



## Visual Field Deficits after Brain Injury

# COMPUTERIZED SCREENING

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### ABSTRACT

*Visual field impairments are a common sequelae of brain injury, including traumatic and vascular etiologies. These impairments are frequently undiagnosed or misdiagnosed because patients do not experience them for what they are and do not "complain" of any problem; indeed patients' lack of recognition of a problem leads therapists to diagnose "neglect" instead. Conventional perimetry is often ineffective or impractical because other effects of brain injury have compromised performance. New techniques, most implemented on IBM- and Apple-compatible computers, are presented, together with illustrative clinical examples. The dynamic nature of the computerized procedures introduces a significant degree of sensitivity and realism for visual information processing in a world in which time to process is limited. These methods emphasize the practical and functional requirements of rehabilitation, albeit with some sacrifice of precision. For difficult-to-test individuals, these methods offer otherwise unavailable information. For others, these methods may help direct and focus subsequent appraisal with conventional techniques.*

### KEY WORDS

*visual fields, brain injury, computerized screening, homonymous hemianopia, visual neglect*

**R**arely are neurologically-based partial losses of visual field experienced in a manner that concords with objective findings. Rather the system "completes" the image<sup>1,2,3</sup> so that, for instance, a driver would see the road, but not necessarily the cyclist or oncoming vehicle in an area of visual non-responsivity. Such field losses are relatively common sequelae of brain injuries, including trauma, cerebrovascular accidents and space-occupying lesions. Visual field deficits, therefore, present a serious obstacle to safety and successful rehabilitation from brain injuries.

Frequently, the visual fields of persons undergoing rehabilitation for the effects of brain injuries are assessed by the insensitive confrontation method.<sup>4</sup> In only a few published studies, e.g., Teuber, Battersby and Bender's<sup>1</sup> classic study of survivors of missile wounds to the brain, has quantitative projection perimetry been used. These investigators found field defects in 46 of 203 cases. On repeated assessment these deficits "showed a remarkable persistence ... unchanged for decades" (p. 113). In one controversial study using the precise Tubinger projection perimeter, Zihl and von Cramon<sup>5</sup> claimed to expand cortically blind fields by stimulating the periphery of the field. They concluded that this technique worked best on field defects with graduated boundaries. Unfortunately, a thorough replication attempt by Balliet, Mt Blood and Bach-Y-Rita<sup>6</sup> failed.

### CONVENTIONAL APPROACHES

Conventional quantitative perimetry<sup>7</sup> is difficult for many brain-injured persons

as it requires concentration and an ability to sustain fixation. The unstructured ganzfeld (homogeneous white interior display) of projection perimeters can be disorienting and difficult to tolerate for this group of patients.

However, manual projection perimetry conducted by a careful and patient examiner and a tolerant examinee can yield meaningful results. I have used the Tubinger projection perimeter (see Figure 1), which offered excellent control over stimulus parameters, especially a wide range of intensities. This permitted quantitative assessment of the central fields. It often took a total of four hours (divided into several sessions), using the manual Tubinger projection perimeter to complete an examination of a brain-injured person's peripheral and central fields. The most effective method was to display the stimulus for 20 msec. in a series of discrete trials. These trials were too brief to permit localizing eye movements. For peripheral field assessment I brought the stimulus in, along a meridian, in series of trials until the examinee saw it. Periodic reliability checks were important, and when the pattern of responding became inconsistent, it was necessary to take a break.

Assessment of the central fields was limited to the horizontal (180 degree) meridian. Stimuli of varying intensity were presented using the limited exposure discrete trial procedure described above for peripheral field testing. Some stimuli were so faint they could only be seen in the very center of the field--the peak of the "hill of vision." The solid line in the upper part of the displays in Figures 2 and 3 shows the minimum intensity visible--the



Figure 1. Photo of Tubinger perimeter.

higher the line the lower the threshold intensity. Normally this value peaks in the center and drops off symmetrically on both sides. In the examples given, there was an accelerated drop off on the affected side. The estimated loss is shown by the shaded area.

Manual projection perimetry, while possible with some patients, is not very practical. Not only is it time-consuming but few perimeters offer the range of intensity values necessary for central field assessment. Establishing and maintaining appropriate head positioning can be difficult, if not impossible, because of the physical disabilities associated with brain injury.

Automated projection perimetry<sup>8</sup> has many advantages for assessing neurologically-intact adults, but is especially difficult for brain-injured survivors because it requires them to make very fine discriminations and a series of rapid judgments. Although the pace of trials can be adjusted, it is still executed in a set fashion and the examination procedure is not interactive so that the pace is not adapted to the individual's capabilities.

Finally, central hemi-field impairments are difficult to assess by conventional measures. Most projection perimeters do not permit sufficient control of stimulus intensity to allow quantitative assessment of the central fields. The Amsler grid, traditionally used for central field defects, has never been sufficient, in my experience, for elucidating the type of field loss associated with acquired brain injury.

