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# METHODS & DESIGNS

# A simple technique for lateralizing visual input that allows prolonged viewing

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**A simplified technique is described for obtaining lateralization of visual input with prolonged viewing. This technique is based on the presence of constant normal lateral limits for horizontal rotation of the eyes with reference to the head. With head movement prevented by use of a standard bite bar, and the eyes rotated to the left and held at their lateral limit, the temporal half of the visual field of the left eye may be used for lateralized input to the right hemisphere or vice versa for input to the left hemisphere. Any form of visual stimuli or visually monitored task can be used if confined within one of the extreme temporal hemifields. In comparison to previous methods, this technique is technically simple, inexpensive, without significant risk or discomfort to the subject, readily applicable to normal and various brain-lesioned subjects, and permits prolonged in-depth viewing. An alternative version of this technique uses a stabilized spectacle frame fitted with adjustable central occluders set to allow vision through only one or both of the extreme temporal hemifields.**

Techniques to selectively lateralize visual input to the separate cerebral hemispheres in human subjects must circumvent the natural tendency of eye movements to transfer the intended half-field stimuli across the vertical meridian into the unintended half-field and hemisphere. This has been achieved most commonly in the past by tachistoscopic methods that limit exposure of visual stimuli in the left or right hemifield to 150 msec or less. This restricts tachistoscopic testing to the use of relatively simple visual stimuli and thus excludes the use of many forms of tests for intelligence, memory, perception, emotion, and other cognitive functions that require more prolonged examination. The need for a better technique that allows prolonged viewing of more complex visual displays (e.g., sentences instead of single words, complex scenes and objects instead of simple line drawings, etc.) and lateralized viewing of manual performance has long been recognized, particularly for studies with commissurotomy subjects.

Early studies obtained prolonged lateralized exposure of visual stimuli by monitoring eye position with electro-oculograph (EOG) recording while stimuli were presented in the left or right hemifield (Butler & Norrsell, 1968; Trevarthen & Sperry, 1973). The stimulus could be removed or trial excluded whenever adverse eye movements were detected. Inherent inaccuracy due to artifact and drift in the EOG potential has restricted this technique primarily to studies involving peripheral vision.

Special contact lenses which limit vision to a single hemifield or a portion thereof have also been employed to prolong visual lateralization (Dimond, Bureš, Farrington, & Brouwers, 1975; Zaidel, 1975). The sophisticated lens system developed by Zaidel is a variation of the stabilized image technique in which a half-field occluder, mounted on a collimator on a specially constructed scleral contact lens, is set in the focal plane of a small viewing lens and moves in unity with the eye. This has proved to be an important advance over previous techniques for many kinds of tests but is subject to a number of constraints that severely limit its application.

Another approach to prolonging lateralized visual input involves the use of a double-Purkinje image eye tracker in conjunction with a mechanical occluder or split-screen video display (Zaidel & Frazer, 1977). Presently in the process of development, this technique, if successful, should relieve some of the limitations of the contact lens approach in that there are no attachments to the eye and only a bite bar is fitted to each subject. However, the eye tracker appliance also is expensive and requires exacting technical adjustments that will presumably limit its use to relatively few laboratories.

In this paper we describe a comparatively simple, new technique for obtaining lateralized visual input with prolonged exposure of visual material. Successful in pilot tests and recent studies with commissurotomy patients, the new method offers a number of significant advantages over prior methods and opens new testing

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possibilities not available with previous techniques. In contrast to previous techniques, the new procedure is inexpensive, involves no significant risk or discomfort for the patient, imposes no stringent limits on the duration or frequency of testing, is widely applicable to normal or brain-damaged subjects, requires no advanced engineering or technological expertise either for its construction or its operation, and permits prolonged in-depth viewing under relatively natural conditions.

## METHOD

The present technique is based upon the normal presence of constant lateral limits for horizontal rotation of the eyes with reference to the head. If head movement is prevented, and the eyes are rotated to the left and held at their lateral limit, the temporal half of the visual field of the left eye can be used for lateralizing input to the right hemisphere or vice versa for the left hemisphere. At these lateral limits of rotation when the head is stabilized, there is no means by which further eye movement can transfer stimuli in the extreme temporal testing fields across the midline into the unintended half-field. The concept was presented earlier in a brief abstract report (Sperry & Myers, 1981).

