LINGUISTIC COMPETENCE AND RELATED FUNCTIONS IN THE RIGHT CEREBRAL HEMISPHERE OF MAN FOLLOWING COMMISSUROTOMY AND HEMISPHERECTOMY

Thesis by

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To

N.G. and L.B.

and to

R.S., D.W. and G.E.

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ABSTRACT

A simple new contact lens technique has been developed to permit the presentation of continuously lateralized visual information to one visual half field at a time. Free unilateral scanning of the information and monitoring of performance in the subjects' lap makes it possible to administer a variety of standard perceptual and cognitive tasks to either hemisphere in order to assess hemispheric specialization under natural conditions. Two representative commissurotomy patients have been fitted with the new device and have undergone an extensive series of language and related studies focusing on the right hemisphere. All tests were administered unilaterally to each hemisphere and subsequently in free vision. The results were correlated with data from a group of three hemispherectomy patients in two of whom the right (non dominant) and in one of whom the left (dominant) cerebral hemisphere has been surgically removed for the treatment of post infantile tumor.

The case of dominant hemispherectomy is particularly rare and permits the study of language competence and performance in a girl whose language lateralization for speech and hearing was well under way (perhaps completed) when the tumor set in. Results of extensive clinical aphasia tests reveal a distinct hierarchy of language functions from a relatively good auditory comprehension through a more severe speech deficit, to almost complete alexia, agraphia and acalculia. Theoretical aphasiological analysis of the pattern of impairment in language functions here shows that in spite of characteristic nonfluency and

anomia in speech, the syndrome is unique and does not correspond to either a Broca's or anomic aphasia. The agraphia and especially the alexia in this patient are more severe than in the separated right hemisphere of the two commissurotomy patients which can read a wide range of individual words and even short sentences. This is in contrast to her superior expressive speech relative to the right hemisphere of the same two commissurotomy patients.

In a series of studies comparing the psycholinguistic abilities of the two hemispheres in the two commissurotomy and three hemispherectomy patients it was shown that the right cerebral hemisphere had extensive ability to elicit meaning from pictures and to recognize semantic associations and form concepts. In particular it was able to ignore perceptual for semantic similarity.

Lateralized tests of visual closure reveal the conditions under which right hemisphere visual feature extraction mechanisms fail. Previous results on superior right hemisphere competence in completing patterns from fragmented information must now be qualified by the provision that when the gestalt of the visual ground is strong and in competition with the figure, the right hemisphere is unable to complete partial patterns. Neither can it recognize complete embedded figures in the face of distracting gestalt in the ground.

Right hemisphere competence in various aspects of auditory language comprehension has been investigated with the aid of an experimental paradigm involving matching an auditory message to one of unilaterally presented alternative line drawings. Lower limit age estimates for right hemisphere comprehension of vocabulary were obtained and it was shown that the right hemisphere can comprehend not only abstract words but also a variety of syntactic structures including verbs, and sentential transformations and to a lesser degree long nonredundant and semantically abstract references. Right hemisphere pattern of syntactic competence has weak correlation with order of acquisition in children and somewhat stronger with aphasics. In contrast, aural vocabulary in the right hemisphere, although consistently inferior to the left, follows the same function of frequency as the left just as do children and aphasics.

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INTRODUCTION

The work reported here is an attempt to initiate a systematic investigation of language competence in relation to perceptuo-cognitive functions in the right hemispheres of commissurotomized and hemispherectomized man. The basic strategy is to compare the performance of left and right disconnected hemispheres of the same commissurotomy patient or the left and right single hemispheres in matched cases of hemispherectomy, on a variety of psycholinguistic tasks in natural testing situations. But the first question to be answered is how much of what can the right hemisphere do rather than how much better or worse is the right hemisphere from the left on a given task. These questions are preludes to an information processing analysis of right vs. left hemisphere differences in perception, cognition and memory.

Organization. The first part introduces the technique used to compare the linguistic competence of the two hemispheres in two commissurotomy patients: N.G. and L.B. Part II analyzes in detail the performance of a rare case of dominant hemispherectomy, R.S., on a variety of language tests for aphasia. The results are correlated with those obtained for aphasic populations. They are also often compared to those scored by the disconnected right hemisphere of the two commissurotomy patients and with those of two cases of nondominant hemispherectomy (D.W. and G.E.). The third part introduces the case histories of the rest of the patients and analyzes the performance of all patients in free vision and of the two commissurotomy patients in unilateral presentation on the Illinois Test of Psycholinguistic Abilities. Finally, Part IV introduces evidence for extensive aural vocabulary comprehension in R.S. as well as in the right hemispheres of N.G. and L.B. and proceeds to investigate in some detail right hemisphere capacities to deal with syntactic and referential aspects of aural linguistic messages.

Notation. In the following, R/H and L/H will stand for right hemisphere and left hemisphere, respectively, and R/h and L/h will denote the right hand and the left hand. RVF reads "right visual half field", LVF is "left visual half field", and FV stands for "free vision". Ages will be denoted by the number of years preceding, and separated by a colon from, the number of months, thus: 6:6 (six years and six months old). CLVP stands for "continuous lateralized visual presentation" and refers to the technique introduced in Part I.

Some paragraphs contain detailed technical material that is dispensable for the main line of argument in the text. These are typed in single space as are figure legends.

I. DESCRIPTION AND EVALUATION OF A TECHNIQUE FOR PRESENTING CONTINUOUS LATERALIZED VISUAL INFORMATION TO HUMAN SUBJECTS

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INTRODUCTION

ON THE HUMAN VISUAL SYSTEM

As is well known the optic nerves in man decussate at the chiasma perfectly or near perfectly so that the optic tracts which reach the subcortical visual centers represent fibers from the homolateral visual fields of each eye. Thus if one imagines a line drawn along the vertical meridian of the eye through the centers of the fovea in man, all or nearly all, fibers nasal to the vertical meridian cross and all fibers temporal to that meridian remain uncrossed (Polyak, 1958, pp. 330-1, reviews experimental evidence for the separation of ipsilateral from contralateral fibers along the vertical retinal meridian). Consequently while each optic nerve represents the retina of its own eye, the portions of the visual system above the chiasma represent ipsilateral homonymous halves of both retinas or contralateral halves of the fields of view. (Fig. 1). Thus the images of the left and right visual fields project to the right and left hemispheres respectively. Cortical integration of brief visual scenes must therefore occur by intrahemispheric temporal integration effected through eye movements, or alternatively interhemispherically via the corpus callosum and especially the splenium. Thus the standard technique for presenting visual information to only one hemisphere has been to have the subject fixate a central mark while a brief

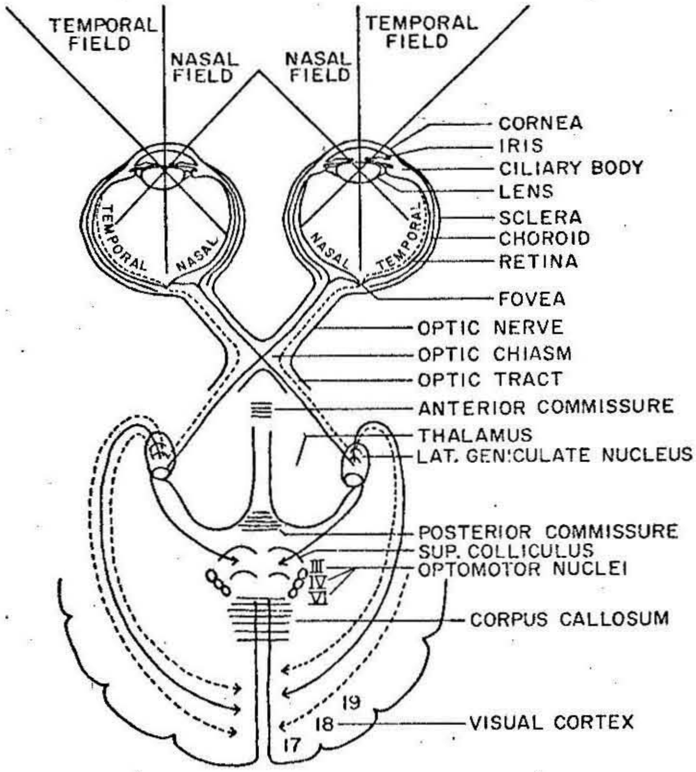


Figure 1
The human visual system (from Young and Lindsley, 1970).

tachistoscopic image was flashed either to the left or to the right of the fixation point. The flash is fast -- shorter than 150 msec -- too quick to permit the initiation of saccadic eye movements.

The decussation of the vertebrate visual system and a preponderantly crossed arrangement of the correlated motor system can be regarded as a mechanism originally created, first, for the inducement of a simple negative response and, subsequently, for the initiation and execution of sustained escape movements (Polyak, 1958, p. 784). With improved visual discrimination, owing to the creation of the chamber eyes, and with the visual system evolving into a positive phototropic analytical instrument, total decussation was even more important in order to maintain a coherent sequence of the details of the total image projected in the two visual centers. In the mammals the process of a gradual change from a totally or almost totally decussated panoramic or largely panoramic to a partly decussated and stereoscopic binocular arrangement can be traced step by step. In man about 40 percent of the fibers or more remain uncrossed allowing identical corresponding points of both homonymous retinal halves to project to the same point of the visual cortex thus forming the basis for binocular stereopsis. Therefore stereopsis mechanisms exist in each cerebral hemisphere.

Complete cerebral symmetry in lower animals and human brain plasticity in childhood, even for highly specialized function such as speech, indicate that hemispheric specialization is an evolving differentiation perhaps now in its preliminary stages. But if each hemisphere is to maintain relative information processing autonomy it can not accept only a partial view of visual stimuli and depends crucially on eye movements and separate intrahemispheric temporal integration mechanisms for successive visual information recorded during intersaccadic fixations, or alternatively, on the capacity of the corpus callosum to relay visual information in both directions.

PREVIOUS TECHNIQUES

The tachistoscopic technique has been used extensively for research on hemispheric specialization in human patients who had undergone section of the forebrain commissures including the corpus callosum and the anterior commissures for control of intractable epilepsy (Sperry, Bogen and Gazzaniga, 1969) as well as on laterality differences in normal children and adults (Knox and Kimura, 1970; White, 1969). In this way both simple pictures as well as single letters, digits and even short words were presented separately to each hemisphere. But the limited exposure duration precluded from direct investigation the analysis of complex visual scenes, the course of temporal integration of visual information and the processing of naturalistic linguistic input.

Tachistoscopic visual presentations introduce a memory factor into the experimental tasks which may bias laterality data of allegedly "pure" perceptual and linguistic experiments. Now, hemispheric differentiation in memory (Milner and Teuber, 1968) is still under intensive investigation (Zaidel and Sperry, 1973a, in preparation) and is by no means completely understood. Furthermore, performance of some commissurotomy patients on certain tachistoscopically presented tasks shows a characteristic distraction effect -- responding to the side of the visual field stimulated instead of a given left-right stimulus characteristic, for example -- which disappears in continuously lateralized visual presentations. While there is now some evidence (Gilbert and Fender, 1969) that visual discriminations in adults are largely independent of eye movements, (i) it is still not known whether there is any difference in the visual acuities or psychophysical characteristics of either disconnected hemisphere and (ii) there is some evidence for hemisphere differences in the processing of temporal information such as simultaneity and successiveness for certain stimulus duration and interstimulus intervals (Efron, 1963). Thus tachistoscopic presentations not only rule out rich testing domains but may also bias memory and psychophysical factors in the stimulus context towards yet unknown but definite laterality effects. At any rate the question of hemispheric differentiation in psychophysical characteristics of the visual system is still open as well as experimentally approachable and may underlie higher order aspects of functional lateralization in man.

Two modifications of the standard tachistoscopic technique have been used in Dr. Sperry's lab in the last decade. In order to study hemispheric specialization in man Butler and Norsell (1968) used an electro-oculographically driven electronic switching system which turned off a small neon lamp thus disenabling a right eye transparency viewing system whenever the subject's fixation deviated more than 2.5^{o} to either side of the central fixation point. Words, numbers or letters were displayed on the transparency between 6^{o} and 10^{o} to the left or the right of a central fixation point. Trevarthen (1970) used an electro-oculographic eye movement monitoring technique in addition to a head rotation recorder to keep track of horizontal displacement in gaze down to $\pm 2^{o}$. This allowed him to present motion stimuli in the peripheral visual fields and study only the trials in which visual fixation remained within the designated center of the field where there were no relevant visual stimuli.

In England, Dimond (1969) has devised a divided visual field technique which permitted selective stimulation of any visual field for either eye separately or simultaneously during central fixation. But no eye-movement control was provided.

None of the above techniques allows free scanning of the input and all are limited to the study of perceptual thresholds. Instead, there is a need for a method to occlude any desired part of either visual field during eye movements of $\pm 10^{\circ}$ to $\pm 15^{\circ}$. These are typical during voluntary search with greater rotations shared between head and body movements (Fender, 1964). Thus, a simple optical device, accurate to within 1° or better during eye movement of $\pm 15^{\circ}$, has been designed that achieves this effect by reducing the visual stimulus image and bringing it close enough to the eye to achieve lateralization by attaching an occluding screen directly to the eye via a contact lens based platform and thus bypassing the need for electronic eye movement tracking system.

THE TECHNIQUE

GENERAL

The technique is a variation on the contact lens-mounted collimator method for stabilizing retinal images (McKay, 1957; Pritchard, 1961; Evans and Piggins, 1963; Evans, 1965; Yarbus, 1967; Cardu, Gilbert and Strobel, 1971). Here, however, the image is not attached to the contact lens. Instead of stabilizing a retinal image of the stimulus, one stabilizes the image of an opaque screen which occludes one half visual field and which is brought into coincidence with the plane of a reduced stationary image of the desired stimulus. The screen caps a small collimator (C in Fig. 2) which is in turn mounted on the central region of a scleral contact lens (A in Fig. 2) so that it follows the subject's eye movements faithfully.

An optical relay system (Fig. 3) consisting of a 5 X 7" first surface mirror, M (Edmund Scientific Stock no. 41,320), a 10 X 4 cm dove prism, DP (Edmund Scientific Stock no. 60,236), and a 25mm TV lens, FL, mounted on a Zeiss operating microscope stand is adjusted in front of the subjects right (dominant) eye while he is seated upright in a dental chair. The image is of a board fixed to the arms of the chair in the subject's lap. The focal length of the field lens is 25 mm and the reduction ratio of the system at 100 cm stimulus-to-lens distance is 40. The collimator contains a small but powerful plano-convex lens, CL, with a focal length of 10 mm and a magnification ratio

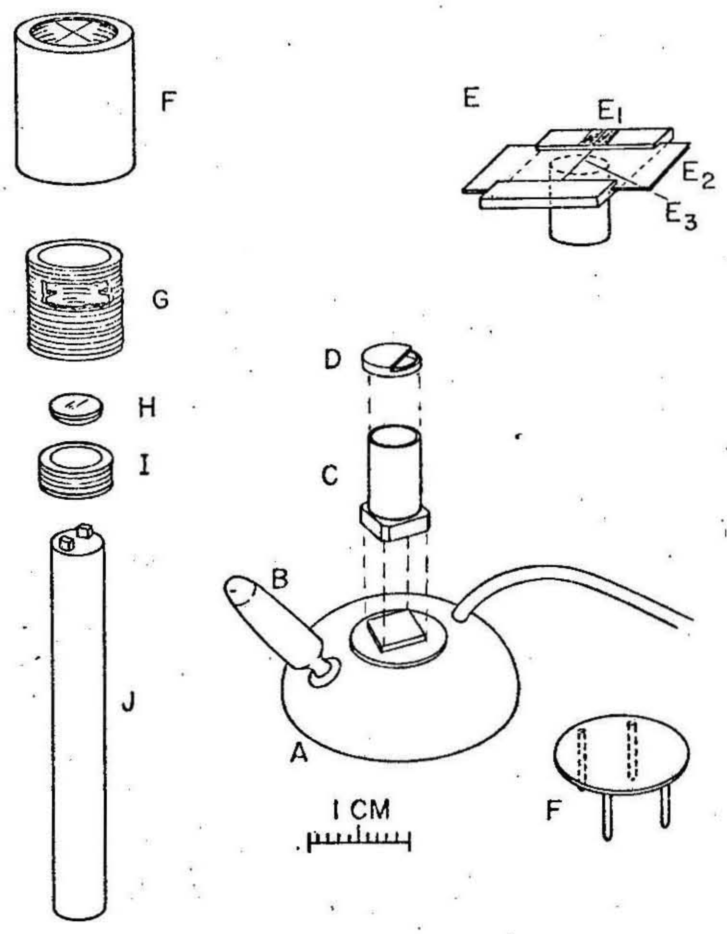


Figure 2

Contact lens, collimator and some accessory components. The contact lens A is shown with the polyethylene tube leading to a bicarbonate of soda manometer and with a suction cap B used to remove the lens from the patient's eye. The collimator C mounts on the optically corrected square shoulder machined on the corneal portion of the contact lens. A cap D occludes a part of the field of view through the collimator. The collimator lens H fits close to the surface of the contact lens. Parts F, G, I, J adjust telescopically to determine the effective focal length of the collimator lens H for a subject when wearing his contact lens. The small plano-convex lens H is inserted into the (inner- and outer-threaded) plastic tube G and fixed in position by the (outer-threaded) tube I with the help of the "screwdriver" J. The tube G is then inserted in the (inner-threaded) tube F, the latter with a cross hairline inscribed on its face. The tube G is screwed in until the cross hairline appears in focus to the unaccommodated eye. The length of the combined tubes now yields the desired focal length from the known dimensions of the components. The clear plastic disc F is mounted temporarily on four pegs on the corneal section of the contact lens before the collimator shoulder is machined in order to establish the line of sight with respect to the contact lens. A clear plastic slide E_2 is marked with a hairline E_3 and moves across a graduated scale E_1. The slide holder E fits on top of the collimator C to verify the line of sight with respect to the collimator.