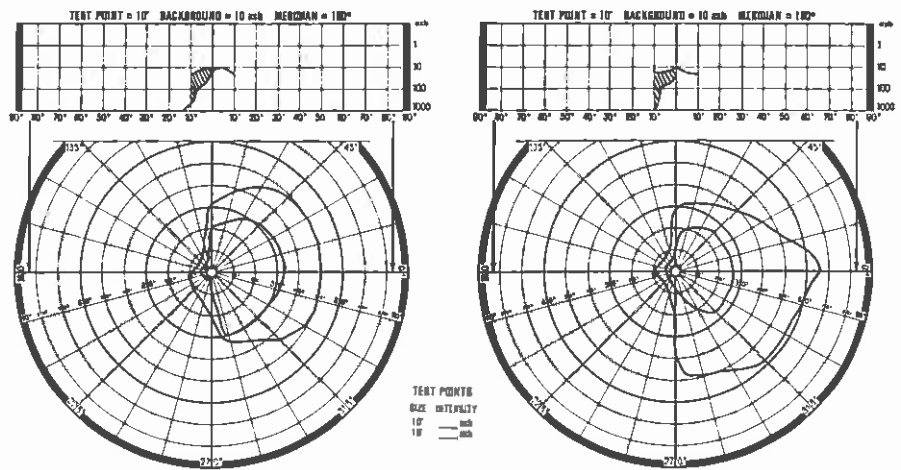


Figure 2. Tubinger visual fields of brain tumor patient "RD," showing left homonymous hemianopia with graduated boundary at the central field. Macular sparing, as might be inferred from the pattern of results on the 180 degree field charts (lower portion of the display), is shown to be only partially preserved by the central field assessment in the upper portion of the display. Shaded area represents estimated loss in the central field, based on responsivity of unaffected side. See text for procedural details.

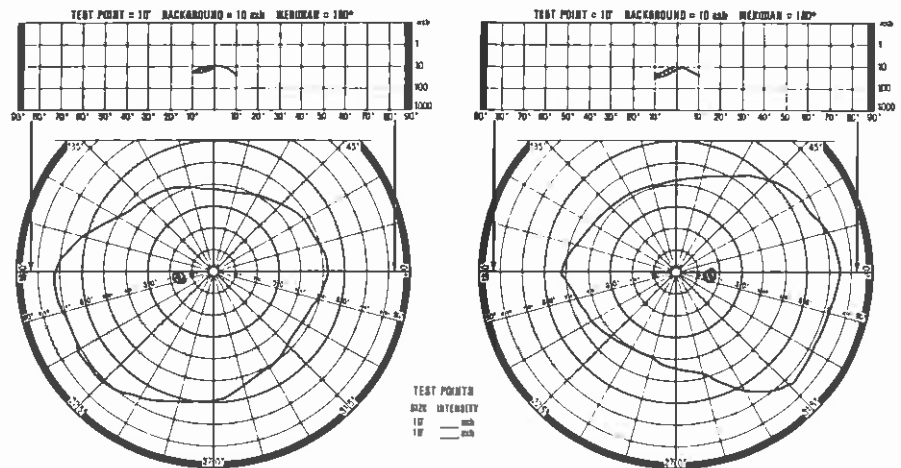


Figure 3. Tubinger visual fields of post CVA patient "RK," illustrating depressed left central hemi-field (upper portion of display). Again the shaded area represents the estimated loss, or depression, of the left central field, based on responsivity of the intact right central field. Peripheral fields (lower portion of display) show no impairment. Her only symptom was an occasional tendency to misread the initial letter or letters of words, or to fail to detect errors involving these letters when proofreading.

## UNDERAPPRECIATED ISSUES

There is also a great deal we do not know or rarely evaluate about the visual fields. Important as these factors would seem to be, they are rarely incorporated into most clinical protocols for evaluating the visual fields. The neglected issues include:

1. What is the role of the secondary (superior collicular) visual system?<sup>9-12</sup> Does this system give some perimetrically unresponsive persons unconscious sensitivity ("blindsight"), which might account for their ability to navigate the

environment relatively effectively compared to others with equivalent perimetrically measured losses?

2. Are fields for moving stimuli the same as for stationary ones? Responsivity to moving stimuli throughout the visual field may not correlate with responsivity to static stimuli. For safe ambulation the former may be more relevant, whereas for reading the latter would be critical.
3. Is the field impairment absolute or relative? Many professionals in brain-injury rehabilitation are unaware of the possibility of relative field losses (i.e.,

depressed fields) and, consequently, fail to test further. An appreciation of this possibility might cause them to reconsider their understanding of hemispatial "neglect." In this phenomenon, persons are thought to have an attentional deficit because they respond to a stimulus in the affected field when nothing is occurring in the intact hemi-field, but not when something is presented simultaneously to the intact field. This phenomenon can be explained by a relative field loss (reduction of visual sensitivity) and may not be caused by "neglect." Hyperattention to the affected field may indeed be necessary to overcome this problem: attention may be part of the solution, but it is rarely the problem.

