Using Spatio-Temporal Data from Trail-Making Tests to Assess Neglect

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Abstract
We designed an app based on the Trail-Making Test for assessment and rehabilitation of hemi-spatial neglect. A randomized controlled trial with thirty-six participants showed that player performance in the game was significantly affected by their cognitive conditions verified by standard neuropsychological tests and the nature of their lesions. A mixed ANOVA revealed that the average time going from one target to the next was significantly affected by the interaction of their neglect scores and the goal position relative to the side of their lesion. The group testing positive for neglect had an average delta time of 3.51 second on targets lateral to the lesion and 5.21 for contra-lateral targets.

Author Keywords
stroke patients; neuropsychology; rehabilitation; attention; hemi-spatial neglect; trail-making test.

ACM Classification Keywords
J.3 [Life and Medical Sciences]: Health; H.5.2 [User Interfaces]: Evaluation/methodology

Introduction
Self-rehabilitation initiatives place emphasis on the growing responsibility that patients and post-rehabilitation patients have for improving their own well-being and progress. Stroke rehabilitation is a lengthy process and the care is

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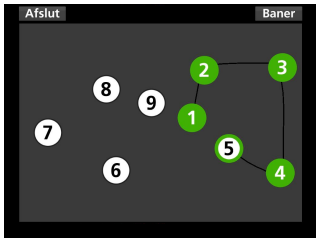

Figure 1: Screenshot of the latest version of the TRAILiT game. The images shows an early type A level.

expensive. However, it leaves time for patients to improve their situation on their own time even while in rehabilitation centers. Games are now being sought as a means to tap into the intrinsic motivation they promote and research investigates to what degree, for example, causal games train cognitive abilities[1].

We believe that purpose-built games that provide more feedback and are simple for patients to understand are better suited for rehabilitation. The demographic is patients who have suffered brain lesions and, as a results, suffer from hemi-spatial neglect or other types of attention deficiency disorders. The apps developed for this project include TRAILiT, which is based on the trail-making test (TMT)[2]. This purpose of this poster is to evaluate temporal performance and target positions in TRAILiT as a method of assessing hemi-spatial neglect.

Background and Related Work

Patients suffering from hemi-spatial neglect will not respond to stimuli on the contralateral to their brain lesion, despite having motor and sensory capacity to do so. This condition is most common, persistent and severe after right hemisphere lesions, and it most often affects visual sensory input, making left-side visual neglect the most common symptom. As a results patients may only groom or dress the right side of their body, or they may only read the right half of a page or only eat from the right half of a plate, negatively affecting daily activities[4].

Cognitive training have been proven to be effective, but research is still required to determine which regimen and conditions result in the best transfer effect[7]. Video games for rehabilitation and cognitive training based on standardized tests have been implemented[6][9] and positively received by users[5][10]. The methods used to engage the player may be able to address the problem of the intensive and repetitive rehabilitation activities[3].

Design

The concept of the game is based on the trail-taking test (TMT). The TMT consists of a sheet of paper with an arrangement circled characters. There are two variations to the test: In type A all of the characters are numbers and the patient has to draw a line between the numbers in the correct order. In type B there are both numbers and letters on the page, and the patient has to alternate between them. For example, 1-A-2-B-3-C. The TRAILiT app consists of 27 levels of each type. A key difference between the app and the traditional TMT is that the user is not required to keep their fingertip on the screen while connecting the numbers and letters[2]. The main objective for TRAILiT is that patients should be able to complete the test on their own and correct their errors. The risk of patients forgetting which target they came from is addressed by giving correct targets a green ring while having them turn fully green when the subsequent target is hit. This is to affirm the correct hit while still keeping it distinct, so that the player can reference it. Also, in order to clearly illustrate when the player makes an error, all targets on the screen, except for the incorrect target and the previous correct target, will lower in brightness. This is to emphasize that player has to go back to that target. A screenshot of the game is shown in Figure 1.