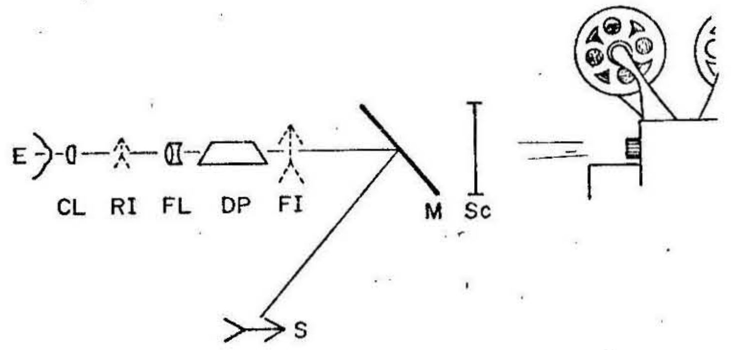


Figure 3

A schematic diagram of the optical relay system. The image of the stimulus S is inverted along the vertical axis by the front surface mirror M and along the horizontal axis by the dove prism DP. The field lens FL reverts back the image and produces a reduced image RI by a factor of 40. The focal length of the objective is 25mm and the stimulus-to-objective distance is 100 cm. The reduced image RI is at the focal point of the collimator lens CL (focal length 10 mm) which presents to the eye E a virtual image FI of the reduced image magnified by a factor of 30. Thus the final image FI is compacted by a factor of 3:4. The stimulus S and mirror M can be replaced by a back projection screen Sc and the dove prism is then rotated 90^o to compensate for changed image inversion.

of about 30. During testing the subject wears an eye patch on his left (non-dominant) eye and wears the lens assembly on his right eye with a cap attached to the end of the collimator covering any prescribed part of either visual field. The experimenter then brings the reduced image to a plane coincident with the outer end of the collimator. The collimator presents an enlarged virtual image, FI, of the reduced stimulus, RI, at normal viewing distance.

In practice the final image is reduced by a factor of 3/4 to allow greater visual viewing field with smaller eye movements. The up-down image inversions in the mirror and field lens cancel each other and the dove prism is adjusted to cancel the lens image inversion in the L-R plane (from the subject's viewpoint). The angle of viewing is as in normal writing and the system permits the subject to view any stimulus on the board or monitor his own performance on a task there. In this way performance on virtually any cognitive task is possible with little or no loss in flexibility as a result of image reduction and displacement. Alternatively the mirror is replaced by a back projection screen which allows one to present slides or films.

VISUAL OPTICAL CALCULATIONS

Fig. 4 illustrates the human eye. Fig. 5 illustrates schematically some average dimensions of the eye and Fig. 6 illustrates the simplified schematic eye of Gallstrand. The computations are all based on these dimensions.

Focusing on the reduced image through the collimator is sensitive to small head movement along the line of sight. Let u, v, f, e denote the distance in cm of the stimulus objects, from the lens, the image from the lens, the focal length of the lens and the distance of the reduced image from the focal point of the lens, respectively. Let v_{min} denote the near point of a given eye.

Then $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ with $u = f - e$ small real e, yields

$$\frac{1}{f-e} + \frac{1}{v} = \frac{1}{f} \quad \text{and} \quad v = f - \frac{f^2}{e} \quad \text{or} \quad e_{min} = \frac{f^2}{f - v_{min}} .$$

For f = 10mm and v_{min} = 15 cm (average near point at age 30) get e_{min} = .625 mm and for v_{min} = 10 cm (age 20) get e_{min} = .9 mm. Comfortable fixation at v = 25 cm yields e = .5 mm. Since image magnification increases with shorter object-to-lens distance, u, v_{min}. yields maximum magnification. Thus head movements of less than 1 mm may cause loss of the picture. In practice subjects have little difficulty in maintaining the image in focus apparently by controlling their head pressure against the pad of the head support on the dental chair. No bite board is therefore necessary.

Suppose half of the visual field is occluded by a cap on the collimator. How much information from the occluded half field will "leak" if the distance between the reduced image plane and the cap is .5 mm? As fig. 7 shows for a limit case this is less than .125 mm. Similarly, can eye accommodation create information transfer from the wrong visual field? Assuming effective power change at the collimator lens = 8.5 diopters, which is average monocular accommodation amplitude at 25 years of age (Emsley, v.1, p. 202, after Duane), or .075 mm

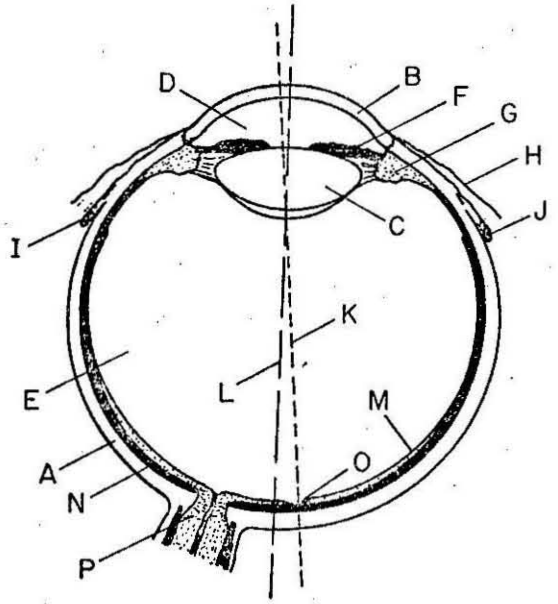


Figure 4

Schematic diagram of a horizontal section of the right human eye. A) sclera; B) cornea; C) lens; D) anterior chamber of the eye; E) vitreous; F) iris; G) ciliary muscle; H) conjunctiva; I) point of attachment of medial rectus muscle; J) point of attachment of lateral rectus muscle; K) visual axis of the eye; L) optical axis of the eye; M) retina; N) vascular membrane; O) fovea centralis; P) optic nerve.

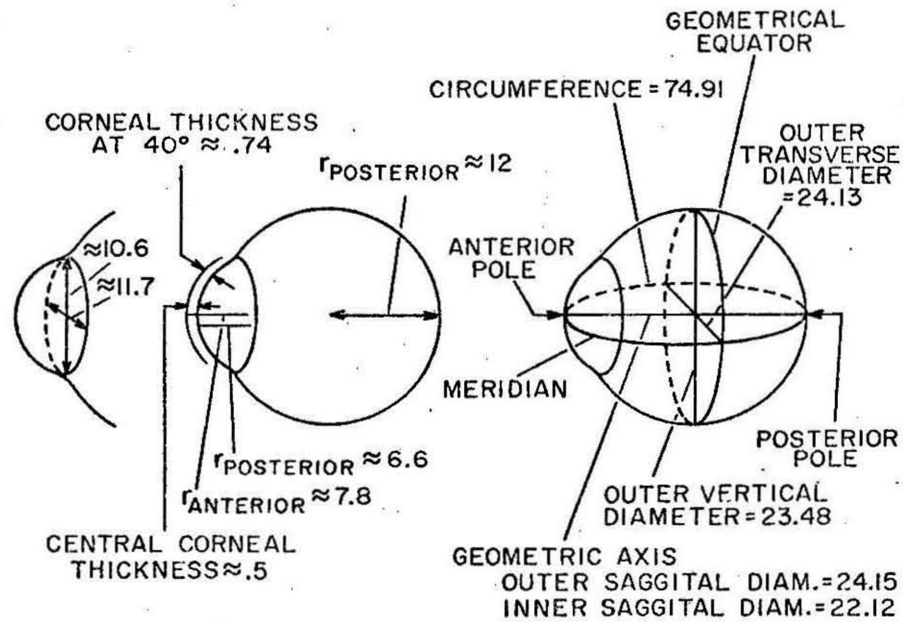


Figure 5

Some average physical dimensions of the eye in mm (after Davson, 1962 and Duke-Elder, 1961).

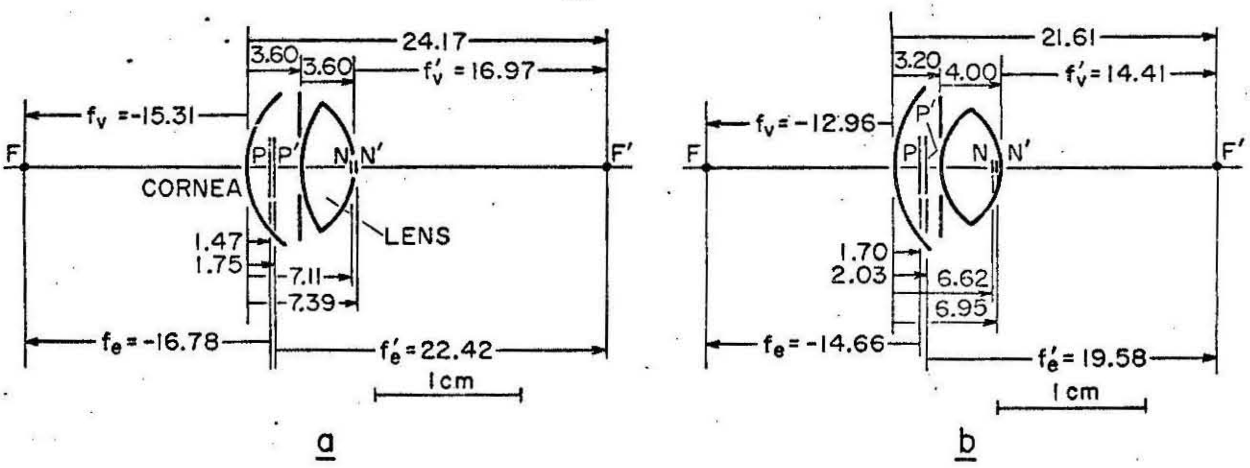


Figure 6

The Gullstrand simplified schematic eye after Bennett and Francis, 1962. a, unaccommodated; b, accommodated 8.62 D. F = anterior equivalent focal length. f'_e = posterior equivalent focal length. f_v = anterior vertex focal length. f'_v = posterior vertex focal length. P and P' = first and second principal points. N and N' = first and second nodal points. (All distances in mm.)

change in effective focal length of the collimator lens, we find that less than .019 mm of the image can possibly transfer at maximum aperture (or 2.5 mm of the final image, i.e. visual angle ~ 0° 34' at 25 cm viewing distance). When the eye scans the edge of the reduced image (Fig. 7) the resulting change in distance between the reduced image and the collimator lens is .19 mm corresponding to a new viewing distance of 23 cm as compared with the original 25 cm. Fig. 7 also illustrates that a lens slippage of 0.05 mm results in .1 mm movement at the image plane or 3 mm of the final image (~0° 40').

CONTACT LENSES

Historical note. The first blown glass scleral lenses were made by A.C. Müller of Wiesbaden in 1887 and in 1911 Zeiss first issued a systematized series of ground contact lenses with various scleral curvatures. But irregularities of the cornea and the discovery by van Csapody (1929-30) of the hydrocolloid dental impression material

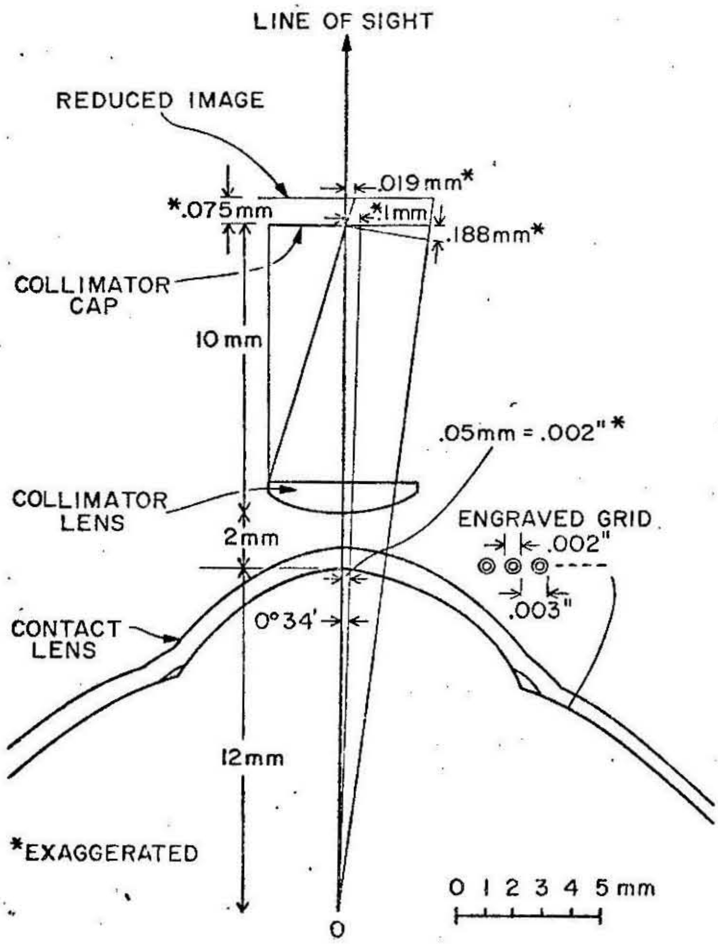


Figure 7

Geometry of the contact lens and collimator assembly illustrating the effects of lens slippage; of possible information leakage to the wrong visual field due to a small separation between the occluding collimator cap and the reduced image; and of increased viewing distance due to focusing the edge of the reduced image. There is a 2 mm clearance between the collimator lens and the contact lens to prevent clouding. O is the center of rotation of the eyeball.

"Dentacoll" enabled J. Dallos (1932-38) to make practicable negative casts of the eye and thus construct molded glass scleral contact lenses for the first time. The first all-plastic lens molded from individual castings was introduced in 1938 in Europe by van Györffy and in the United States by Obrog. Obrog was also the first to use fluorescein to assess contact lens fit.

Types of contact lenses. When the present system was designed a variety of contact lenses mainly for stabilized retinal image research had already been used and their characteristics analyzed in some detail. All have been designed to minimize lens slippage on the eyeball, some at the expense of wearing comfort and most for applications involving small involuntary eye movements of less than 1-2°. Following is a description of the main types.

1. Corneal lenses. Microcorneal lenses for normal wear are designed to fit loosely on the eyeball to permit free interchange between the solution beneath the lens and the normal tear solution. They are therefore unsuitable for studies which require high lens adherence. Nevertheless, Cardu et al (1971) have used a corneal lens as a base for a stabilizing system for retinal images (Fig. 1.10e). Subjects reported disappearance of the viewed images and the degree of lens fit was assessed by ultraviolet light observation of the infiltration of sodium fluorescein from the sclera to the cornea under the lens. However, no direct measure of lens slippage is available.

2. Double-curvature scleral lenses. This type is simple to fit and use. It consists of a small plastic shell formed of two spherical sections. The larger portion fits onto the sclera, seating over a band about 3 mm wide (Fig. 8 top). The smaller corneal bulge is chosen to have radius of curvature of the inside surface which will just clear the cornea itself. About 80 percent of all subjects can be fitted (but not corrected) using a 4 X 3 trial case of lenses providing 4 scleral and 3 corneal curvatures (Fender, 1964). The corneal bulge is usually extended beyond the limbus to avoid pain. If the lens forms a good seal on the sclera, osmotic action and eyelid pressure reduce the hydrostatic pressure in the buffer solution to about minus 20 mm of mercury within 5 to 10 min. This may be speeded up by a small hole in the lens covered with a rubber flap through which excess fluid leaves the lens and which helps maintain the negative pressure. Yarbus' device is an extreme example of this principle.

3. Yarbus' suction cap (Yarbus, 1969) (Fig. 10a). This is a light aluminum spinning frame based on the sclera to which small optical components can be fastened. The cap is fitted with a rubber sucker which generates the negative pressure for adherence. The field of view can be as wide as 50°. Yarbus' is in effect a universal lens. The edge of the cap in contact with the sclera is slightly serrated for increased adhesion. The pain incurred in wearing these lenses necessitates the use of a local anesthetic such as amethocaine. Anesthetic may affect the eyelids and extra-ocular muscles and modify typical eye movements. Also the eyelids must be taped back.

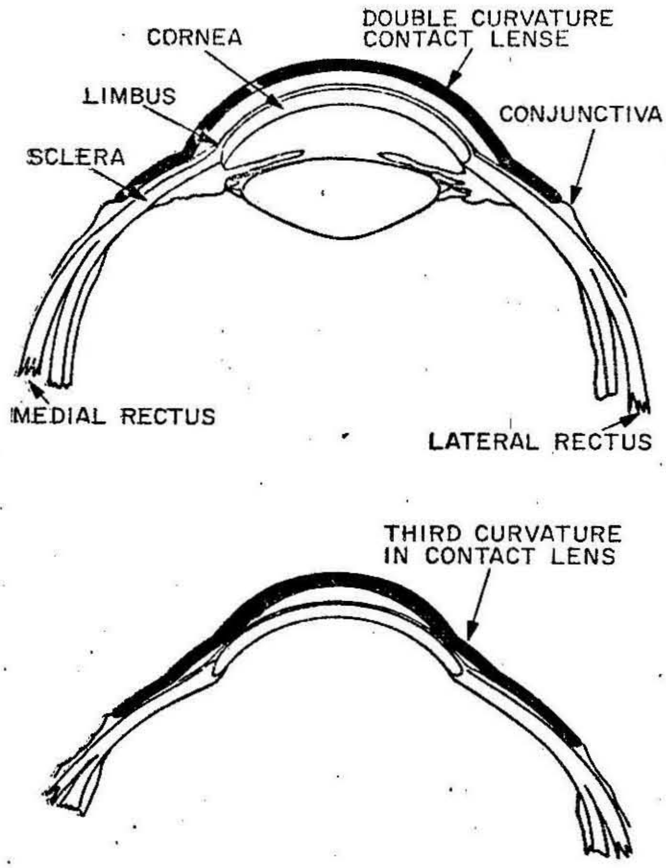


Figure 8

Top: Double curvature contact lens with spherical scleral portion.

Bottom: Triple curvature contact lens with molded scleral fit and ring contact around cornea. (After Fender, 1964).