4. What is the pattern of peripheral field loss? Many rehabilitation practitioners only consider hemi- or quadrantanopic types of loss. The wider range of possibilities is not considered. Blind spots (scotomata), as illustrated in Figure 7 (to be discussed later), are frequently not investigated when the individual appears aware of peripheral information.
5. What is the pattern of central (macular) field impairment? Again, oversimplification prevails: typically, in hemianopia only two possibilities are considered: either the macula is said to be "split" along the vertical meridian and thus completely unresponsive on the affected side, or "spared" on the otherwise affected side. This latter interpretation is the one which would usually be given for the fields in Figure 2. However, in most cases of sparing, including the case in Figure 2, there is measurable impairment--the macula is only partially spared. I will describe some practical diagnostic clinical procedures which explain reading problems caused by a partially spared macula.
6. Is it possible to have a reduction in sensitivity in the central hemi-field without any loss in the periphery? I have found several cases like this in which the peak of the metaphoric hill of vision is partially destroyed, much as the peak of Mount St. Helens was subject to volcanic destruction. In one stroke survivor I was able to confirm this "Mount St. Helens" phenomenon perimetrically (see Figure 3).

## NEW PROCEDURES

It is clear that visual fields, while vulnerable to brain injury but essential for safe and successful functioning, are not adequately assessed in this population when conventional procedures are used. The net result is that adequate evaluation of this important ability frequently does not occur. There is a need for practical and functional assessment, appropriate to the needs of rehabilitation. The procedures to be described were developed with an emphasis on practicality and functionality, the application to everyday life. These procedures represent techniques which can be used to screen for a variety of visual field deficits, offering information which can be followed up by optometrists using more formalized measures. Concordance between these findings and conventional procedures has to date been limited to a small number of case studies and clinical experience. Further research would be welcome.

The procedures to be described here are all included in the *Computer Programs for Cognitive Rehabilitation*.<sup>a</sup> All but "Error Detection" (a paper and pencil procedure) are available for IBM and Apple II compatible computers. However, laptop computers with liquid crystal displays (LCD) are NOT suitable for these or any other procedures which involve rapid, precisely-timed displays.

We will consider procedures which address peripheral and central fields separately. The central fields correspond to the area subtended by the macula and are involved with foveal vision. The peripheral fields include the remaining area. By this terminology, automated perimeters which contain programs for the "central 30" degrees are assessing the near periphery.

## PERIPHERAL FIELDS

Before describing specific procedures for addressing the peripheral fields, certain general features will be mentioned: All procedures are conducted with the examinee seated before a computer monitor (see Figure 4), and can only address that portion of the peripheral field subtended by a computer screen, rarely more than 40 degrees of visual angle. The larger the screen and the closer the individual to the screen, the greater the field.



Figure 4. Photo of person using switch to do REACT.

For most practical everyday purposes, this area is sufficient, even though it is less than that assessed by conventional procedures.

The contrast of the display on the screen is controlled by contrast and brightness settings, as well as the surrounding illumination. In practice the procedures are usually conducted in ordinary room lighting, avoiding glare or bright reflections. The examiner chooses a comfortable level of contrast and verifies that the examinee can see it easily. This level is considered the normal (high) contrast value. To explore reductions of sensitivity, lower the contrast to one or two just-noticeable differences above the point where the display is barely visible to the examinee. More precise calibration of the contrast is often beyond the scope of the available equipment, and, though of obvious value in standardizing the findings, is probably not necessary to check for reductions in sensitivity. Formal perimetric assessment would address the extent of the reduction quantitatively.

The present approach is functional and practical: most vision occurs in ordinary room lighting and in many rehabilitation settings control of illumination is limited. Other constraints, e.g., fixed head position and distance from target, are not precisely maintained in the proposed procedures, although they could be. Not only would they be burdensome to the patient but in everyday situations positions and distances are not fixed. Binocular assessment with eyes free to move is justified on

the same pragmatic grounds. It is therefore suggested that the findings be characterized as a "functional visual field"--which corresponds to the area of responsivity for an individual under ordinary viewing conditions.

Understandably, there is some sacrifice in the precision of the resulting fields. This is justified on the grounds that some information is better than none. Furthermore, there is nothing to prevent subsequent evaluations with tighter constraints, e.g., monocular, eyes fixed, etc. Initially, the assessment is done in the most comfortable and normal way possible. Often, once the patient has the idea, further constraints are usually tolerated.

### REACTION TIME MEASURE OF VISUAL FIELD (REACT)

In this procedure<sup>13</sup> examinees press a response key as soon as they become aware of stimuli which appear in unpredictable locations on the screen. Initially, the screen itself is basically clear (except for a fixation stimulus which is present when the procedure is to be done with fixation). Usually the stimulus is a two-digit number which increases in hundredths of a second (see Figure 4). (The changing digits appear to move in place and this stimulus display is therefore called "kinetic." REACT offers the option of a static stimulus, but as yet there is no comparative information on it.) When the individual responds, the counter stops and displays the response time. Shortly, the display clears and after a random delay the next trial begins. In case the individual does not respond, a time limit, usually two seconds, is set, after which the display clears for the next trial.

