interviews. In this setting, there were therefore not known external influences that could have affected the results. The first usability testing was carried out at the test participant's home. In this case, the prototype was therefore not tested in a real on-site environment. As there was also personal contact in this case, the result could be slightly distorted. It can be observed that this participant took a lot of time to complete the tasks, which may be due to the comfort factor in the participant's own home. The other four participants were tested in their respective workplaces and therefore in the actual user setting. In this room, there were distractions caused by other conversations. The lighting conditions were also more difficult to regulate here, which caused some of the users to describe problems when carrying out the test. Nevertheless, it should be mentioned that all of these factors also contributed significant findings about the prototype. An optimal starting situation would most likely not have reflected a real case scenario and therapy no results regarding environmental factors would have been gathered. It is therefore assumed that the conditions are very similar to a real setting and that the prototype must be adapted to such influences.

When considering the way, the expert interviews were conducted at the beginning, it should be noted that the interviews were conducted directly by the project manager. This could have potentially distorted the results, as there were already pre-existing relationships with both of the experts. Bias can therefore not be completely ruled out. In retrospect, it must also be analysed whether the questions posed in the interview guidelines were truly aimed towards answering the research question. For example, no specific questions were asked regarding possible parameters for quantifying neglect symptoms, which limited the relevant findings. A more detailed discussion of the interview guidelines prior to conducting the interview would probably have had a positive influence here. The testing scenario which was used during the usability test was described as understandable by all of the participants. However, since a high level of support was necessary here, especially for the first task, it remains to be questioned whether a more detailed explanation of the prototype would have been necessary before starting the usability testing. On the other hand, these initial uncertainties also provide information about the potential for improving user-friendliness. With regard to the final interview, it must also be analysed whether the questions could have been formulated more specifically in order to generate more comprehensive answers. It is important to note that the longest interview lasted for eight minutes and twenty seconds, while the shortest interview lasted no longer than three minutes and forty-seven seconds. A longer interview guide could have been a good reference point for obtaining a more extensive range of findings. A more direct inquiry to gather additional information would have been necessary for a thorough analysis. For instance, precise details regarding what aspects of user-friendliness were perceived positively were not specifically asked, despite this being another important aspect of the research question. Regarding the usability testing and the subsequent interviews, no influences or distortions are expected due to the assistance of an external person. An important and noteworthy point is the data evaluation. Since only one person evaluated and interpreted all the collected data, errors in the processing can be expected. Despite detailed planning and assistance through various checklists, human errors in this context cannot be ruled out. Regarding the evaluation of the obtained information through the collection of user experience metrics, there were frequent challenges. For example, the analysis of Time on Task metrics was difficult, as some participants only read the description of the first level, while others read the descriptions of all levels. Therefore, different amount of time was spent on completing the actual task. Also, collecting the Task Completion Rate was occasionally difficult despite precisely defined criteria. The differentiation between a single agreement with a self-explanatory question and five different and detailed questions during a task is, for example, rated equally in this scoring system. A more detailed breakdown in this case could have been helpful for a better overview. Also, the evaluation of the qualitative data was done by only one person. A coding system was used to minimize possible subjective interpretations of the content. The presentation of the data was mainly done through tables and various bar charts within the thesis. Correlations and means were calculated to gain a better understanding of the results and to facilitate the identification of relationships. Nevertheless, it should be noted that further statistical tests would not be significant due to the small amount of data and were therefore not conducted.

In summary, the limitations of the study are mainly attributable to the time constraint. A longer period for project implementation might have allowed the completion of the fourth and fifth steps of the user-oriented design process. This would have enabled a more comprehensive view and a complete run-through of the process. Due to the time limitation, the project was completed after the third phase. Additionally, limitations in participant recruitment are evident due to the time constraint. With more time available, more, and potentially diverse, participants could have been recruited. Another limitation is the execution of the entire project by only one person. A larger project team would have been beneficial for data analysis as well as for the interpretation to reduce potential bias from possible subjective approaches. Due to the author's own role as an occupational therapist, subjective influences on tool selection could not be completely ruled out. An extensive literature review was therefore conducted more intensively to substantiate professional information with current research findings. Despite the strengths, weaknesses, and limitations of the project listed here, it is worth mentioning that the data collected for the prototype can be interpreted as meaningful.

5.3 Implications for Further Research Projects

For future research projects and investigations, various areas emerge from the reflected topics that could be further explored. One possibility, for example, is to expand the number of participants by involving a larger number of occupational therapists. Additionally, an actual detailed and comprehensive survey with patients affected by neglect is also essential. A survey like this should particularly consider and analyse different starting situations, such as wheelchair users, individuals with additional motor limitations, or other cognitive deficits. Expanding usability testing in this regard could contribute to a better and more comprehensive understanding of the device's requirements, as well as its application in various contexts. Further investigations are also recommended to evaluate the possibilities of adaption of the screen surface. This includes aspects such as changing the viewing angle to improve performance or adjusting the brightness of the screen in different environments. Generally, investigations regarding various lighting conditions are pursued to gain insights into improved device usage in different settings. Another important aspect is to implement standardization of the applied testing procedures. On one hand, this could involve testing the extent to which the validity of existing testing procedures remains when they are represented and conducted in a different format on the touch table. On the other hand, this context might also allow for the development and examination of new testing procedures with different approaches. Standardizing the applied assessments is essential for clinical use in either way. In this regard, consideration should also be given to integrating various tools into the system. These include not only various assessments for evaluating a neglect syndrome but also different training methods. The potential for a Multitouch table is also seen in terms of group therapy or interactive training, guided by the therapist. Expanding the system could significantly enhance its applicability in therapeutic settings. Finally, consideration is given to whether the additional use of various hardware utensils could represent a possibility for improving therapy outcomes. The haptic factor was described in interviews as a foundation of occupational therapy, suggesting that hardware implementation should be considered. For example, this could already involve using a touch pen for conducting neglect tests. However, potential effects of such a pen on test results should be investigated and analysed. The integration of a touch pen may enhance the user-friendliness of the system and make it accessible to a broader patient group.