The technique can be readily adapted to normal and brain-damaged populations and can be coupled with reaction time responses to obtain laterality measures in the presence of the commissures. Any form of visual stimulus or test may be used, provided it is confined to one of the extreme temporal testing fields. Input lateralized to the separate hemispheres in this manner utilizes directly comparable pathways involving the nasal hemiretina and crossed optic pathway to each hemisphere. Since different eyes are used to lateralize input to the different hemispheres, differences between the eyes, such as differences in acuity, may need to be taken into account in making left-right comparisons. For subjects requiring visual correction, a set of corrective lenses may be laterally positioned to cover the testing fields.

No limit is imposed on the duration of lateralized viewing other than the natural development of ocular fatigue from holding the eyes in the extreme sideward position. If fatigue occurs, it is readily relieved by simply relaxing the eyes and directing the gaze forward or to the opposite side. In most cases the eyes need not be held at the lateral limits for an extended period. A series of short views may be allowed and their initiation left to the discretion of the subject. In our experience to date, a single viewing duration of up to approximately 10-15 sec appears to be well tolerated.

### Head Fixation

A comfortable means for firmly holding the head of the subject in a fixed position is required during testing. A bite bar is quite adequate for this purpose. If interference with the clarity of oral response becomes a problem, the subject may be allowed to release the bar for response after removal of the stimuli. Other means of head fixation may be preferable in studies emphasizing oral performance concurrent with lateralized viewing. When freedom of head movement is important, it may be possible to substitute occluders affixed in spectacle fashion to a stabilized head frame and set to block vision in all but the extreme temporal testing fields.

The bite bar is made from 1/16-in. stainless steel cut into a 1/2-in.-wide U-shaped plate to fit the pattern of the bite. Perforations in the steel plate help to hold in place dental impression compound, which is heated and applied around both arms of the bar and then quickly resoftened in hot water for making the dental impression. Removable bridgework should be taken out prior to fitting and before subsequent testing sessions. Numerous bars can be prepared in advance, ready to be reheated and fitted as needed. The bite bar plate is rigidly bolted to a solid supporting upright bar and firmly fixed to a table at a height comfortable for the subject when seated in testing position. The bite bar is mounted with a slight forward tilt of 4-5 deg to match the natural tilt of the jaw when the head is held level.

### Determination of Testing Fields

The inner boundaries (i.e., the vertical midlines of the visual field at the limits of rotation) of the left and right testing hemifields (see Figure 1) are determined in advance for each subject for use in all subsequent testing. The lateral limits of fixation for most subjects are reported to be in the range of 45-50 deg from the forward midline (Duke-Elder & Wybar, 1973). Because of individual variation, we determine these limits for each subject by reference to the blind spot of each eye as described below. In the event of a superimposed visual field scotoma, as occurred with one of our subjects, these same measurements can be taken using the abnormal, rather than the normal, blind spot as the reference. In tests in which acuity is not critical and peripheral viewing is acceptable, the two testing fields can be safely demarcated with their inner boundaries at least 50 deg lateral from the forward midline, eliminating the need for more precise measurements. For expedience in making measurements and locating the testing field boundaries, a large perimetric semicircle is marked on the table top, centered below the middle of the bite bar, with a radius corresponding to the desired viewing distance and with angular displacements from the forward midline marked in the region of the testing fields.

The positions of the vertical midlines of the visual fields at the limits of lateral rotation are determined with the subject seated comfortably at the table and the bite bar in place. One eye is occluded while the subject fixates a small hairline cross presented at eye level, centered directly ahead on a white tangent screen at the desired viewing distance. The angular displacement from the vertical midline to the nasal edge of the blind spot, usually about 13 deg, is determined by moving a small black target of 1-deg diameter slowly back and forth across the screen along the horizontal meridian, noting on the screen where the subject either verbally or manually indicates its disappearance from view.