A butterfly-shaped array of 16 trials, preceded by five center trials, has been used for standardization purposes, although REACT permits easy design of one's own stimulus arrays. A normal observer can complete a standard series in less than 2.5 minutes. In practice, several such runs are suggested, exploring the effect of different options, such as performing the procedure with or without fixation, monocular vs. binocular mode and normal (high) vs. low contrast. Since running all possible combinations of conditions would be excessively time-consuming and tedious for the individual, it is customary to sample the conditions, pursuing

hypotheses as needed. I usually begin with normal contrast, binocular, eyes free to move, in order to establish the procedure. Under these conditions, response times typically range from .2 to .4 sec. throughout the display. If it seems likely that the field is intact, I then proceed to the most demanding conditions (eyes fixated, monocular, low contrast). Success in these conditions, obviates the need to run conditions of intermediate difficulty.

For each run there are two graphic displays of results. The first is illustrated in Figure 5 for "NF," a 56-year-old aphasic man recovering from a severe stroke. Communication was extremely limited because of his language impairment and it would have been difficult to explain conventional procedures, including a fixation requirement. The top panel represents findings with normal contrast on the display and the bottom with low contrast. The reaction times are printed in a location approximating that in which the stimulus appeared. This patient was generally slower to respond to stimuli on the right side of the display. This effect, which was more pronounced with low contrast, suggested a relative, not absolute, impairment. In this case REACT offered some information: "NF" was otherwise untestable.

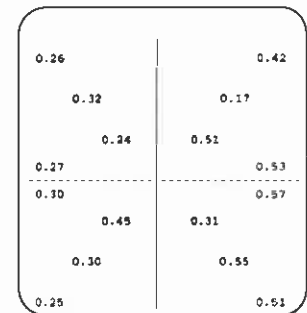
REACT also produces a trial by trial bar graph which exposes practice and fatigue effects. Statistical summaries, including means, medians and standard deviations, are offered for each side of the display, upper vs. lower portions, center vs. periphery and for each quadrant.

The REACT settings which most closely parallel conventional tangent screen field testing are normal contrast, monocular viewing, and with fixation. An important difference is that in REACT the response time is measured as opposed to the "saw it or did not see it" response obtained in static campimetry. This degree of quantification introduces sensitivity into the procedure which may make up somewhat for the limited field being tested. Fixation is best monitored by direct observation, preferably through a small mirror near the screen which allows the examiner to see the display at the same time. Fixation can also be evaluated using stimuli presented in the area subtended by the physiological blind spot (e.g., 3 to 5 inches temporally from the fixation point at 14 inches viewing distance). Good

### REACTION TIME MEASURE OF VISUAL FIELDS (REACT)

Name: "NF"—aphasic, left hemisphere stroke  
Conditions: 10" wide @ 16", both eyes moving freely, 2 sec time limit

#### NORMAL CONTRAST



#### LOW CONTRAST

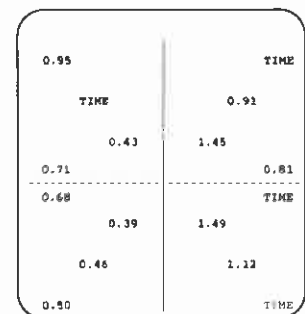


Figure 5. Reaction Time (REACT) "field" of "NF," a severely aphasic post-stroke patient who would have been too confused to engage in conventional visual field tests. The numbers represent time in seconds to respond to a flickering stimulus (a counter incrementing in hundredths of a second). The location of the numbers corresponds to the location of the stimulus on the computer screen. He was tested binocularly and his eyes were free to move and did so easily, but not actively. The top display was obtained using normal contrast, while on the bottom display, contrast was reduced. Results show generally longer response times on the right side of each display, with a more pronounced lateral difference and greater variability with reduced contrast.

### REACTION TIME MEASURE OF VISUAL FIELDS (REACT)

Name: "TJ"—multiple strokes  
Conditions: Both eyes moving freely, 4 sec time limit

#### NORMAL CONTRAST

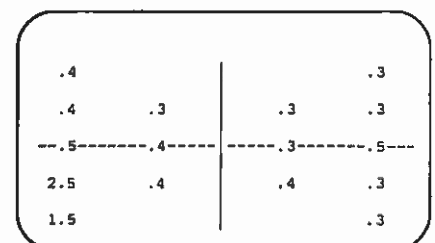


Figure 6. Reaction Time (REACT) "fields" of "TJ," a survivor of several strokes, showing delayed responding in lower left quadrant. This display was generated by an early version of REACT with less precise timing and other superficial differences in the format of the printout.