4. Triple curvature scleral lenses (Fig. 8 bottom) have a third spherical curvature worked in them between the corneal and scleral portions. Thus the lens stands well clear of the limbus but has a ring contact with the corneal surface just above the margin of the limbus. These lenses are also available with three spherical curvatures or with the scleral portion molded to the eyeball.

Gilbert (1968) used this type of lens together with water manometer suction applied to the lens through a thin polyethylene tubing. He has also observed through a microscope the movement of scleral blood vessels relative to marks on the inside surface of the lens. But an apparent error in estimating the grid size probably renders his slippage data useless. With no suction the lens remained immobile for saccades and drifts up to 30 min arc. Slippage was apparently minimized at 23 cm of water pressure with blinks displacing the lens by almost a degree and with the lens returning to its final position within 5 sec. following the blink. Gilbert argues that the contact lens rests not on the sclera proper but on the conjunctiva and extra-ocular muscle insertions which shift the lens over the sclera as they stretch and contract with movement of the visual axis. Gilbert also estimates the maximal torque with respect to the center of the eye caused by his lens assembly during maximal flick acceleration (27,000 deg/sec^2) to be 1360 gm/sec^2.

5. Evans (1965) describes a universally fitting contact lens (Fig. 10d). The lens is of perspex with a diameter of 1.7 cm and with a deep corneal indentation to give clearance to almost any eye. On the corneal haptic portion stands a raised "button" of plexiglass with no optical power. Onto this is fitted an aluminum tube to accomodate the telescopically adjustable focusing system (a micro lens and a gate for photographic miniatures, etc.). No attempt was made to measure adherence. Furthermore, no control over the precise positioning of the lens with respect to the line of sight is possible. Adapting such a lens to the presentation of continuously lateralized visual information will require to replace the target by a large enough opening to permit the line of sight of any subject to fall within it. This may be impossible or may result in prohibitively heavy collimator and will require a separate measurement of the line of sight in each session.

6. Flush fitting lenses. These have been used by Ditchburn's group (Byford, 1962) in a version which makes contact with the limbus and necessitates local anesthetic. Barlow (1963) compares this type to Yarbus' and concludes that the full scleral lens may slip as much as ± 3.5 min arc during fixation while the suction type slips only ± 40 sec arc under this condition. Barlow's measurements rely on a subjective judgment of an afterimage located extrafoveally.

For the experiments on the commissurotomy patients the best solution seemed an individually molded flush-fitting scleral lens with limbal clearance and buffer solution manometer suction.

The subjects right (or dominant) eyes are individually fitted with flush-fitting plexiglass scleral contact lenses (Fig. 2c) (except for a small clearance around the sensitive limbus). The lenses are molded from heated plastic, press-cut, thinned by grinder and then the base curve is optically corrected and polished. The first lenses were fitted by Dr. R. Graham of Pasadena and later thinned down to specifications in order to reduce their weight. More recent lenses were made by Dr. S. Braff (in Calcon Labs) with thickness varying from .7 mm at the periphery to 1.5 mm at the corneal region and with an approximate weight of 700 mg and approximate overall diameter of 24 mm at the periphery.

Suction. To enhance contact lens adherence suction is applied to the contact lens as follows. A small hole is drilled on the edge of the limbal clearance and a thin polyethylene tube (Intramedic PE 50, .023" inside diameter, .038" outside diameter) is attached to it. The outer end of the tube is attached to a simple water manometer which can be raised and lowered to vary the pressure between the lens and the eyeball. The manometer, tubing, and lens-cornea space are filled with a sodium bicarbonate buffer solution (20 gr/1280 cc). The aqueous humor, the cornea and the buffer solution have virtually the same refractive index and therefore act as a single optical medium (Duke-Elder, vol. 5, 1961, p. 713). Pressure of -23 cm of buffer solution is applied. Ditchburn and Bennet-Clark (1963) have applied 0-6 cm Hg negative pressure to the liquid-filled cavity between the eye and a haptic contact lens and report about equal slippage (as measured by disappearance of a stabilized retinal image) for 2-6 cm of mercury. It would seem that optimum pressure varies between lens types and with the desired application (eye movement range).

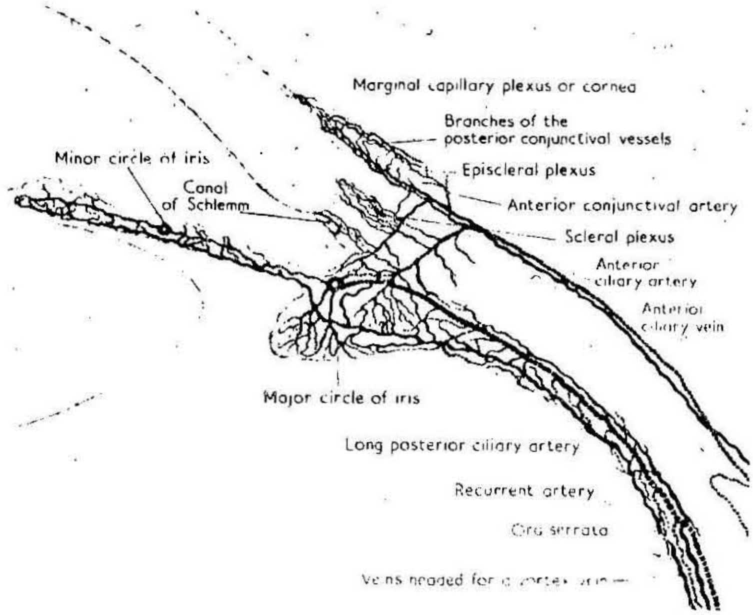
The cornea itself is avascular, receiving much of its nutrition from surrounding episcleral blood vessels (Fig. 9 top). Since the contact lenses fit quite tightly, they interfere with the limbal circulation of the blood and with the oxygen exchange between the cornea and the atmosphere. Depending on the lens and on the individual corneal threshold for edema (from 1 to 14 hr) the lens occlusion of the blood supply may lead to anoxia and corneal edema first noticed as a blurring of vision or veiling (Duke-Elder, vol. 5, 1961). This is a result of increased water uptake in the cornea which moves irregularly apart the parallel layers of collagen fibers of the cornea; the cornea then thickens and becomes turbid (Fender, 1965). Thus subjects wear their lenses under tight fit for only about 30 min. a session usually for two sessions a week.

Lens insertion and removal. The lens insertion and removal procedure is simple and can be performed either by the subject or by the examiner. The subject stoops his head down with his face parallel to the floor; without moving his head he looks down toward his chin while raising the upper lid with his left hand, holding the lens 3/4 filled with buffer solution in his right and touching the upper edge of the lens to the top of his eye, then sliding the lens up under the lid as far as it will go. Remaining in the same head and right hand position he then moves his left hand to pull down his lower lid and at the same time "looks up" and slides the lens in. It is important for good fit that no air bubbles be formed inside the lens. For removing the lens the subject is instructed to look up while in normal upright head position and his upper lid is raised by the examiner who then attaches a suction tube (B, Fig. 2) to the lens, moves it up to clear the lower lid and then down and out of the eye in a sliding motion.

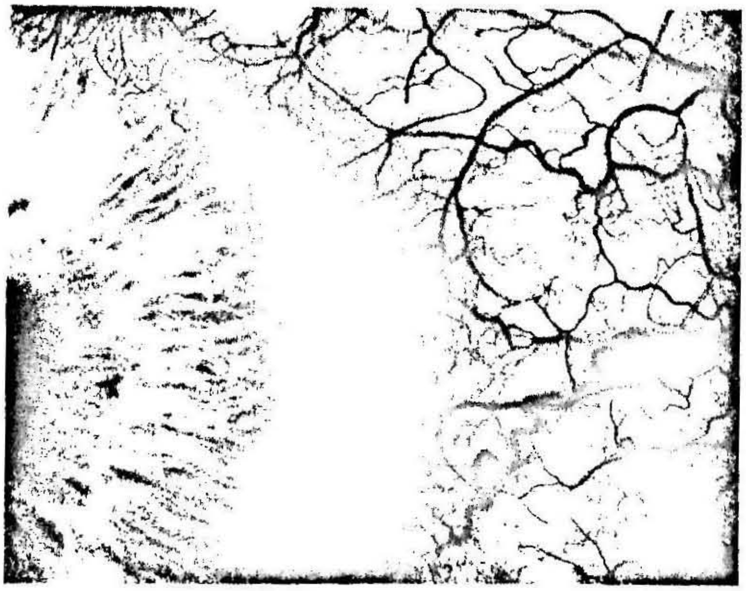
THE COLLIMATOR

Collimating methods using small and powerful but relatively highly aberrated lenses have been used for contact lens-based

Figure 9



(From Goodwin, 1972) Blood vessels of the anterior portion of the eye. Arteries are shown as dotted lines and veins as solid lines. Redrawn from Davson (1962).



Capillaries at the limbus (X9). Redrawn from Duke-Elder (1961).

stabilizing image instruments by Yarbus (1967), Pritchard (1961), Evans and Piggins (1963), Evans (1965) and Cardu et al. (1971) (Fig 10). When we have explored the possibility of effectively embedding the collimating lens in the contact lens by constructing high power plexiglass contact lenses, the manufacturer indicated 30 diopters as the upper limit for such a correction. This would involve a screen (cap) support system longer than 3 cm with a resulting prohibitive weight and moment of inertia. Ditchburn and Pritchard (1960) report a 25 diopters contact lens carrying a thin aluminum pointer as image. McKay (1957) has in fact used a 60 diopter contact lens but Pritchard (1961) has rejected this approach due to the bad optical quality of the plexiglass lens in favor of the collimating system shown in Fig. 10b which incorporates a separate glass collimating lens.

Yarbus manufactured his own collimating lenses and describes the procedure in Yarbus (1969). Our main considerations in the choice of lens have been small focal length (maximum 10mm), light weight (maximum 50 mg), and hence also small diameter (maximum 5 mm) as well as freedom from aberrations. Simple plano-convex lenses proved adequate with a 1/4 weight of achromats with comparable dimensions. Only Pritchard's instrument allowed for varying the image position on the retina and none of the techniques describes a procedure for aligning the collimator with the line of sight.

The collimator used here consists of a thin and light aluminum tube about 5 mm in diameter and 12 mm in length with walls approximately .007" thick and weighing approximately .50 mg. In one end there

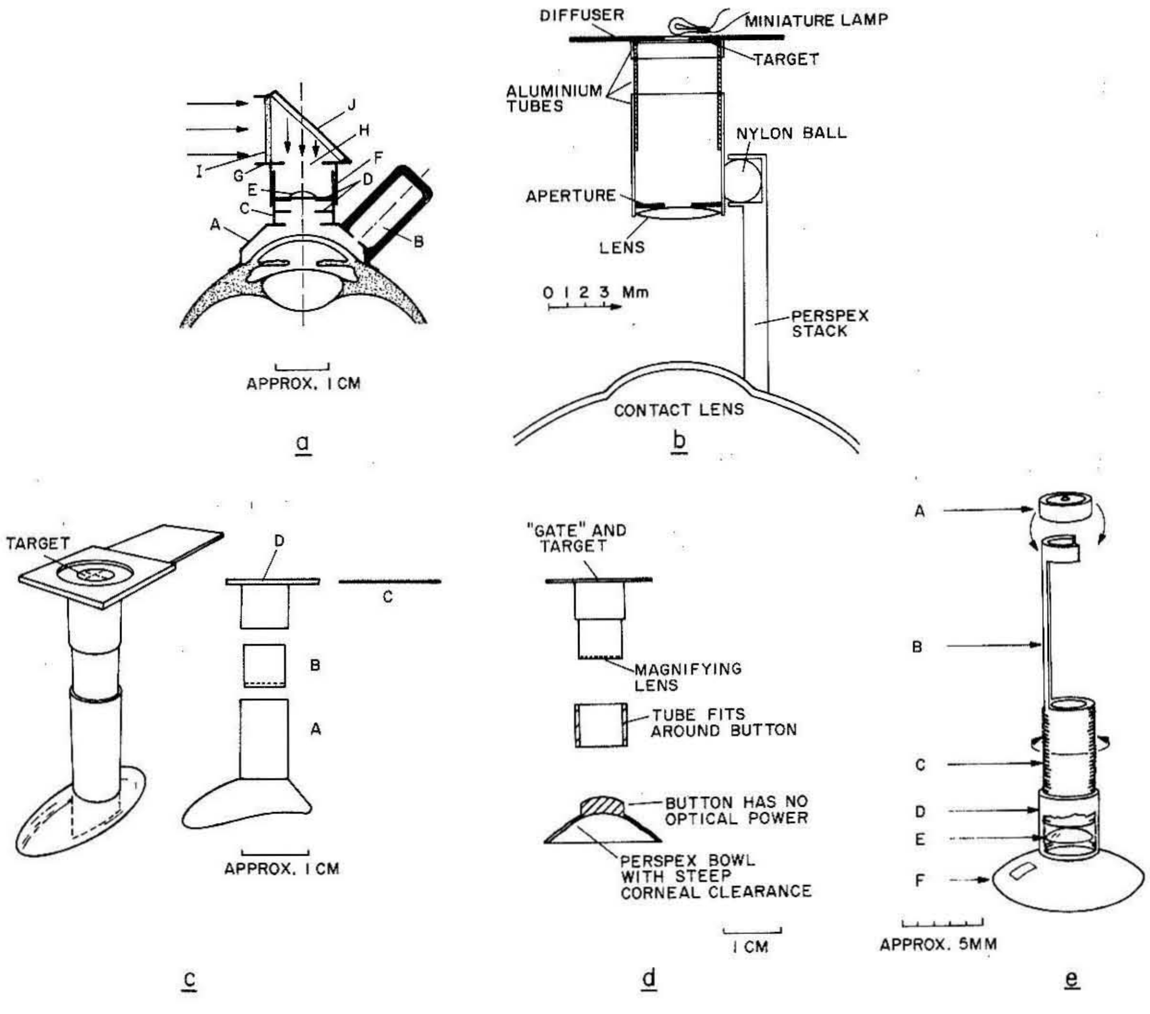


Figure 10

Contact lens based collimators for stabilizing retinal images.

Fig. 10

a: The suction cap P6 of Yarbus (1967). A narrow beam of light shown by arrows illuminates the 2mm thick frosted glass I. Against this background reflected in the mirror J the target at H is viewed. The collimating lens E has a 5-8 mm focal length and is separated from the cornea by about 3 mm (to prevent clouding) and two aluminum diaphragms D .1 mm thick and with 1.5 and 2.5 mm apertures respectively. The sharpness of the image is adjusted by moving the paper cylinder F held by fraction along the .1 mm thick aluminum cylinder C. The aluminum frame A has a corrugated and polished surface of contact between the frame and the eye. Suction is formed by pressing the hollow rubber side-piece B. The weight of the cap without the adaptor F is .15-20 gr.

b: Pritchard's (1960) collimator system for stabilizing the retinal image. The aluminum collimator contains an achromat with 10 mm focal length although a simple double convex lens was found to be equally successful. A 1.5 mm diameter aperture is located at the surface of the lens. The collimator has a total mass of .27 gm. In this apparatus the target is viewed with effective magnification of about 30, so that a distance of 0.4 mm at the target represents 2^{o} in the visual field.

c: Evans and Piggins stabilizing system (Evans and Piggins, 1963). A: light weight seamless aluminum tube mounted on the corneal bulge of the contact lens. B: telescoping aluminum tube holds focusing lens. C: photographic negative or positive. D: gate holds the target and adjusts for focus and position. The targets used subtended a visual angle of approximately 5^{o} of arc and the entire visual field of the subject subtended 30^{o} arc. The total lens + collimator weight is slightly under 800 mg. Subjects lay on a couch during the experiment but no slippage measurement is reported.

d: Evans' (1965) perspex universal lens supports an aluminum collimator on a double curvature lens with a deep corneal indentation which clears almost any eye. Focusing is achieved by telescopic adjustment. Stabilization of a 25 degree field may be obtained with the optimum size of the target approximately 5 degrees.

e: The corneal lens based collimator stabilization apparatus of Cardu et al. (1971). A = stimulus carrier, 3.5 mm in diameter and 1.5 mm high; B and C = holder, 3.0 mm in diameter and 17 mm in length; D = base of the collimator, 3.5 mm in diameter and 4 mm high; E = convex lens; F = corneal lens. The plexiglass collimator is centered in the apex of the corneal lens F. A 50 diopters double convex lens was used in the collimator. The entire structure weighed 120 mg. Subject was lying on his back.

fits a small plano-convex lens (Rolyn Optics, Arcadia, California, Stock no. 10.0010) weighing 50 mg with a 5 mm diameter and 10 mm focal length so that an image just on the outer surface of the collimator appears clear to the unaccommodated eye when viewed from the other end.

The collimator has a square base which fits a machined step on the contact lens and can be mounted on the lens in a tight fit and removed from it while the contact lens is in the patient's eye. This is to make the orientation of the collimator with respect to the contact lens fixed. The collimator is not glued permanently to the contact lens surface in order to avoid vapor forming in the clearance between the contact lens and the small collimator lens due to temperature differences. A number of aluminum caps which occlude various ammounts of the visual field were constructed to fit on the outer edge of the collimator (D, Fig. 2).

The distance between the plano-convex lens and the outer edge of the collimator is that distance of the lens from the reduced image (Fig. 3) which creates a clear final image to the unaccommodated eye through the contact lens. This focal length is determined individually for each subject-contact lens combination with the help of a specially designed plastic device (parts F, G, I, J in Fig. 2) using a telescopic adjustment. The device accepts lenses with diameters from 3 to 7 mm and with focal lengths from 5 to 15 mm. It turns out, however, that optical corrections introduced into the contact lenses of individual patients make it possible to use the same collimator for a group of subjects.

Alignment. The collimator lens has a small aperture and the technique relies on good centering of the collimator around the pupil area of the contact lens and on correct alignment of the collimator with the subject's line of sight. The alignment measure should furthermore be easily reproducible in an instrument shop milling machine where the contact lens shoulder for mounting the collimator is machined.