The subject is then directed to rotate the exposed eye laterally to its extreme limit while keeping the gaze level, and the screen is relocated to the approximate center of gaze. The location of the nasal edge of the blind spot with the eyes laterally rotated to their extreme limit is determined as before, by having the subject indicate the disappearance and reappearance of the target as it moves across the screen along the horizontal meridian. This is repeated until the subject is unable to cause the target

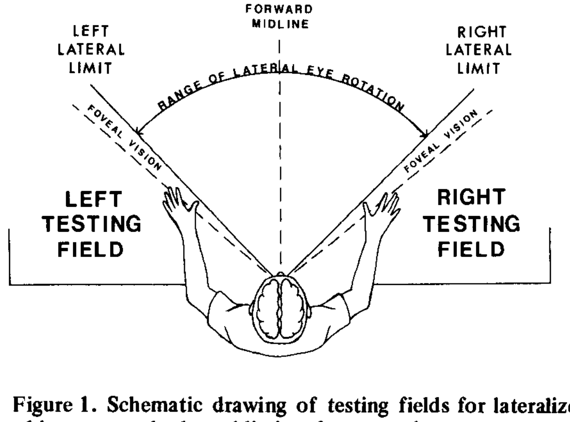


**Figure 1. Schematic drawing of testing fields for lateralized visual input as set by lateral limits of eye rotation.**

to reappear by further lateral eye rotation. Oblique eye rotations cause the position of the blind spot to shift on the tangent screen and therefore can be ruled out by this procedure. By positioning the tangent screen so that the blind spot is aligned with the previous markings, the vertical midline or nasal boundary of the testing field can be determined and will correspond to the location of the fixation cross. The procedure is then repeated in mirror directions for the opposite eye and testing field. With commissurotomy subjects, the inability to name novel stimuli in the left visual hemifield can be used in determining or verifying the boundary of the left testing field.

Each of the testing fields is congruent with the temporal visual half-field of the corresponding eye at its lateral limit of rotation. For many subjects, the nasal view of the opposite eye is not completely obstructed by the bridge of the nose, so that a small area of the testing field near the midline is open to binocular viewing. Generally no eyepatch is necessary on this opposite eye because the conjugate nature of eye movements ensures that stimuli within a testing field will project to the same hemisphere through either eye.

The method permits rapid alternate testing or comparison of stimuli within the left and right fields, although testing with lateralized input to both hemispheres simultaneously is excluded. The presence of the blindspot within the testing field is not a major concern because it falls well beyond the foveal region and can be compensated by vertical eye movement as well as by normal tendencies to effect perceptual completion.

### Stimulus Displays with Combined Manual Tasks and Responses

In tests to date we have used mainly two-dimensional stimuli in the form of cards and test booklets incorporating pictures, words, numbers, and so forth, and common three-dimensional objects. Slides and films with moving or animated stimuli can easily be presented through back projection or video monitor displays. Lateralized viewing of live action (e.g., facial expressions, hand movements, etc.) is also possible. It is useful to have a way to keep the stimuli hidden from the subject and to quickly reveal and obscure the stimulus displays, especially in tests involving sequential presentations. Plywood panels can be used for this purpose, with the testing fields occluded by individual screens that can be dropped or raised as desired.

Lateralized visual monitoring of manual responses to choice arrays and tasks that involve manual stereognosis, object manipulation, drawing, writing, tracking, and so forth, can all be accommodated within the testing paradigm. In tests with commissurotomy patients, when the left hand is working in the left testing field and the right hand in the right field, visual feedback from responses is available exclusively to the responding hemisphere. For example, visually guided selections from a choice array can be obtained without cuing the nonresponding hemisphere. Among other things, this allows direct controls for successful lateralization of input or for interhemispheric leakage of information by obtaining responses from each hemisphere in sequence. The central area between the lateral testing fields may be utilized to incorporate standard tachistoscopic presentations and test procedures involving both hands and/or free vision.

### Alternative Version

An alternative version of the present technique utilizes fixed occluders that move in unity with the head and that exclude all vision except in the extreme temporal hemifields. The central occluders are attached to a firm spectacle frame or headband and are individually set to the lateral limits of eye rotation and adjusted for tilt. While somewhat more involved technically, this approach eliminates the need for head fixation. In addition to increasing the general freedom of movement, this permits unimpeded oral performance and allows the subject to scan stimulus displays through head movement. Tilting of the vertical meridian due to compensatory eye rotations when the head is inclined must be provided for to avoid leakage to the unintended hemifield. Preliminary tests with this version of the technique have been promising.

