Objective. The objective of this pilot study was to examine the use of a visual attention analyzer in the evaluation and retraining of useful field of view in clients with stroke.

Method. Fifty-two clients with stroke referred to a driving evaluation service were evaluated with a visual attention analyzer referred to as the UFOV. The UFOV assesses three aspects of visual attention: processing speed, divided attention, and selective attention. Seven participants were retested to determine the test–retest reliability of the UFOV. Six participated in the development of a training protocol and in a 20-session visual attention retraining program.

Results. UFOV scores indicated substantial reduction in visual attention in clients after stroke, with older participants performing the most poorly. Test–retest reliability was moderate (ICC = .70). Mean UFOV scores improved significantly after retraining.

Conclusion. Although UFOV scores indicated poor visual attention skills in clients with stroke, preliminary information suggests that UFOV scores significantly improve with training.


Driving a motor vehicle, although frequently an integral component of a person’s reintegration into the community, is a highly complex functional skill that is often affected by the wide range of sequelae following a stroke. Occupational therapists are often involved in evaluating clients’ abilities to drive after a stroke. Accuracy in measuring driving safety is crucial to ensuring that clients who are safe drivers are not prevented from maintaining their independent mode of transportation and to preventing clients who are unsafe drivers from posing a danger to themselves and others. In addition, developing effective driving retraining programs to assist our clients to attain a higher level of independence and improved quality of life is important and appropriate.

Automobile driving is a routinely performed complex activity, with an estimated 90% of the informational input to the driver being visual (Simms, 1985). Licensing board evaluations typically include the sensory testing of vision. However, the association between scores on tests of primary visual functions and driving accidents appears to be weak (Gresset & Meyer, 1994; Hills, 1980). Evidence suggests that visual acuity and peripheral field sensitivity do not adequately reflect the complexity of the driving task (Ball & Owsley, 1992; Ball, Owsley, & Beard, 1990). The demands

Note. The authors do not benefit in any way from the marketing or sale of the UFOV.
of driving include navigating a vehicle within a visual environment cluttered with distracters and involve the simultaneous use of central and peripheral vision (Ball & Owsley, 1992). These visual processing skills are among those necessary for safe driving because visual-perceptual errors are known to be a major contributing factor to automobile accidents (Hills, 1980); however, they are rarely formally tested by licensing agencies during routine driving evaluation.

As a complement to the measurement of primary visual functions, efforts are now being made to examine the importance of higher order visual attention skills on driving performance (Ball, Owsley, Sloane, Roenker, & Bruni, 1993). A visual attention analyzer has been developed to map a person's functional visual field, or useful field of view (Ball, Beard, Roenker, Miller, & Griggs, 1988). Useful field of view is the area of the visual field in which visual information can be acquired and processed without eye and head movement. The visual attention analyzer developed by Ball et al. (1988) is referred to as the UFOV. The UFOV is a large-screened computer that uses specialized software to evaluate three aspects of visual attention: visual processing speed, divided attention, and selective attention.

Studies examining performance on the UFOV in a group of healthy elderly persons indicated a decline in processing speed and divided and selective attention with increasing age (Ball et al., 1988; Goode et al., 1998; Owsley & Ball, 1993). In addition, poor performance on the UFOV, as indicated by a large percent reduction in the useful field of view area, was associated with a high rate of traffic accidents. In a retrospective study examining the driving records of 53 elderly persons, those with reduction in the area of useful field of view of 40% or more had a rate of prior accidents four times greater than those who performed well on the UFOV (Owsley, Ball, Sloane, Roenker, & Bruni, 1991). In addition, they experienced a 15 times greater number of accidents at roadway intersections (Owsley et al., 1991). In a subsequent study, the odds ratios for traffic accidents were higher for persons with greater impairments of 41% to 60% (OR = 13.6) and > 60% (OR = 17.2) reduction (Owsley, McGwin, & Ball, 1998). This same team of researchers conducted a prospective study to examine the association between UFOV scores and subsequent driving performance. Participants with poor UFOV scores (≥ 40% reduction) were 2.2 times more likely to be involved in a crash over the subsequent 3 years than those with UFOV scores of < 40% reduction (Owsley, Ball et al., 1998). Although the results clearly suggest an association between performance on the UFOV and driving ability, the researchers measured visual attention only once and did not consider that changes in visual attention in this population may have occurred over the 3-year follow-up.

