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Title:

Adaptive Attention

- Challenge adjusting application for sustained attention

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Project group no.: 141038

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Abstract:

This report aims to investigate how a current exercise within brain damage rehabilitation can be designed and implemented to allow for extensive tracking of patients performance and apply the information to accommodate for distractions in immediate environment. Based on theory regarding visual search and endogenous attention were three features designed and tested as aiding tools during distractive situation with the intention of lowering the challenge of the exercise. One feature showed significant results regarding time reduction. The test was performed on healthy individuals and should be repeated with patients affected by brain damage.

Adaptive Attention

Challenge adjusting application for sustained attention training

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2 PREFACE

This report is developed as a 10th semester thesis project and was created in cooperation of Brønderslev Neurorehabiliteringscenter.

References in this report follows the Chicago style with surname of the author and year of publication. All references can be found under the references heading. Figures and tables are referenced as Figure or Table along with their number. Cross-references states the name of the heading referenced.

3 INTRODUCTION

This report aims to investigate three features that can help ease a current exercise in the field of processing training.

Brønderslev Neuro-rehabiliteringscenter has requested an integration of digital devices into their present treatment program, as a modernised alternative to the low fidelity exercise currently in use. A possible solution is investigated and presented with regard to the current understanding of brain damage and the care that must be taken concerning the treatment.

4 BACKGROUND RESEARCH

4.1 ATTENTION

Cognition can be split into five major subcategories each being their own field of further studying.

- Attention
- Visual Processing
- Information Processing
- Memory
- Executive Functions

The connection between these subcategories relates in a bottom up process where each subsequent field relies on the previous and therefore, if one part of the process chain does not function properly, the entire process suffers.
Attention is the basic skill and underlines all other cognitive processes. According to (Sohlberg and Mateer 1987) attention is considered a multimodal cognitive capacity and can be further divided into 5 levels.

- *Focused*
  - The ability to respond to visual, auditory or tactile stimuli.
- *Sustained*
  - The ability to maintain a focused respond to repeated stimulus. A skill that is essential for the brain to extract information of the perceived stimulus. Inflicted brain trauma can for an individual easily lose concentration during difficult tasks if this ability is affected.
- *Selective*
  - The ability to ignore irrelevant stimulus from the surroundings and instead keep a sustained attention to a specific stimulus. A skill that that when affected by brain trauma causes the individual to become hypersensitive to stimulus and is therefore easily distracted by the surroundings such as noise and light.
- *Alternating*
  - The ability to switch focus between multiple stimuli in a controlled manner.
- *Divided*
  - The ability to split sustained attention between multiple stimuli simultaneously, which commonly phrased is multitasking.

Attention is the cognitive ability that makes a living being able to react upon the surroundings from sensory inputs as well as the ability to filter out the input. It is an ability that works unconsciously, though can also be controlled to an extent, with the intention of continuously retrieve information from a single source. Attention can at the same time function as a warning signal in the sense that if any pattern in stimuli is broken the mind will - for a short while - be forced to deal with this broken pattern. An example of this function is a clock that stops ticking or water dripping into a sink. While the clock was ticking normally it did so in a pattern with equal frequency between the ticks, however the moment it stopped ticking that pattern was broken. During the time of its ticking, the sound of it was filtered by the ability of attention though still registered. With the drips, if the frequency is too slow the pattern is not easily registered and each drip acts as a new distinctive stimuli.
Research in attention has led to many methods breaking down how it functions. A popular approach for this involves a cueing paradigm. A person is told to focus their attention on a dot i.e. a fixation point. Above the dot is shown an arrow that points to one of two squares located on

each side of the dot. The person is informed that an object which he or she should locate is shown in the square to which the arrow is pointing. In 80% of the cases the arrow points to the right box, however in 20%, the direction is wrong and the person must change their focus to the second box. Results indicate that when a person is informed of the targets location he or she will indirectly focus on the foretold location. In the cases where the target did show up the predicted location the responds time was faster than if the opposite was the case. This technique investigates the covert movement of attention where the eyes are fixated and remain still while the mind is indirectly focused elsewhere. A second task similar in approach examines how quick the responds time is when the squares are cued by flashing. This affects the attention differently by suddenly catching ones attention instead of indirectly focusing on it. (Posner 1980).
Adding neutral trials to the approach further explores the cost and benefits of covertly focusing on a location where the target is cued to be. (Jonides and Mark 1984)
Covertly focusing on something without directly looking at it is termed *endogenous* and is very much a conscious skill. Reacting to a sudden movement or sound that "catches our attention" is termed *exogenous.* Both systems appear to perform the same task however differently and while the *endogenous* system requires constant conscious effort it can remain sustained while a cue is processed. When performing a distracting assignment the endogenous attention does not provide an efficient effect while the *exogenous* attention still reacts as effectively and is hard to ignore. However, exogenous attention is a transient effect and can even delay performance for cueing due to an inhibition of return with repeated stimuli. (Müller and Rabbitt 1989).
Sustained attention, the ability to focus on single stimuli for a prolonged period is shown to be affected by brain damage. While a reaction to stimuli is the first step in perception, remaining sustained on the stimuli is necessary to process the information. (Slovarp, Azuma and LaPointe 2011), (Whyte, et al. 1995), (Weber 1988)

4.2 Distraction

During ordinary treatment training, the surroundings are often performed in quiet and controlled environments. This is often necessary because of the otherwise negative effect busy and distractive conditions have on people suffering from brain injury. Distraction can be any kind of uncontrolled stimuli that can be difficult to distinguish. A common example is termed the cocktail party in which many conversations happen simultaneously. While a healthy person is able to focus his or her attention to a single conversation while at the same time ignoring the rest, this ability is decreased in tbi patients. (Schnabel and Kydd 2012).

4.3 Neglect

Neglect is a condition related to attention that affects the individuals' ability to process information on one side of their sensory view. The stimuli neglected is on the opposite side of the lesion in the brain. A common task to test for visual neglect is having the patient copy a drawing of a clock. In the case of neglect the drawing will often include all the numbers due the persons knowledge that 12 numbers is shown in a clock, though all the numbers are placed on the side where neglect is not present. (P and KM. 2012)
There exist variations of neglect. People with personal neglect fails to register half of their body when for example getting dressed or putting on makeup the affected side is ignored, the same is seen when a person is eating and only half of the plate is eaten. (Heilman, Valenstein and Watson 2000), (Driver and Mattingley 1998).

Neglect has also been shown to be both object based as well as spatial oriented. Object oriented is seen with the cases mentioned above, while spatial oriented is expressed by the patient's lack in ability to discern the subjective horizontal or vertical visual orientation. (Kerkhoff 1999)

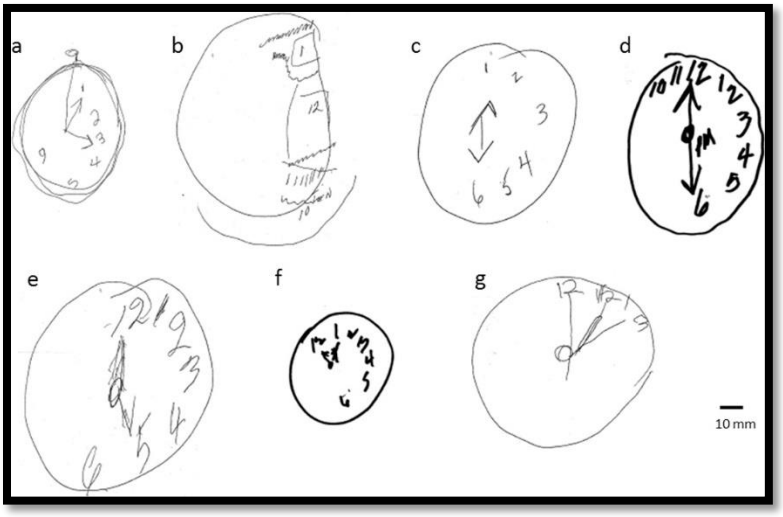

Figure 1. Clock drawings performed by patients suffering from neglect caused by a lesion in the brain. It shows how the left side of the clocks are left out. (P and KM. 2012)

4.4 Brain Training Treatment

4 approaches is considered essential in Cognitive rehabilitation training CRT.

- *Attention Process training*
  - The attention processing training is a treatment program that has the patient continuously perform stimulus driven exercises designed to affect the afflicted areas of attention. Many tested and validated processing exercises have been designed and can be used as both measuring tools as well as attention-improving tasks. (Barker Collo 2009), (Moore, et al. 2000),
- *Strategy training*
  - This approach considers the individual's ability to compensate for the affected functionalities by implementing helpful tools into everyday interactions. If for example memory processing has been reduced utilities such as notebooks and alarms can provide the necessary support to overcome an otherwise restricting disability.
- *Functional activities training*
  - By practising functional activities, the individual relearns cognitive functional abilities in everyday situations. Examples could be taking the bus by themselves or with help from a grocery list buy necessary products in a supermarket.
- *Education*
  - By educating them about their condition, the individual gets an understanding for the treatment and the necessity for the rest of the training. This is to provide motivation as well awareness of the progress has to make.

It is advised that all four approaches are necessary to accomplish improvements in the treatment of brain-damaged individuals. (Sohlberg, et al. 2003), (Moore, et al. 2000)

Process training, is considered a solution to individuals with traumatic brain injury TBI, and based on positive results regarding the brains ability to modify the neural processes caused by a change in environment, behaviour or injury. This ability is termed *neuroplasticity*, a physical aptitude for a long time considered unlikely due to the conviction of the brain as hardwired after a certain age. It

has however been shown that this function is still applicable throughout the entire life, though with a degrading efficiency as the individual ages. (Pascual-Leone, et al. 2011)

4.5 VISUAL SEARCH

When observing many objects at the same type and are searching for a single one. There are several ways to distinguish the objects, be it colour, shape or orientation. If all the objects are seemingly, identical it can be difficult to find the single object and in order to locate it one must systematically go through all of them. This method is labelled serial search. However, if the object being sought is remarkably different compared to the rest then the amount of other objects does not matter because the brain will instead perform what is called parallel search. This ability does not seem to have any constrains of attention and for that reason, is tremendously efficient. (Wolfe and Horowitz 2004)

4.6 CURRENT TREATMENT

Now the treatment provided at Brønderslev neuro centre is limited to low fidelity exercises that includes pen and paper. The exercises varies in design, though the core concept remains the same and for that reason implementing a digital oriented environment allows for more efficient tracking than what is currently available. Trail making tests and Schulte table are among some of the exercises as they provide a simple concept for the patients to follow and for the therapists a quick representation of the patient's state concerning neglect.
The Schulte table consists of a grid of tiles each marked with a unique symbol such as a numbers, letters etc. The task is for the patient to locate each tile in a specific order. Counting from the smallest value to the highest, and vice versa or for example only every second. This requires a continuous sustained attention on the grid and a working short-term memory recalling the current tile in the series. At the same time in order for the patient to locate all the numbers he or she will have to challenges the neglected part of the visual field. For most of the exercises an assistant will be present to help and guide through the in challenges the patients might have by pointing out locations of objects, help them remember numbers in a series and ease the exercise by modifying the paper edition for example by covering parts of the active field in a search and find exercise.

4.7 DIGITAL ALTERNATIVES TO CURRENT TREATMENT

The current alternatives in the digital area does provide a diversity in the adaption of the low fidelity version with a variety in changeable features. None of them; however seem to provide the necessary statistics, which are necessary to note any improvement in progression. At the same time, the exercises are not very versatile concerning logging of multiple users of the same tablet. This makes sense, as tablets are rarely used by more than one person, when using them in a treatment facility however, the devices will be shared, and a profile management will be a necessary implementation.
Searching in the Google Play store brought up a few examples for the Schulte table. The two most popular ones were named Schulte Tables (*Schultz tables* in the application) (Alexeychuk 2013) and Schulte Table (Alekseyt 2011). Both applications offer a simple design with a black on white and white on black colours. Schulte Table furthermore provides the option of having two series shown at the same time one in white coloured numbers and the other in red as can be seen in Figure 2. However, it is not explained in the application nor in the description found on the play store how to carry out the exercise with the two series shown. When carrying out the exercise in Schulte

Table no feedback is provided besides the numbers switching places on each click and a counter in the in the top right corner. The counter is not explained, though after repeated play it seems to be the time spend between the previous tile and the current. It does not make a difference which of the tiles is clicked for the application to randomize their positions and display the time spend. There is no tracking of any other information such as whether or not the numbers clicked were done so in a correct series nor how much time in total was spend on the entire exercise.