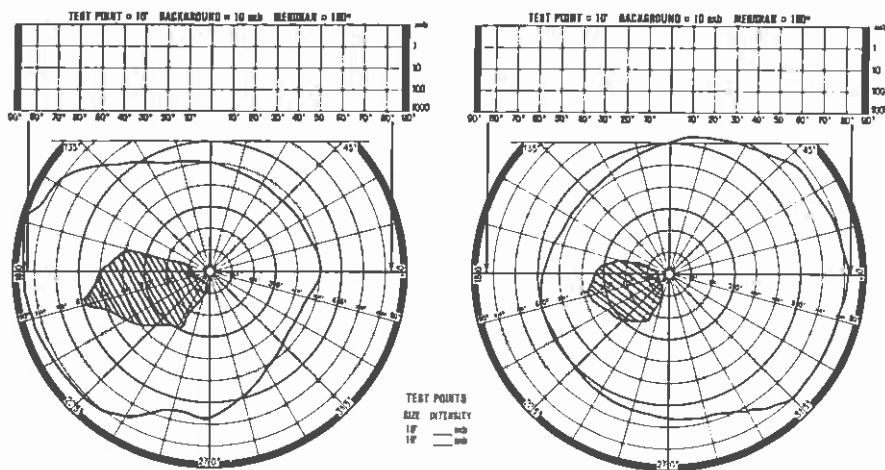


Figure 7. Tubinger visual fields of same post-CVA patient ("TJ"), showing homonymous lower left quadrant scotoma.

fixators will be totally unresponsive to stimulus trials presented in their blind spots.

One of the advantages of this procedure with the brain-injured population, illustrated by "NF's" case, is that it is simple to do. Indeed, REACT can be done by anyone who can sustain consciousness and consistently respond to a stimulus. (At the same time neurologically intact people enjoy the challenge of seeing how quickly they can respond.)

A second example of REACT findings (Figure 6), with corresponding perimetric visual fields (Figure 7), comes from "TJ," a gentleman, described by Gianutsos and Matheson,<sup>14</sup> who had sustained multiple cerebrovascular accidents and was completing in-patient rehabilitation. On REACT he consistently missed or was delayed on stimuli presented in the lower left, especially when he was required to fixate. The problem occurred no matter which eye was tested. Perimetry with a Tubinger manual projection perimeter (Figure 7) revealed a large lower left quadrant scotoma. In occupational therapy, he was observed to have some difficulty in visual perceptual tasks, e.g., working jigsaw puzzles. Otherwise, he was quite unaware of a problem and was looking forward to going for a drive in a rental car upon his discharge. Treatment consisted of repeated opportunities to practice REACT in different conditions, allowing him to confirm the problem and the limits of compensatory scanning. This practice was complemented by counseling regarding visual

field losses and implications for everyday activities, including driving.

### SINGLE AND DOUBLE SIMULTANEOUS STIMULATION (SDSST)

This computerized task is based on a classic neurological examination procedure in which stimuli are offered to either one or both sides. Some people are responsive to stimuli on each side, but are said to show "extinction" of the affected side when stimuli are presented to both sides simultaneously.<sup>15</sup> This extinction effect has been interpreted as hemi-inattention.<sup>16</sup> In the computerized SDSST<sup>17</sup> a minus (-) and an equals (=) sign are used as test stimuli. There are no fixation requirements, although the individual is given a central stimulus to look at and is asked to press the space bar to begin a trial. Single and double stimulus trials are mixed unpredictably with blank (no stimulus) trials. On single trials, stimuli are presented briefly on either the extreme left or extreme right side of the computer monitor. On simultaneous trials both these locations are used. The degrees of visual angle subtended by the two stimuli depends on the size of the monitor and the distance of the observer. A 10-inch display with an observer at 14 inches subtends approximately 40 degrees. A monocular viewer fixating in the center might fail to detect stimuli 3 to 5 inches from center because that is the area subtended by the physiological blind spot—an unintended outcome against which one must guard.

Ordinarily this problem does not affect the SDSST outcome, as testing is done binocularly without fixation requirements.

A series of 45 discrete trials is conducted representing all possible combinations of single and double (simultaneous) stimulus presentations, as well as five "catch" (blank) trials. Presentations are brief (less than 1/2 second) and the individual's responses are keyed into the computer.

Normative data for SDSST have been taken from college students: at normal contrast they rarely made errors; indeed, more than two errors on the standard series of 45 trials was very unusual.

At the conclusion of trials, SDSST displays a stimulus-response matrix containing counts of all possible combinations of stimulus and response patterns as illustrated in Figure 8. The columns represent the computer-presented stimuli, while the rows categorize the individual's responses. The leftmost column represents the blank "catch" trials. The second to fifth columns represent single stimulus trials, while the last four columns are double simultaneous trials. Correct responses, where the stimulus (column) corresponds to the response (row), are therefore represented in the diagonal of this matrix.

Error patterns can be studied through analysis of the off-diagonal items. Look for any lateralized disparity as well as any tendency to confuse (e.g., report "-" instead of "=") stimuli, as opposed to omitting them altogether. Further, distinguish errors made on simultaneous from single trials. A pure sensory deficit would be reflected by errors on both types of trials; whereas, "extinction" would manifest as errors involving the affected side on double presentations only. Neurological patients with injury to one hemisphere are most likely to show lateralized performance differences. If there is an absolute field loss, omissions would prevail; whereas with a relative loss, expect confusions (rather than omissions) on the affected side or, on simultaneous presentations, extinction of the stimulus on the affected side.