Studies examining the use of the UFOV in retraining of visual attention skills in elderly persons have obtained encouraging results. Twenty-four elderly persons who received training using the UFOV showed marked improvement in useful field of view; this improvement was retained over a 6-month period. These highly significant gains occurred in all age subgroups (Ball et al., 1988). Additionally, in a study using a randomized controlled trial, the effectiveness of training on the UFOV was compared to simulator training in 77 high-risk elderly participants. In turn, these participants were compared with low-risk, untreated control participants. Participants in the UFOV group exhibited significantly fewer risky driving behaviors than participants in the other groups during an on-road driving test as well as showed improved reaction time during complex visual tasks. A limitation of this study was that the group treated on the simulator received only 2 hours of training compared with an average of 4.5 hours received by the UFOV group (Roenker, Cissel, Ball, & Niva, in press).

The results of these studies with elderly persons indicate a positive association between driving performance and test scores on the UFOV. In addition, evidence supports that retraining using the UFOV is effective in improving visual attention skills in an elderly population. These findings may have important implications for clients with stroke who have serious impairments in visual processing speed and ability and who wish to resume driving. Thus, the global objective of this pilot study was to examine the use of the UFOV visual attention analyzer in the evaluation and retraining of visual attention skills in clients with stroke. The specific objectives were to (a) determine the distribution of scores on the UFOV in a sample of clients with stroke, (b) determine the test–retest reliability of scores on the UFOV, and (c) identify change in performance on the UFOV after a 20-session training program. The information resulting from this study assisted in the development of the methodology for a randomized clinical trial designed to evaluate the effectiveness of a UFOV training program for clients with stroke.

Method

Participants

All clients referred to the Driving Evaluation Service at the Jewish Rehabilitation Hospital (JRH) in Quebec, Canada, for driving evaluations following a stroke were eligible for inclusion in the study. Persons with medical conditions that precluded them from driving, including homonymous hemianopsia, primary visual impairment that does not meet the licensing bureau's criteria, class IV cardiac status, and seizures, were not eligible. Other exclusion criteria included a Functional Independence Measure (FIM™); Hamilton, Granger, Sherwin, Zielezny, & Tashman, 1987) comprehension score of less than 5, indicating an inability to comprehend simple verbal instructions; impaired cognition as determined by a score of less than 6 on the Pfeiffer

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2FIM™ is a trademark of the Uniform Data System for Medical Rehabilitation, a division of UB Foundation Activities, Inc.
cognitive test (Pfeiffer, 1975); and severe perceptual or motor impairments deemed incompatible with driving by the interdisciplinary stroke team. All eligible persons who were referred to the service over an 18-month period and who agreed to participate were included in the study. One hundred forty-four potential participants who were admitted to the JRH and who were driving before their stroke were examined for eligibility. Eighty-seven were deemed ineligible to participate and five eligible persons refused to participate. Fifty-two persons were eligible and consented to participate. Participants ranged in age from 36 to 82 years (M = 65.2 years, SD = 11.3); 75% were men. Participants were evenly divided according to side of lesion. The average time since stroke at the time of evaluation was approximately 2 months (69 days, range = 35–194 days). Forty-eight (92%) participants were inpatients at JRH, and four were recruited as outpatients. Mean score on the FIM was 115.8 (SD = 9.9).

Procedure

Assessment of useful field of view was performed on all participants using the UFOV visual attention analyzer3. The UFOV is a specially designed software program that presents visual stimuli onto a large computer screen. As stated previously, this tool tests three components of visual attention: processing speed, divided attention, and selective attention. An occupational therapist conducted the evaluation in a darkened room free of distraction. The therapist presented scripted instructions to each participant in either English or French and described and then demonstrated tasks in a darkened room free of distraction. The therapist presented scripted instructions to each participant in either English or French and described and then demonstrated each task, using two examples presented on the screen. The participant was then presented with four practice trials, which were similar to the actual test items but presented on the screen for a longer duration. The demonstration and practice trials were repeated until the therapist was certain that the participant understood the procedures.

