Severe Neglect and Computer-Based Home Training
A Case Study

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Abstract. Cognitive rehabilitation from a functional perspective often requires intensive training over a longer period of time. In the case of rehabilitation of unilateral neglect, the frequency and intensity needed is expensive and difficult to implement both for the therapists and the patients. For this reason, this case study tests the possibility of using computer-based training in the rehabilitation efforts for a patient with severe neglect who had no previous skills in computer usage. The article describes the results of the training both in terms of neuropsychological tests and the reading ability of the patient.

Keywords: optokinetic training, home training, computer-based training, unilateral neglect, prism adaptation training, bottom-up.

1 Introduction

"All I want is to be able to read again". These were the first words from the patient PK, when I met him in July 2013. PK had fallen down a flight of stairs in March the same year and had been committed to care and rehabilitation for almost 4 months prior to this meeting. Although his behavior expressed textbook neglect to a degree you rarely see 4 months after injury, he also demonstrated an impressive ability to maintain an artistic composition in memory and the will to fight his way back to life.

The MRI and CT scans showed no apparent, recent injury. However, PK had a severe and maltreated renal condition and also a previous history of infarcts. From the MRI and CT scans it was imminently clear that PK had shown an extraordinary ability to overcome the effects of the previous injuries, despite the apparent extent of physical damage.

In this paper, I will try to illustrate how computer-based training was used in the patient's home to accommodate the intensity needed to get effects from bottom-up cognitive training. I will go into details about injury, the assessment, the training and the results so far. I will outline the tools used for assessment as well as the computer-based training and also show how the reading ability of PK changed over time as the speed of visual perception improved. The paper will demonstrate how cognitive rehabilitation of neglect may benefit from intensive home training using computer-based prism training, optokinetic training and scanning training but also how much is required by the patient and the therapist.

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2 Etiology

PK is a 75 year old male, with an academic education as a geologist. PK is a renowned artist, painter, sculptor and essayist and has travelled extensively around the world completing the latest of 16 polar expeditions to the arctic areas of Greenland in 2011.

In 2000, PK suffers from a sudden, large intracerebral hemorrhage in the right parietal lobe. A four centimeter hematoma is formed in deep tissue and an emergency evacuation had to be performed. Although subsequent CT scans reveals extensive damage to the right parietal and temporal lobe, PK recovers fully over time and is able to return to work after a brief period of recovery.

In 2009, PK has another cardiovascular incident on a trip to Greece. Subsequent CT scans reveal ischemic changes in the left temporal-occipital lope. The neuropsychological test confirms that PK has lost color vision, the ability to recognize faces, has an upper right quadranopia, unilateral neglect and reduced reading ability.

The hospital records indicate that PK demonstrates symptoms of neglect both after the first incident in 2000 and the second in 2009. PK is offered assistance and rehabilitation in 2009, but he declines and after some months of recovery, he is able to resume his artistic work both as a painter, sculptor and essayist. According to him and his wife, he never recovers from prosopagnosia but color vision returned to normal after a while.

In early spring 2013, PK accidentally falls down a flight of stairs in his home suffering a contusion. CT and MRI scan reveals only small superficial injuries and no new major incidents but PK is severely disoriented and the old neglect symptoms return in full force. Prolonged hospitalization is required due to a severe inflammatory, renal condition and the treatment seems to further aggravate the neuropsychological deficits. In July 2013, PK is released from hospital with severe neglect, and left sided hemiparesis rendering him tied to a wheelchair.

3 Unilateral Neglect

Neglect is a cognitive attention deficit that is defined as a failure to respond to, attend to, report, or orient toward stimuli presented in the contralesional side of space, which cannot be attributed to primary motor or sensory dysfunction [1, 2]. Space, in this context, should be understood in the broadest sense of the word. It includes occurrences in the physical environment outside an arm's reach of the patients (extrapersonal space), the immediate surroundings (peripersonal space) and even the body (personal space)[3] and internal representations of body (the proprioceptive model) [4]. In addition to a particular spatial domain, neglect may be observed from different midline-frames of reference, one being viewer-centered in which the neglected area is positioned relative to a midline projection from the retina, the head or the torso; the other being an allocentric reference frame where the neglected area is positioned relative to the stimulus or object [5].

3.1 Symptoms of Neglect

Neglect is a challenging syndrome in that it leaves the patient unaware of the consequences and effects of the impairment [6]. Patients, however, will often complain about bumping into things, not being able to locate objects in their homes or bruising the contralesional side of the body because of the inattention. The ability to read may also influenced in various ways either at word or sentence level [7]. The most common behavior of neglect patients is extinction, which is the inability to detect stimuli presented to the contralesional side, if stimuli are presented simultaneously to the ipsileasonal side [8]. Extinction has been demonstrated in different modalities with visual, auditive or somatosensory stimuli, either individually or in combination [e.g. 2, 9, 10].