The data in Figure 8 represent the performance of "RD," a lawyer who had had a large meningioma removed and whose chief complaint was reading problems. His visual fields, presented earlier (Figure 2), showed a left homonymous

**SINGLE AND DOUBLE SIMULTANEOUS STIMULATION (SDSST)**

Name: "RD"—after removal of meningioma  
Conditions: Normal contrast, 45 trials

**STIMULUS DISPLAY**

	Blank	Single				Double			
	..	.-	..	..	..	..	..	..	..
R	5	2	2	0	0	0	0	0	0
E	0	0	1	0	0	0	0	0	0
S	0	3	2	0	0	0	0	0	0
P	0	0	0	4	4	4	4	3	3
O	0	0	0	1	1	0	0	1	2
N	0	0	0	0	0	0	0	0	0
S	0	0	0	0	0	1	1	1	0
E	0	0	0	0	0	0	0	0	0

**Analysis of Errors**

Single	Left	Right	
	----	-----	
Confusions	4	5	
Omissions	4	0	
(subtotals)	8	5	13
Double			
Confusions	1.5	3.5	
Omissions	14	0	
(subtotals)	15.5	3.5	19
TOTALS	23.5	8.5	32 (71.1%)

**Figure 8.** SDSST (Computerized Single and Double Simultaneous Stimulation) results for "RD." Columns represent the nine different combinations of stimulus presentations, ranging from blank trials (column 1), to single (columns 2-5), and double (columns 6-9) trials. The rows represent the patient's response as indicated by the corresponding box in the extreme left column. Entries in the diagonal, where the stimulus corresponds to the response, represent instances of correct responses (out of 5). Errors (off-diagonals) are subdivided into omissions (e.g., the two entries in column 2, where a "-" on the left was responded to as a blank trial) and confusions (e.g., the three entries in column 2, where a "-" on the left was responded to as an "=" on the left). Fractional error counts occur when both stimuli in a display are responded to incorrectly, e.g., "=" is reported as "-." and is scored as .5 left omission and .5 right confusion.

hemianopia with a relative impairment in his left central field. More information about him is contained in the review chapter by Gianutsos and Matheson.<sup>14</sup> The SDSST findings show that he had difficulty monitoring the periphery, and was prone to omissions of stimuli on the left side, particularly on double (simultaneous) presentations. In other words, these SDSST findings indicate impairment in the left peripheral field.

Experience has shown SDSST to be a very sensitive screening tool for visual field deficits in the horizontal meridian because very little time is given for compensatory eye movements. To explore this issue, I asked therapists to attempt to train "RW," a head injury survivor with a dense

right homonymous hemianopia, to compensate on SDSST. He was instructed to stare at a red sticker placed on the computer screen, where the right side stimulus would appear and initiate the trial. This technique enabled him to see the stimulus on the right; however, he no longer could accurately discriminate the stimulus on the left, even though he always knew when a stimulus was presented there. By moving his fixation to the right to compensate, he was forced to view the left side stimulus in the periphery where acuity is reduced. This phenomenon, compensating for a field loss at the expense of reduced responsiveness on the intact side, is so common in brain-injury rehabilitation that I call it the "robbing Peter to pay Paul" effect.

**CENTRAL FIELD IMPAIRMENTS**

Most vision clinicians associate central field impairments with conditions such as retinitis pigmentosa, cataracts and macular degeneration. When the central field is impaired by central nervous system injury, it is thought to be associated with pre-chiasmic optic nerve damage. The syndrome of hemi-spatial impairment is thought to be limited to macular splitting homonymous hemianopia. The possibility of isolated central hemi-field impairment has not been recognized in the literature.

In working with brain injury sur-

vivors, however, my associates and I<sup>18</sup> noted a syndrome of lateralized misreading exhibited by some individuals. Typically, persons with right hemisphere injury would misread the beginnings of words, so that GRAIN would become BRAIN. Substitutions were the rule; truncations (GRAIN becoming RAIN) were the exception. Such individuals did not always exhibit symptoms of peripheral field impairment; indeed, the statistical analysis showed central and peripheral factors to be distinct and independent. "RK," whose visual fields are shown in Figure 3, had this kind of isolated central hemi-field impairment. A proofreader by profession, she was recovering from a stroke. Neither she, nor any of her therapists, had noted symptoms of visual hemi-field impairment. My suspicions were, however, raised when I noted consistent misreadings of the beginnings of words on a Speeded Reading of Words Lists procedure.<sup>19</sup> Because of a speech impairment (dysarthria) caused by the stroke, she found this oral reading procedure cumbersome at best. She inspired me to design a proofreading task (Error Detection) which would systematically capture any tendencies to misread the beginnings or ends of words without requiring oral reading.