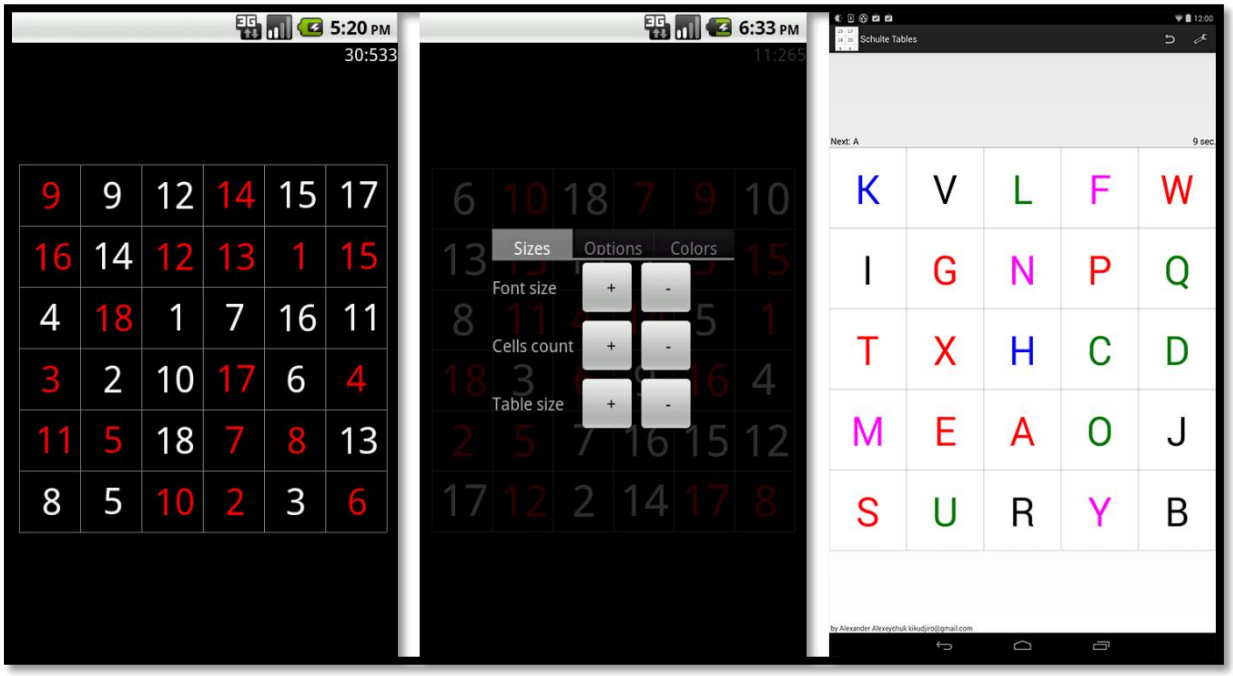

Figure 2. Two popular applications for the Schulte table exercise. Left and middle is the Schulte Table application with the option of two series exercise and adjustment of scales, as well as colours of tiles and background. The right is Schulte Tables (Schultz tables in app).

The second application, Schulte Tables, includes a few more options concerning data about the exercise. The time for a complete session is tracked and for every interaction with a tile, it is clear whether an action was correct or wrong. In the top left corner of the grid the ID, be it a letter or number of the next tile to click is displayed. Whenever a tile that does not match the ID in the corner is clicked the tile flashes red and a distinct noise sounds. Clicking the correct tile is rewarded with a green flash and a somewhat more comfortable sound. In the top right corner is the total time currently spend on the exercise, which is shown counting continuously throughout the entire session. The application has the option to choose between numbers and English and Russian letters as well as changing the colours from all black to multi-coloured.

The second application seems intuitive and requires minimum setup. For this reason, it does not allow for the any modifications concerning level design such as adjusting difficulty by adding fewer or more tiles as well as help finding a tile should one get stuck in the search. These applications might work well when utilized while assisted, though on their own they lack in guidance as well as progression tracking.

5 Problem statement

Considering the research results discussed in the previous sections it is clear that the level of treatment can be improved by implementing a more adaptive application. The application must gather information regarding the patient's performance in order to display the progression so that the patients recognises the impact of the treatment as well as for the therapists to discover any improvements as well as lack off.
The application must at the same time accommodate for any distractions in immediate environment and if possible modify the challenge of the exercise accordingly.

How can an exercise in attention processing treatment be designed to accommodate for distractions in immediate environment so that complexity of exercise decreases with level of disturbances while at the same time track progression of the patient's performance.

6 CONCEPT AND DESIGN

Based on the requests from Brønderslev Neurocenter for a digital solution to the current treatments and the alternatives currently available mentioned in the Background Research the concept for a potential solution is outlined in the following section.

Based on the analysis in Distraction environmental stimulus can seem distracting for a person suffering from TBI and any treatment should consider this. The current treatment provided to the patients utilize pen and paper and for that reason loses many potential data gathering that could otherwise proof beneficial in future diagnosis and reinforce any signs of improvement the patient have shown throughout the process of treatment. The data missing could furthermore provide results that support future development in better and more versatile treatment projects. The concept of this application will therefore implement the functionality, and design accordingly to the above statement and accommodate for these needs.

6.1 THE EXERCISE

The Schulte table is one of the treatments currently in use because of its simple concept that can easily be repeated with new positions of the tiles. It also requires the entire field of the grid to be analysed to find the correct tile, which necessitates that the patient challenges the side of their field that is being attentively neglected. Having the objects presented in a constant position and relative to their neighbours will allow for a quick overview of the field of action in which the patient must locate any targeted objects. This allows for a limited field of search and at the same time indicates the scope of the necessary amount of potential targets. At the same numbering every tile further hints to the progress the patient has made since with the basic task of counting from the minimum to the maximum amount of tiles, gives a clear indication of how far the patient has reached in the assignment as well as how many tiles are left to locate. The current low fidelity version does not involve any immediate feedback and is therefore challenging without the help from external assistance. The digital version should therefore implement feedback upon interaction with the grid and ensure that the counting of the grid is performed in a correct manner. As was utilized in the alternative found on Google play store (Alekseyt 2011), the tiles changed colour based on the action of the user. If the tile clicked was not the correct, tile would quickly flash red, and green if the opposite was the case. This gave a simple indication if one could continue the count or keep searching for the current tile. Combined with audio it became a multimodal feedback and appeared even more obvious the consequence of ones interaction. Thus, the application should incorporate a colour change as well as audio, as feedback.
While some tablets do provide tactile feedback it is in the minority and a function mostly implemented in mobile phones only. If hardware for tactile feedback is available, it should be implemented to further weigh the immediate indication that the system did receive an action from the patient be it correct or not.

6.2 ADAPTIVE BEHAVIOUR

As pointed out in Distraction surrounding stimuli can have an effect on the sustained attention in tbi patients for that reason requires a controlled environment to carry out the exercises in the treatment. The alternative would be to lower the challenge of the exercise when distractions are registered or the performance of patient drops. This can be achieved by incorporating an adaptive behaviour into the application. Adaptive behaviour is a system seen in certain games and is also termed dynamic game difficulty scaling. It has been shown that playing a game that employs an

adaptive behaviour concerning the difficulty of a challenge is preferred to a static behaviour (Hagelbäck and Johansson 2009).
For that reason, it is necessary to track the interaction with the patient has with the tablet and how well he or she is performing. From a developers perspective tracking of user interaction in games is very common and is practised in many game companies worldwide to analyse how their users behave when playing the games and what challenges that might arise intentionally or not and based on the data and act consider new concepts and redesigns. This practise is termed *game analytics*, and has emerged as a subset to business intelligence. (El-Nasr, Drachen and Canoss 2013).

While game analytics is as the name implies meant for games, many games are created for mobile platforms, which makes data recording of these devices significant and termed telemetry, which by definition is remote measurements. The mobile platform today is being utilized in many different situations and for that reason the hardware and software that are utilized by these devices increase in performance and compliance. To embrace and improve the user experience a growing amount of sensors are implemented into the phones and tablets adding the ability to track behavioural inputs about the users' performance, location and interaction with the devices.

Of the available sensors in a general mobile phone not all of these are likely available in tablets due the difference in general usage. However, with the growing capacity and decrease in size of hardware parts it is likely that these will be implemented in future edition of tablets. The sensors most useful for the task of tracking the patient's behaviour along with the surroundings during the exercise are:

- Proximity Sensor
- Light Sensor
- Microphone
- GPS
- Accelerometer

These sensors allow the tracking of the surroundings around the tablet and its user during any interaction with the device. Due to the common usage of tablets, the proximity sensor is rarely integrated since the purpose for mobile phones is to shut off any screen interaction, while the user holds it to his ear during phone conversations, and for that reason, is not a necessary functionality in tablets.
Light sensor is available in seemingly every tablet and mobile phones developed today because of the shared purpose in the devices ability to automatically change the screen brightness based on the incoming light intensity and therefore increase the eases the reading the on the screen in lid up situations.
Microphone is also a common sensor implement as a standard feature in every tablet and mobile phone with the phone being the obvious implementation due to the necessity of phone conversations however, with video calls using applications such as Skype these features are also a common necessity to tablets.
With the possible tracking of light intensity, audio, acceleration and position the environment can be analysed and along with tracking the input of the user's performance, it is now possible to implement an adaptive behaviour by calibrating both abilities against each other.

Based on the analysis regarding attention deficits and hemi spatial neglect it is necessary to consider how current exercises can be improved to accommodate for an adaptive behaviour while at the same time remain a challenge in order to constantly train and push the patient's ability further.

One of the necessary elements the low fidelity versions of the exercises lack is the ability to provide feedback to the patient. Whenever the patient interacts with the paper and pen edition it is only possible to mark the objects of interest be it in trail marking tests, memory-working tests and so on. However in order for the patients to understand if their actions in the exercise were performed correctly according to criteria it is not possible without the present of a supervisor thus feedback based on their actions should also be implemented.

The supervisor during the exercise can provide help by forcing the patient into focusing on specific areas of the exercise by limiting the "active" area by applying a piece of paper on top of the area that are to be ignored. While this is an option easily applicable during supervision, it is not an option should the patient attempt to perform the identical exercise on their own. Thus, it is essential for the application to implement this feature and act as the supervisor and in the case of observed difficulty from the patients perspective carry out the same task as the supervisor and ease the challenge. Furthermore should the patient have trouble in finding the

6.3 Cues

As mentioned in the Attention section, the ability to use covert attention to focus on some point outside you focal point is termed *endogenous* attention. This ability allows for a prolonged indirect focus while at the same time having the eyes fixated in a different location. This can be utilized in providing assistance during an active exercise without directly pointing out the exact location of a correct tile. While the cue in the exercise by (Posner 1980) was a fixated arrow pointing in a direction applying motion to the cue could further enhance the capability of covertly sustain focused on it.

Taking advantage of this ability by combining both a direction and movement will likely enhance the changes for the patient to locate and limit the area of the correct tile faster than by only implementing a direction. Without further cluttering the field of the tiles to search through, placing the cues on the brim of the grid would likely become less distractive. Considering the grid as a x and y coordinate system requires the two cueing objects in order to isolate a single point. Thus placing two objects, one considering the columns i.e. x-values and the other the rows and thus the y-values. With the next correct tile to find is for example placed in the top middle in a 5x5 grid the cues would move to $x = 3$ and $y = 5$. This solution avoids any interference with the grid itself while at the same time provides a cuing option to locate certain tiles that could otherwise be difficult to pinpoint.

Considering the condition of hemi spatial neglect the placement of the cues, need to consider both sides of the screen in order to not be overlooked and ignored. Thus instead of only two objects providing the visual cue, implementing four objects, two for each axis would likely be a better alternative. The concept can be seen below in Figure 3.

