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# Driving ability in stroke patients with residual visual inattention: A case study

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Driving ability of three patients having a right hemisphere infarct and residual visual inattention was examined. The neuropsychological examination included the Peripheral Perception Test and the Signal Detection Test from the Vienna Test System, and the Behavioural Inattention Test (BIT). Driving ability was assessed with an on-road evaluation. The patients had no neglect based on the BIT and had normal visual fields, but they showed slightly poorer visual search on the left side. All patients passed the official on-road driving test and were considered capable of driving. This study raises the question if acute neglect can recover to a degree in which driving may be possible.

***Keywords:*** Driving ability; Recovery; Stroke; Visual inattention.

The driving ability in patients with neglect is a critical and yet less examined question. According to some studies, neglect predicts poor functional recovery and inability to manage activities of daily living (ADL) after stroke (Cherney, Halper, Kwasnica, Harvey, & Zhang, 2001; Jehkonen, 2002; Jehkonen et al., 2000, 2001; Katz, Hartman-Maier, Ring, & Soroker, 1999). Neglect may be a persisting syndrome or it may recover within a few months (Appelros, Nydevik, Karlsson, Thorwalls, & Seiger, 2004; Cassidy, Lewis, & Grey, 1998; Hier, Mondlock, & Kaplan, 1983). The severity of neglect can vary from mild to severe (Robertson & Halligan, 1999) and residual visual inattention in this study is defined as a post-neglect condition that may only emerge non-laterally in complex long-term visual search tasks. It has been found that patients with convalescent neglect later on have difficulties with complex and novel daily activities, such as managing in traffic situations (Taylor, 2003). Moderate or severe visual neglect is thought to be a definite obstacle to driving (Tant, 2002), but the evaluation of driving ability in patients with residual visual inattention is a multi-faceted question that clinicians often encounter at their work. Residual visual inattention may impair safe driving, for example, by causing difficulties in maintaining driving lines, and narrowing and slowing the perception of the whole environment.

Despite the requirements of safe driving, research has failed to identify any consistent pattern of neurological, motor, perceptual, or neuropsychological deficits that renders a person unfit to drive (Galski, Holly, McDonald, & Mackevich, 2003). There has been only limited research into the relationship between standard clinical tests of visual neglect and

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reaction time tests, but there is some evidence that the measurement of reaction time may be sensitive in detecting visual neglect (Taylor, 2003). It has been suggested that neglect syndrome with reduced reaction time is an absolute impediment to driving (Robertson & Halligan, 1999; Sivak, Olson, Kewman, Won, & Henson, 1981). However, this topic has not yet received very much attention, and as Tant (2002) pointed out we need to be careful not to generalize too far since there is still a scarcity of objective research on the relationship between hemispatial neglect and fitness to drive.

There is a broad recognition of the need for a multidisciplinary approach in which neurological and neuropsychological assessments are followed by an on-road driving test (Akinwuntan et al., 2002, 2003, 2005; Heikkilä, Korpelainen, Turkka, Kallanranta, & Summala, 1999; Tant, 2002). In addition, there is some evidence that the standard tests used to evaluate neglect do not reveal all forms of clinically important unilateral neglect (Appelros, Nydevik, Karlsson, Thorwalls, & Seiger, 2003) especially mild neglect in later phases of recovery. This suggests that a reliable, multidisciplinary assessment of driving ability in stroke patients must take into account at least the cognitive and psychomotor functions that are critical in driving as well as traffic-related laboratory tests if an on-road driving test is not possible (Heikkilä et al., 1999). According to Akinwuntan et al. (2002) the combination of an on-road test, side of lesion, kinetic vision and visual scanning had the best predictive value for the decision to drive.

The purpose of this study was to explore and describe the impact of residual visual inattention on driving ability. For this reason we introduce three patients with residual visual inattention after a right hemisphere stroke who attended to a driving ability evaluation conducted by a specialized multidisciplinary team.

## PATIENTS AND METHODS

Three patients were selected from a larger group of recovering stroke patients referred to a specialized multidisciplinary driving ability evaluation. All of them were male suffering from visual neglect without hemianopia in the acute phase due to a right hemisphere infarction. In all three cases the acute neurological diagnosis was supported by a computerized tomography of the brain. They had no previous neurological disorders. All the patients had had a valid driving license immediately prior to their stroke, and they were active non-professional drivers.

### Methods

#### *Neurological and neuropsychological examinations*

A complete neurological examination including confrontational assessment of visual fields (Goldman perimetry) and evaluation of traffic vision was performed prior to the neuropsychological examination and the on-road driving test.