**ERROR DETECTION**

This proofreading task, which is included in the manual of Vol. 2 of the *Computer Programs for Cognitive Rehabilitation*,<sup>17</sup> consists of 10 passages, several of which fit single-spaced on one page. Each passage contains 12 errors, six of which involve the initial letter of the word and six the last. These are distributed so that half are on the left side of the page and half on the right. An example is contained in Figure 9. The circled items represent the errors found by "RD," the lawyer with the left homonymous hemianopia (Figure 2) who produced the illustrative responses for SDSST in Figure 8. The underlines and marginal annotations represent the examiner's scoring. On the full series he failed to detect 47 out of 60 errors involving the beginnings of words, while he found 49 out of the 60 errors involving final letters. This marked tendency to misread the beginnings of words is suggestive of a depressed left central hemi-field, an interpretation which



**ERROR DETECTION (FORM B)**

Name: "RD"—s/p meningioma resection

CIRCLE EVERY ERROR.  
TAKE YOUR TIME, BUT DO NOT GO BACK OVER YOUR WORK.

**YOUR HEART**

Your heart is made of muscle and is only about the size of a fist. It works like a pump to send blood to all parts of your body. But what makes it beat?

The sound of the heartbeat is caused by the closing of the valves in your heart. These valves open and close to keep all the blood flowing in the right direction. When they close, they go "thump." But what makes the valves open and close?

There is a small strip of tissue in the heart called the pacemaker. This sends out an electrical impulse and automatically keeps your heart beating. If this pacemaker wears out, doctors can replace it with one that is artificial.

**THE SNAIL**

You know that the snail can hide in its shell. But did you know that a snail eats with its foot? That's right! On the bottom of its one slimy foot is a mouth with little teeth. As it slides over leaves and grasses, the snail chews on them.

Here is something else you may not know. A snail has a homing instinct, just like a pigeon. Even if it goes far from home, it will find its way back. How does the snail do it? No one knows.

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The exposure duration is included on the display. As the individual progresses, these times become shorter until the limit of progress is reached. On the computer printout, this limit is reported as the "consistently best time." For "KB," a gentleman recovering from a ruptured arteriovenous malformation, whose performance is shown in Figure 10, it was .11 sec.

Most revealing, however, is the pattern of the errors which are produced by forcing the individual to attempt to read fast displays. "KB" was taught to analyze his own errors into the following categories: "L" if the leftmost letter or letters are wrong (and the rightmost letter is correct),

"M" if middle letters are wrong (and the first and last letters are correct), "R" if the rightmost letter or letters are wrong (and the leftmost letter is correct), and "O" for other errors and omissions. The distribution of errors (mostly "L" and "M" and no "R's") indicates a left central hemi-field impairment. The errors are substitutions,

not truncations, suggesting that the impairment is relative, not absolute. Its effects on "KB's" typing are captured in the run-on words in his comments. He was totally unaware of this problem and, indeed, much therapy was directed to building his awareness through practice and analysis of his own errors. Awareness, at an intellectual level, would enable him to appreciate the need for careful self-monitoring in situations where accuracy is important. Practice would allow him to determine whether and how to compensate for this problem. "KB's" peripheral fields, tested perimetrically on two occasions by an optometrist, and using REACT, were intact.

Normally, on FASTREAD, adults will achieve consistently best times of less than .05 sec. and will only make occasional errors before reaching their limit. Errors in neurologically intact persons are more likely to involve the middle letters, with the first and last letters correct.

While left central hemi-field impairments produce the most dramatic errors, errors involving the endings of words are suggestive of right central hemi-field deficits. These are not uncommon in persons with left-hemisphere brain injury. Since this type of brain injury often affects language (aphasia) also, it may complicate the use of linguistic tasks for assessment of visual perception.

Figure 9. Error Detection passage with responses of "RD," the lawyer whose fields (Figure 2) and SDSST results (Figure 8) showed a left homonymous hemianopia with a relative loss in the left central field. Failures to detect typically involve the first letters of words, a pattern suggestive of a left central hemi-field impairment.

was confirmed by projection perimetry with the Tubinger perimeter: his visual fields (Figure 2) showed a left homonymous hemianopia with a graduated loss extending in to the central field.

A limitation of the Error Detection task is the fact that the individual must deal with multiple lines of continuous text. Persons who have binocular dysfunction or other reading problems can be overwhelmed. Enlarged stimuli, use of a straight edge or finger pointing to guide scanning are techniques which can be helpful.

**TACHISTOSCOPIC READING (FASTREAD)**

An alternative is a computerized Tachistoscopic Reading Task, FASTREAD.<sup>20</sup> Words are displayed very briefly in the center of the display in discrete trials initiated by the examinee, who then (if capable) types in what has been seen. Correct responses lead to faster presentations on subsequent trials. Eventually the individual fails; whereupon the display is slowed slightly. The trials continue and exposure typically varies around the limit of the individual's capability. A printout (Figure 10) shows the stimulus and, if different, the individual's response.

**TACHISTOSCOPIC READING (FASTREAD)**

Name: "KB"—after ruptured anterior cerebral artery aneurysm

Conditions: File = "LEFT/WL", 1 work/trial, Initial display time - .5 sec.