3.2 Neural Correlation of Neglect

The diversity in neglect symptoms reflects the degree to which attention depends on different neural mechanisms [11] and as a consequence different types of lesions may trigger one or more neglect behaviors. Neglect is often characterized as being a contralesional impairment and it is more frequently observed with right hemisphere damage than left hemisphere damage [12-14].

The most common cause of neglect are lesions to the right posterior parietal cortex [15-17] but also damage to the inferior temporal region and the superior/middle temporal gyri have been found to correlate with neglect [18]. In a recent study, Verdon et al. [19] found that damage to the right inferior parietal lobe was correlated with perceptive and visuo-spatial components of neglect. They also found that damage to the right dorsolateral prefrontal cortex was correlated to impairments in exploratory/visuomotor components and, finally, that damage to deep temporal lobe regions was a component of allocentric/object-oriented neglect.

3.3 Prevalence

Neglect is a fairly common, cognitive impairment in patients with brain injury. Across studies, there seem to be amble agreement that neglect behavior fades rapidly, and after 3-4 weeks only approx. 8-10 % of patients will test positive for neglect [20]. Long-term chronicity of neglect does not seem to correlate with sex, handedness or lesion volume but both the severity and persistence of neglect do increase with age [13, 21]. Right hemisphere lesions have been measured to cause neglect symptoms that are more persistent and less responsive to spontaneous remission [18] and therapy [22]. The severity of the neglect behavior in the acute stages of injury has been found to be a strong predictor for the subsequent severity of symptoms a year post onset [23]. Finally, the presence of visual field disturbances and defects has been shown to be more prevalent amongst patients with chronic neglect [23].

4 Assessment of PK

It is always a challenge to assess all aspects of a multifaceted syndrome like neglect. The cause as well as the expression of neglect may vary from patient to patient and symptoms fade and change over time as patients acquire some compensatory techniques such as positioning their body or head differently when solving tasks. In the case of PK, assessments from previous incidents had established that neglect was present. The current task was to ascertain the current level and to choose tests that would assist in the choice of training and be sufficiently sensitive to measure progress. For this reason, a combination of tests was used to determine the type, extent and severity of the neglect and to distinguish perceptual from spatial neglect as the literature indicates a difference in effect from training depending on the type [24]. The choices also took into consideration that we wanted to avoid fatigue in the patient when administering the tests.

Schenkenberg's line bisection [25] was chosen to assess both perceptive and visuomotor neglect. In this test, 17 horizontal lines of various lengths have to be divided at the middle. In the visuomotor task, the patient is asked to divide the lines by setting a mark. In the perceptual task, the therapist moves a pencil along each line from left to right and the patient indicates orally when the middle of the line is reached. Next used was the Mesulam cancellation tasks [26] including both the letter and the object cancellation tasks to assess neglect behavior. The baking tray test [27, 28] was used to assess spatial neglect and the computer-based Test of Attentional Performance (TAP) (subtests visual field test and neglect test) was used to assess visual field and extinction and the processing speed of the perceptual system. Due to PK's initial reduced performance, a special version of the TAP test was used in which the detection period was extended to 10 seconds per trial for the first two tests. A simple estimation test was used to confirm perceptual neglect [24]. Finally, picture copying of a star, a flower and a cube was used to test visuospatial difficulties.

These tests have been used to assess progress throughout the training period and have been administered when major changes to training were instigated. The scores from the tests can be found in chapter 6.

All tests indicated severe egocentric visuo-motor and perceptual neglect along with highly reduced processing speed and difficulties in combining visual stimuli to a usable percept.

5 Training of PK

Almost immediately upon arrival at the Center for Rehabilitation of Brain Injury, PK was subjected to intensive physiotherapy training at least 1.5 hours a day for 4 days a week. He still maintains this practice 6 months later. He was mobile and out of the wheelchair after 3 months and is now able to walk about without support. Due to the intensity of the physical training, PK needed a long daily break before starting any other training. We discussed the requirement for intensity and daily cognitive training and together with PK we decided that training at home would offer the best flexibility for PK.

Apart from the neglect, the most severe problem observed in PK was the reduced processing speed of the perceptual system (fig. 2). We therefore chose to a bottom-up strategy in training to try to ameliorate as much of the basic problems as possible. No single treatment has been demonstrated effective for all types of neglect [29], in the latest report on rehabilitation from brain injury from the Danish Board of Health [30], an analysis based on 17 papers concludes that best effect of treatment of neglect is achieved through a combination of therapies.