The first task, processing speed, requires the participant to identify a centrally located object, either a car or a truck, presented in a white box. The participant must indicate that he or she saw a car or truck by touching the appropriate image on the computer screen after each trial. The duration of object presentation is gradually decreased until the participant can no longer identify which of the two objects was presented. The duration of presentation ranges from 250 msec to 12.5 msec.

The second task, divided attention, requires the participant to identify the centrally presented target and to locate a simultaneously presented peripheral target. The participant must perform the central and peripheral tasks concurrently. The peripheral target appears unpredictably at any one of 24 locations, representing all combinations of eccentricity (10°, 20°, 30° of visual angle) and directions (4 cardinal, 4 oblique axes). Divided attention is tested at varying exposure durations, ranging from 240 msec to 40 msec.

The final and most complex task is the evaluation of selective attention. This subtest provides a measure of distractibility by having participants perform the same task as in the divided attention task with the addition of distracters in the field. White triangles are presented throughout the screen to evaluate the participant’s ability to differentiate the peripheral target from the distracters.

The score for each of the three subtests is automatically calculated by the computer as the percentage reduction from the maximum area of useful field of view. Each subtest score ranges from 0% to 30% reduction. The total percentage loss of useful field of view is a composite of the three subtests and can range from 0% to 90% reduction. The time taken to complete the test is also recorded.

Distribution of UFOV scores. A descriptive study was used to examine the performance of visual attention tasks in clients after a stroke. The charts of all clients referred to the Driving Evaluation Service were examined for eligibility. For those eligible to participate, the occupational therapist approached the client to explain the purpose and procedures of the study. Upon receiving written informed consent, a convenient time for a one-time evaluation on the UFOV was arranged. During testing, to ensure that all participants viewed the stimuli in the same manner, their foreheads and chins were positioned against a metal rest with their eyes positioned at the midlevel of the screen. The evaluation was conducted using a uniform method of administration. A score for each subtest and a total score were recorded for all participants.

Test–retest reliability. The first seven participants who agreed to participate were selected for the test–retest reliability phase of the study. They completed the UFOV evaluation twice within a 2-day period.

UFOV training. The first six participants who agreed to participate in the training program completed 20 training sessions and were then reassessed on the UFOV to identify changes in performance after training. Training on the UFOV consisted of manipulating several parameters that enabled practice sessions to be offered at a level of difficulty appropriate to the individual participants. For example, the therapist was able to vary the color of the peripheral target. White is the most difficult target to see, whereas more distinct colors, such as blue, red, green, and yellow, were used to reduce the level of difficulty of the task. The distracters were presented using either a dim or a normal setting. The dim setting was used to reduce the degree of distraction and thus facilitate the task. The duration of presentation on the computer screen ranged from 40 msec to 400 msec, with processing of the shorter durations requiring greater visual attention ability. The eccentricity of presentation of the peripheral target could be set at 10°, 20°, or 30°. Targets presented at greater eccentricities were located more peripherally and required a higher...
level of ability. In addition, extra training to the right, left, top, or bottom of the screen was provided according to the participants’ specific needs.

During the training sessions, these six participants assisted in the development of the training protocol. Criteria for selecting the training parameters were developed on the basis of the training program described in an earlier study with elderly drivers (Ball et al., 1988). The standard training protocol was developed according to the participants’ performance during the training sessions. They began training on one of the three modules available—processing speed, divided attention, or selective attention—according to the results of initial testing. For example, the training began with the processing speed task when total test scores indicated UFOV reduction of > 80% or when the threshold duration was > 20 msec (i.e., participants achieved 75% accuracy with a duration exposure of > 20 msec). When a participant scored between 40% and 80% reduction, training started with the divided attention task. Participants with scores of < 40% reduction began training with the most complex task, selective attention. A standardized method of progressing through the training program was devised. All participants began at the slowest speed and smallest eccentricity. Eccentricity was increased from 10° to 20° to 30°, and duration of presentation was then reduced from 400 msec to 400 msec as the participant correctly identified 75% or more of the presentations. When the participant reached a level where he or she was no longer capable of accomplishing the task, the peripheral target was changed to a color (progressing from little to greater contrast), and training progressed until duration of presentation was decreased two levels (80 msec). If the participant was unable to respond correctly to 75% of the presentations with the color target at these faster presentations, the distracters were set to dim to decrease the demands of the task. Once participants were capable of accomplishing this task with the color peripheral targets, they returned to the previous level of training. An experienced occupational therapist manipulated the presentation parameters and completed detailed reports of each training session. These reports contained information about the specific parameters selected during each trial and the participants’ successes and failures.