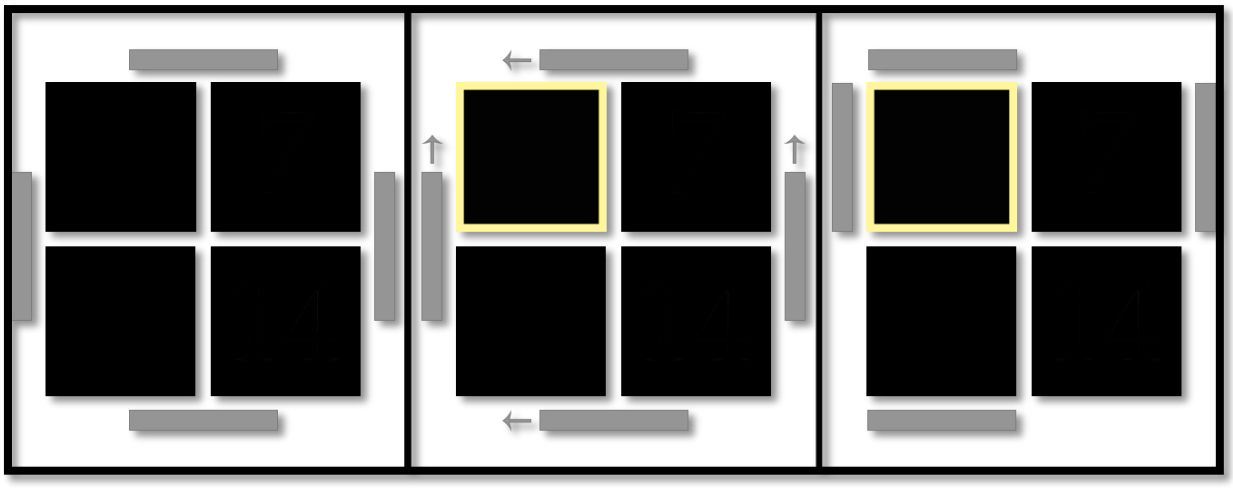

Figure 3. Moving cues locate the correct tile by sliding near the edges of the grid avoiding visual distraction on the grid.

6.4 VISUAL SEARCH

To find objects that appear very similar in shape and colour are difficult to distinguish from one another and is the case when performing the exercise of the Schulte table. As mentioned in **Attention** the visual search is greatly reduced when certain aspects of an object stands out of its surroundings. Both shape and colour can make a distinction between its neighbours if it differs, however if the contrast of the colour must be big enough for the visual search to switch from serial to parallel. (Nagy and Sanchez 1990), (Wolfe and Horowitz 2004). Thus by adding changes to the correct tile searched for should ease the search. Though having it suddenly change in colour will cause the cue to catch the exogenous attention and according to (Müller and Rabbitt 1989) can cause an inhibition of return and hinder performance for a longer time than endogenous attention. Instead, by gradually change the difference i.e. colour of the target tile should instead affect the endogenous attention and perform the visual search in parallel. See **Figure** 4.

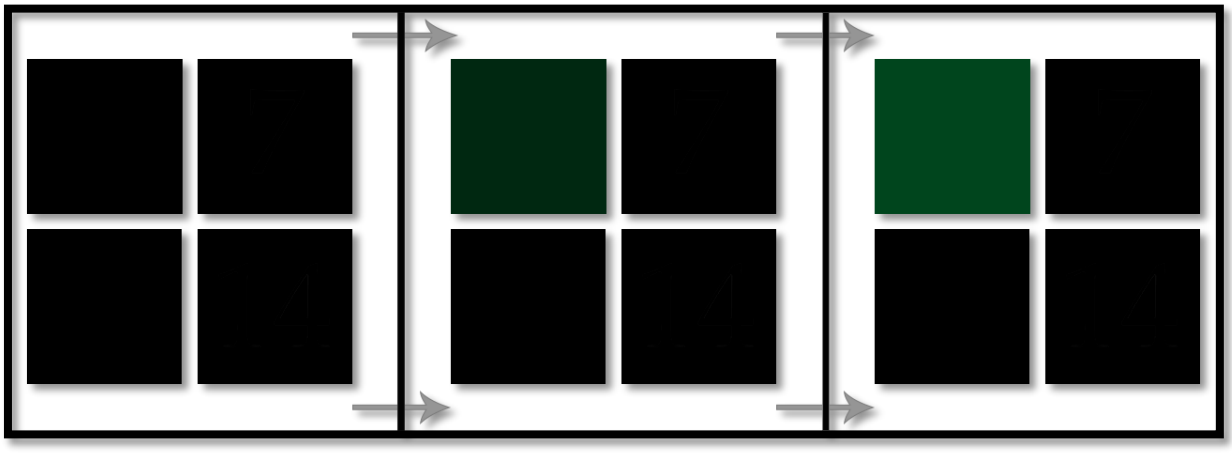

Figure 4. Gradual colour change switched the visual search from serial to parallel making the search for distinguished object faster.

Another option, which gradually ease the visual search, though without utilizing the ability of parallel search, is to lower the active area in which the search takes place. Since serialized search requires that the user systematically validates every single tile amount of tiles has the greatest impact on time of search. The option can be either begin the exercise with a low amount of tiles by default, or mark the ones already found and thereby removing them from the pile of potentially

correct tiles. At the same time this will implement a visual progression of how far in the exercise the patient have reached and should further increase the motivation as well as performance, as reaching the goal of finishing the exercise becomes progressively more attainable. (Klein, et al. 1999).

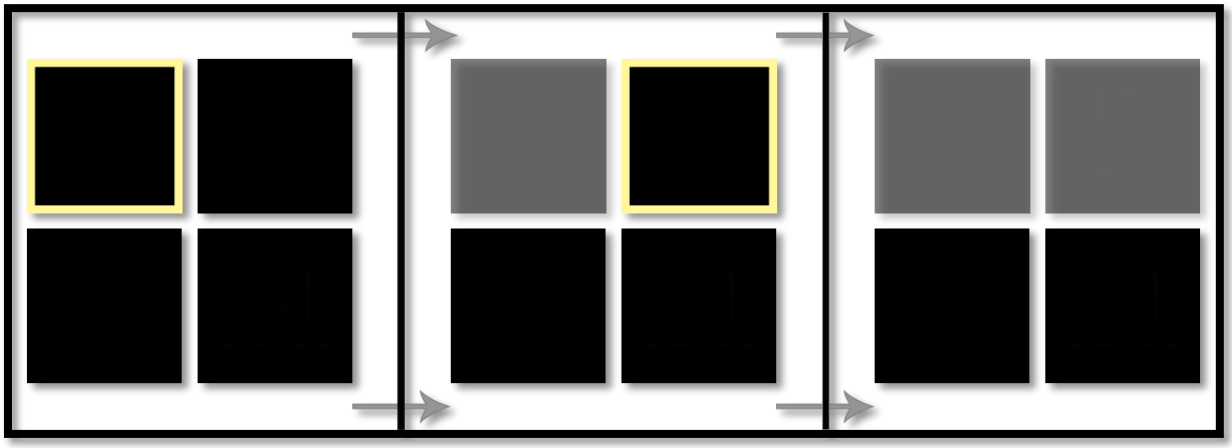

Figure 5. Changing the colour permanently after the correct tile has been clicked will progressively lower the difficulty of the exercise.

6.5 Distraction

Because of necessary modification in design to accommodate for healthy people in the test, a distraction should be implemented to act as additional stimuli during the exercise.

To avoid any visual overstimulation the graphical design of the application should remain simple and prevent overly distracting features and unnecessary swift actions as well as overabundance amount of visual feedback often presented in tablet games. The design should remain simplistic and at the same time provide clear visual feedback to ensure that every action performed by the user further develops their mental model of the device and the application itself. According to (Norman 2013) it is important for the design to signify its usage with both negative as well as positive feedback, and if possible relate to real world objects while at the same time effectively copy their action. Designing a virtual button should visually act as a real one when pressed i.e. show two stages: One when clicked and one when not clicked. This affords its functionality to the user when it is not possible to implement any tactile feedback that would otherwise be the case with a real button. To ensure a developing understanding and a low learning curve the design should keep a consistent theme where similar actions result in similar consequences in regards to both the visual aspects as well as the interactive functionality.

6.6 Grid

A chosen amount of tiles of which the user is to click on will be placed randomized within a grid. In order to emphasise the distinction between each tile there should also be a clear distance between each of them. With a greater distance, the risk of unintentionally clicking the wrong tile is also decreased. (Microsoft n.d.)

Since the current low-fidelity-treatment utilizes pen and paper, where the paper is placed on the table and the patient points or taps on the tile, it can be favourable to implement a similar style to embrace the visual environment the patients usually deal with. Thus by adding a texture simulating a piece of paper the similarities might have a positive effect on their understanding and improve their mental model of the interaction with the tablet and the exercise based on prior knowledge.

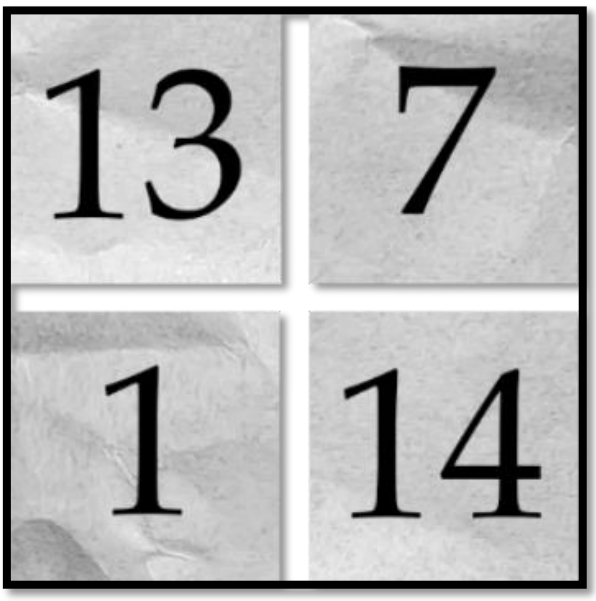

Figure 6. The texture design of the tiles. Keeping the low fidelity identity to ensure an easier transition between pen and paper to digital device.

Feedback is important in every situation where interaction takes place. Without feedback and prior knowledge about the object interacted with it is impossible to know how any actions performed by the user has any consequences and if nothing is signified about its state subsequent to interaction the device might either be broken or badly designed. (Norman 2013). In that regard, interacting with the tiles must provide both a positive and negative feedback based on whether the tile current tile clicked was in fact the correct one or not. An optimal feedback would be to provide a colour change as for the single tile clicked on demonstrating both that the tile was indeed clicked on as well as inform the user about the correctness of the interaction. Colour theory is a well-researched area and a common understanding of the interpretation of the meaning each colour signifies. The opinion of the colour can however change across cultures and one colour might signify one thing in western culture compared to eastern and vice versa. Taking the parallel understanding of go and stop in traffic lights red means stop while green means go. It is also a common colour for buttons online on webpages to provide these positive and negative signifiers based on the consequences.