## BEHAVIORAL ASSESSMENT

### Basic Deconnection Phenomena

In view of phenomena associated with unilateral neglect and uncertainties regarding the influence of body schema kinetics on the representation of psychological space, it cannot be assumed a priori that hemispheric representation for visual space with the eyes rotated laterally to their extreme limit will be identical to that obtained with the eyes directed straight forward. However, tests to date with commissurotomy subjects N. G. and L. B., patients of Drs. P. J. Vogel and J. E. Bogen, indicate a good conformance between the results obtained with the present technique and those obtained with other methods. The same basic functional disconnection symptoms are found in the relation of the left and right visual half-fields to language production and to manual stereognosis. For example, novel objects or pictures of objects are readily named when presented in the right, but not in the left, testing field. Stimuli in the left hemifield that the subject claims verbally not to be able to identify can subsequently be retrieved with left-hand tactual perception from a multiple-choice array hidden from view or presented in the left testing field. Such stimuli, following retrieval with the left hand, still cannot be named or retrieved by the right hand. Conversely, objects or pictures of objects presented in the right testing field cannot be correctly retrieved by the left hand from a hidden array but can subsequently be named. Similar results apply to novel objects identified by unimanual stereognosis. Attempts to point to pictures of such objects in a multiple-choice array succeed only when the array is presented in the corresponding, and not in the opposite, testing field.

The general inability to name or cross-identify stimuli presented in the left visual field or left hand is subject to substantial exceptions in these two subjects, L. B. and N. G., who have been most extensively tested since the surgery 16 and 18 years previously. However, similar exceptions apply to the other testing methods when used in recent sessions with these same subjects. Such exceptions appear to be the result of gradual functional compensation and reeducation processes through the many years of postoperative testing. Subject L. B. in particular often succeeds in vocally identifying familiar objects presented in his left visual field or left hand. Also, both subjects can frequently select the match to a stimulus presented visually in one testing field from a visual array presented in the opposite field, although L. B. (but not N. G.) fails when nondescript forms are used.

### Right Hemisphere Language

Test findings concerning the language abilities of the right hemisphere have in the past most distinguished the different techniques for lateralizing visual input. Results with the present technique replicate the early data obtained tachistoscopically (Gazzaniga & Sperry, 1967; Sperry & Gazzaniga, 1967; Sperry, Gazzaniga, & Bogen, 1969) in showing, for example, that the right hemisphere understands, at a moderately high level, words spoken aloud by the examiner and comprehends the meaning of printed object names exposed in the left visual field, as demonstrated by selective manual retrieval or by selection of the corresponding object or picture in a multiple-choice array. Comprehension of object names presented in the left visual hemifield is also apparent in the ability of these subjects to answer yes/no questions regarding characteristics of the object, such as its use, appearance, composition, likely context, and so forth, or to select the correct answer when alternatives are listed orally.

The present technique also replicates results obtained with the contact lens method (Zaidel, 1975, 1976, 1978) to the extent that these results have been tested. For example, the subjects can often correctly select from a multiple-choice array of pictures presented in the left testing field the item that matches a printed or spoken name or that fits an oral description, vocal cues, and so forth. The right hemisphere fails, however, to derive the sound of a word or picture name presented in the left testing field, nor can it analyze the word or name into component letters, as shown by the inability to make matches based on the sounds of words (rhyming, homonyms) or to select for component letters (e.g., which picture name starts with the letter "b"?). The right hemisphere is also seen with the present technique to be unable to decipher long, nonredundant sequences of spoken words, as when items of the Token test are performed in the left testing field.

Although tests with the scleral contact lens have brought results that in general confirm or extend, rather than revise, the earlier findings obtained by tachistoscopic methods, the two methods have yielded contradictory results in regard to the right hemisphere capacity for processing verbs as opposed to nouns. Zaidel (1976) reported equivalent oral comprehension by the right hemisphere for nouns vs. verbs and action names matched for frequency, whereas the early tachistoscopic findings indicated a selective deficiency in verb processing by the right hemisphere. When we readministered the same set of verbs used in the test by Zaidel to L. B. and N. G. with the "lateral limits" technique, but used the infinitive form of the verbs rather than participles, the results showed a marked decline in the performance of the right hemisphere. These preliminary results thus favor the conclusion that the right hemisphere is relatively deficient in the processing of verbs as opposed to nouns.

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