6 Conclusion

The present work provides a comprehensive analysis of functional as well as technical requirements and user experience of a touch table prototype for the evaluation and training of neglect symptoms caused by a stroke. The research questions concerned the identification of the symptoms of a neglect symptom, functional and technical requirements as well as the evaluation of the prototype. In order to answer these questions, interviews were conducted to collect qualitative aspects and in addition, three different user experience metrics were recorded for a quantitative analysis. The identification of the parameters required to determine and consequently quantify a neglect was carried out before the prototype was developed in order to meet the expectations of experts as closely as possible in accordance with the user-centred design process. Expert interviews with two participants were therefore used to evaluate different needs, particularly in terms of user-friendliness. With regard to the ease of use, it was determined that a straightforward and intuitive user interface is particularly essential when working with patients with spatial deficits. An improvement of the simplicity regarding different operating elements in order to minimize possible errors is essential when implementing the prototype to daily clinical practise. During the survey of technical and functional requirements, it was determined that an essential aspect is the adaptability of the device in order to be able to respond individually to the respective patient in the therapeutic context. The device was also seen as an ideal way to redesign neglect training, particularly due to the size of the screen. This primary aspect meant that the prototype would have significant added value for clinical practice. The various metrics indicated that the use of the device can be learned quickly in just a few minutes. This is mainly due to the simplicity of the user interface, but also to the small number of features. The experts would like to have a device with a larger number of different test and training tools in order to be able to adapt it more individually to the patient. It can therefore be said that a therapy device on this scale would represent clear added value for the treatment of neglect, provided there were sufficient options for adapting it to the individual patient.

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List of Figures

List of Tables

Appendix

A. Declaration of Consent

Einwilligungserklärung zur Erhebung und Verarbeitung personenbezogener Daten für wissenschaftliche Zwecke

Datum:	
Beschreibung des Projekts durch:	O Mündliche Beschreibung O Schriftliche Beschreibung
Aufzeichnung	Die Durchführung des Testszenarios wird, für die weitere Auswertung, sowohl durch Video- als auch durch Tonaufnahme aufgezeichnet. Das anschließende Interview wird durch eine Tonaufnahme aufgezeichnet. Die Aufnahmen werden nach der Testung hinsichtlich personenbezogener Daten anonymisiert und ausschließlich von der durchführenden Projektleitung verschriftlicht und analysiert.
Datenschutz	Personenbezogene Kontaktdaten werden von den relevanten Interviewdaten getrennt und für Dritte unzugänglich gespeichert. Nach Beendigung des Masterprojekts werden die Daten der interviewten Person automatisch gelöscht.
Aufklärung	Die Testung sowie das Interview erfolgen freiwillig. Es ist jederzeit möglich, die Testung und das anschließende Interview ohne Angabe eines Grundes abzubrechen, ohne dass Ihnen dadurch Nachteile entstehen.

Ich erkläre mich einverstanden, im Rahmen des oben erwähnten Masterprojekts an einer Usability Testung sowie einem Interview teilzunehmen.

- O Ja.
- O Nein.

Name: ______________________________________

Geschlechtsidentität: ___________________________

Geburtsdatum:________________________________

Unterschrift: __________________________________

B. Testing scenario

Testszenario

Evaluationstool	Starten Sie bitte die Neglecttestung zur Evaluierung der Vernachlässigung. Führen Sie die gesamte Evaluation einmal durch. • Bitte berühren Sie mind. 10 Zielreize auf der linken Bildschirmhälfte. • Bitte berühren Sie mind. 15 Zielreize auf der rechten Bildschirmhälfte. • Bitte machen Sie auch mind. 2 Fehler.
Trainingstool Level 1	Starten Sie bitte das Trainingstool und führen Sie das Level 1 für mindestens eine Minute durch. • Verändern Sie dabei mind. zweimal die Geschwindigkeit des Balles. • Bitte machen Sie auch hier mind. 2 Fehler. Beenden Sie das Level, ignorieren Sie vorerst die Auswertungstabile und kehren Sie in Hauptmenü zurück.
Trainingstool Level 2	Starten Sie bitte das Trainingstool und führen Sie das Level 2 für mindestens eine Minute durch. • Verändern Sie dabei mind. zweimal die Geschwindigkeit des Balles. • Bitte machen Sie auch hier mind. 2 Fehler. Beenden Sie das Level, ignorieren Sie vorerst die Auswertungstabile und kehren Sie in Hauptmenü zurück.
Trainingstool Level 3	Starten Sie bitte das Trainingstool und führen Sie das Level 2 für mindestens eine Minute durch. • Verändern Sie dabei mind. zweimal die Geschwindigkeit des Balles. • Bitte machen Sie auch hier mind. 2 Fehler. Beenden Sie das Level, ignorieren Sie vorerst die Auswertungstabile und kehren Sie in Hauptmenü zurück.
Auswertung	Wechseln Sie bitte nun den Platz und setzen Sie sich auf die gegenüberliegende Seite des TouchTables (also die Seite, auf der normalerweise die Therapeutin / der Therapeut sitzen würde). Öffnen Sie nun die Auswertung. Bitte tragen Sie alle geforderten Informationen in die beiliegende Tabelle ein. Bitte downloaden Sie auch die Datei der Evaluation.
Beendigung	Sobald Sie mit allen Teilschritten fertig sind, melden Sie sich bitte bei der Projektleitung.