An extensive neuropsychological assessment was carried out for each patient. Detailed results are reported for the Behavioural Inattention Test (BIT; Wilson, Cockburn, & Halligan, 1987), the Peripheral Perception Test (Schuhfried, Prieler, & Bauer, 2004) and the Signal Detection Test (Schuhfried, 2003). The patients underwent six conventional paper-and-pencil subtests of the BIT. The inclusion criterion of this study was a normal performance (score >129) in the BIT at the time of driving evaluation, which indicated the recovery of visual neglect.

Two computer-based tests from the Vienna Test System were used to assess residual visual inattention: the Peripheral Perception Test (PP) and the Signal Detection Test (SIGNAL). The PP is a test for assessing the perception and processing of peripheral visual information. Subjects are instructed to focus on a simple visual tracking task presented on a computer screen. At the same time, they should react by pressing a pedal when they notice critical visual stimuli that are presented on a visual stimulus background to their left or right visual periphery using special horizontal led-screens. Two variables were used to estimate peripheral visual perception: (1) the subject's entire field of vision in degrees (the minimum range for driving a vehicle according to EU directives is a total field of vision of 120°), and (2) the number of omitted reactions to stimuli on the left and the right side (accepted range for each side: 0–16 omissions; according to the reference data of the Vienna Test System). The test takes about 15 minutes to administer, including the test instructions.

The SIGNAL is a test for evaluating long-term selective attention, namely the visual differentiation of a relevant signal within irrelevant signals. Patient's task is to press a response button when a target stimulus (constantly changing pattern of four white dots on a black background) forms a square in any part of the computer screen. The main variable calculated is the sum of correct reactions in each quadrant of the visual field. The accepted performance for the correct reactions is >60% according to the reference data of the Vienna Test System. This test takes about 20 minutes to administer, including the test instructions.

### On-road driving assessment

The on-road driving assessment was conducted after the neurological and neuropsychological examinations by a licensed driving instructor, who was not informed of the results of the neurological or neuropsychological examinations. The one-hour driving test took place during the daytime in various situations in city traffic. Patients driving ability was evaluated according to the principles of the official driving examination presupposed for all road-users in Finland. This was ensured by using a structured form following the official guidelines of the Finnish Vehicle Administration (1998). The main domains assessed in the driving instructor's evaluation in the on-road driving test are presented in connection with case descriptions.

### Results

The results of the neuropsychological examination are given in Table 1, and the results including the main domains of driving ability in the on-road driving test are described in Table 2. A telephone interview was carried out 2 years after the on-road driving assessment in order to check the patients' current driving situation. All patients said they had driven successfully since the driving test.

## Case 1

H.E. is a 67-year-old right-handed male. His total driving experience 1 year prior to stroke was 10,000 km. In the acute phase of stroke H.E. had mild hemiparesis in the left side of face and arm, but no sensory impairment in his left leg, and he showed severe visual neglect.

In the driving assessment 9 months after stroke, the patient had no hemiparesis, and no signs of neglect according to the BIT. His field of vision in the PP was 139°. H.E. performed within normal limits for his age in PP and SIGNAL, but there was a slight difference between the left and right side of his field of vision as he detected critical stimuli up to 65° on the left and up to 74° on the right. In the SIGNAL his reactions to the lower left quadrant were the weakest.

H.E.'s performance varied between moderate and good in the domains of driving ability (Table 2; scoring: 1 = poor, 5 = excellent). His performance was mainly moderate (score = 3), but the ability to understand driving order, the ability to follow traffic lights and signs, and the ability to keep distance to other vehicles was good (score = 4). Although there was some slowness and inaccuracy in anticipating novel situations and in reactions to lane

**TABLE 1**
The three patients' test results in the Behavioural Inattention Test and two subtests of the Vienna Test System (Peripheral Perception Test and Signal Detection Test)

| | *Case 1 (H.E.)* | *Case 2 (K.E.)* | *Case 3 (K.M.)* |
|---|---|---|---|
| *Behavioural Inattention Test*[1] | | | |
| Total score (range: 0–146) | 146 | 142 | 146 |
| *Peripheral Perception Test*[2] | | | |
| Left visual field (degrees) | 65 | 83 | 82 |
| Right visual field (degrees) | 74 | 75 | 87 |
| Omitted reactions: left (range: 0–20) | 14 | 7 | 7 |
| Omitted reactions: right (range: 0–20) | 12 | 8 | 3 |
| *Signal Detection Test*[3] | | | |
| Correct reactions in upper left quadrant (%) | 75 | 75 | 67 |
| Correct reactions in lower left quadrant (%) | 67 | 67 | 61 |
| Correct reactions in upper right quadrant (%) | 76 | 76 | 76 |
| Correct reactions in lower right quadrant (%) | 81 | 88 | 75 |

[1]The cutoff score for visual neglect is 129 (0–129 = neglect; 130–146 = normal).
[2]Visual field: the minimum for entire field 120° (according to EU directives); omitted reactions: accepted range 0–16 (according to the reference data of the Vienna Test System).
[3]Correct reactions: accepted performance >60% (according to the reference data of the Vienna Test System).