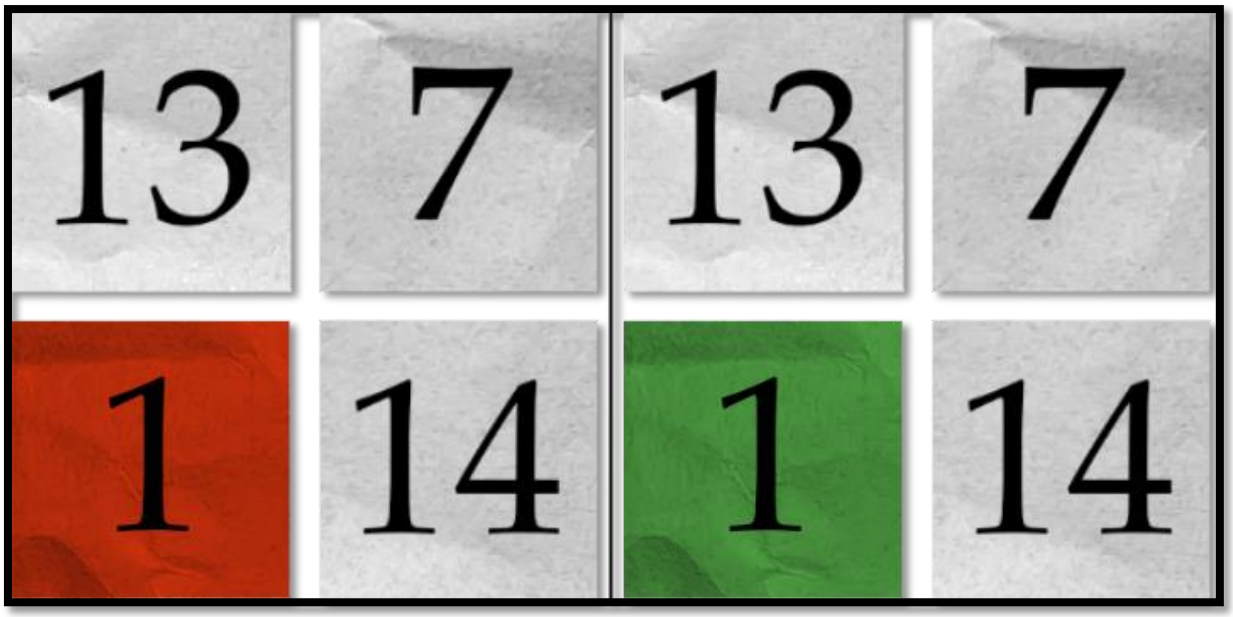

Figure 7. Clicking a tile provides immediate feedback based on if it was the correctly chosen tile or not. A correct tile is highlighted as green, while a wrong tile is highlighted as red.

By following the results mentioned in Attention, the application should implement features assisting the patient to overcome the challenge more easily if the tile turns out to be too demanding to locate. Several reasons causing this increased difficulty were cited, and possible solutions to accommodate these situations were suggested in

Concep. Decreasing the amount of “visual clutter” shown on the screen with the seemingly indifferent tiles can be designed by either lowering the initial amount of tiles for the entire exercise. However, while this is an option it does lower the overall challenge for the entire exercise rather than just aid with a single obstacle. Instead by implementing a gradual decrease difficulty which at the same time shows the progression in the exercise

7 IMPLEMENTATION

Choosing tablet as the platform was as mentioned due to its mobility giving the patient the opportunity to use them at home, and provided the correct feedback be delivered in the application there should be no need of any supervision during the exercises.
Android was chosen as the OS platform because of its ease of access for development because of its acceptance toward open-source applications.
Unity3D was utilized as the engine because of its user-friendly GUI and the author's prior experience in working with this particular environment. Unity3D with the latest version now implements 2D view as a workable standard and with its integrated porting to several different platforms makes it very versatile for future development and expansion to other OS systems.

7.1 DATA

During gameplay, it is necessary to track the constant interaction from the patient to both analyse and act upon the performance thereof. With the intention of accessing the data from a pc to display the progression the data was collected into lists and send in a frequent manner every time the an interaction took place. The triggers for interaction was during the exercise only set to clicking on the tiles and in the menu for the buttons to begin tutorial and session. The code for calling the method to read data can be seen in Figure 10. Although future iterations could benefit with an analysis of how the user might hold the tablet for example by tracking finger positions near the edges of the screen this was not tracked during the exercise.
In order to track surrounding inputs data tracking was initially set up to collect and send every frame. However, early in the process it was realised this was not an option because of the limited resources the tablet possess' and the amount of data was unnecessary large. Instead, the frequency was changed to collect and send every second. Which provided less data though still enough to perform to register any changes from the environment and interaction like movement of the device. For easier access and with future iterations in mind, concerning remote data display, the collections were send via Unity's integrated network class to an online MySQL database, setup for this project.

27 individual variables were tracked and can be divided into four metrics:

1. Identification
2. Exercise specific
3. Environment Specific
4. Interaction Specific

Following the terminology of game analytics (El-Nasr, Drachen and Canoss 2013), the identification would be phrased as customer metrics and the exercise and interaction specifics as gameplay metrics. However, to keep it within the environment of this application, and the fact that no transactions has taken place, the listed terms were considered more appropriate.
.
Identification deals with the necessity of being able to determine which user performed a specific exercise, and when the exercise was carried out. This is furthermore used when repeating the exercise over time to determine if a user displays progression of any kind.
The variables used for identifications were:

- *UserID* – The name the participant writes prior to beginning the test. The name is then anonymized by removing the spaces in the string and randomizing the letters into a unique word.

- *SessionID* – Each session was given a unique ID based on a combination of UserID, Date of exercise and activated features.
- *CurrentDateTime* – The time of the beginning of the exercise is noted down to the second this can function as an alternative sessionID, though would have to crossreference to *UserID* and the features activated.

Exercise specific data concern the any information regarded the exercise itself including the fixed variables that changed for each session as well as the variables determining how well the exercise was carried out such as completion time and the amount of errors done by the end of each session. This is also the data that that combined with the identification can provide details about whether the users improves in performance in such cases as decreased time spend in clicking all tiles or clicking fewer wrong tiles in a session. This category also deals with the feedback provided and whether or not it was activated or present during the exercise as well as how much the user had to use it in order to complete the exercise.

The variables for exercise specifics were:

- *PermTileFeedback* – This is a fixed binominal variable indicating whether or not the feature of permanent change in alpha value is activated for the current session.
- *NoiseOn* – The distraction played during half the sessions also a fixed binominal variable.
- *ColorOn* – The third binominal variable, this is the change of colour of the correct tile to click.
- *CueEdgeOn* – The fourth and final fixed binominal variable. The cueing brackets moving near the edges of the grid.
- *TimePerFrame* – The time of the exercise recorded for each batch of data being send. Termed 'perframe' because it was originally coded to record and send each frame. However, the tablet did not possess the computation power to do so.
- *TileID* – Each tile was given a unique ID, an integer equivalent to its visually presented number.
- *Correct* – A binominal value indicating if the tile clicked was indeed the correct one.
- *TimeBetweenTiles* – The time the participant spend between each clicked tile whether correct or wrong.
- *TileDistance* – The distance between the tile just clicked and the previous.
- *WrongTilesClicked* – The amount of wrong tiles clicked per session.
- *CorrectTilesClicked* – The amount of correct tiles clicked per session. A variable used to identify if a session ran correctly by finished upon reaching max tile count.
- *TotalTilesToClick* – The maximum amount of tiles for each session.

Environment specific deals with the sensory input the tablet can provide. While many tablets lack greatly in the desired sensors many mobile phones does provide an extra array of useful sensory inputs. Thus should the sensors be available this category tracks any surrounding factors such as the presence of sound and light in order to determine if these factors can prove to be a distraction for the user and thus adapt the exercise accordingly.
The variables for environment specifics are:

- Light – Light intensity registered by the front light sensor.
- Sound – Sound is recorded, though only as a float value for volume using the inbuilt microphone.

The sensory input from mobile devices are not explicitly available via the Unity api and while writing a plugin for Unity was an option it was considered too time consuming for the project scope and was instead integrated using an available plugin in the Unity store named GyroDroid

(cortex 2014). By activating each of the sensors in Unity and given the sensor was available in the device offered instant tracking of the following sensors:

- Rotation Vector
- Gyroscope
- Accelerometer
- Linear Acceleration
- Gravity
- Light
- Proximity
- Orientation
- Pressure
- Magnetic Field
- Processor Temperature
- Ambient Temperature
- Relative Humidity
- Magnetic Field (uncalibrated)
- Gyroscope (uncalibrated)
- Game Rotation Vector
- Step Detector
- Step Counter
- Geomagnetic Rotation Vector

Interaction specific tracks any interaction the user performs with the tablet. How they move it around and rotate it during the exercise as well, as how they interact with the screen.

- Acceleration – The acceleration of the tablet during exercise as a 3D-vector
- AccDist – the length of the acceleration vector.
- RotationRate – The rotation of the tablet in its own reference frame.
- TouchPosition – The position on the screen in pixel coordinates where the user clicked touched the screen. This records the entire screen and not just interaction with the tiles.

7.2 TEXTURES

As mentioned in **Error! Reference source not found.** the visual appearance of the tiles were chosen to be a piece of paper with numbers on to draw a parallel to the familiar environment experienced with the traditional exercise. The texture chosen is a stock image of a piece of crumbled paper to emphasize the paper surface. On top of the image was created a new layer and after setting up a 7 x 7 grid 49 numbers were added within the grid. This was the atlas sprite for the all the grids making it possible to create a grid with a max of 49 tiles. Creating the negative and positive feedback for the tile clicks a colour overlay in green and red was added. The number 49 was chosen due to an original intention of implementing a greater grid, though was adjusted to 25 due to time consumption for the test.

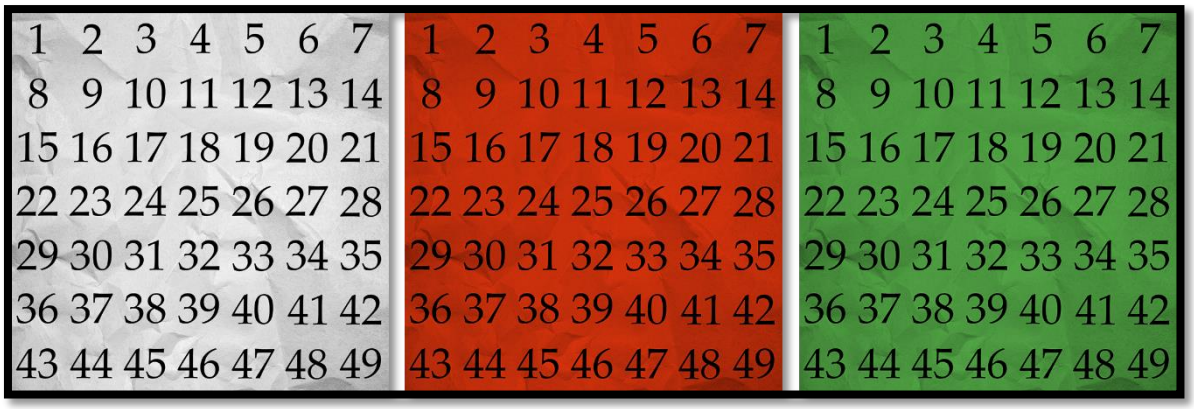

Figure 8. The three atlas textures used for the grid in the exercise. The default white and the negative and positive feedback when clicking on the tiles.

The background texture was chosen based on the same premise as the grid and resembles a table as seen from above. The colours were adjusted to become slightly more vivid and warm as well as increased the contrast to the paper grid. The start button and tutorial button seen in the menu system and Figure 9 were created using the same wood stock image as the background. A square section of the image was selected and slightly scaled to give the sense that it was on top of the background and closer to the viewer. Shadow effect and Bevel & Emboss was added as well as a new layer with the text "Start Game". The text was given the effects inner shadow and satin, this created the illusion that it was carved into the button. Creating the state of the clicked button was done by lowering the distance of the shadow and the Bevel & Emboss by a few pixels and downscaling both the size of the text and texture.