Study

The participants were volunteers recruited from Brønderslev Neurorehabilitation Center by the therapist supervising the experiment. Inclusion criteria for participating were suffering from a form of acquired attention deficit disorder as a results of a brain lesion, being able to use the tablets, and give informed consent. The study was a randomized control trial in which the participants were randomly distributed into

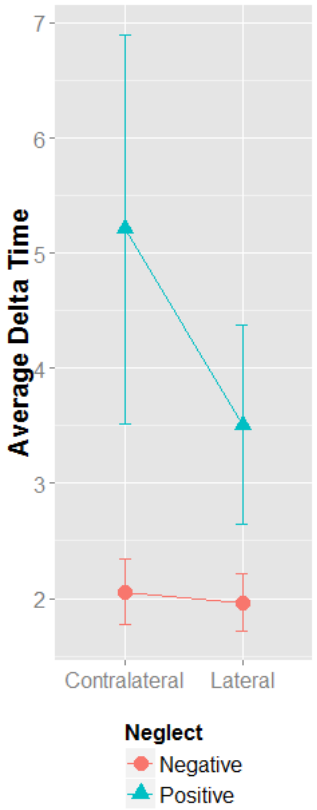

Figure 2: The average delta time, including 95 % confidence interval, split between targets that are lateral and contralateral to the brain lesion and between neglect and neglect positive and negative participants.

a test group and a control group. During their trial period, both groups continued regular rehabilitation, but the test group additionally got to use the apps. The control group played only at the introduction and end to the trial, but their performance data was used for this analysis, regardless. If any participants in the test group asked a therapist for help concerning the tablets or apps after the initial introduction they received assistance and a therapists took notes on the problems encountered.

Participants

Originally, 52 patients of a rehabilitation clinic volunteered to participate and were randomly assigned to either test or control group. Some participants had their trial interrupted due to moving facility. Additionally, this analysis focuses on patients with a lesion known to be on either the right or left side. Eight women and twenty-eight men (64 years old on average, SD: 15.72) are included in the analysis, equally split between left and right hemisphere lesions. We relied on Jehkonen et al's test suite (line bisection, line cancellation and letter cancellation [8]) and their cut-offs from the literature. A positive outcome in one of the three test classified participants as having neglect. Eleven participants tested positive for neglect, six with right hemisphere lesion and five left hemisphere lesions, and twenty-five tested negative.

Results

At an average of 30 days in the trial the test group played an average of 8.76 minutes per day (SD: 7.77). The dataset consists of 195 thousand samples. We performed a mixed ANOVA on the time it took the participants to search for and hit a target (delta time) depending on which horizontal half of the screen the target is located on (target position), the horizontal direction relative the previous target (target direction). Each participants contributes their average delta time according to these factors. As such, they contribute four points each to the ANOVA. Additionally, we tested whether these two factors correspond the lesion hemisphere of the participant's brain (isLesionSide and isLesionDirection). Whether the participants tested positive in any of the standardized tests (Neglect) as well as the side of the lesion are used as between-subjects factors.

The ANOVA revealed that the lesion side, target side and direction did not significantly affect the delta time, so they are excluded from future analyses. Significant factors were Neglect ($F(1, 34) = 15.46$, $p<0.001$), isLesionSide ($F(1, 102) = 14.36$, $p<0.001$), the interaction between isLesionSide and isLesionDirection ($F(1, 102) = 6.85$, $p<0.01$) and the interaction between isLesionSide and Neglect ($F(1, 102) = 23.31$, $p<0.001$). The group testing positive for neglect had an average delta time of 3.51 second on targets lateral to the lesion and 5.21 for contralateral targets. Average delta time for neglect negative participants was 1.96 seconds for lateral targets and 2.06 seconds for contralateral targets. The average delta time of 4.36 seconds for the neglect group and 2.00 seconds for the non-neglect group. The resutls are summarized in Figure 2.

Discussion

As expected from [4], for participants testing positive neglect their performance is worse for the region of the screen contralateral to their lesion. Also, patients with positive neglect scores have lower performance overall compared to other as to be expected from their comparatively worse condition. The significance of the relative position of the target in interaction with the absolute position is likely caused be the fact that a target to the right of the outset is more likely to be on the right-hand side of the screen than the left. Even through the target position relative to the lesion is significant on its own, the statistics illustrated in Figure

2 shows performance for either position is identical for the non-neglect group.

Conclusion

We set out to design an app for assessment and rehabilitation of hemi-spatial neglect based on the trail-making test. We can conclude that player performance in the game is significantly affected by their cognitive conditions based on standardized neuropsychological evaluation and the nature of their lesions.

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