**TABLE 2**
Driving instructor's assessment of patients' performance in on-road driving test

| *Domains of driving ability* | *Case 1 (H.E.)* | *Case 2 (K.E.)* | *Case 3 (K.M.)* |
|---|---|---|---|
| Awareness of other vehicles and road users | 3 | 4 | 3 |
| Appropriate adjustment of speed | 3 | 4 | 4 |
| Signalling one's intentions, predictability | 3 | 3 | 4 |
| Driving lines | 3 | 4 | 4 |
| Understanding correct driving order, e.g., at intersections, junctions, roundabouts | 4 | 3 | 4 |
| Ability to follow traffic lights and traffic signs | 4 | 4 | 4 |
| Distance to other vehicles and obstacles | 4 | 4 | 4 |
| Vehicle handling and vehicle control | 3 | 3 | 5 |
| Independence and ability to map out one's driving | 3 | 3 | 4 |
| Ability to anticipate events in traffic | 3 | 3 | 4 |
| Concentration on driving | 3 | 4 | 5 |

Scoring: 1 = poor, 2 = below average, 3 = moderate, 4 = good, 5 = excellent.



changes, the driving instructor's overall evaluation was that H.E. was capable of driving safely in all places due to the compensatory factors (good traffic vision, intact awareness of his residual cognitive difficulties and good driving experience).

## Case 2

K.E. is a 58-year-old right-handed male. His total driving experience 1 year prior to stroke was 20,000 km. At the acute phase of the stroke he had severe hemiparesis in his left arm, left leg and in the left side of his face. He had moderate visual neglect and anosognosia for illness.

Eighteen months after onset K.E. had no hemiparesis, no signs of neglect were detected according to the BIT and his insight into his illness had recovered. His field of vision in the PP was 158°. K.E.'s left visual field was wider than the right visual field in the PP as he noticed critical stimuli up to 83° on the left and up to 75° on the right side. In the SIGNAL patient's performance was the average for his age, but his reactions to the lower left quadrant were the weakest.

In the driving assessment K.E.'s performance varied between moderate (score = 3) and good (score = 4) in the domains evaluated (Table 2). The driving instructor's overall on-road evaluation was that K.E. was capable of driving safely in all places, but only in good road conditions, because his motor functions in the left leg were slightly inaccurate and there was some decline in his reaction speed compared to the average for his age. The compensatory factors were taken into account in the evaluation.

## Case 3

K.M. is a 38-year-old left-handed male. His total driving experience 1 year prior to stroke was 20,000 km. In the acute phase he had severe hemiparesis in his left hand and arm, and in the left side of his face as well as moderate visual neglect and anosognosia for illness.

At the time of the driving ability assessment 6 months after onset K.M. did not have hemiparesis, and no signs of neglect according to the BIT. His field of vision in the PP was 169° as he detected critical stimuli up to 82° on the left side and up to 87° on the right side. In the SIGNAL his performance was below the average for his age. Both left quadrants were weaker than the right quadrants, but the lower left quadrant was the weakest.

In the driving assessment K.M.'s performance varied from moderate (score = 3) to excellent (score = 5) (Table 2). Performance was mainly good (score = 4), but the ability to be aware of other vehicles was moderate and the vehicle handling and control as well as the concentration on driving were evaluated excellent. The driving instructor's overall on-road evaluation was that K.M. was capable of driving safely in all places and in any road conditions although some decline in his reaction speed was detected compared to the average for his age. The compensatory factors were taken into account in the evaluation.

# DISCUSSION

This pilot study introduces three cases of right hemisphere stroke patients in order to examine and to question the effect of residual visual inattention on driving. All patients had acute visual neglect which recovered and turned into residual visual inattention by the time of the driving assessment. The patients' residual visual inattention and driving ability was assessed with a multidisciplinary evaluation and an on-road driving test within 6 to 18 months after stroke depending on the recovery of neglect. At the time of driving evaluation the patients had an intact neurological status and no signs of visual neglect according to the BIT. However, they showed residual visual inattention in the computer-based visual tasks, and the on-road driving test revealed mild difficulties. One interesting finding was that in the computer-based SIGNAL, the weakest area of visual field for all patients was in the lower left quadrant. Despite the residual difficulties, the patients were granted permission to drive, bearing in mind the compensatory factors. In a post-study telephone interview 2 years after the on-road assessment, all the patients reported that they had since then driven successfully.