Figure 9. The two states of the startButton.

```
    public void CheckForCorrectTile(GameObject tileClicked)
    {
        gameManager.gameSessionBegun = true;
        int tileNumberID = tileClicked.GetComponent<TileClass>().numberID;
        Vector2 gridPosition = tileClicked.transform.position;
        tileCounter++;
        CheckTimeBetweenTiles();

        if(tileClicked.GetComponent<TileClass>().numberID == correctTileCounter + 1 &&
tileClicked.GetComponent<TileClass>().tilePicked == false)
        {
            correctTileCounter++;
            tilesCorrectLeft = correctTileArray.Length - correctTileCounter;
            CurrentTileInfo(tileNumberID, gridPosition, 1, tileCounter, tilesCorrectLeft);
            tileIsChecked = true;
            tileClicked.GetComponent<TileClass>().ClickedCorrectly();
            tileClicked.GetComponent<TileClass>().tilePicked = true;

            if (gameManager.cueEdgesOn == 1 && correctTileCounter !=
correctTileArray.Length)
            {
                edgeCue.tileXValue =
gameBoard.gridArr[correctTileCounter].transform.position.x;
                edgeCue.tileYValue =
gameBoard.gridArr[correctTileCounter].transform.position.y;
            }

            if (tileNumberID == 1 && gameManager.gameBegun == true)
            {
                timeDiff = Time.time;
                highScore.showScore = false;
                exerciseDateTime = DateTime.Now.ToString("yyyy-MM-dd hh:mm:ss");
                if (invokeBegun == false)
                {
                    InvokeRepeating("ReadData", 0, 1);
                    invokeBegun = true;
                }
            }
            tileDistance = Vector3.Distance(tileClicked.transform.position, oldPosition);
            oldPosition = tileClicked.transform.position;
        }
        else
        {
            CurrentTileInfo(tileNumberID, gridPosition, 0, tileCounter, tilesCorrectLeft);
            tileIsChecked = true;
            wrongTileCounter++;
            tileClicked.GetComponent<TileClass>().ClickedWrongly();

        }

        if (gameManager.gameBegun == true)
        {
            ReadData();
        }

}
```

Figure 10. Whenever a tile is clicked the method ReadData() is called and when the first tile in a session is clicked the invoke method is called. This method repeats every second and calls ReadData() as well. ReadData() consist of the list of variables being collected send.

```
       void Start () {
        datalog = GameObject.Find("ScriptHolder").GetComponent<DataLog>();
        background = GameObject.Find("Background");
        tileTexturesArr = Resources.LoadAll<Sprite>("Textures/TileSpritesWhite");
        tileTextureClickedArr = Resources.LoadAll<Sprite>("Textures/TileSpritesClicked");
        tileTextureNegativeArr = Resources.LoadAll<Sprite>("Textures/TileSpritesNegative");
        tileTexturePositiveArr = Resources.LoadAll<Sprite>("Textures/TileSpritesPositive");
       }
 public void InstantiateTiles(int gridX, int gridY)
    {
        // Clean for a new array of tiles
        DestroyGridArray();
        arraySize = gridX * gridY;
        gridArr = new GameObject[arraySize];
        gridTileObj.transform.localScale = new Vector3(tileScale, tileScale, 0);
        gridLength = Mathf.Abs(((spacing - 1) * tileScale) * (gridX -1)) + (tileScale *
gridX);

        datalog.EmptyCorrectTileArray(arraySize);
        int posInArray = 0;

        //Instantiating the 2DGrid with scalable tiles
        for (int X = 0; X < gridX; X++)
        {
            for (int Y = 0; Y < gridY; Y++)
            {
                Vector3 pos = new Vector3(X * tileScale, Y * tileScale, 0) * spacing;
                tempGridTileObj = Instantiate(gridTileObj, pos, Quaternion.identity) as
GameObject;

                gridArr[posInArray] = tempGridTileObj;
                posInArray++;
            }
        }
        //Centring the camera - offset by 0.5 due startPos in first tile is centered in 0.0
       mainCameraObj.transform.localPosition = new Vector3(gridLength / 2 - (tileScale /
       2), gridLength / 2 - (tileScale / 2), -10);
       background.transform.localPosition = new Vector3(gridLength / 2 - (tileScale / 2),
       gridLength / 2 - (tileScale / 2), 1);

        // Adding sprite and ID to each Tile
        for (int i = 0; i < gridArr.Length; i++)
        {
            gridArr[i].GetComponent<SpriteRenderer>().sprite = tileTexturesArr[i];

            gridArr[i].GetComponent<TileClass>().numberID = i + 1;
        }
        RandomizeTilePos(gridArr);
    }
    //Randomizes tile positions within the grid
 public void RandomizeTilePos(GameObject[] gridArray)
    {
        for (int t = 0; t < gridArray.Length; t++)
        {
            Vector3 tmp = gridArray[t].transform.position;
            int r = Random.Range(t, gridArray.Length);
            gridArray[t].transform.position = gridArray[r].transform.position;
            gridArray[r].transform.position = tmp;
            gridArr[t].GetComponent<SpriteRenderer>().sprite = tileTexturesArr[t];
        }
        datalog.EmptyCorrectTileArray(arraySize);
    }
```

Figure 11. Instantiation of a new grid of tiles with placement being randomized and camera position updated accordingly. Each tile is given a unique sprite and ID to be identified visually, and data wise.

8 TEST / METHOD

Prior to the test, the participants had been screened to ensure no other variables would affect the results. It was required than none of the participants had trouble with their hearing as well as no sign of colour blindness and number blindness. These three variables could affect the results in a negative manner because of the numbered tiles and colour feedback given when activating the tiles.
Due to several technical challenges, it was not possible arranging a test with patients having tbi in time, and as such, the test was redesigned to accommodate for healthy participants.

The test was carried out by having participants placed at a table with the tablet in front of them positioned in a slight angle. Attached to the tablet was a headset, which they were instructed to don prior to launch the exercise. Prior to the exercise, all participants had been screened for colour blindness and dyscalculia (number blindness) as the current iteration of the exercise does not implement features to accommodate these disabilities. The four features noise, permanent change of tiles, colour change of tiles and the moving cue brackets were explained along with how they would show in the exercise.

Each of the cue features i.e. not the noise were visually shown and tried in a tutorial similar in setup to the exercise itself with the difference of no distraction as well as only nine tiles in the grid instead of the full size of 25. Each features was shown by itself without any crossover from other features and the tutorial was designed in a cyclic manner repeating each feature after the other. The participants were encouraged to play through the tutorial until they had a strong understanding of the concept and each individual feature, and felt at ease with clicking the tiles. This was to ensure the learning curve of the exercise and the tools would not affect the outcome of the first few sessions. This was further prevented by counterbalancing each beginning session with a different one per individual participant.

The task of the assignment was explained: 25 tiles is shown and the task is to click each tile in an ascending order from one to 25. It is important that the task be performed in the fastest manner possible and with the fewest mistakes. Should a wrong tile be clicked the task is to locate the correct tile and continue from that one. Using the features is only an option and it is not necessary to wait for neither colour change or cue brackets to take effect before clicking on the next tile.

Should the participant be in need of a break during the test, this was allowed though only after a session had ended and before beginning a new, in order not to influence the data collection. None of the participants decided for a break. Data was collected during each session and reset when the final tile of a session was activated.

After the exercise was completed, the participants were asked to fill out a short questionnaire regarding the different helping features as well personal information.

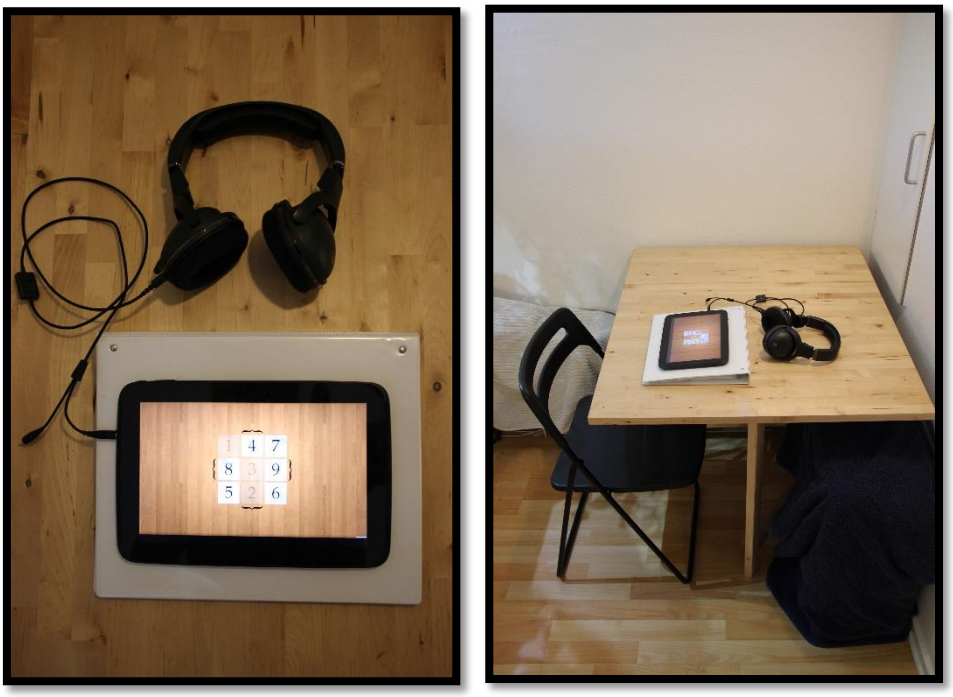

Figure 12. The participants were placed at a table with the tablet in front of them.

Figure 13. The setup for the exercise. Headset attached to the tablet. Tablet is showing the tutorial with the feature of permanent marking of the tiles.

9 RESULTS

9 participants partook in the testing of which data gathered from 8 of them could be used for further analysis. During the test problems occurred with the recording of data for a participant and only a minor part was transferred and for that reason had to be discarded from further analysis. The results were examined for any outliers that might affect the outcome. Three outliers were found and analysis was carried out with these in mind.

Testing a Schulte table to determine how focused the participant was and their ability to complete the exercise is done by measuring the time of completion per level. However to provide further details that can be useful in sessions of treatment and evaluation of progression measuring of the amount of errors made is also of importance as this can have an effect on time due to repeated actions in the need of clicking additional tiles.

The groups shown in the graphs and the variables mentioned in the results follow the pattern:

- Permanent change in tiles when clicked - PC
- Noise as distractor - NO
- Correct tile gradually changes colour - CC
- Moving cue brackets and eventually shown the location of the correct tile - CB

In the charts and boxplots, because of the limited space for the 16 groups each variable are given a binominal number to indicate whether it is activated or disabled in the given session. Therefore to read groups are to be understood as following:

- 0000 indicates that none of the variables in the session is activated and is therefore the control group.
- 1000 indicates that PC is activated while the rest remain disabled.
- 0100 – NO is the only activated variable.
- 0010 – CC is activated. The rest are disabled.
- 0001 – CB is enabled and the rest disabled.

A combination of any of these binominal numbers therefore indicate whether a certain variable is present or disabled as well as if several variables are present simultaneously.

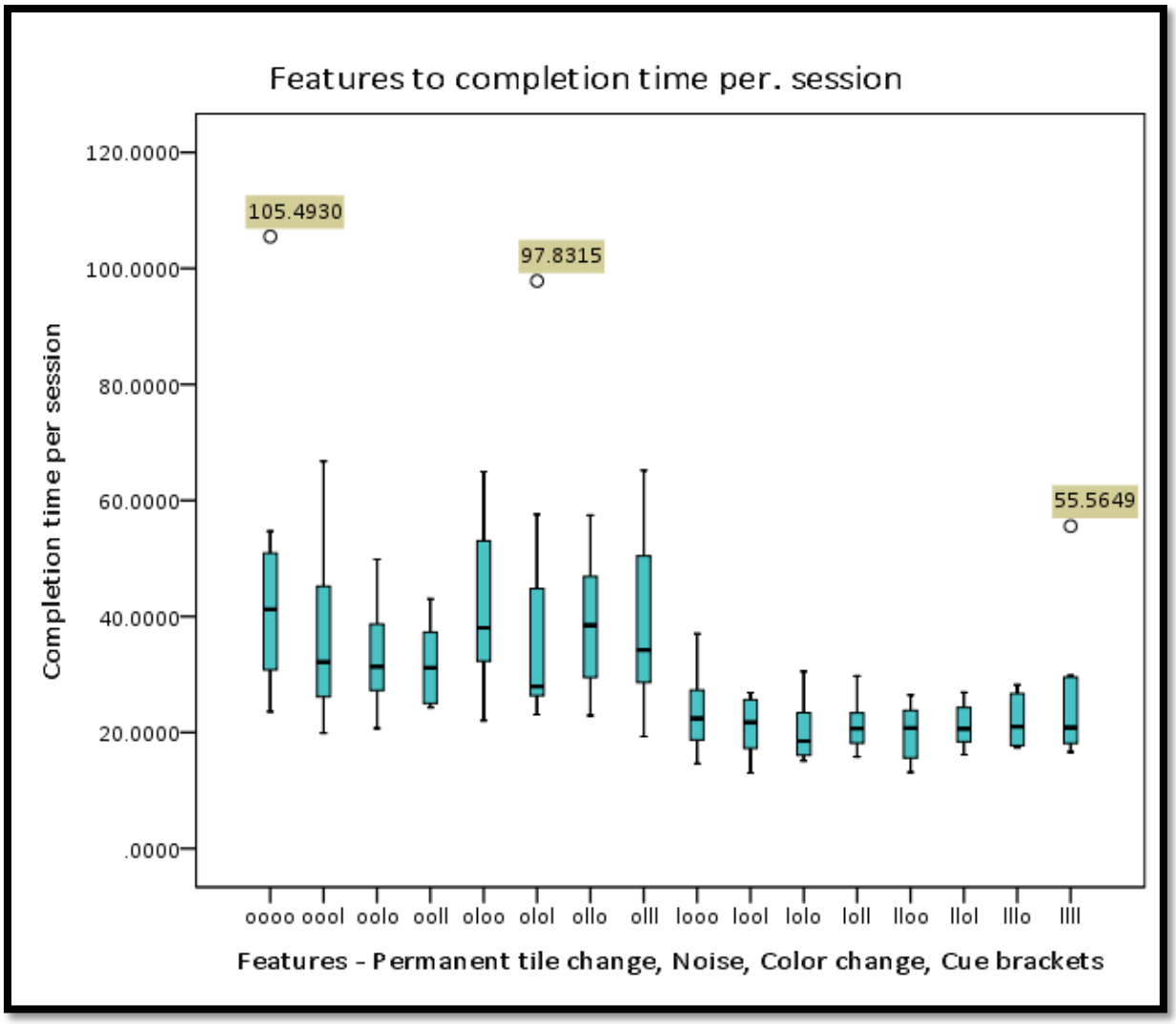

Figure 14. Three outliers were found in the data collection.