In 1998, Rossetti et al. published a seminal study which demonstrated that exposure to prism adaptation might alleviate some of the symptoms related to egocentric visual neglect in patients, regardless of the severity of neglect [31]. Internal data used to interpret sensory feedback from different modalities must be kept in alignment to ensure that action and attention are directed towards the same location [32]. Rossetti et al. hypothesized that the visuomotor realignment of the internal representation of the personal midline observed in standard prism exposure studies might alleviate symptoms of neglect. Prism Adaptation Therapy (PAT) has since become one of the most promising therapies in the treatment of egocentric visual neglect [33-36].

Since PK had shown visuomotor problems, we decided to start up with PAT twice a day for two weeks. The author provided a computer-based prism adaptation system for the purpose of training and follow-up. In this version of computerized PAT, the patient performs three training sets at each of the two daily sessions. In the first set, the patient performs 30 pointing trials on a touch monitor, 10 trials at each of three locations with no visual feedback. This set measures baseline performance at the session. In the second set, the patient performs 90 pointing trials, 30 at each of three locations this time wearing prism goggles. The goggles cause a deviation of visual input 10 degrees to the right. At the end of each trial, the patient receives terminal feedback (seeing his fingertip when touching the monitor) and is asked to attempt to adjust to the deviation. In the final set, the patient removes the prism goggles and performs an additional 60 pointing trials, 20 at each of the three locations again without feedback. The aftereffect from the prism exposure is measured to determine if adaptation is taking place. Data is collected and stores at the computer for each trial, set and session for further and later processing. PK could not administer PAT training on his own so helpers and the spouse were trained by the author to assist PK during the two weeks of training.

As PK had also demonstrated perceptual neglect problems and reading difficulties, it seemed appropriate to try computer-based optokinetic stimulation, in which patients are asked to attend to targets on a background moving towards left [37-39]. The system EyeMove from www.medicalcomputing.de was chosen based on the documented results [40, 41]. Rather than using the preset versions for training, we started out with a single dot moving towards the left at three preset speeds. After a week, the speed and size and number of moving objects were adjusted to ensure that PK was practicing at the limit of his ability. PK trained once a day for 45 minutes for three weeks and after 6 weeks, PK managed to train at the highest level of difficulty. After the first three weeks, we added a picture naming task using the computer-based system

"Afasi-assistant" from www.afasi-assistent.dk where the task was to read a word and find the matching object amongst first 2 and later 4 pictures. In November, we added cancellation training using the iPad APP "Visual Attention" from the suite TherAppy from the company www.tactustherapy.com. Table 1 summarizes the training schedule.

Once a week, the training regimen was adjusted by the therapist. On a daily basis the spouse or hired helpers would assist PK in the starting the appropriate application.

Table 1. Training regimen at home. Training was adjusted weekly to constantly challenge the ability of the patient.

Type	**Period**	**Intensity**
Test 1		
Prism Adaptation Training	2 weeks	2 x 30 minutes, daily
Test 2		
Prism adaptation Training	1 week	1 x 30 minutes, daily
Optokinetic training 1	3 weeks	45 minutes, daily
Test 3		
Optokinetic training 2	Ongoing	45 minutes, daily
Therappy Visual Perception	4 weeks	15 minutes, daily
Afasi-assistent, object determination	4 weeks	20 minutes, daily
Test 4		

PK has since continued to practice with the optokinetic system every morning as he feels that it "warms" up his perceptual system and further reduce the perceptual effects of neglect for a period of 30-60 minutes after practice.

6 The Result so Far

As can be seen in table 1, PK was tested before and after each major change in training. The results from the line bisection tests before and after the training have been listed in figure 1. PK's scores are vastly different in the two tests, which is indicative of separate systems being activated in the bisection task[42]. PK improved on both tests after PAT (test 2) and on the perceptual part after the optokinetic training (test 3). However, test 4 indicates that the effect has not been stable although PK is still improving but at a slower rate.

The cancellation tasks (table 2) show some improvement at Test 3 but at Test 4 the effect to the left has disappeared.

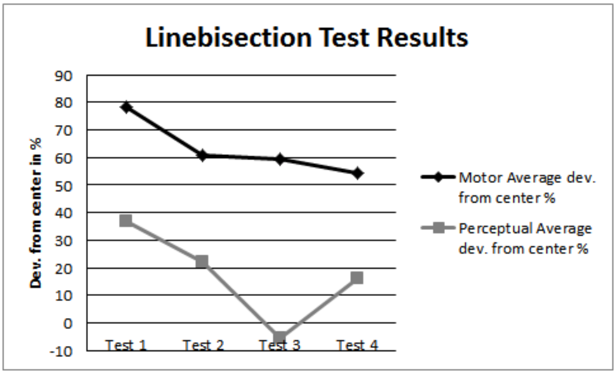

Fig. 1. The results from the line bisection tasks. "Motor" indicates the result where PK set the mark with a pencil and "Perceptual" is where the therapist sets the mark on PK's request.