According to our study one might argue that residual visual inattention might not always be an obstacle to driving. It also emphasizes the importance of a multidisciplinary evaluation of driving ability after stroke. The reliability and validity of an on-road driving assessment has been thoroughly reported by Akinwuntan and collaborators (2003, 2005). As Akinwuntan et al. (2002) found the side of lesion, kinetic vision, visual scanning, and an on-road test formed the best model for the multidisciplinary team's decision on the patient's ability to drive. Interestingly, Akinwuntan et al. (2002) used a very similar computer-based test (Zimmermann & Fimm, 1995) as we did in our study to assess visual scanning (SIGNAL), which was one of the best predictors included in the model of Akinwuntan et al. (2002) to predict fitness to drive.

As Taylor (2003) has pointed out that there is some evidence that the measurement of reaction time may be sensitive in detecting visual neglect. According to Taylor (2003) in patients with mild visual neglect, the unattended area may be relatively small or obvious only under certain circumstances. This is in line with our findings that although all three patients had some difficulties with the computer-based visual search tasks and showed some slowness in their reactions during the on-road driving test, they were able to compensate their residual visual inattention during the driving test. Driving is an over learned skill and all the patients had a good driving experience. In addition, all the patients had an intact awareness of their possible cognitive restrictions.

In a more recent theory of driver behavior, Fuller (2005) takes into account the interaction between driver capability and task demand. He presents that when driver capability exceeds task demand, the task is easy to perform. On the other, when driver capability equals task demand, the driver is operating at the limits of his capability, and the task is difficult, but he can succeed in it. When task demand exceeds capability, then the task is too difficult and the driver fails. In this study, we interpret that our patients' capability equals task demand. This requires optimal attentional effort due to residual visual inattention, but the patients can succeed in the on-road driving test because of the compensatory strategies.

In our study, the weakest area of visual field for all the patients was the lower left quadrant. Especially on the right-hand traffic, this may emerge as driving too near of the midline. In the contrary, on the left-hand traffic a patient may drive too close or hit the kerb, and not leave enough room when passing parked cars.

Sundet, Goffeng, and Hofft (1995) have pointed out, the presence of neglect-related symptoms, especially anosognosia may be an additional risk for the patient's ability to drive. This was clearly shown in the case of K.E., who had severe acute anosognosia and who therefore could not take his driving test until 18 months after onset, twice as long as in the case of the other two patients. K.E. also stood apart in the PP where his left visual field was wider than the right visual field. We considered this to be due to the tendency of learned overcompensation to the left side as a sign of residual visual inattention. This phenomenon is also seen in rehabilitation settings with patients who have specific training for visual neglect (Robertson & Halligan, 1999). Paradoxically, they often focus more intensively on the trained left side and at once 'neglect' their right side of space.

To the best of our knowledge, neglect research has still not addressed the relationship between driving ability and visual neglect. The tide of opinion certainly regards visual neglect as a definite obstacle to driving, but the effect of residual visual inattention on driving ability is a controversial issue. Our study raises the question if it is possible that some patients with residual visual inattention might be capable of driving safely. However, the strength of this study is the long enough on-road test so that the effect of any residual inattention on driving can be reliably assessed. We suggest that at least a minimum follow-up period of 6 months after acute neglect is needed in order to take into account possible fluctuation in visual neglect (Jehkonen, Laihosalo, Koivisto, Dastidar, & Ahonen, 2007), when driving is not permitted.

To summarize, the assessment of driving ability after stroke is a complex and multi-faceted process in which it is important to take into account the results of the multidisciplinary evaluation and each patient's compensatory mechanisms. If a stroke patient performs adequately in the driving evaluation, if he has good driving history, if he recognizes his possible residual cognitive difficulties and is aware of his limits in traffic (for example, does not drive when tired), then residual visual inattention may not necessarily be a definite risk for driving. One should also take into account the ecological validity and clinical importance of a specific test finding of mild left-sided inattention if a patient's performance is within acceptable range and it has no functional manifestations. There is a need to evaluate the relationship between driving ability and residual visual inattention in a larger group of stroke patients taking into account neuropsychological test findings as well as more functional based assessment, namely the on-road driving test.

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