Data Analysis

Descriptive statistics were used to present the distribution of scores on the UFOV. One-way analyses of variance (ANOVAs) and t-tests were used to examine potential differences according to important participant characteristics, including age, gender, and side of lesion. Pearson product-moment correlations were calculated to examine the association between UFOV scores and the participants’ clinical characteristics. To determine the test–retest reliability of scores on the UFOV, intraclass correlation analysis was performed with the SAS procedure, PROC VARCOMP (SAS Institute, 1996). This computer program computes the variance components in a general linear model. Paired t-tests were used to determine significant differences between pretraining and posttraining scores. The SAS statistical program was used for all analyses.

Results

Distribution of UFOV Scores

Scores obtained on the UFOV for the group as a whole are presented in Table 1 and Figure 1. The mean percentage reduction in UFOV in our participants with stroke was 39.5%. Twenty-five (48%) obtained total scores > 40% reduction, indicating a clinically significant reduction in visual attention. Examination of the subset scores demonstrates that visual attention performance diminished as the complexity and demands of the task increased. High scores on the selective attention subset indicate serious difficulty in the performance of this complex task in our sample. In addition, the wide range of scores (12.5%–90% reduction) indicates a large variation in visual attention performance within this population with stroke.

Table 2 presents the distribution of scores on the UFOV according to age, gender, and side of lesion. The results of testing using one-way ANOVA indicated that scores worsened with increasing age, F(3, 48) = 3.21, p = .03. Participants ≤ 54 years of age performed significantly better than those ≥ 65 years of age. No significant differences in scores according to side of lesion (p = .79) or gender (p = .34) were seen. Pearson product-moment correlations indicated no significant association between percentage reduction in UFOV and FIM scores, r = −.16, p = .26, or time since stroke, r = −.02, p = .90.

Test–Retest Reliability

The seven participants in the test–retest reliability component of the study were slightly older than the group as a whole (M = 73.3 years); five were women, and four had a left cerebrovascular accident. The intraclass correlation coefficient (ICC) was .70, indicating moderate test–retest reliability.

UFOV Training

The six participants who participated in the training portion of the study were slightly younger than the whole group (M = 60 years) and had equal numbers of men and women, with five of the six having a left-sided lesion. Their
pretraining and posttraining scores are presented in Figure 2. The mean initial total UFOV score indicated a reduction of 36.3% (range = 22.5%–45%) compared with a posttraining mean total score of 6.3% reduction (range = 0%–17.5%). Three of these participants achieved a score of 0.0% loss. Paired $t$ tests indicated a highly significant difference between pretraining and posttraining scores ($p < .0001$). Participants improved on all three subtests (processing speed, $p = .09$; divided attention, $p = .009$; selective attention, $p < .0001$). All six obtained a posttraining score of 0.0% reduction on the processing speed and divided attention tasks.

Discussion

The results of this pilot study examining the use of the UFOV in a group of clients with stroke undergoing rehabilitation indicate a wide range of performance. Overall, a significant decline in the three aspects of visual attention abilities measured by the UFOV was found in this sample. Although norms for a similar age population without stroke are not available, the distribution of scores found in our sample is similar to that seen in Ball et al.’s (1993) study of 294 persons 65 to 85 years of age. Ball et al. determined that 43% of their elderly group obtained scores greater than 40% reduction on the UFOV, whereas 38% of the participants with stroke evaluated in the present study scored higher than 40% reduction. Because the age distribution of their sample (Ball & Rebok, 1994) is much older than for this sample, and scores on the UFOV are known to decline with increasing age, speculation of the actual relationship of the scores to the visual attention sequelae of stroke is difficult.