Table 2. Results from the Cancellation tasks over time

	Figure				Letter			
	Upper left	Lower left	Upper right	Lower right	Upper left	Lower left	Upper right	Lower right
Test 1	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
Test 2	N/F	N/F	N/F	N/F	0	0	1	5
Test 3	2	1	6	4	1	0	5	8
Test 4	0	0	7	7	0	3	7	7

The baking tray test improved dramatically after the PAT (table 3) and at the most recent test, all 16 "buns" were spread out equally across the "tray".

Table 3. The results from the baking tray test

	Left	Right	Comment
Test 1	0	16	
Test 2	8,5	7,5	Skewed right
Test 3	7	9	Still skewed towards right
Test 4	8	8	Spread all over the plate

The TAP test was used in an attempt to establish whether the visual field was intact. It also provides data on processing speed by measuring the time from stimuli onset until button activation by the patient. Albeit a rough estimate, it is still a good indicator for overall processing speed of the perceptual system. The results over the training period are shown in figure 2.

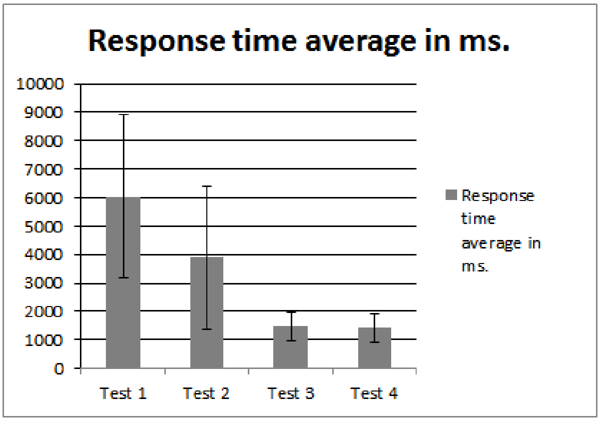

Fig. 2. The change in response time to stimuli presented during the TAP test. Changes between Test 1, Test 2 and Test 3 were tested highly significant ($F_{3,60}$=35.1, p < 0.005).

Reading ability was monitored by administering reading tests. At Test 1, PK was not even able to read two letter words. At Test 2, PK still had trouble even reading single words. After the optokinetic training, PK was able to read poetry again and shorter pieces of prose (Test 3). However, he still has some problems keeping track of the lines losing the position in the text lines and has to use his finger or a ruler to keep track.

PK's ability to draw from memory has been intact for almost the entire training period. The performance on copying of drawings has improved so PK is able to copy a star, a cube and a flower. Introduction of new drawings in test 4 did, however, show a bias to the right in one out of three drawings.

The most encouraging improvements so far has been in relation to PK's work as an artist. He has been able to resume his work as an artist and the most recent improvement has been intermittent periods of resumed color vision and absence of neglect when painting. Previously, he was unable to leave his work for just a little as he was unable to recognize his work from visual input alone. Although he still cannot recognize older pieces of work as his own, he is able to return to current work in progress and recapture how far he is using visual cues from the painting. We will keep monitoring overall progress for the next 6 months.

7 Discussion and Conclusion

In this study, we tested if training of severe neglect could be accomplished by setting up training systems at the home of a patient with no previous experience in the use of computers.

The first obstacle was the need for assistance in initiating the daily training of PAT. Although the program could be started with one click, moving boxes back and forth and putting on prism goggles required assistance from the spouse and local helpers who had to be trained in the execution of PAT. It was fairly expensive, but it did allow PK to train as intensive as required. The optokinetic training was much easier to use although it was impossible to start the program without having to go through several menus. Being unable to read, PK was unable to start the program by himself for many weeks and had to have assistance from helpers. The Afasi-assistant could be setup to start with only one click and so could the TherAppy APP on the iPad.

PK was and still is extremely motivated for training. He has meticulously trained almost every day and been good at stating when training became too easy or required adjustments. Adjustments to the programs were done at a weekly basis by a visiting therapist (the author) and this worked well for all parties. The visit at home provided an opportunity to observe and respond to changes and improvements in activities of daily life. When asked about the advantages of being able to train at home, both PK and his wife stated that above all, the flexibility of being able to train when time and strength allowed it was very important for keeping up motivation to train. The disadvantage was the requirement for hired help. Using the spouse as assistant trainer was not a success and created marital conflicts and aggravation to the disappointment of both parties. The reason for this is currently being investigated and be dealt with in a subsequent paper.

Often, patients have to practice once or twice daily for 2-5 weeks and the training needs to be adjusted frequently as the function and processing speed improves. It has been pointed out many times that computer-based training offer solutions to these challenges and the advance of AI algorithms and online profiling will eventually alleviate adjustment challenges. However, even fairly simple computer-based training like PAT and optokinetic training will require assistance to start up the programs, adjust the equipment and monitor the progress of the patient.

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