++ = correct, (L) = left side error, (M) = middle error, (R) = right side error, (o) = other

#	Time	Stimulus -> Response	#	Time	Stimulus -> Response
1	.50	EIGHT -> FLIGHT (L)	30	.15	LASTED ++
2	.56	REPOSITORY ++	31	.13	GROWN ++
3	.50	BABBLE ++	32	.11	HEARD ++
4	.44	THRILLING ++	33	.09	SENDING ++
5	.39	DANGER ++	34	.08	FRIGHT -> READY (O)
6	.35	FLARE ++	35	.09	FRANK -> FLANK (M)
7	.31	PITCH ++	36	.10	PLUMBER ++
8	.27	DEPOSITORY -> REPOSITORY (L)	37	.08	EXPRESS -> EXPRESS (M)
9	.30	BREAD ++	38	.09	GRAM -> BRIM (L)
10	.26	WASHING ++	39	.10	MASHING -> WARNING (L)
11	.23	RACKET ++	40	.12	MASHING -> WARNING (L)
12	.20	WALLET -> VALLET (L)	41	.14	RATCHET -> RACKET (M)
13	.23	PRETEST -> RETEST (L)	42	.16	RANKING ++
14	.26	DRANK ++	43	.14	WALLET ++
15	.23	OUTER -> FORGOT (O)	44	.12	FIGHT -> FLIGHT (M)
16	.26	LEATHER ++	45	.14	MALLET -> WALLET (L)
17	.23	TREAD -> THREAD (M)	46	.16	OUTER -> OTHER (M)
18	.26	HATCH ++	47	.18	BEARD ++
19	.23	GLAND ++	48	.16	GAUNT -> GAUNT (M)
20	.20	EIGHT ++	49	.18	CRUMBLE -> GRUMBLE (L)
21	.17	FLANK ++	50	.20	RACKET -> PACKET (L)
22	.15	EIGHT ++			
23	.13	BRAIN ++			
24	.11	DECEIVE -> FORGOT (O)			
25	.13	BREAD ++			
26	.11	GRILLING -> CELLING			
27	.13	BEARD -> BREAD			
28	.15	RANKING -> BANKING (L)			
29	.17	GLARE ++			

Comments: Before --"SOFARNOPROBLEM"  
After - "GUESS DID NOTPAY OFF"

Totals: L M R O  
11 6 0 3

Impression: Reduced left central field

Figure 10. FASTREAD results for "KB," a post-stroke patient with symptoms of left central hemi-field impairment. Peripheral fields were intact. I was not able to test the central fields perimetrically.

## SHAPE MATCHING (MATCH)

For individuals who have difficulty dealing with linguistic stimuli, whether due to a profound aphasia (language impairment), or history of dyslexia, I designed a non-verbal shape matching task, MATCH.<sup>17</sup> Two similar nonsense shapes are displayed one over the other in the center of the screen. Upon making a same or different judgment, the examinee presses a key which causes the shapes to be erased, following which the decision is recorded. If the decision is wrong, the stimuli are presented again. The two shapes differ by only a small detail which is located either on the left, right or on both sides of the stimulus. Lateral differences in judgment times or error rates are indicative of central hemi-field impairment.

## DISCUSSION

Visual field impairments caused by brain injury can manifest themselves in both absolute and relative form, involving central as well as peripheral fields. What little evidence exists on visual fields following acquired (non-progressive) brain injury, such as missile wounds to the brain<sup>1</sup> suggests that there is little spontaneous recovery after the acute phase. Although interventions which will enable the individual to recover these fields<sup>5</sup> or to give access to them optically have been proposed,<sup>21,22</sup> supportive data are limited.

Recovery, indeed, is confounded by the fact that significant losses may have occurred without corresponding changes in the individual's experience. Rarely, if ever, are hemianopias described as black curtains covering half of space. It is unusual to observe a brain injury survivor attempting to peer around a blind spot, as occurs with other kinds of visual field impairment. This lack of awareness is as significant for the individual's ability to function as is the loss of vision itself. Treatment, therefore, must begin with aggressive diagnosis because we cannot expect the individuals to "complain" of losses they do not consciously experience. Once we can clarify the nature of the problem, further treatment is instituted to help the individual understand the problem, if not to "see" it. This objective is best accomplished by offering experiences in which the nature of the loss is revealed by outcomes, clarified and explained by a

supportive therapist. Each of the techniques described above can be useful in this process.

One of the main differences between these procedures and conventional approaches to visual field measurement is their dynamic nature. Stimuli are either presented for short intervals or the time to notice or perceive is measured. This attribute increases the sensitivity, and most probably the validity of the procedures, as everyday perception is a dynamic "real time" process. This approach changes the response demands on the patient, who may have a great deal of difficulty with fixation requirements in conventional perimetry.

An important feature of the present methods is their redundancy. If a right visual deficit is found using REACT, it should be confirmable using SDSST. If a relative left central hemi-field deficit is suggested by Error Detection findings, it should also affect performance on FASTREAD and MATCH. Given the variability in performance associated with certain neurological diagnoses, and the limitations on procedural and environmental controls, such redundancy allows independent confirmation of findings.

Finally, I believe these are new and practical methods which address central hemi-field impairments in brain injury survivors. These methods do not measure the central fields directly; however, they do permit differentiation of left and right side deficits.

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