We anticipated that participants with right-sided lesions would demonstrate poorer performance on the visual attention tasks because of the known visual-perceptual deficits associated with this condition. However, no significant differences in scores on the UFOV according to side of lesion were found. This finding may be due to the exclusion of persons with severe deficits in perception from the study, potentially increasing the overall level of performance of our sample. Although some studies (Barer, Edmans, & Lincoln, 1990; van Ravensberg, Tyldesley, Rozendal, & Whiting, 1984) have reported higher proportions of participants with perceptual impairments following right-sided lesions than left-sided lesions, Marshall, Grinnell, Heisel, Newall, and Hunt (1997) found no differences in performance between these two groups on a visual divided attention task. The possibility exists that completion of the tasks on the UFOV requires a combination of skills, such as attention and concentration skills affected by both left-sided and right-sided lesions.

An understanding of the test–retest reliability of the UFOV is important for the interpretation of repeated testing results. An ICC of .70 indicates a moderate level of reliability over repeated testing. However, the small sample size results in an extremely large confidence interval for this value. Several client factors may affect the consistency of performance. The medical and functional status of clients in the early stages after a stroke may be changing. The UFOV evaluation is complex, and learning of the tasks with repeated measurement may affect subsequent performance. Indeed, of the seven participants who participated in this phase of the study, four performed better during the second test session.

The standardized training program was developed.

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Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>UFOV Score M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 54</td>
<td>8</td>
<td>21.9 (9.9)</td>
</tr>
<tr>
<td>55–66</td>
<td>12</td>
<td>39.8 (21.0)</td>
</tr>
<tr>
<td>65–74</td>
<td>21</td>
<td>42.1 (18.9)</td>
</tr>
<tr>
<td>≥ 75</td>
<td>11</td>
<td>46.8 (18.5)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>39</td>
<td>40.6 (21.4)</td>
</tr>
<tr>
<td>Female</td>
<td>13</td>
<td>36.0 (12.1)</td>
</tr>
<tr>
<td><strong>Side of lesion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left CVA</td>
<td>26</td>
<td>38.8 (20.3)</td>
</tr>
<tr>
<td>Right CVA</td>
<td>26</td>
<td>40.2 (19.0)</td>
</tr>
</tbody>
</table>

*F(3, 48) = 3.21, $p = .03$. Significant differences: ≤ 54 vs. 65–74 and ≤ 54 vs. ≥ 75.*

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Figure 1. Distribution of total scores on the UFOV for all study participants. Note. Low scores indicate better performance.

Figure 2. Pretraining and posttraining UFOV ($n = 6$). Note. Low scores indicate better performance.
while working with six participants and appears to be a feasible method of retraining visual attention in the stroke population. Methods of training were attempted and revised according to the participants’ responses. Although the systematic training progression was successfully used with these six clients, not all scenarios could be foreseen, and future instances may exist where the program cannot be carried out as planned.

The six training program participants all showed marked improvement in their performance on the UFOV. In the absence of a control group, it is not known whether this improvement would be similar in an untreated group. Although the results of test–retest reliability did not indicate a strong learning effect over the two evaluation sessions, the use of the UFOV as a measure of outcome may reflect a training effect rather than a significant change in the level of attention. Whether this improvement is associated with an improved ability to perform functional tasks requiring high levels of attention, such as driving, is still not known.

The results of this study indicate that clients with stroke who were undergoing rehabilitation exhibited substantial loss in visual processing skills as measured with the UFOV. Although an association between UFOV scores and functional driving performance in elderly persons has been demonstrated, this relationship has not yet been examined in clients with stroke. In addition, highly significant improvement in UFOV scores was demonstrated after training on the UFOV. Although these preliminary results suggest that the UFOV may be a useful tool to assist occupational therapists in the treatment of impairments in attention, the impact of this approach to training on the performance of functional tasks is not yet known. Because this study did not include a control group, whether this positive change represents improved visual attention or isolated learning of the UFOV tasks is uncertain. Further study is needed to determine whether the improved UFOV scores translate into enhanced functional performance in activities that highly depend on visual attention, such as automobile driving. These findings formed the basis for a randomized clinical trial examining the impact of retraining visual attention skills using the UFOV on on-road driving performance in clients with stroke.

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