The outliers were found after the test had been performed and the participant had left the vicinity. However, before they left a short conversation regarding the test took place and it was discovered that some participants had failed to interpret the feedback given by the tiles upon interaction. This means that when a tile signalled red it was not considered an indication of the tile as incorrect in the sequence thus instead of searching for the correct tile, simply continued their counting toward 25. Thereby failed to realise that none of the tiles had been correctly clicked. This behaviour only affected the completion time in the session 0101 (97.8315 sec) where the participant clicked 28 tiles in the wrong order. The 0000 completed the exercise with 0 mistakes and for that reason should not be discarded for the further analyse despite being a remarkable outlier. The outlier caused error counting due to poor feedback should be discarded, as it is the assistant features being tested and not the interactive feedback. However, it should be noted that colour feedback alone is not enough to ensure a users' understanding of interaction with the tiles.

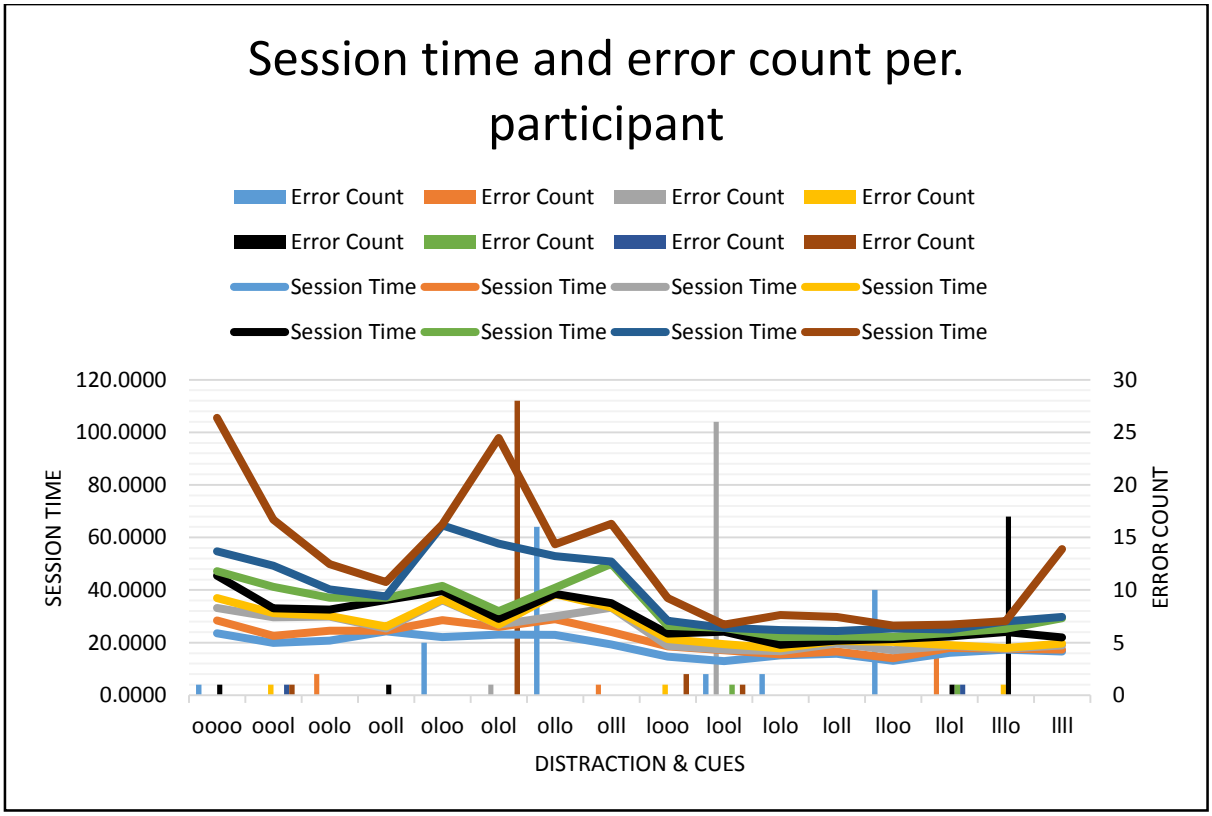

Figure 15. The graph illustrates the amount of errors each of the 8 participants did through each session as well as the completion time for the same sessions. Each participant is colour coded. The red participant performed badly in the control group, caused an outlier, and at the same time did a great amount of errors causing another outlier in the session with NO and CB activated.

The collected data from the exercise was analysed using a single-factor ANOVA to establish any significant differences between the control group – with all features disabled, and compared to the crossover and single-feature groups. With the dependent variable as completion-time of the sessions, a significant difference was shown $F_{15, 126} = 4.704, P < 0.05$.

Table 1. ANOVA of Completion time among groups of mixed features. A $P < 0.05$ significance between groups was found.

ANOVA

CompletionTime

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9469.455	15	631.297	4.704	.000
Within Groups	14897.679	111	134.213		
Total	24367.134	126			

To establish which of the combinations of variables that caused the significant difference a Tukey *a posteriori* test was performed. See Table 2. Due to the amount of comparisons, the list here is displaying only those that showed a significant difference in comparison. The full list is attached in the appendix. When mentioning positive and negative effect on completion time, the expression is to be understood as negative effect on time, means the time was shorter compared to that of the control group and vice versa for positive.

The control group 0000, shows a significant difference to 8 other combinations of variables with a positive effect on time completion. This means with all features disabled the control sessions were completed with a significant slower time than the rest of the combination. The two greatest differences is seen with the combination 1010 and 1100 meaning these two combination had the shortest completion time. The first combination 1010 is the permanent marking of tiles and the change in colour. It was expected that this combination would be among the most efficient due to both removal of potential targets as well as increasing the parallel search. What is remarkable is the combination 1100 as this is the permanent marking combined with the noise distraction. It was assumed that any combination with the distraction activated would result in an increase in completion time. This however is not the case. While it does explain the reason as to why the NO apparently provides a boost exercise completion it is noticeably the all 8 combinations shares the PC feature and the four combinations with both NO and PC are significant different to the control. None of the other features sharing NO is shown as significant to control and for that reason, it can simply be that PC is that much more efficient and NO as a secondary feature does not have an effect on its own despite being seemingly the best combination time wise.

Analysing the comparison between the distraction and the ones showing as significant different it again becomes obvious that NO does have a negative effect on time. When comparing the differences between the controls group NO shows as having mean values close to 20 while the control group is closer 24 meaning NO alone is 4 seconds faster. While this is not a significant difference compared to control it is again a remarkable observation. As with the control group all the compared group showing significant difference, once again contains the activated PC feature.

The remaining combinations all share the same significant differences to control group and NO as only activated feature.

Table 2. Tukey post hoc test completion time compared between the three helping tools and the distraction. The names are binominal and stands for 1 = active, 0 = disabled for each feature. The names consist accordingly: PC, NO, CC, CB

Multiple Comparisons

Dependent Variable: CompletionTime

Tukey HSD

(I) Group	(j) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
oooo	looo	23.3170375*	5.7925237	.010	3.007866	43.626209
	lool	25.7196750*	5.7925237	.002	5.410504	46.028846
	lolo	26.6696126*	5.7925237	.001	6.360442	46.978784
	loll	25.6226375*	5.7925237	.002	5.313466	45.931809
	lloo	26.8871250*	5.7925237	.001	6.577954	47.196296
	llol	25.6489625*	5.7925237	.002	5.339791	45.958134
	lllo	24.8195500*	5.7925237	.004	4.510379	45.128721
	llll	20.7258250*	5.7925237	.040	.416654	41.034996
oloo	lool	20.5734505*	5.7925237	.044	.264279	40.882621
	lolo	21.5233880*	5.7925237	.027	1.214217	41.832559
	loll	20.4764130*	5.7925237	.046	.167242	40.785584
	lloo	21.7409005*	5.7925237	.024	1.431729	42.050071
	llol	20.5027380*	5.7925237	.045	.193567	40.811909
	lllo	19.6733255	5.7925237	.068	-.635846	39.982496
	llll	15.5796005	5.7925237	.351	-4.729571	35.888771
looo	oooo	-23.3170375*	5.7925237	.010	-43.626209	-3.007866
lool	oooo	-25.7196750*	5.7925237	.002	-46.028846	-5.410504
	oloo	-20.5734505*	5.7925237	.044	-40.882621	-.264279
lolo	oooo	-26.6696126*	5.7925237	.001	-46.978784	-6.360442
	oloo	-21.5233880*	5.7925237	.027	-41.832559	-1.214217
loll	oooo	-25.6226375*	5.7925237	.002	-45.931809	-5.313466
	oloo	-20.4764130*	5.7925237	.046	-40.785584	-.167242
lloo	oooo	-26.8871250*	5.7925237	.001	-47.196296	-6.577954
	oloo	-21.7409005*	5.7925237	.024	-42.050071	-1.431729
llol	oooo	-25.6489625*	5.7925237	.002	-45.958134	-5.339791
	oloo	-20.5027380*	5.7925237	.045	-40.811909	-.193567
lllo	oooo	-24.8195500*	5.7925237	.004	-45.128721	-4.510379
llll	oooo	-20.7258250*	5.7925237	.040	-41.034996	-.416654

Table 3. A ranking of the means between the features combinations show 5 significant different combinations in top with PC and NO ranking as the most efficient combination.

CompletionTime

Tukey HSD[a,b]

Group	N	Subset for alpha = 0.05		
		1	2	3
lloo	8	19.984538		
lolo	8	20.202050		
lool	8	21.151988		
llol	8	21.222700		
loll	8	21.249025		
lllo	8	22.052113	22.052113	
looo	8	23.554625	23.554625	
llll	8	26.145838	26.145838	
olol	7	31.613529	31.613529	31.613529
ooll	8	31.766412	31.766412	31.766412
oolo	8	33.128288	33.128288	33.128288
oool	8	36.696338	36.696338	36.696338
ollo	8	38.750688	38.750688	38.750688
olll	8	38.880688	38.880688	38.880688
oloo	8		41.725438	41.725438
oooo	8			46.871663
Sig.		.102	.071	.394

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 7.929.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Ranking the mean values as seen in Table 3 further establishes the combination of PC and NO as the most efficient with the combination of the other two helping features close behind. The control is shown at the very bottom as the least efficient, which was expected though still assumed to be slightly faster than the NO combination.

An ANOVA was also run on the amount of wrong tiles had been clicked. However, no significance was shown between various groups.