A two step procedure is used. First the subject wears his contact lens under suction and the point on the corneal region of the lens which lies directly on the center of the pupil is marked. This is repeated for several sessions. Next the lens is removed and a small piece of clear plastic disc marked with a fine mesh grid is attached to the contact lens on small pegs (F, Fig 2) so as to intersect the line of sight. The lens is then inserted again, the subject is seated in normal testing position and is directed to fixate a small mark on the objective of an alignment telescope (The Gaertner Scientific Co., Chicago) about two meters away, directly in front of, and at the same height as the patient's eye. The examiner meanwhile observes the contact lens through the telescope and records the grid point on the clear piece of plastic sheet which falls directly on top of the marked center of the pupil on the contact lens.

The lens is now removed from the patient's eye. Using adhesive clay it is mounted on an open brass cylinder containing two cross-hairs 5 cm apart (Fig. 11a). The cylinder is mounted on an optical bench and is prealigned with another alignment telescope (Fig. 11b) by superimposing the cross-hair in the telescope with the two cross-hairs in the cylinder. The imaginary line connecting the centers of the two cross-hairs in the cylinder (and now also the center of the cross-hair on the telescope) defines the final line of sight. The cylinder is precision built to fit in and align with a milling machine in the instrument shop to within .001". Now while observing through the telescope the contact lens is manipulated on the finger of the cylinder (C, Fig. 11a) until the two marks on the contact lens and plastic disc, respectively, coincide with the center of the cross-hair on the telescope. The actual line of sight defined by the contact lens now coincides with the line through the centers of the cross-hairs in the cylinder. The cylinder and attached contact lens are removed from the optical bench and liquid plaster of paris is poured into the "dish" portion of the cylinder (A, Fig. 11a) to fix the lens without covering its corneal region. When the plaster is dry, the plastic disc is removed from the contact lens and the cylinder is ready to machine the step for the collimator in the instrument shop in correct alignment with the line of sight with respect to the lens.

The second step is to determine the vertical meridian of the visual field with respect to the outer surface of the collimator. For that purpose a small clear slide marked with a hairline and moving across a graduated scale (.1 mm divisions) can be fitted to the end of the collimator (E, Fig. 2) at its focal point. Next, the subject is presented with a stimulus consisting of a cross whose (reduced) image plane during fixation coincides with the plane of the slide. Now the subject moves the slide so that when he fixates the center of the cross, the hairline on the slide coincides with the vertical line of the cross. An average of several readings gives the location of the vertical meridian of the subject's visual field with respect to the outer face of the collimator to within .05 mm. This indicates what part of the face of the collimator needs to be occluded in order to obscure precisely one half visual field or any other desired amount with an appropriate cap.

The total weight of the contact lens-collimator-cap assembly does not exceed 800 mg as compared with over 1100 mg for lenses used by Fender and his associates, and 1500 mg for the modified lens used by Bennet-Clark and Ditchburn (1963).

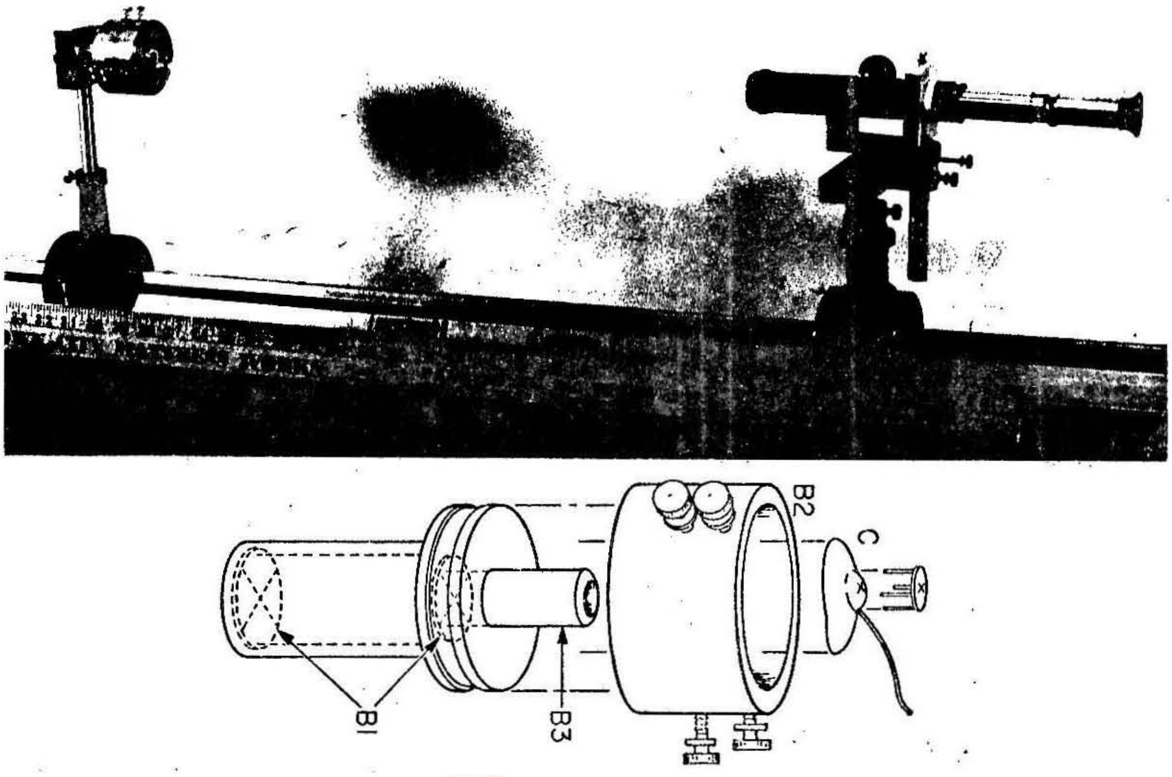


Figure 11

a: A cylinder containing two cross hairlines B1 for determining the line of sight with respect to the contact lens. The contact lens C is temporarily attached to the "finger" B3 with adhesive clay and fastened to it after alignment with plaster of paris poured into the "dish" portion of the cylinder, B2. Part B2 separates from the rest of the cylinder by loosening screws following machining of the collimator "step" in order to ease the removal of the lens and plaster of paris.

b: Optical bench, cylinder and telescope used to establish line of sight.

CONTROLS

INTRODUCTION

Alternative interpretations of our data in general and particularly of verbal responses to left visual field stimuli fall into three classes. First there is the possibility that some visual information does get across to the right visual field. Thus one can argue that lens slippage during right-to-left saccades in which lens movement lags very briefly behind the movement of the eye permits a brief transient "spill" of the information into the right visual field even when that visual field is presumably occluded. Transient slippage of this kind may produce normal subliminal perceptual effects with no verbalization and recall but adequate recognition (Neisser, 1967). This is very unlikely for kinematic reasons and will not be discussed further. Second, there is evidence for information transfer from the left visual field to the left cortex. And finally there is the possibility of bilateral cortical representation of the fovea around the vertical meridian, making precise one half field occlusions insuffient to prevent information cross-over to the hemisphere which is contralateral to the occluded visual field. Each of these three conditions will now be discussed briefly.

LENS SLIPPAGE

To the extend that the lens does not follow the eye movements faithfully it will lag slightly behind the eye and if the movement is away from the occluded field, more of that field will now be exposed thus possibly permitting incomplete lateralization of the input. It is therefore necessary to measure lens slippage with eye movements up to $\pm 15^{o}$. Slippage varies from subject to subject and in one case from session to session making necessary repeated individual slippage measurement for each subject. Standard theoretical slippage arguments apply. The moment of inertia of the lens assembly is small compared to that of the eyeball (Riggs, Armington and Ratliff, 1954) and the maximum frictional force required to accelerate the lens is well within that presumed to be the capability of a scleral contact lens (Fender, 1964). Also when a pattern on a miniature slide is attached to the outer face of the collimator, there occurs image fragmentation and disappearance as expected. Slippage varies with individual subjects and lenses, but for large eye movements it is a function of the weight of the lens. Accordingly lenses can be made to order with a thin periphery and a thick corneal section so that it can be machined to accommodate the collimator. The outer surface of the lenses can then be ground and thinned after the collimator has been fit.

Slippage measurements in contact lenses. Byford (1962) measured slippage of lenses similar to ours by comparing the contact lens data with concurrent high speed cinematographic records of the eye during fixation and nystagmus. He found lens slippage of less than 6 min arc for movements up to 9^{o}. But this is unusual. Byford also observed with a microscope the relative movement of a fine mark on the dorsal surface of the contact lens and a neighboring scleral blood vessel.

St-Cyr and Fender (1969) measured the motion of an ocular blood vessel relative to an engraved grid on the contact lens during saccades, and concluded that the amount of slippage was unacceptable. By introducing a suction of 23 cm water, they reduced the slippage to 9 mm arc for a 4 degree saccade. 26 cm water is said to develop naturally between the eye and a close fitting triple curvature lens which clears the corneal bulge but creates a seal around the sclera (Fender, 1964). However this is said to take about 10 min to develop and it is not known how individual lenses and eyeballs affect this pressure or how stable it is. In fact I have observed lens slippage without suction to far exceed that with a pressure of -23 cm even after 15 minutes of wear.

Barlow (1963) had his subjects compare a stabilized retinal image with an afterimage, which may be considered ideally stabilized, and found that the two images deviated by as much as 3½ min arc. But this applies only to drift during fixation. Barlow's technique of stabilizing the image by mounting it on a 25 mm long aluminum stalk attached to the contact lens most probably introduces a greater moment of inertia to the lens than ours. On the other hand his lens weighed only 350 mg. Indeed, Riggs and Schick (1968), who used an external optical system with only a small plane mirror embedded in the lens, found that during a time period of 1 min. the image shift had a maximum of about 1 min arc with standard deviation of .4 min arc.

Cardu et al. (1971) have used standard techniques of fluorescopy to assess the fit of their corneal contact lens collimator stabilizing system. A few drops of sodium fluorescein are applied to the sclera and the amount of infiltraded fluorescein is detected with an ultraviolet lamp. I found this method to be unacceptable. When applied to the scleral lenses without suction it showed no infiltration while direct surveying disclosed an unacceptable slippage of about 10 percent with movements between 1^o-15^o. With corneal lenses much greater slippage is in fact expected.

Lens slippage due to flicks. One can approximate an upper bound for the weight of the lens + buffer solution by a thin spherical shell with radius of 12 mm and weight of 800 mg. This yields a rotational inertia ($I = \int r^2 m$) of $< .4$ gm cm^2. If we also approximate from above the collimator by two point masses -- one at the collimator lens with r = 15 mm and m = 100 mg; the other at the end point of the collimator with r = 24 mm and m = 100 mg -- we get a moment of inertia of $< .8$ gm cm^2 for a total of < 1.2 gm cm^2. During a flick the maximal torque transmitted through the lens-scleral junction about the center of the eye is equal to the product of the rotational inertia of the lens and the maximum flick acceleration (27,000 deg/sec^2 or 470 rad/sec^2). The torque, therefore, is < 564 gm cm^2/sec^2. Extrapolating from Gilbert's data (1968) we may conclude that this leads to a transient slippage of <3 min arc which partially neutralizes the observed tendency of the lens to lag behind the eyeball during slow smooth saccades.

The direct surveying method. The method used here was adopted from Goodwin (1972). A grid of 10 dots averaging .002" in diameter at .003" interval was inscribed by needle on the inside surface of the lens. Black wax rubbed over the dots enhanced their visibility. The dots were positioned so as to intersect a suitably chosen blood vessel situated temporally to the limbus at approximately right angles to it. When observed from outside the eye (Fig. 9 bottom) two networks of blood vessels in the pericorneal plexus around the limbus overlap. First and outermost there are the superficial conjuctival vessels, while more deeply situated are the cilliary arteries of the episcleral tissue (Fig. 9 top). The conjunctival vessels are more clearly noticeable but move with the conjuctiva. Thus it is important to choose a short relatively fainter but deeper radial episcleral blood vessel as a reference for slippage measurements.

Slippage was observed through a Zeiss operating microscope (objective 200 mm) at magnification X40 with diffused light illuminating the subject's eye. Lens slippage increased approximately linearly with angular saccadic displacement and a slippage of lens less than one grid division or .003" was easily obtained with eye movements of up to $\pm 15^{\circ}$. The resolution of the method is about .001". Slippage of .002" observed for 15° saccades translates into .004" at the outer face of the collimator (Fig. 7) (reduced image plane) or into a final visual angle of 0^{o} 34' arc. Air bubbles between the lens and eye reduce adherence and must be avoided (cf. Byford, 1962). In case air bubbles are formed, the lens is removed, refilled and reinserted.

Session-to-session stability of line of sight with respect to the contact lens. When inserted in the approximately correct position, and after suction is applied the contact lens will settle itself automatically in the correct orientation within 60 sec. Repeated measurements in two male subjects (one normal adult and one commissurotomy patient) of the line of sight with respect to the axis of the collimator for a period of half a year reveal consistent positioning to within .1 mm or a visual angle of approximately 1^{o}. These measurements are made using a plastic collimator mount with a hairline inscribed on a clear slide that moves across a graduated scale (E, Fig. 2). However, a third subject -- a 39 year old female commissurotomy patient -- does not show complete session-to-session stability. Three different lenses (all made from the same mold) show occasional deviations of the line of sight by as much as 1 mm on the surface of the lens or 0^{o} 43' arc in visual angle. The time pattern of deviations suggests they are due to changes in the shape of the eyeball associated with the menstrual cycle. Increased interocular pressure during this period is known to induce changes of from .5 to 1.5 diopters in visual acuity and of up to 45^{o} in the direction of astigmatism due to bulging of the cornea (Fender, 1972, personal communication), caused by fluid retention. Similar effects may be associated with certain birth control pills.

VISUAL ACUITY

As a rule during testing the visual field is occluded 2^{o} past the determined fixation line thus counteracting lens slippage and possible objections from bilateral retinal representation about the vertical midline (see below). It was found that, in general, this incurs no significant loss of visual acuity for the purpose of reading and processing line drawings in tasks which have been so far employed in commissurotomy studies. From Fig. 12 we see that 2^{o} off the central fovea reduces the visual acuity to about 50 percent. However, since the stimulus size and some of its psychophysical characteristics such as contrast can be controlled, adequate acuity can be easily obtained for the commissurotomy patients with stimuli as far as 10^{o} from the fixation point.

Woodworth (1938) reviews research done in the early 1900's on indirect vision in reading and points out that much of efficient reading involves indirect vision. Indeed literate readers fixate an average of 4 times per line of print (Woodworth and Schlosberg, 1954). Ruediger (1907) found that at 2.9^{o} from fixation single letters printed in eleven point type were recognized correctly 98 percent of the time. A group of meaningless letters must be brought somewhat closer to the fixation point in order to be read accurately (Korte, 1923). But in reading meaningful words, phrases, and sentences, context and redundancy facilitate recognition at wider angles off the fixation point.

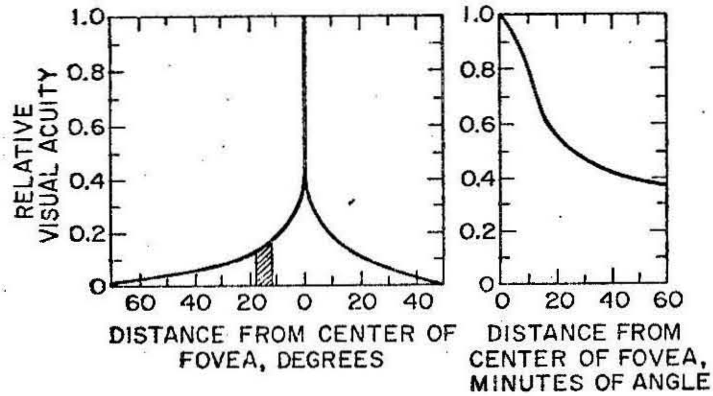


Figure 12
Relative visual acuity as a function of the angular separation from the center of the fovea.

Visual acuity measurement during CLVP testing. The amount of occlusion of the unexposed right visual field extending past the vertical meridian to be used in standard right hemisphere testing was determined empirically by observing meaningful pointing but no verbal responses to left visual field stimuli, with the provision that at least 2^{o} past the midline will be occluded in the exposed visual field. The line of sight was determined independently using a behavioral technique described above. Visual acuity was measured independently at the standard occlusion as well as in bilateral contact lens presentations using Snellen's "illiterate E" eye chart. The subject is asked merely to indicate with a finger of the hand ipsilateral to the stimulated half field the direction in which the prongs of the E are pointing. Thus used the test is equally applicable to left as to right hemisphere presentations.

The chart used was manufactured by the American Optical

Corporation (No. 11969) for use at a viewing distance of 14". Under normal testing conditions, i.e. under the usual illumination at normal testing distance and image size transformations with the chart as a stimulus on the tray in the subject's lap, bilateral (monocular) vision through the contact lens collimator is equivalent to that of a normal person at 21" away from the chart.

Test chart acuity is conventionally recorded in the form of a fraction the numerator of which gives the testing distance and the denominator of which gives the distance at which the letters are just distinguished and subtend 5 minutes of arc and at which they would be read by an eye with normal, or unit, acuity.

Table 1 presents the chart designations for the smallest line correctly perceived in standard testing conditions. LVF pointing responses could not be elicited in one case and may be regarded an underestimate in the other.

Patient	Exposed Visual half field	Screen used	Smallest line perceived	
			Chart acuity rating	Chart visual efficiency rating
L.B.	L + R	-	14/21	95%
	R	+3 LVF*	14/35	50%
	L	+3 RVF	14/42	40%
N.G.	L + R	-	14/28	90%
	R	+2 LVF	14/56	20%
	L	+2 RF	14/56**	20%

* Screen occludes left half of collimator face plus .3mm of right half.

** Patient could not correctly point with her left hand to the direction of the "E"s but could match a given "E" with another one in the same row which is oriented in the same way.

Table 1

Equivalent visual acuity ratings for standard CLVP testing conditions

It should be remembered that acuity reduction under standard testing conditions is attributable not only to partially occluded foveal vision but also to image degeneration through optical relay. The subjects report no loss of acuity because of inability to keep the target in focus as a result of head movements.