ANOVA

WrongTilesClicked

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	185.805	15	12.387	.739	.740
Within Groups	1877.125	112	16.760		
Total	2062.930	127			

10 FUTURE ITERATIONS

The adaptive behaviour should be fully implemented in order to verify if this functionality indeed does serve as a helpful and nonintrusive tool when acting upon user performance as well as sensory input from the surroundings.

Implementation of additional cueing features should also be considered. The current features focuses on the brains ability to perform parallel search and endogenous attention. However, designing for exogenous attention is likely also an option that can be integrated in a cueing paradigm and should be tested to determine if it can provide a positive effect on outcome of time. This could be quick flashes and movements of the targeted tile as well as sudden limitations of search area that catches the user's attention.

A levelling system should be implemented to accommodate for a progression of the user's ability besides the single exercise that utilizes cues.

The menu should also be expanded and include a graphical overview of the patients progression with the exercise. The current version only covers the completion time for a single session and without the option to compare it against other sessions.

The amount of tiles present should also be considered. As the results show, the speed of clicking the correct tile increases with the decline of available tiles to choose from. This is would be a fundamental feature in providing a levelling system.

Distance between tiles should also be considered as a variable that could affect the difficulty of the exercise. Especially with the patients, suffering from hemi spatial neglect placement further to the left side will likely prove more challenging and therefore a potential variable for integrated difficulty. This could also be implemented as part of the aforementioned levelling system.

The current design does not take into account if the user is colour blind or suffers from dyscalculia that is consequence for some tbi patients, and therefore should be a necessary design implementation.

Statistics and graphical view of which parts of the grid the patient experiences increased challenges. Listed by ID i.e. number, letter etc. and position. This will help improve the understanding for future iterations and design as well as indicate toward the therapist and the patients themselves where the challenges may be during the treatment.

11 DISCUSSION

After the test was performed, a short discussion with the participants took place and it was noted that not all had made the connection of a short colour change of the tiles being clicked. While the feedback was designed to signify, whether or not the tile clicked on was correct or not, this was not understood by all participants. This did alter the result in and consequently had to be discarded from the analysis. While one was found to be an outlier and could easily be establish it is unknown whether poor design can have further polluted the rest of the results in a negative manner.

According to some participants, the current texture environment imitating the low fidelity model did not provide a positive reaction. There was a variety in the in texture used for the grids, which gave each tile a different colour that appeared distracting. As this was not the intention of the design, this should be changed in future iterations and instead given a persistent colour for each tile and only have the identifying number or symbol be the default difference. A long with the poor feedback this could have had an impact on the results.

The original plan for project was to design and test on patients with tbi. However, due to technical issues during the development of the application and a prolonged period with alternative design evaluations. By the time, the application was ready for testing, such a test was not possible to arrange in such a short notice. Instead, the application was further modified to accommodate for healthy participants. Due to this alternative arrangement, the results must be considered under these conditions and before any further conclusions can be determined should be tested under the intentional circumstances.

Due to unknown technical issues, tracking of one of the participants test sessions failed and the remaining data had to be discarded. While it is impossible to discern the reason for this failure it should be considered to implement an offline log as alternative tracking in case the issues was caused by connection complications.

12 CONCLUSION

The problem statement was:

> *How can an exercise in attention processing treatment be designed to accommodate for distractions in immediate environment so that complexity of exercise decreases with level of disturbances while at the same time track progression of the patient's performance.*

While the project only went through a single iteration it was determined that a significant decrease in the challenge happened, when applying the researched features aimed to help during the exercise. The test was carried out with healthy individuals and as such can be expected to provide a different result than had the participants been patients with traumatic brain injury. The test was designed to accommodate for this discrepancy, though the result shows that the distractive element had no significant impact on the result regarding completion time. It was however noted by some of the participants, that the noise was considered distracting, though not enough to accommodate for the superiority of the healthy participants. This does support the theory regarding selective attention in which the ability to disregard irrelevant stimuli is functional in healthy people and as such does not find it difficult to ignore such a distraction.
The features tested were designed based on the theory of endogenous attention and visual search. A significant difference was found between several combinations of the features and as such has an effect on the difficulty of the exercise. Permanent marking of the tiles revealed to have the greatest negative impact on time and for that reason, is the most efficient. This was expected with the continuously lowering of the amount of active tiles.
The second feature used was designed to have a direct influence on the visual search by changing the significance in colour toward the rest of the tiles. By radically standing out the visual search changes from a serial search, to a parallel search and thus lowers the impact on memory capacity.
Third and last feature employed the endogenous attention by having the user covertly focusing on the grid in search of the tile while being cued toward its location.
Neither of the last two features showed to have any significant impact on completion time compared to the control group and for that reason, cannot be regarded as efficient in lowering the challenge of the exercise. However, before entirely disregarding the features more testing should be performed concerning choice of colour, speed of change and location for the endogenous cuing.
The adaptive behaviour did not make it in the first round of tests though is planned to be implemented and tested for upcoming iterations.

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14 APPENDIX

14.1 CONSENT FORM

Samtykkeerklæring

Formålet med denne applikation er at inkorporere feedback kontrolleret af sensorisk input, samt implementere en adaptiv adfærd influeret af kontinuerlig kalibrering af brugerens progressive præstationsevne.

Jeg deltager i en øvelse, hvor data vil blive indsamlet omkring min præstationsevne under varierende variabler.

Jeg er indforstået med at denne test forekommer som led i en iterativ proces og mine data, derfor kan indgå på sigt i et større projekt, samt offentliggøres i forbindelse med begrundelse for afgørende valg foretaget i udviklingsprocessen.

Alt indsamlet data indgår anonymt og jeg kan under testens forløb vælge at stoppe, og bede om at få alt data fjernet omkring min deltagelse.

_____ _____

Underskrift Dato

14.2 TUKEY POST HOC TEST

14.2.1 Completion Time

Multiple Comparisons

Dependent Variable: CompletionTime

Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
oooo	oool	10.1753250	5.7925237	.926	-10.133846	30.484496
	oolo	13.7433750	5.7925237	.572	-6.565796	34.052546
	ooll	15.1052500	5.7925237	.404	-5.203921	35.414421
	oloo	5.1462245	5.7925237	1.000	-15.162946	25.455396
	olol	15.2581339	5.9958317	.448	-5.763855	36.280123
	ollo	8.1209748	5.7925237	.990	-12.188196	28.430146
	olll	7.9909750	5.7925237	.991	-12.318196	28.300146
	looo	23.3170375*	5.7925237	.010	3.007866	43.626209
	lool	25.7196750*	5.7925237	.002	5.410504	46.028846
	lolo	26.6696126*	5.7925237	.001	6.360442	46.978784
	loll	25.6226375*	5.7925237	.002	5.313466	45.931809
	lloo	26.8871250*	5.7925237	.001	6.577954	47.196296
	llol	25.6489625*	5.7925237	.002	5.339791	45.958134
	lllo	24.8195500*	5.7925237	.004	4.510379	45.128721
	llll	20.7258250*	5.7925237	.040	.416654	41.034996
oool	oooo	-10.1753250	5.7925237	.926	-30.484496	10.133846
	oolo	3.5680500	5.7925237	1.000	-16.741121	23.877221
	ooll	4.9299250	5.7925237	1.000	-15.379246	25.239096
	oloo	-5.0291005	5.7925237	1.000	-25.338271	15.280071
	olol	5.0828089	5.9958317	1.000	-15.939180	26.104798
	ollo	-2.0543502	5.7925237	1.000	-22.363521	18.254821
	olll	-2.1843500	5.7925237	1.000	-22.493521	18.124821
	looo	13.1417125	5.7925237	.647	-7.167459	33.450884
	lool	15.5443500	5.7925237	.355	-4.764821	35.853521
	lolo	16.4942876	5.7925237	.259	-3.814883	36.803459
	loll	15.4473125	5.7925237	.365	-4.861859	35.756484
	lloo	16.7118000	5.7925237	.240	-3.597371	37.020971
	llol	15.4736375	5.7925237	.362	-4.835534	35.782809
	lllo	14.6442250	5.7925237	.459	-5.664946	34.953396
	llll	10.5505000	5.7925237	.903	-9.758671	30.859671
oolo	oooo	-13.7433750	5.7925237	.572	-34.052546	6.565796

	oool	-3.5680500	5.7925237	1.000	-23.877221	16.741121
	ooll	1.3618750	5.7925237	1.000	-18.947296	21.671046
	oloo	-8.5971505	5.7925237	.982	-28.906321	11.712021
	olol	1.5147589	5.9958317	1.000	-19.507230	22.536748
	ollo	-5.6224002	5.7925237	1.000	-25.931571	14.686771
	olll	-5.7524000	5.7925237	1.000	-26.061571	14.556771
	looo	9.5736625	5.7925237	.954	-10.735509	29.882834
	lool	11.9763000	5.7925237	.781	-8.332871	32.285471
	lolo	12.9262376	5.7925237	.673	-7.382933	33.235409
	loll	11.8792625	5.7925237	.791	-8.429909	32.188434
	lloo	13.1437500	5.7925237	.647	-7.165421	33.452921
	llol	11.9055875	5.7925237	.788	-8.403584	32.214759
	lllo	11.0761750	5.7925237	.865	-9.232996	31.385346
	llll	6.9824500	5.7925237	.998	-13.326721	27.291621
ooll	oooo	-15.1052500	5.7925237	.404	-35.414421	5.203921
	oool	-4.9299250	5.7925237	1.000	-25.239096	15.379246
	oolo	-1.3618750	5.7925237	1.000	-21.671046	18.947296
	oloo	-9.9590255	5.7925237	.937	-30.268196	10.350146
	olol	.1528839	5.9958317	1.000	-20.869105	21.174873
	ollo	-6.9842752	5.7925237	.998	-27.293446	13.324896
	olll	-7.1142750	5.7925237	.997	-27.423446	13.194896
	looo	8.2117875	5.7925237	.988	-12.097384	28.520959
	lool	10.6144250	5.7925237	.899	-9.694746	30.923596
	lolo	11.5643626	5.7925237	.822	-8.744808	31.873534
	loll	10.5173875	5.7925237	.905	-9.791784	30.826559
	lloo	11.7818750	5.7925237	.801	-8.527296	32.091046
	llol	10.5437125	5.7925237	.904	-9.765459	30.852884
	lllo	9.7143000	5.7925237	.948	-10.594871	30.023471
	llll	5.6205750	5.7925237	1.000	-14.688596	25.929746
oloo	oooo	-5.1462245	5.7925237	1.000	-25.455396	15.162946
	oool	5.0291005	5.7925237	1.000	-15.280071	25.338271
	oolo	8.5971505	5.7925237	.982	-11.712021	28.906321
	ooll	9.9590255	5.7925237	.937	-10.350146	30.268196
	olol	10.1119094	5.9958317	.946	-10.910080	31.133899
	ollo	2.9747503	5.7925237	1.000	-17.334421	23.283921
	olll	2.8447505	5.7925237	1.000	-17.464421	23.153921
	looo	18.1708130	5.7925237	.135	-2.138358	38.479984
	lool	20.5734505*	5.7925237	.044	.264279	40.882621
	lolo	21.5233880*	5.7925237	.027	1.214217	41.832559
	loll	20.4764130*	5.7925237	.046	.167242	40.785584