BILATERAL CORTICAL REPRESENTATION OF THE FOVEA AROUND THE VERTICAL MIDLINE

Even though no conclusive direct evidence is available there is general agreement that decussation of retinal fibers in the human splits the retina perfectly into temporal and nasal halves (McIlwain, 1972, p. 298). Any region of the fovea which projects to both hemispheres is problematic for laterality research methodology. But as Westheimer and Mitchell point out (1969), the upper limit of overlap of cortical projections from the two halves of the visual field is well below 1.5^{o} even according to the most optimistic advocates of a neural origin of macular sparing in hemianopia, and other estimates are on the order of few minutes of arc (Westheimer and Mitchell, 1969; Thorson et al, 1969). Thus the occlusion of 2^{o} past the vertical midline adopted in our technique suffices to counter a possible objection from a nasotemporal overlap as a possible cause of interhemispheric interaction in presumably lateralized visual presentations.

BEHAVIORAL CONTROL

So far two commissurotomy patients from the group operated on by Drs. Vogel and Bogen and one normal adult have been fitted with contact lens collimators. Together these patients (L.B. and N.G.) are believed to exhibit a representative hemispheric disconnection syndrome (Sperry et al., 1969). Two more patients are expected to be fitted in the near future. Initial studies focused on auditory language comprehension in the minor hemisphere. One experimental paradigm often used consists of a continuously lateralized visual presentation (CLVP) of arrays of 4-6 pictures presented to the left visual field while the examiner spoke a word or a phrase or utters a sentence. The patient has to point out with his left hand the picture best characterized by the spoken message. When the right visual field is occluded the patient can point with his left hand to the correct picture, but when asked to verbalize the contents of a designated picture no accurate and immediate response is forthcoming as it does when the visual scene is presented to the right visual half field. Lack of speech production functions in the minor hemisphere has come to serve as a standard control for adequate lateralization of the input in commissurotomy studies. However, two qualifications must be mentioned.

First, there seems to exist an uncrossed projection of the left visual field to the left cortex. Using the CLVP technique we have verified the existence of what seems to be an uncrossed (extrageniculostriate) visual projection system (Trevarthen, 1970) which makes it possible for the patient to verbalize simple geometric contours from the left visual field or some extracted contour and shape features of more complex stimuli which need bear no semantic relation to the actual stimulus. Thus a ball is easily verbalized as a "circle", a spear as a "long thin line" and prison bars as "parallel lines". The same system seems to mediate the transfer of crude brighteners, intensity and hue information from color stimuli to the left visual half field to the speech centers in the left hemisphere. There is no evidence that this system mediates only motion stimuli (Trevarthen, 1970) although scanning eye movements in CLVP may have simulated the steady fixation + motion stimuli condition of Trevarthen's paradigm. This uncrossed projection explains the difficulty in designing and interpreting experiments directed to determine the extent of nasotemporal overlap following commissurotomy. It is conceivable that the same uncrossed visual system partially mediates "global" stereopsis based on clues from the selection of special features of visual stimuli in the intact brain (Bishop, in press).

Second, there occurs in at least one patient (L.B.) the phenomenon of verbal cross-cueing. When allowed a considerable exposure time (10 sec and more) the patient will often be able to verbalize the name of a simple object presented pictorially to the left visual field (cf. also Zaidel and Sperry, 1973b, in preparation, for some geometric shapes) apparently as follows. The left hemisphere goes quickly through the alphabet subvocally and at the same time the left hand traces the shapes of the corresponding letters. When the correct letter is reached the right hemisphere recognizes it -- presumbably its characteristic auditory phonetic signal -- and "indicates" that fact to the left. The left hemisphere can now "read off" the correct letter or sound and with some extrapolation guess the word after two, three letters or phonemes.

Occasionally there is considerable evidence that the right hemisphere itself is the source of the written automatized alphabetical sequence (Zaidel and Sperry, 1973b; Smith, 1966; Zangwill, 1967). When the context is sufficiently nonredundant making possible a more efficient cueing by enumerating an exhaustive list of alternatives, L.B. will often use such a strategy. For example, when tested for color naming in the minor hemisphere he would often report that he is silently "going through" a list of the primary colors partially spelled and respond with the one seemingly closest to the stimulus, often qualifying his response by relative brightness information presumably transformed through the uncrossed fibers hypothesized above.

In support of this cross-cueing model there is now evidence for extensive auditory language comprehension and some writing in the minor hemisphere. When the words are not spelled phonetically and no contextual cues exist this cross-cueing method typically fails. The duration of the strategy, overt signs of it (e.g., silent mouthing of the alphabet accompanied by slow left hand index finger tracings of the letters) as well as subjective reports are adequate control for the occurrence of cross-cueing. In contrast, left hand pointing reaction to a left visual field scene in CLVP in response to an auditory linguistic message is immediate and unhesitant.

NATURALISM

As already mentioned the moment of inertia of the lens assembly about the center of the eye (< 1.1 gm cm^2) is small. The moment of inertia of the lens increases the total moment that must be driven by the extra-ocular muscles by about 10 percent (Beeler, 1965) but Robinson (1964) has shown that the moment of inertia of the eyeball has negligible effects on the flicks, which are most sensitive to this moment. Beeler argues that the contact lens increases the flick rise time by less than 2 percent and thus may be assumed to produce negligible change in the dynamic characteristics of the orb. Robinson (1964) compared saccades measured with a contact lens technique to those measured by Westheimer using corneal reflexion and by MacKenson using an electro-oculogram, and found no discrepancies. Further coincidences of results of various experiments using contact lenses and other methods all suggest that the contact lens techniques maintain naturalism (Goodwin, 1972).

Also mentioned was the fact that unlike lenses for normal wear, these flush-fitting scleral lenses are not designed for loose fit and do not permit free interchange between the solution beneath the lens and the normal tear fluid. This interferes with the metabolism of the cornea especially by restricting its blood supply. In order to avoid permanent damage to the eye the period of wear is restricted to half an hour. However, wearing the lenses incurs no discomfort whatsoever and no local anesthesia is necessary. One of the patients (NG) fails regularly to recognize the presence of a new (smooth, unmachined) lens in her eye.

Most tasks tested to date under CLVP involved simple pointing, tracing or writing responses. Since the slow hand movements are visually guided and the subjects can monitor and correct their performance, reduced image and displaced vision incur no difficulties (Harris, 1965). In tasks more sensitive to the 3:4 image reduction ratio such as maze tracing, the image can be made 1:1 at the expense of a larger field of view by using a 35 mm field lens for image reduction (FL, Fig. 3).

Target focusing is sensitive to head movements and the image disappears with a displacement of less than 1 mm between the plane of the outer surface of the collimator and the reduced image plane. Nevertheless the subject can easily maintain fixation or easily correct it, while supported by the head rest of the dental chair and no bite board or similarly restricting devices are necessary. All the same, for that reason in its present form the technique is not suitable for accurate reaction time studies.

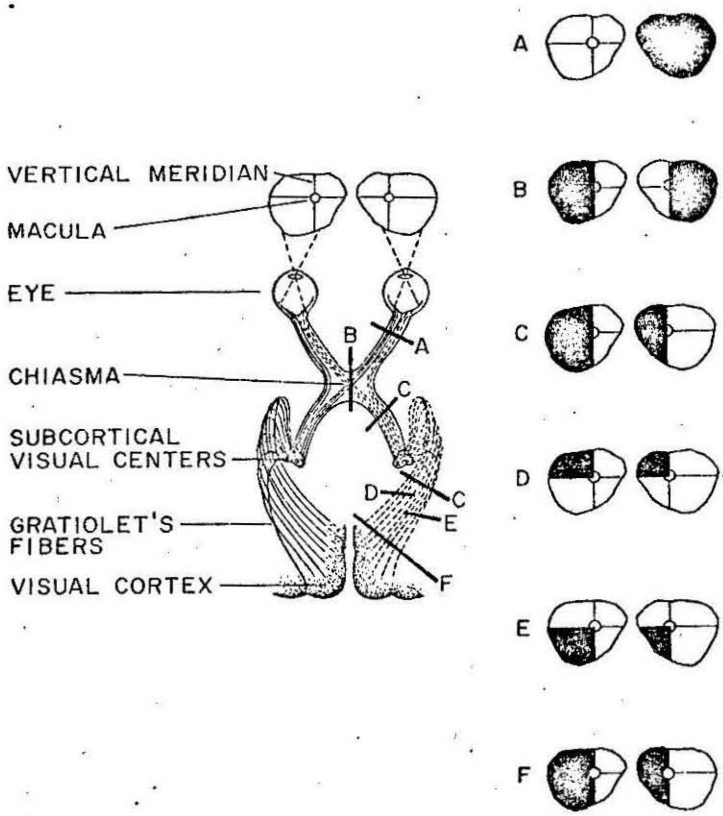


Figure 13

Diagram of the human visual pathways and centers and of visual field defects resulting from lesions in different locations. The blind area in the visual field is shaded.

A: Monocular blindness in the right eye due to lesion of right optic nerve.

B: Heteronymous (bitemporal) hemianopia due to chiasm section.

C: Left homonymous hemianopia due to interruption of either the optic tract or the optic radiation.

D: Left upper quadrant anopsia due to partial interruption of the right optic radiation, presumably in its ventral sector.

E: Left lower quadrant anopsia due to partial interruption of the right optic radiation, presumably in its dorsal sector.

F: Left homonymous hemianopia with macular sparing due to destruction of the terminal projection of the optic radiation in the right occipital lobe.

CONCLUSION

The contact lens mounted collimator solution to the problem of presenting continuously lateralized visual information to a single hemisphere is a simple technique particularly suitable for a small group of subjects such as the commissurotomy patients of Drs. Vogel and Bogen studied in Dr. Sperry's lab at Caltech. In effect the technique simulates monocular viewing with chiasm section (B, Fig. 13). The main drawbacks of the method are its nontransferability, relative nonmodifiability and experimental inflexibility. Thus it is not possible to automatically control the extent of occluded fields, to permit automatically triggered selective bilateral visual field stimulation or to present a preselected visual scanning pattern in either field as would be possible in a system which relies on and has access to the horizontal signal of an optico-electronic eye movement tracking system. The advantages of the system are its simplicity of design and construction. It is particularly suitable for intensive analysis of complex tasks in individual case studies but not for reaction time experiments.

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LINGUISTIC COMPETENCE FOLLOWING DOMINANT HEMISPHERECTOMY FOR TUMOR -- THE RIGHT HEMISPHERE AS APHASIC

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INTRODUCTION

Cases of patients who had undergone removal of one cerebral hemisphere for post infantile tumor constitute an important source of data on hemispheric specialization. Theoretical inferences from such cases are more incisive than from deficits in populations of patients with unilateral brain damage where localization is always doubtful and pathological inhibition of healthy by damaged tissue is always a possibility. Surgery for hemispherectomy is radical and the prognosis of left (dominant) hemidecortication is poor. With one exception, (Smith, 1966), none of the handful of cases of post infantile dominant hemispherectomy reported in the literature, underwent systematic neurophyschological testing and data on residual language capacities in particular is mostly informal.

It is, therefore, important to examine with particular care the rare case reported here of a 14 year old girl (a patient of Drs. P.J. Vogel and J.E. Bogen) whose dominant hemisphere was removed when she was 10 years old. Initial testing of some language and cognitive functions in this patient was performed by Dr. P. Gott (1973). The present study persued a systematic examination of linguistic competence using extensive standardized test batteries for aphasia. The results are interpreted in light of and correlated with findings of linguistic competence in the disconnected right hemisphere of two commissurotomy patients (L.B. and N.G.) as well as in two cases of nondominant hemispherectomy, D.W. and G.E. (Appendix 1).

One particularly interesting approach to the analysis of language functions in the right hemisphere is by comparison with classical aphasiological syndromes. Conceivably, although not necessarily, analogy with localization data from left hemisphere lesions could shed light on symmetric language structures in the right.

R.S. CASE HISTORY

Born on 9-7-59 R.S. was a normal right handed child until May 1967 when she was 7 years and 8 months old, and when persisting frontal headaches, drowsiness and vomiting began to occur leading to right sided seizures. On her eighth birthday a craniotomy for the removal of a left intraventricular ependymoma tumor was performed. Following surgery the patient did quite well (walking with a cane and braces and apparently talking and writing) until June 1969 when headaches recurred and a right homonymous hemianopia appeared. On July, 1969 craniotomy and resection (subtotal removal) of a recurring tumor was performed followed by a left hemispherectomy including the basal ganglia (the candate nucleus and upper portion of the thalamus) on Sept. 16, 1969.

Since hemispherectomy, multiple operations for treatment of infected wounds and relief of undrained cerebrospinal fluid which led to intractable seizures were performed. On November 14, 1969 a ventriculocardiac (Ventro-jagular) shunt was installed in an obstruction of the right lateral ventricle through a right parieto-occipital incision. Additional surgeries for shunt revision and for control of infection were performed terminating in 10-20-70, following which a drastic behavioral improvement was observed. Nevertheless a right occipito-parietal lesion may be assumed to be present.

Today R.S. is non-ambulatory with a right hemiplegia and is confined to a wheel chair though she does attend school. She needs assistance at the toilet and in dressing but virtually no assistance with feeding, combing her hair or toothbrushing. She can not perform simple housekeeping skills.

R.S. is a pleasant cooperative and sociable girl with reportedly substantially "normal" emotional reactions, but short attention span and reduced mentation and intelligence. Her mother reports her to have been an alert but quiet kindergartener who learned to recognize numbers and was musically inclined early. Prior to initial surgery on 9-6-67 she is also said to have been able to read and write and add and subtract small numbers. But she had already exhibited slowness in learning and particularly in reading during first grade and since she was among the youngest in her class, parents and teacher decided to have her repeat first grade at age 7. She could read, write and speak following the first surgery although she had some spelling difficulty which responded to phonetic training. Similar paucity of aphasic symptoms is said to have followed the second tumor removal in July 1969 but progressively worsening aphasia prior to hemispherectomy suggests that no functional right hemisphere take-over of language functions has occured at that time.√ In spite of extensive tutoring in reading, writing, and calculation, these skills remain largely unfunctional. Learning is slow and protracted. Writing improvement, especially in the motor control of letter tracing, has been more noticeable than reading improvement. In school she is easily distracted, and lacks continuity of effort and perserverance.

Psychological group testing records indicate the following preoperative scores.

I. Preoperative:	10-65	Lorge-Thorndike	KQ 110
	2-67	Kuhlman-Anderson	IQ 100
	5-67	Stanford Achievement Reading	1.8
II. Prehemisph.	3-21-68	Stanford Binet CA 8:6, MA 7:6	IQ 86
		WRAT Reading	1.3
		Spelling	2.0
		Arithmetic	2.6 (2nd grade)
III. Post operative:	11-8-71	WISC verbal IQ	60
		Peabody Picture Vocabulary Test IQ	64
		MA	6:10
		Bender-Gestalt:	moderate to severe visual perceptual distortions

METHOD

<u>Schuell's Minnesota Test for Differential Diagnosis of Aphasia</u>. This test (Schuell, 1965) is a comprehensive and sensitive clinical tool and has been continuously revised in response to clinical findings from

1949-1955. The book by Schuell, Jenkins and Jiménez-Pabón (1964) summarizes test data for the 1955 research edition of the test of which the version used in this study is the 1965 revision. The test is useful to classify the patients' general language behavior in terms of overall pattern of performance on this 69 test battery without further commitment to Schuell's classification of the aphasias, to the relationship of congenital vs. acquired reading and writing disorders or of dyslexia to aphasia. Schuell, Jenkins and Jiménez-Pabón (1964) describe detailed studies of the patterns of impairment on the Minnesota Test of a heterogeneous population of 157 aphasic subjects including factor analysis and correlations with neurological findings. This test is perhaps more sensitive to subtle variations in symptoms than the Boston Diagnostic Aphasia Examination of Goodglass and Kaplan (see below) but the latter provides a valuable analysis of test performance pattern in terms of current neo-classical approaches to aphasiology.

Schuell et al (1964) explicitly reject the 3-way relay system classification of aphasic patients and the expressive-receptive dichotomy or the amnesic-syntactic distinction because these are not mutually exclusive categories. The authors distinguish the following five major empirical categories within a unitary concept of language disorder.

Group 1: Simple aphasia, defined as reduction of available language in all modalities, in the absence of specific perceptual, sensori-motor, or dysarthric components. Group 2: Aphasia complicated by central involvement of visual processes. Group 3: Aphasia with severe reduction of language in all modalities complicated by sensori-motor involvement. Group 4: Aphasia with some residual language preserved, and scattered findings that usually involve both visual involvement and dysarthria. Group 5: An irreversible aphasic syndrome characterized by almost complete loss of functional language skills.

Goodglass' Boston Diagnostic Aphasia Examination. The test was published only recently (Goodglass and Kaplan, 1971) but has been used for diagnostic purposes at the Boston Veteran's Administration Hospital and the Aphasia Research Center in the Department of Neurology at Boston University for about a decade. In contrast to Schuell's concept of a unitary language disorder underlying aphasia, Goodglass' approach is based on combination of modern psycholinguistic and classical anatomo-neuropathological classification of the major aphasia syndromes, (Broca's, Wernicke's, anomic, conduction, transcortical sensory and motor aphasia as well as the "pure" aphasias: aphemia, pure word-deafness, pure alexia and pure agraphia). The Minnesota test was conceived with a strong empirical bias and the Boston examination with a decidedly theoretical one. While both provide a comprehensive diagnostic range the Minnesota test seems superior in this respect, especially since it is based on richer clinical experience leading to several revisions. One important feature of the Boston test is that the pictorial stimuli for various modalities testing are the same and this makes cross modal comparisons of deficit especially easy.

On the other hand the Minnesota test provides very weak localization data and its prognostic assessment is based almost exclusively on direct empirical correlations with groups of aphasics classified by statistical analysis while the Boston test relies more on diagnosis through association with traditional syndromes, i.e. their anatomico-pathological structures. Certainly the Boston test provides a rich and ready source of interface with the traditional as well as modern aphasiological literature. The Z-score profile chart of the Boston battery is based on the range, mean and standard deviation of 207 aphasic patients at severity levels 1 through 5 on each subtest.

Results on the Minnesota and Boston batteries are recorded on Z-score profiles. A subtest score corresponding to a 0 Z-score represents the mean of the aphasic population on which the tests have been standardized. The forms of the Minnesota test do not provide for a graphic representation of the results and the Z-score profile had to be constructed expressly for this thesis on the basis of the mean scores and standard deviations of the patients on each subtest as given in Schuell (1965). Note that the Boston Z-score profile records number of correct responses while the Minnesota test records number of errors. Paraphasia scores on the Boston profile are an exception in that low score denotes normal performance (absence of paraphasia). The Z-score profiles of R.S. on both the Minnesota and Boston batteries also include for comparison the scores of N.G. (denoted by a □) and of L.B. (denoted by a ○) on selected subtests administered in LVF-L/h CLVP.

Functional Communication Profile. This technique for the evaluation of aphasia was developed by M. Taylor-Sarno (1966) in order to complement standard clinical tests of language disorder. Formal aphasia tests, such as Goodglass' or Schuell's, sample clinical performance in a laboratory situation. They may not, however, reflect functional communication residuals employing the unforced, voluntary, and habitual utterances which characterize normal spoken language. In particular, clinical aphasia batteries may fail to note or their results may be biased by accurate but inconsistent patients' responses. Furthermore, some aspects of natural language are never accounted for in formal tests. Among these are gestures, body cues and visual cues. Critchley (1964) and others (Greenberg, 1966; Taylor, 1965) have often referred to the discrepancies noted between performance on formal testing and the use of natural language of aphasics.

The Boston Diagnostic Aphasia Examination includes an Aphasia Severity Rating Scale (figure 4) which assesses the patient's capacity for oral communication on the basis of a conversational and expository speech interview on a "zero" (no communication possible) to "five" (no perceptable handicap) scale. But the scope of the interview is limited and it does not assess directly non-verbal features of communication.

Clinical testing in a formal setting may be said to tap the patient's linguistic competence rather than his natural performance even though the two may be affected differently in aphasia (Sarno, 1966, but see Weigl and Bierewisch, 1970; Goodglass et al, 1972). Furthermore, if one believes, as some of the subsequent data in the thesis suggest, that the right hemisphere tends to function optimally in semantically redundant contexts, then formal testing situations frequently bias the results against it.

RESULTS, OBSERVATIONS AND DISCUSSION

GENERAL

<u>The Functional Communication Profile</u>. Figure 1 presents R.S.'s functional communication profile. As casual observation suggests, comprehension or understanding is least, though substantially, impaired;

speech is quite severely impaired and reading is virtually unavailable. Taylor's note in her monograph (1966) that there is no discrepency between functional and clinical performance in reading, is born out in R.S. On the other hand, the functional communication profile emphasizes what failed to emerge from the aphasia batteries (see below), namely, that R.S.'s comprehension is superior to her speech and that her use of non verbal communication is extensive.

Rating was done seperately by three independent judges including the author and R.S.'s mother. The first two ratings were in close agreement while the mother's rating was generally more generous, especially in the speech and understanding categories. However, the relative trend of results in the five major groups of items remained the same in all three ratings. The final profile is the result of an active discussion and cross evaluation of the three profiles.

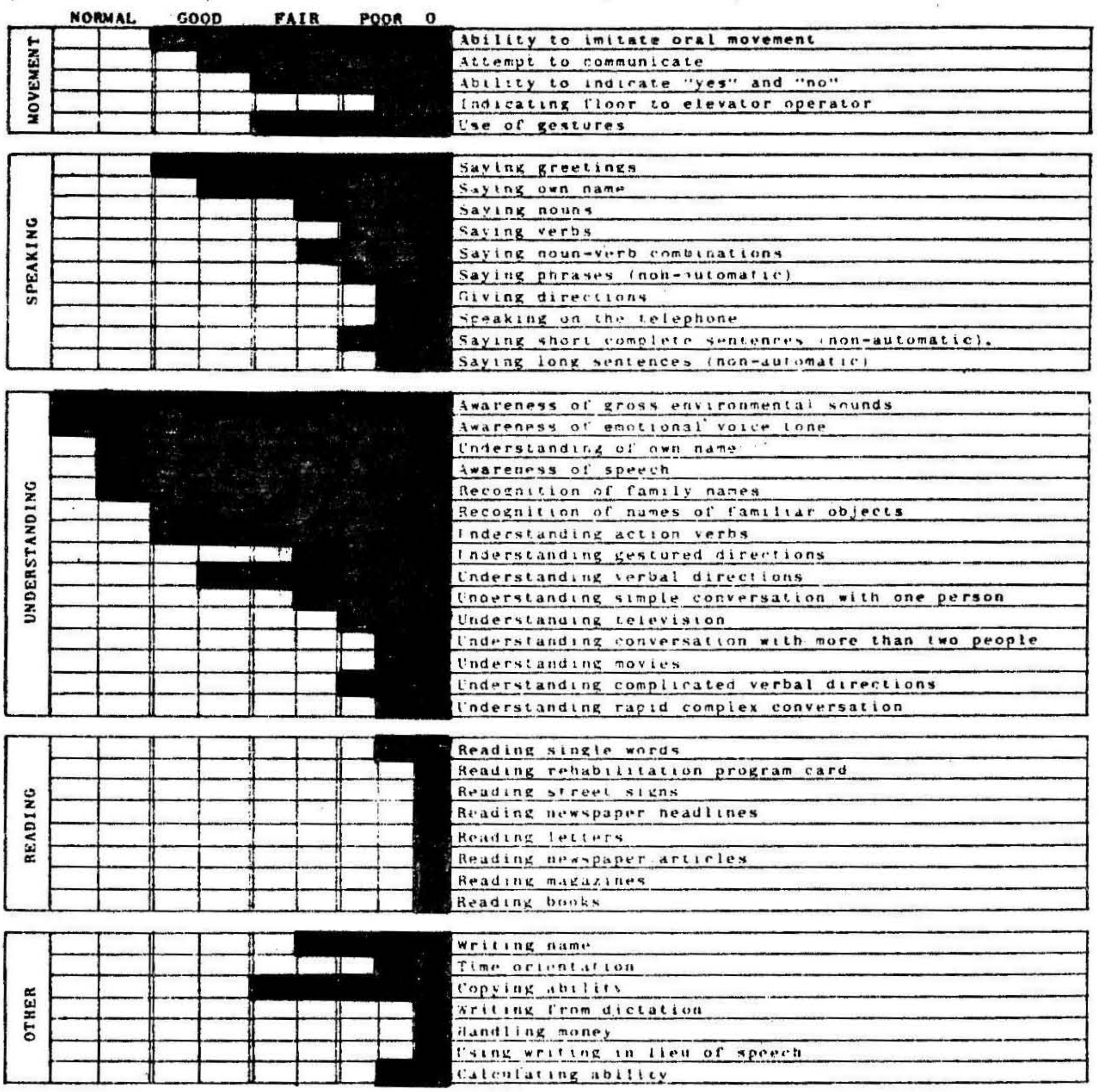
The profile is purely phenomenological; it makes no reference to symptomatology or diagnostic categories and does not attempt to explain why a patient does not use a particular behavior. Neither does the profile suggest a rationale or direction for treatment. Ratings for each listed behavior were made on a point scale from zero to normal, on the basis of extensive observations of the patient in a non-structured conversational interaction.

In interpreting the profile visually one should bear in mind the following exception to standard rating procedures. Normally a patient is rated relative to his premorbid behavior level. However, this is not possible in the case of R.S. who had first shown evidence

R.S.

FUNCTIONAL COMMUNICATION PROFILE

EVAL (Blue)	RE-EVAL (Red)	RE-EVAL (Red)	RE-EVAL (Red)
Date 3-14-73	Date ______	Date ______	Date ______
M 20 50% (13.0)	M ___ ___% (.)	M ___ ___% (.)	M ___ ___% (.)
S 26 32% (5.8)	S ___ ___% (.)	S ___ ___% (.)	S ___ ___% (.)
U 67 56% (13.4)	U ___ ___% (.)	U ___ ___% (.)	U ___ ___% (.)
R 1 2% (0.3)	R ___ ___% (.)	R ___ ___% (.)	R ___ ___% (.)
O 9 16% (2.2)	O ___ ___% (.)	O ___ ___% (.)	O ___ ___% (.)
Overall 34.7%	Overall __ __.__%	Overall __ __.__%	Overall __ __.__%



ESTIMATED TOTAL SPEAKING VOCABULARY: 0 1-50 50-100 100-500 500-1000 over 1000

Figure 1

of lesion at age 7½ at which time reading and writing skills had not yet been acquired to a substantial degree. Consequently in rating her behavior, "normal" was taken to be average performance for a child her own age (13) and with her particular (middle class) socio cultural-economic background. In the rating of individual behaviors, a high "poor" rating corresponds to 25%; a high fair rating to 50%; and high "good" and "normal" ratings correspond to 75% and 100%, respectively.

The profile is self explanatory and indicates a severe language deficit in all modalities. The estimate of residual speech capacity is at 32% while that of comprehension is 56%. As for interpretation of numerical scores, it should be noted that the Conversion Table for the weighting of the patients percentage score for a particular dimension in the Overall Percentage Score, was derived from a population of post CVA (cerebrovascular accident) aphasic right hemiplegic adults. Hence the weights are not valid for children or even patients with damage in the nondominant hemisphere (consequently the weighted percentage scores should be interpreted with special caution). Taylor notes that often patients with damage to the nondominant hemisphere display verbal impairment which is not aphasic in nature. These disorders are generally related to impaired memory, disorientation, and judgement.

Results on the Minnesota Test. Figure 2 represents R.S.'s performance on the Minnesota battery as mean percentage of errors over modalities, and figure 3 summarizes test-by-test error Z-scores. Since the scores are normalized it is possible to compare directly the score in one subtest or modality with the score in another. The higher error

Mean Percentage of Errors Over Modalities in the Minnesota Test

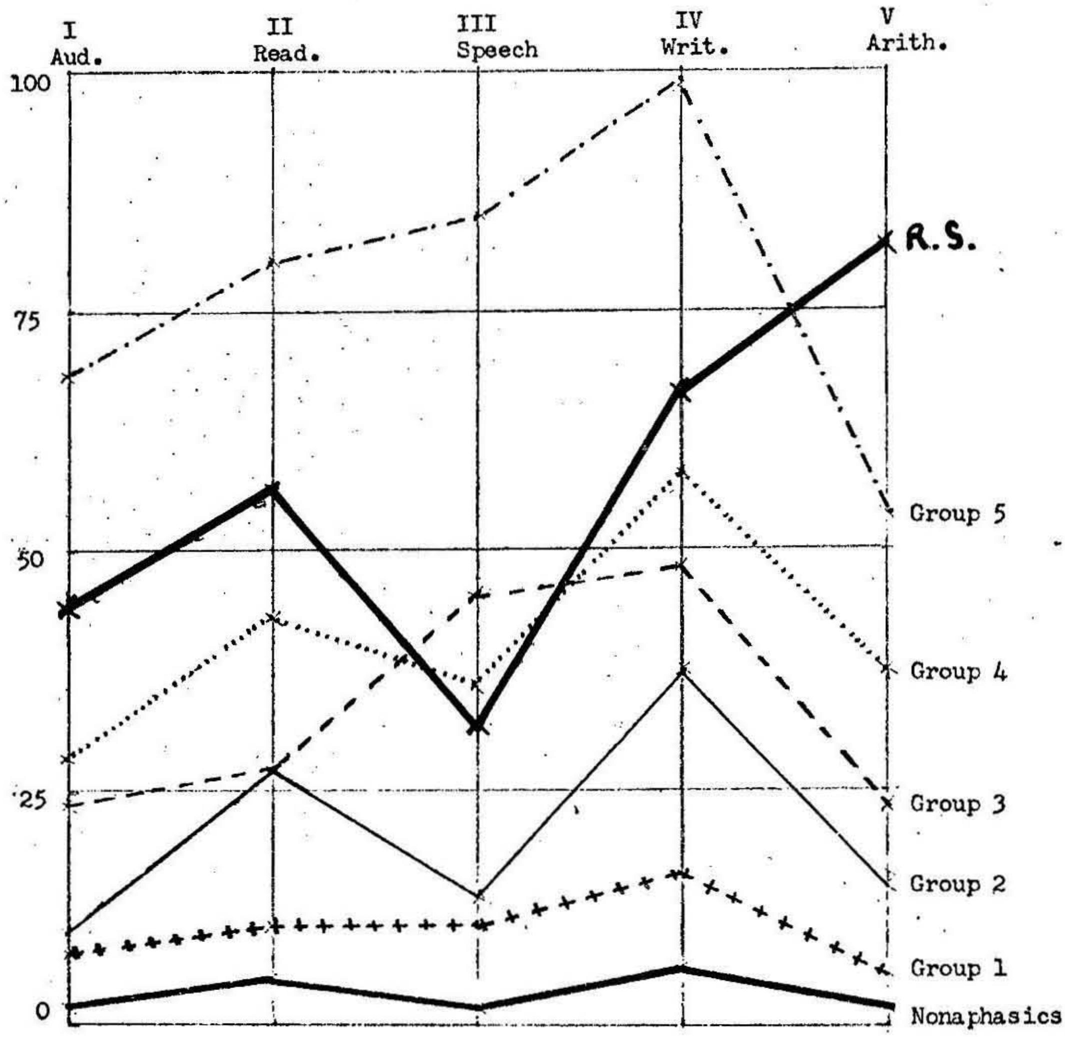


Figure 2

R.S.'s errors by modality on the Minnesota test in comparison with Schuell's aphasics (1964).

Patient's name: R.S.

Date of Testing: 9-17-72
Scored by: E.Z. and M.B.K.

OVERALL PATTERN OF IMPAIRMENT ON THE MINNESOTA TEST

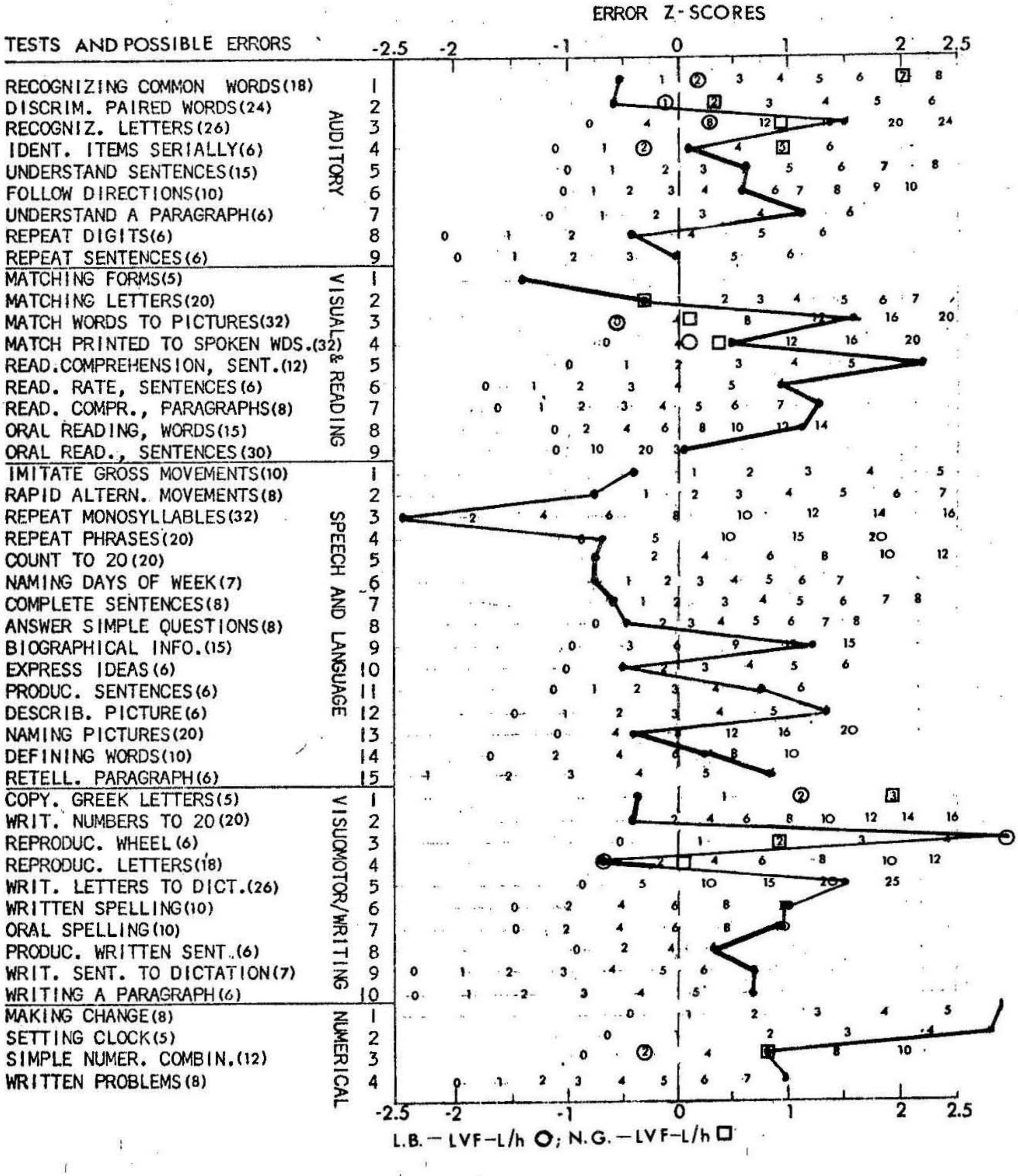


Figure 3

rate on auditory than on speech functions does not indicate a correspondingly more severe impairment in auditory language comprehension than on speech. The auditory deficits are various and include the inability to recognize letters, a short term verbal memory deficit, and impaired comprehension of complex material.