	lloo	21.7409005*	5.7925237	.024	1.431729	42.050071
	llol	20.5027380*	5.7925237	.045	.193567	40.811909
	lllo	19.6733255	5.7925237	.068	-.635846	39.982496
	llll	15.5796005	5.7925237	.351	-4.729571	35.888771
olol	oooo	-15.2581339	5.9958317	.448	-36.280123	5.763855
	oool	-5.0828089	5.9958317	1.000	-26.104798	15.939180
	oolo	-1.5147589	5.9958317	1.000	-22.536748	19.507230
	ooll	-.1528839	5.9958317	1.000	-21.174873	20.869105
	oloo	-10.1119094	5.9958317	.946	-31.133899	10.910080
	ollo	-7.1371591	5.9958317	.998	-28.159148	13.884830
	olll	-7.2671589	5.9958317	.998	-28.289148	13.754830
	looo	8.0589036	5.9958317	.993	-12.963086	29.080893
	lool	10.4615411	5.9958317	.930	-10.560448	31.483530
	lolo	11.4114786	5.9958317	.869	-9.610511	32.433468
	loll	10.3645036	5.9958317	.935	-10.657486	31.386493
	lloo	11.6289911	5.9958317	.852	-9.392998	32.650980
	llol	10.3908286	5.9958317	.933	-10.631161	31.412818
	lllo	9.5614161	5.9958317	.966	-11.460573	30.583405
	llll	5.4676911	5.9958317	1.000	-15.554298	26.489680
ollo	oooo	-8.1209748	5.7925237	.990	-28.430146	12.188196
	oool	2.0543502	5.7925237	1.000	-18.254821	22.363521
	oolo	5.6224002	5.7925237	1.000	-14.686771	25.931571
	ooll	6.9842752	5.7925237	.998	-13.324896	27.293446
	oloo	-2.9747503	5.7925237	1.000	-23.283921	17.334421
	olol	7.1371591	5.9958317	.998	-13.884830	28.159148
	olll	-.1299998	5.7925237	1.000	-20.439171	20.179171
	looo	15.1960627	5.7925237	.394	-5.113108	35.505234
	lool	17.5987002	5.7925237	.171	-2.710471	37.907871
	lolo	18.5486378	5.7925237	.115	-1.760533	38.857809
	loll	17.5016627	5.7925237	.177	-2.807508	37.810834
	lloo	18.7661502	5.7925237	.104	-1.543021	39.075321
	llol	17.5279877	5.7925237	.176	-2.781183	37.837159
	lllo	16.6985752	5.7925237	.241	-3.610596	37.007746
	llll	12.6048502	5.7925237	.711	-7.704321	32.914021
olll	oooo	-7.9909750	5.7925237	.991	-28.300146	12.318196
	oool	2.1843500	5.7925237	1.000	-18.124821	22.493521
	oolo	5.7524000	5.7925237	1.000	-14.556771	26.061571
	ooll	7.1142750	5.7925237	.997	-13.194896	27.423446
	oloo	-2.8447505	5.7925237	1.000	-23.153921	17.464421
	olol	7.2671589	5.9958317	.998	-13.754830	28.289148

	ollo	.1299998	5.7925237	1.000	-20.179171	20.439171
	looo	15.3260625	5.7925237	.379	-4.983109	35.635234
	lool	17.7287000	5.7925237	.162	-2.580471	38.037871
	lolo	18.6786376	5.7925237	.108	-1.630533	38.987809
	loll	17.6316625	5.7925237	.168	-2.677509	37.940834
	lloo	18.8961500	5.7925237	.098	-1.413021	39.205321
	llol	17.6579875	5.7925237	.167	-2.651184	37.967159
	llll	16.8285750	5.7925237	.230	-3.480596	37.137746
	llll	12.7348500	5.7925237	.696	-7.574321	33.044021
looo	oooo	-23.3170375*	5.7925237	.010	-43.626209	-3.007866
	oool	-13.1417125	5.7925237	.647	-33.450884	7.167459
	oolo	-9.5736625	5.7925237	.954	-29.882834	10.735509
	ooll	-8.2117875	5.7925237	.988	-28.520959	12.097384
	oloo	-18.1708130	5.7925237	.135	-38.479984	2.138358
	olol	-8.0589036	5.9958317	.993	-29.080893	12.963086
	ollo	-15.1960627	5.7925237	.394	-35.505234	5.113108
	olll	-15.3260625	5.7925237	.379	-35.635234	4.983109
	lool	2.4026375	5.7925237	1.000	-17.906534	22.711809
	lolo	3.3525751	5.7925237	1.000	-16.956596	23.661746
	loll	2.3056000	5.7925237	1.000	-18.003571	22.614771
	lloo	3.5700875	5.7925237	1.000	-16.739084	23.879259
	llol	2.3319250	5.7925237	1.000	-17.977246	22.641096
	llll	1.5025125	5.7925237	1.000	-18.806659	21.811684
	llll	-2.5912125	5.7925237	1.000	-22.900384	17.717959
lool	oooo	-25.7196750*	5.7925237	.002	-46.028846	-5.410504
	oool	-15.5443500	5.7925237	.355	-35.853521	4.764821
	oolo	-11.9763000	5.7925237	.781	-32.285471	8.332871
	ooll	-10.6144250	5.7925237	.899	-30.923596	9.694746
	oloo	-20.5734505*	5.7925237	.044	-40.882621	-.264279
	olol	-10.4615411	5.9958317	.930	-31.483530	10.560448
	ollo	-17.5987002	5.7925237	.171	-37.907871	2.710471
	olll	-17.7287000	5.7925237	.162	-38.037871	2.580471
	looo	-2.4026375	5.7925237	1.000	-22.711809	17.906534
	lolo	.9499376	5.7925237	1.000	-19.359233	21.259109
	loll	-.0970375	5.7925237	1.000	-20.406209	20.212134
	lloo	1.1674500	5.7925237	1.000	-19.141721	21.476621
	llol	-.0707125	5.7925237	1.000	-20.379884	20.238459
	llll	-.9001250	5.7925237	1.000	-21.209296	19.409046
	llll	-4.9938500	5.7925237	1.000	-25.303021	15.315321
lolo	oooo	-26.6696126*	5.7925237	.001	-46.978784	-6.360442

	oool	-16.4942876	5.7925237	.259	-36.803459	3.814883
	oolo	-12.9262376	5.7925237	.673	-33.235409	7.382933
	ooll	-11.5643626	5.7925237	.822	-31.873534	8.744808
	oloo	-21.5233880*	5.7925237	.027	-41.832559	-1.214217
	olol	-11.4114786	5.9958317	.869	-32.433468	9.610511
	ollo	-18.5486378	5.7925237	.115	-38.857809	1.760533
	olll	-18.6786376	5.7925237	.108	-38.987809	1.630533
	looo	-3.3525751	5.7925237	1.000	-23.661746	16.956596
	lool	-.9499376	5.7925237	1.000	-21.259109	19.359233
	loll	-1.0469751	5.7925237	1.000	-21.356146	19.262196
	lloo	.2175124	5.7925237	1.000	-20.091659	20.526683
	llol	-1.0206501	5.7925237	1.000	-21.329821	19.288521
	lllo	-1.8500626	5.7925237	1.000	-22.159234	18.459108
	llll	-5.9437876	5.7925237	1.000	-26.252959	14.365383
loll	oooo	-25.6226375*	5.7925237	.002	-45.931809	-5.313466
	oool	-15.4473125	5.7925237	.365	-35.756484	4.861859
	oolo	-11.8792625	5.7925237	.791	-32.188434	8.429909
	ooll	-10.5173875	5.7925237	.905	-30.826559	9.791784
	oloo	-20.4764130*	5.7925237	.046	-40.785584	-.167242
	olol	-10.3645036	5.9958317	.935	-31.386493	10.657486
	ollo	-17.5016627	5.7925237	.177	-37.810834	2.807508
	olll	-17.6316625	5.7925237	.168	-37.940834	2.677509
	looo	-2.3056000	5.7925237	1.000	-22.614771	18.003571
	lool	.0970375	5.7925237	1.000	-20.212134	20.406209
	lolo	1.0469751	5.7925237	1.000	-19.262196	21.356146
	lloo	1.2644875	5.7925237	1.000	-19.044684	21.573659
	llol	.0263250	5.7925237	1.000	-20.282846	20.335496
	lllo	-.8030875	5.7925237	1.000	-21.112259	19.506084
	llll	-4.8968125	5.7925237	1.000	-25.205984	15.412359
lloo	oooo	-26.8871250*	5.7925237	.001	-47.196296	-6.577954
	oool	-16.7118000	5.7925237	.240	-37.020971	3.597371
	oolo	-13.1437500	5.7925237	.647	-33.452921	7.165421
	ooll	-11.7818750	5.7925237	.801	-32.091046	8.527296
	oloo	-21.7409005*	5.7925237	.024	-42.050071	-1.431729
	olol	-11.6289911	5.9958317	.852	-32.650980	9.392998
	ollo	-18.7661502	5.7925237	.104	-39.075321	1.543021
	olll	-18.8961500	5.7925237	.098	-39.205321	1.413021
	looo	-3.5700875	5.7925237	1.000	-23.879259	16.739084
	lool	-1.1674500	5.7925237	1.000	-21.476621	19.141721
	lolo	-.2175124	5.7925237	1.000	-20.526683	20.091659

	loll	-1.2644875	5.7925237	1.000	-21.573659	19.044684
	llol	-1.2381625	5.7925237	1.000	-21.547334	19.071009
	llll	-2.0675750	5.7925237	1.000	-22.376746	18.241596
	llll	-6.1613000	5.7925237	.999	-26.470471	14.147871
llol	oooo	-25.6489625*	5.7925237	.002	-45.958134	-5.339791
	oool	-15.4736375	5.7925237	.362	-35.782809	4.835534
	oolo	-11.9055875	5.7925237	.788	-32.214759	8.403584
	ooll	-10.5437125	5.7925237	.904	-30.852884	9.765459
	oloo	-20.5027380*	5.7925237	.045	-40.811909	-.193567
	olol	-10.3908286	5.9958317	.933	-31.412818	10.631161
	ollo	-17.5279877	5.7925237	.176	-37.837159	2.781183
	olll	-17.6579875	5.7925237	.167	-37.967159	2.651184
	looo	-2.3319250	5.7925237	1.000	-22.641096	17.977246
	lool	.0707125	5.7925237	1.000	-20.238459	20.379884
	lolo	1.0206501	5.7925237	1.000	-19.288521	21.329821
	loll	-.0263250	5.7925237	1.000	-20.335496	20.282846
	lloo	1.2381625	5.7925237	1.000	-19.071009	21.547334
	llll	-.8294125	5.7925237	1.000	-21.138584	19.479759
	llll	-4.9231375	5.7925237	1.000	-25.232309	15.386034
llll	oooo	-24.8195500*	5.7925237	.004	-45.128721	-4.510379
	oool	-14.6442250	5.7925237	.459	-34.953396	5.664946
	oolo	-11.0761750	5.7925237	.865	-31.385346	9.232996
	ooll	-9.7143000	5.7925237	.948	-30.023471	10.594871
	oloo	-19.6733255	5.7925237	.068	-39.982496	.635846
	olol	-9.5614161	5.9958317	.966	-30.583405	11.460573
	ollo	-16.6985752	5.7925237	.241	-37.007746	3.610596
	olll	-16.8285750	5.7925237	.230	-37.137746	3.480596
	looo	-1.5025125	5.7925237	1.000	-21.811684	18.806659
	lool	.9001250	5.7925237	1.000	-19.409046	21.209296
	lolo	1.8500626	5.7925237	1.000	-18.459108	22.159234
	loll	.8030875	5.7925237	1.000	-19.506084	21.112259
	lloo	2.0675750	5.7925237	1.000	-18.241596	22.376746
	llol	.8294125	5.7925237	1.000	-19.479759	21.138584
	llll	-4.0937250	5.7925237	1.000	-24.402896	16.215446
llll	oooo	-20.7258250*	5.7925237	.040	-41.034996	-.416654
	oool	-10.5505000	5.7925237	.903	-30.859671	9.758671
	oolo	-6.9824500	5.7925237	.998	-27.291621	13.326721
	ooll	-5.6205750	5.7925237	1.000	-25.929746	14.688596
	oloo	-15.5796005	5.7925237	.351	-35.888771	4.729571
	olol	-5.4676911	5.9958317	1.000	-26.489680	15.554298

ollo	-12.6048502	5.7925237	.711	-32.914021	7.704321
olll	-12.7348500	5.7925237	.696	-33.044021	7.574321
looo	2.5912125	5.7925237	1.000	-17.717959	22.900384
lool	4.9938500	5.7925237	1.000	-15.315321	25.303021
lolo	5.9437876	5.7925237	1.000	-14.365383	26.252959
loll	4.8968125	5.7925237	1.000	-15.412359	25.205984
lloo	6.1613000	5.7925237	.999	-14.147871	26.470471
llol	4.9231375	5.7925237	1.000	-15.386034	25.232309
lllo	4.0937250	5.7925237	1.000	-16.215446	24.402896

*. The mean difference is significant at the 0.05 level.