Figure 4 shows that R.S. is not orally apraxic and that she can produce automatized speech sequences quite well but that she cannot relate prescribed complex material or respond to linguistically abstract tasks. The reason that her reading and writing scores are not as low as informal observation suggests they should be is that they include matching and copying tasks, respectively, in which R.S. is quite good.

R.S.'s profile of mean errors over modalities does not coincide with any of the aphasic groups classified by Schuell et al (1964). In particular, she shares neither visual involvement (in the sense of agnosia) nor dysarthria with group 4 whose profile comes closest to her own. R.S. also possesses a particularly severe calculation deficit in comparison with the whole aphasic population of Schuell et al.

Results on the Boston Examination. Figure 4 presents an aphasia severity rating of R.S. as defined by the Boston examination and figure 5 records R.S.'s Z-score profile of aphasia subscores on that examination. As may be anticipated, automatic speech and music abilities score highest, but unexpectedly the auditory language comprehension scores fall consistently under the mean of Goodglass and Kaplan's aphasic population. It is instructive to compare R.S.'s profiles with those of D.W. and G.E. (figures 1-8, Appendix 1), two cases of nondominant

Patient's Name R.S. Date of rating 1-26-73

Rated by E.B.

APHASIA SEVERITY RATING SCALE

0. No usable speech or auditory comprehension.

1. All communication is through fragmentary expression; great need for inference, questioning and guessing by the listener. The range of information which can be exchanged is limited, and the listener carries the burden of communication.

(2.) Conversation about familiar subjects is possible with help from the listener. There are frequent failures to convey the idea, but patient shares the burden of communication with the examiner.

3. The patient can discuss almost all everyday problems with little or no assistance. However, reduction of speech and/or comprehension make conversation about certain material difficult or impossible.

4. Some obvious loss of fluency in speech or facility of comprehension, without significant limitation on ideas expressed or form of expression.

5. Minimal discernible speech handicaps; patient may have subjective difficulties which are not apparent to listener.

RATING SCALE PROFILE OF SPEECH CHARACTERISTICS

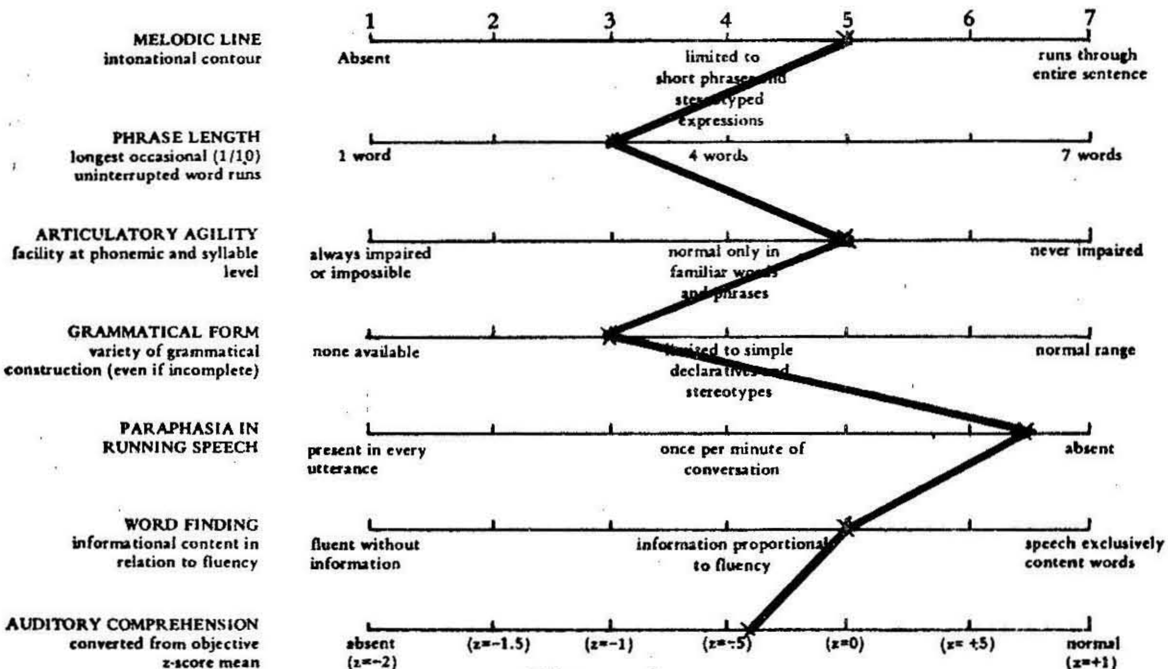


Figure 4

Rating of aphasia severity and speech characteristics of R.S. on the Boston Examination.

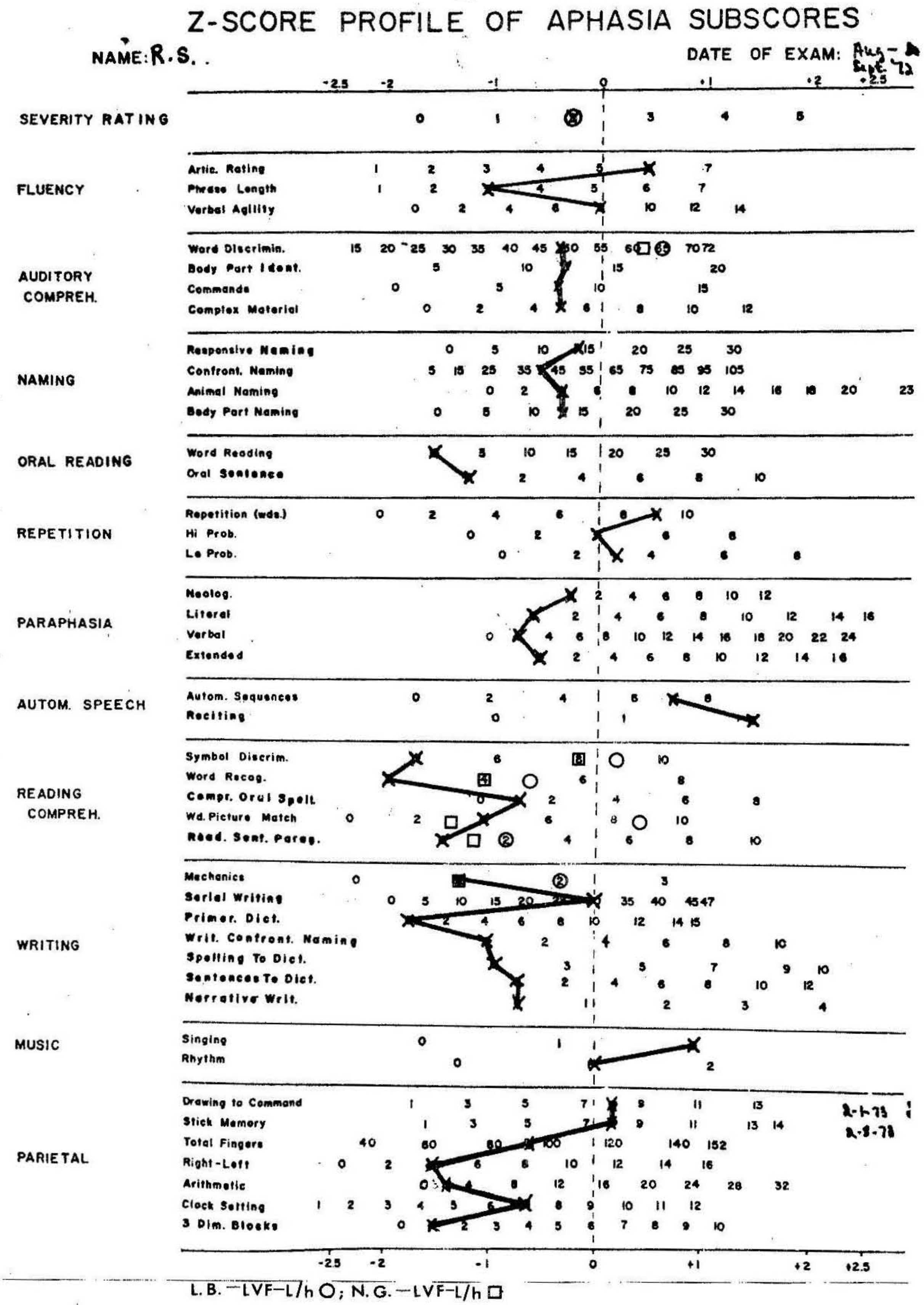


Figure 5

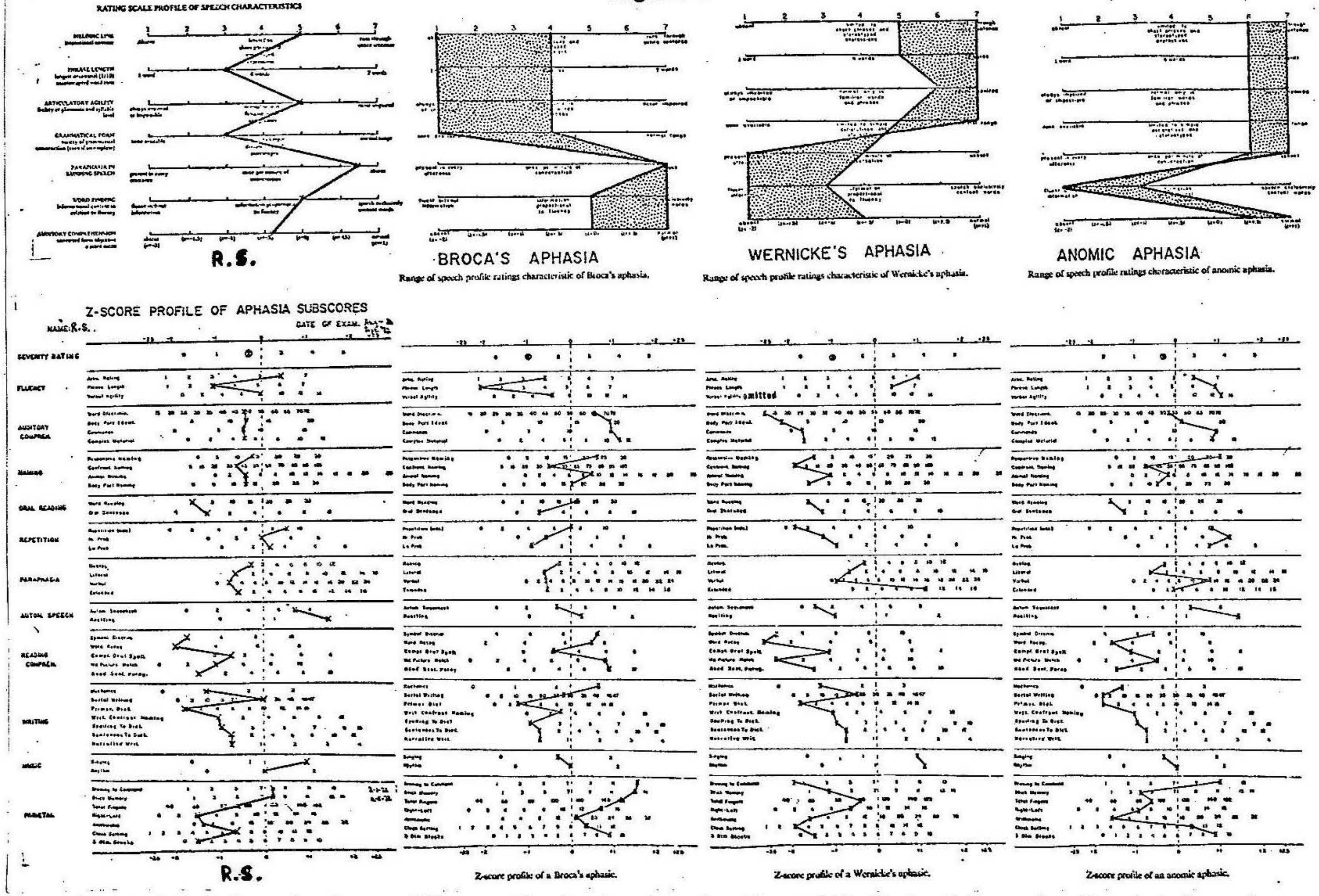
Aphasia profile of R.S. on the Boston Examination and right hemisphere scores for N.G. and L.B. on selected subtests.

hemispherectomy (case histories of both patients are reported in Part III of the thesis). D.W. was left handed but left hemisphere dominant for speech by preoperative amytal test. Today he suffers from severe alexia, agraphia, and acalculia. G.E. shows few explicitly verbal deficits but even she shows characteristically subtle language comprehension deficits (Eisenson, 1962). All three show a severe parietal deficit syndrome on the Boston Examination although there are some qualitative differences between R.S. and between D.W. and G.E. (E. Zaidel, in preparation).

Of particular theoretical significance is the fact that R.S.'s profile fails to coincide with any classical aphasic syndrome (figure 6). Absence of fluency and of paraphasia, and perhaps also auditory comprehension and naming patterns resemble those of a Broca's aphasic; reading and writing capacities are quite similar to a Wernicke aphasic's; good automatic speech and poor reading and naming (but not responsive naming) bear resemblance to the pattern of an anomic aphasic; and finally oral reading deficit, facility in automatic speech and superiority of singing over rhythm in music abilities resemble most those of a transcortical sensory aphasic (Goodglass and Kaplan, 1972). A more detailed theoretical analysis of R.S.'s syndrome vis-a-vis classical aphasiological diagnostic groups will be presented below.

<u>Comparison of R.S. with other recorded cases of dominant hemispherectomy for tumor.</u> Altogether I have seen reference to eleven such cases in the literature. These exclude hundreds of cases of hemispherectomy at various ages for infantile hemiplegia. McFie (1961) reported

Figure 6



Comparison of R.S.'s aphasia profile on the Boston Examination with that of Broca's, Wernicke's and anomic aphasics (Goodglass and Kaplan, 1972). For headings please see figures 4 and 5.

that language and verbal reasoning deficits before and after right or left hemispherectomy for infantile hemiplegia indicated greater attenuation in the development of language than of nonlanguage functions. Carlson et al (1968) also reported no differences between effects of left and right hemispherectomies for infantile hemiplegia but were unable to demonstrate any disturbances of language functions as measured by specific language tests for assessment of dysphasic disorders. Basser (1962) similarly reports no significant differences in preoperative verbal intelligence between left and right hemiplegics and no such differences after left and right hemispherectomy. McFie (1961) also notes that language deficits are less likely following injury in the first year of life. And Wilson (1970) concludes that patients who were hemiplegic before the acquisition of speech had no gross clinical disturbance of speech after hemispherectomy, irrespective of which hemisphere was removed. When the hemiplegia had followed the acquisition of speech, removal of the dominant left hemisphere led to failure of speech functions but with later recovery in virtually all cases.

Zollinger (1935) reports the case of a 43 year old female with progressively severe aphasia (monosyllabic speech) preoperatively and further reduced speech vocabulary following hemispherectomy. At least residual auditory language comprehension is indicated by her ability to show her teeth when asked to, several hours postoperatively. A small increase in vocabulary (from "all right", "yes", "no", to "thank you", "please", "sleep") was achieved through training before death on the seventeenth postoperative day. The author speculates on a gradual development of a speech center in the right hemisphere prior to surgery.

Crockett and Estridge (1951) describe a case of a 37 year old male who had undergone left hemispherectomy sparing half of the globus pallidus, a third of the caudate nucleus and the entire thalamus. Immediately postoperatively he could comply with simple commands, distinguish left from right and say yes and no. Speech started deteriorating one month postoperatively due to recurrent tumor until death 117 days postoperatively.

French et al (1955) report of a case of a 38 year old male with a severe preoperative global aphasia and comparable postoperative language (fair speech comprehension and production). The authors believe that the right hemisphere had assumed language functions from the left preoperatively.

Of the six cases of dominant hemispherectomy for tumor including the basal ganglia and the anterior dorsal porions of the thalamus in right handed adult males reported by Burkland (1971) two (case 5, 21 years old when operated, and case 8, 37 years old when operated) demonstrated no postoperative language function, either expressive or receptive until their death two and a half months and two days postoperatively. Two other cases (case 10, 48 years old; and case 12, 47 years old) demonstrated the ability to comprehend and carry out simple commands 24 hours and four hours following surgery, respectively, but not thereafter until death 7 and 6 months postoperatively, during which period they responded to no verbal or written stimuli. But Burkland believes these cases to be atypical.

Of the remaining two cases one (case 4, 54 years old) who survived for one and half months had expressive aphasia one year preoperatively although he then responded to simple commands and reacted appropriately to jokes. Following left hemidecortication the language functions were unchanged until only a few days prior to his death when he was too ill to respond to verbal stimuli. Preoperative right hemisphere takeover of language functions is likely in this case.

The last case (47 years old, surgery on 1965) was studied extensively by Smith (1966) and showed expressive and receptive aphasia postoperatively. Immediately after surgery he attempted but was unable to speak using solely expletives and short emotional phrases. He could not repeat words but could follow simple verbal commands. A gradual pattern of postoperative improvement of language functions together with improved attention span shows the ability to sing complete familiar songs with good articulation 5 months after surgery, as well as better repetition and occasional propositional speech 10 months postoperatively. Simple arithmetic could be performed and one out of five colors could be selected to aural or written names (5-66), there was minimal writing ("cow") and a substantial 85/112 items correct on the Peabody Picture Vocabulary Test (1-6-66).

Finally, Hillier (1954) reports the case of a 14 year old boy who had undergone left hemispherectomy on 1952. The boy disclosed no speech immediately following surgery but could utter simple words (mother, father, house) on the 6th postoperative day. At discharge, 36 days after surgery, he appeared to have "normal powers of comprehension" and to enjoy music considerably. A constant improvement in the motor aphasia was noted even at 27 months postoperatively but occasional anomia persisted. He could read individual letters but not words.

Thus R.S. presents a syndrome midway between complete right hemisphere takeover of language functions following infantile hemiplegia and between the severe global aphasia following hemispherectomy for tumor in adults. Her clinical symptoms parallel those of Hillier's boy and demonstrate that laterlization of speech is probably complete by age ten and hence right hemisphere takeover of language functions at that age is not superior to that at age 14. Substantial preoperative takeover of speech by the right hemisphere of R.S. may be ruled out since recurrence of a left hemisphere tumor immediately prior to hemispherectomy resulted in progressively worsening aphasia.

In particular, R.S. as well as other cases consistently show better right hemisphere comprehension than speech, automatized and stereotyped utterances being available first, including the ability to articulate well in song the same utterances which they could not produce on demand in responsive speech.

Note. In the following discussion subtest references to Schuell's Minnesota Test for Differential Diagnosis of Aphasia and to Goodglass' Boston Diagnostic Aphasia Examination will be abreviated as follows: The third test in the third section of Schuell's battery, for example, is denoted S.C.3 and the second test in the second section of the fourth part of Goodglass' battery will be denoted G.IV.B.2. In conjunction with the following discussion of results on specific tests, figures 3 and 5 should be consulted often.

COMPREHENSION

R.S. shows no signs of auditory agnosia and her sound localization is good.

The pictorial reference of aural lexical items is intact (S.A.1) although the range of available comprehension vocabulary is limited (G.II.A.). Thus auditory perception is also shown to be intact. Indeed a test for pnonemic discrimination (S.A.2) shows no deficit.

As far as deficit on specific semantic word categories are concerned (G.II.A.) R.S. could not identify one out of 6 objects (hammock), and one out of 6 actions (smoking), two out of six colors (pink, red), two out of six geometric forms (spiral, square) six out of 18 body parts (G.II.B: ankle, middle finger, thigh, eyebrow, cheek, index finger), three out of six numbers (700, 1936, 15) and four out of six letters (L,H,T,S). This pattern parallels that of aphasics regardless of diagnostic group (Goodglass et al, 1966). The errors in the recognition of letters (cf. also S.A.3, 19 errors out of 26) and numbers are due to fundamental deficits in reading, writing and calculation (alexia and agraphia, and acalculia). Similarly, evidence of impaired body image emerges from tests of finger agnosia and left-right discrimination (see below). Body part comprehension was found to be most frequently depressed in Wernicke's aphasics, relative to other groups (Goodglass et al, 1966). Even on the most impaired semantic classes of the Goodglass Word Discrimination Test (G.II.A) there is no case in which R.S. failed to attend to the correct category of item grouping (geometric forms, letters, numbers, colors, etc. all appear on separate sections of the test card). Thus the "sphere" of meaning of the word is retained even when its specific referent is not. An analysis of laterality effects in perceptual and linguistic aspects of color discrimination reveals comparable right and left hemisphere capacities for color matching, discrimination and object association but right hemi - sphere color anomia (E. Zaidel, in preparation).

But increasingly severe impairment is demonstrated on tests involving no perceptual reference as the semantic complexity of the stimulus and the need for inference from extra linguistic factual knowledge increases. It should be remembered that these tests were designed for adults and presuppose average adult ability. Thus the impairment indicated in R.S. by these tests is somewhat exaggerated.

On the Minnesota Sentence Understanding Test R.S. scored 4 errors out of 15 possible. All four errors involve yes responses to questions requiring negative responses (Does the sun rise in the west?). Indeed there is evidence for a positive (acquiescent) response bias stronger in aphasics than in normal subjects (Schuell, 1965, p. 32). For example to the sentence "does everyone put money in the bank?" she has responded affirmatively perhaps because of the association of money and bank, or perhaps through the egocentric application of the question to herself. (An account on her name was opened at the bank by her parents.)

A severe deficit is evident in the failure to comprehend an aural paragraph which can not be attributed to extralinguistic factors. The difficulty increases with the length of the paragraph and reflects an inability to deal with relatively abstract integrated linguistic material (S.A.7; G.II.D).

The limited auditory pointing span of R.S. (S.A.4) shows that the auditory verbal trace of words is unstable. On the other hand R.S. can classify concepts quite well by sorting spontaneously and to instruction pictures belonging to the same class: animate, human, avian ("that has to do with flying things") etc.

Comprehension of syntactic constructions. The Goodglass Supplementary Language Tests include some tests for the comprehension of possessive relationships, prepositions of location, "before" and "after", and passive subject-object discrimination. In addition, Ombredane's Cat and Chair test for comprehension of spatial prepositions was administered (Ombredane, 1951). The tests show a functional though unstable capacity to comprehend sentences involving possessive inflections (1 out of 4 errors) passive sentences (2/5 errors) and the temporal prepositions "before" and "after" (3/6 errors).

On the Cat and Chair test R.S. correctly identified the pictures corresponding to the prepositions "on", "under", and "in front" with occasional errors on "behind" and consistent confusions of left and right. R.S. could not respond reliably to 3-term series problems of the kind: "A is taller than B and B is taller than C, who is tallest?" nor was performance facilitated by substituting real names or objects (which are semantically neutral with respect to the task). Even comprehension of simple comparative constructions ("A is shorter than B. Who is shorter (taller)?") was often incorrect as measured by verbal response. Neither does R.S. demonstrate consistent comprehension of conditionals.

Simple tests for following instructions demonstrate that the comprehension of the logical connectives, "and", "or", "without", and "...but not", is intact. But "if _a_ do _b_" constructions yield the response _b_ even when _a_ is false.

Following instructions. Of concern here is the linguistic proper rather than practic or mnestic components of these tasks. Pierre Marie's three paper test, for example, does not distinguish these elements but since it has been found over the years to possess good diagnostic value in identifying mild receptive aphasics it was administered to R.S. Quite surprisingly she performed successfully two different versions of this and is thus superior to D.W. (a 16 year old boy with nondominant hemispherectomy).

But when a series of instructions involving a variety of common objects -- all within view -- was administered, R.S.'s performance became very labile and irregular. On one occasion she could not simply ring a bell or put the bell between a penny and the spoon (recognition of all objects had been ascertained previously) while on another or in the next minute she could correctly place the penny between a pencil and a key.

A proponderance of perseverative responses in which additional objects are minipulated after the instruction proper has been followed, suggests that the 3-paper test has facilitated freedom from the binding semantic context of the several concrete objects by employing three similar objects (pages of different sizes) with limited associative semantic value and variety. Both on the Minnesota Following Directions Test (S.A.6) and on the Boston G.II.C R.S. scored only 50% correct responses (lower than the mean for the respective aphasic populations and far inferior to D.W.'s). The deficit may be attributed to a poor speech regulation of action in the minor hemisphere due to independent functions served by the language receptive and practic mechanisms in it. Indeed there is little evidence of apraxia on a test of movements to oral command (Bucco-facial, intransitive-limb, and transitive-limb; Boston Examination Supplementary Apraxia test).

SPEECH

Conversational speech is severely limited and is usually restricted to holophrastic utterances. These are semantically relevant and often incisive but syntactically simplified and malformed, especially through the omissions of parts of phrases or sentences. Much of ongoing speech -- spontaneous as well as in response to questions -- is stereotyped and some of the most common stereotypes are "yes", "no", "I'd know", "that's all", "I mean", and "I can't say it". These responses are always semantically appropriate and the last two occur as signs of recognition of speech difficulties. The ability to convey information in spite of incomplete, fragmented or defective sentence structure is enhanced by rich intonation which conveys syntactic as well as semantic information. Speech is persistently but not severely dysarthric; it is often labored but rarely unintelligible. Significantly less naming difficulties occur in single-word than in ongoing-speech responses to pictorial stimuli. Sentence context in the stimulus seems to provide self-initiated cues and help ellicit semantically concrete, informative and generally well formed words even though syntactically illstructured phrases. Response to questions tend to ellicit complete phrases when the questions specifically cue multiple components of the desired answer phrases. E: "what's he doing, what's going to happen to him?" (both pronoun, verbs and auxiliary verb are cued). R.S.: "he's gonna fall."

The following are characteristic responses to picture confrontation. When, for example, E (= examiner) asked her to describe a picture of a sad boy with his hand in a cast she answered: "cast...that's all ...'n this...that's a..." E: "and what's this?" (pointing to a picture of a hold-up) R.S.: "robry (robbery)...robbery yes n' naughty...hands up...this...'n dis...".

Speech responses of R.S. are usually syntactically malformed and yet a variety of syntactic structures occurs. When the deficit takes the form of one word responses it resembles a Broca's aphasia. For example, E: "What did you do today?" R.S.: "learn". E: "What did you learn?" R.S.: "School". E: "How do you get to school?" R.S.: "A bus". E: "Why weren't you in school today?" R.S.: "Holiday". Frequently the response is in the form of a fragmented sentence or phrase punctuated by long pauses. Nouns tend to occur more frequently than other lexical items, especially in the form of enumerative responses: E: "Can you tell me something about what you did on Thanksgiving?" R.S.: "had turkey...eh...stew...and eh..." E: "what have you been doing in school when you went?" R.S.: "I worked...puzzles, eh... math." Correct phrases are likely to be common or stylized: E: "What happens on Christmas?" R.S.: "bulbs...Christmas vacation...all presents...and you get one too." E: "you are?" R.S.: "you are". Personal and possessive pronouns which are sometimes omitted -- especially in one-word phrase contractions -- do frequently occur intact as parts of fragmented noun or verb phrases. E: "who goes there?" R.S.: "My sister and her brother". Thus the agrammatic speech of R.S. is not characterized by specific syntactic alterations but represents a general tendency towards fragmentation and simplification of sentence structure.

Following are R.S.'s responses to the "cookey theft" picture (figure 7) (Boston Examination) on two different occasions.

(10-18-72) "The water is floating...this...and...the water is

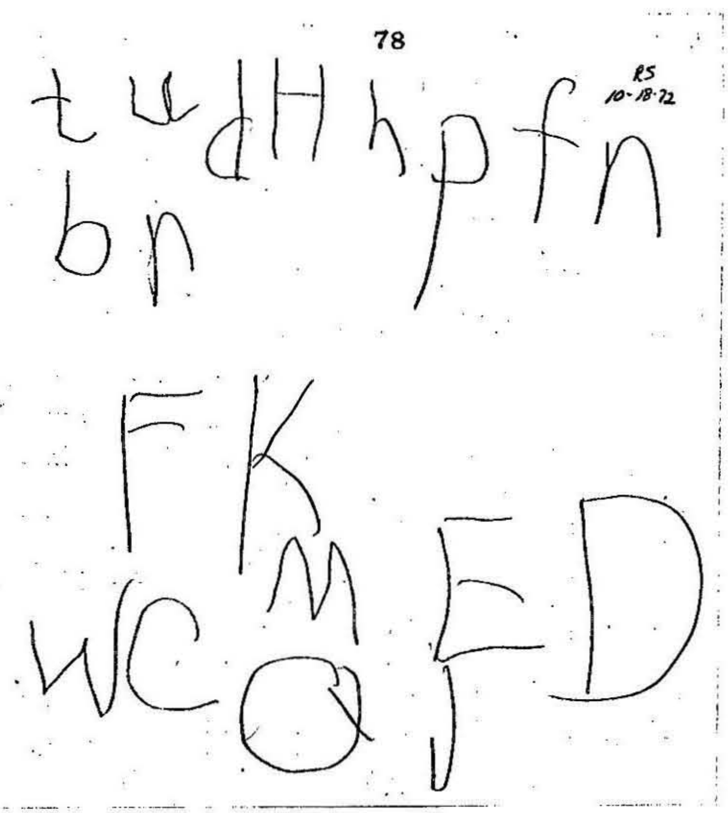


Figure 9. Sample letter reproductions by R.S.

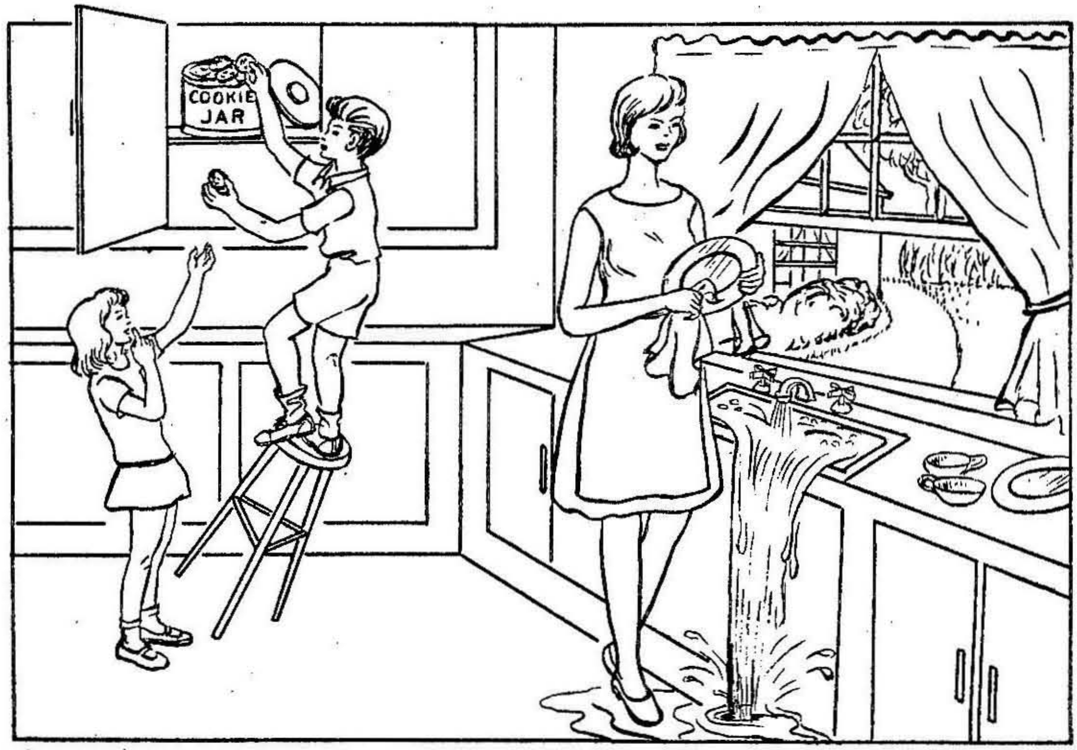


Figure 7. The Cookie Theft picture from the Boston Examination (Goodglass and Kaplan, 1972).

falling...it's a mess...dishes...falling, he's falling...the cookies... girl...there, can not see him...cug dishes...mother and... (E: "Mother is not paying attention to the children") mother is not paying attention...children...water." (Extensive questioning and pointing by examiner).

(12-19-72) "...a cookey this...i-it's flowing...(labored, protracted). (E: "What is it?") water, it's flowing...(protracted) (E: "What else? Tell me everything you can think of about this picture.") 'n da children...is going-down-here, but this (pointing), he's falling. That's all...shoun't put the...she's, I mean, should-have-listened-to-his (staccato), his mama, I mean, daddy... (E: "and while she's doing the dishes?") i - it's floating... (E: "What's he doing? What's going to happen to him?") he's gonna fall. (E: "And what is she doing?") have some cookies... (E: "she wants some cookies too. Can you think of anything else about the picture?") ...m-m...that's all. (E: "can you tell me anymore about the picture?") Those...

By way of comparison following is the response of a Broca's aphasic patient of Goodglass (1962) to the same picture: "Ah...little boy...cookies, pass...a...little boy... Tip, up...fall. Wipe dishes... ah, dishes, wipe... Water spill off."

Aside from the syntactic problems there is evidence in the above responses of failure to describe the scene in a semantically coherent and integrated fashion. Instead, only the component details of the scene are related in a fragmented fashion; they are ellicited only after extensive questioning and fail to impart the core of the scene. This may reflect a corresponding deficit of comprehension.

Sentence and phrase structure fragmentation rarely maintains skeletal noun-verb-object or agent-action-object structures and tends to split noun from verb phrases. Often one of the phrases -- typically the noun phrase -- is omitted. Split phrases may be accentualized by lack of agreement: "...the children...is going-down-here..." Verb omissions are rare since the verb usually accompanies either the noun or the object but they do occur occasionally as in the following description of a picture of a boy eating an apple: "...he...the who, this whole up".

Intonation is very good. Only very rarely is there evidence of dysrythmic speech with no intonational link as if words are enumerated rather than grouped syntactically, and then always in connection with a brief transitory dysarthria. As mentioned,good melodic line extends throughout the sentence and is not limited to stereotyped expression. In fact intonation serves a distinctive syntactic function in the speech of R.S. and renders its structure apparent and its meaning clear. The rating of melodic line in the Boston examination rating scale profile of speech characteristics is misleading because it rates melodic line only relative to fluency or phrase length. Literal paraphasias such as in substituting floating for "flowing" are very rare.

Naming. In visual confrontation just as in spontaneous speech and in normal conversation R.S. has frequent difficulty in elliciting the same words which she recognizes promptly when they are presented to her aurally and which refer to objects whose comprehension she can demonstrate by various non-verbal means. Often she substitutes a skill-ful, even subtle, pantomine or a nonlinguistic vocal imitation or singing in place of the unavailable name. In all cases there is general awareness of the deficit.

R.S.'s loss of lexical items -- especially object names -- may be labeled anomia. It is modality non-specific and is not a residual of sensory aphasia as Marie would have it. Words which can not be ellicited as names on request may appear spontaneously and respond to some cues -- notably sentence completion -- better than others. This suggests a retrieval rather than a storage deficit in the organization of the lexicon.

On Schuell's picture naming test (S.C.13) R.S. scored 6 errors out of 20 possible errors. In a characteristic manner all the erroneous responses and some of the initial answers to the other items constitute semantic associations (chair → "you sit", clock → "time", calendar → "month"). The semantic associate is, in fact, a distinguishing feature of R.S.'s naming responses, (25% association errors on this test) and these occasionally eventually led her to the correct answer (fork → "dinner" → "spoon" → "fork"). Further, the errors increase with decreased word frequency; this, however, being a common and general observation across aphasics (Howes, 1964).

There is also a notable lack of paraphasic responses.

Visual Confrontation Naming (G.III.H.), Body Part Naming (G.III.J) and Animal Naming (G.III.K) Tests afford a tentative classification of errors by semantic categories. The following classes are listed in order of increasing errors by R.S.: actions (running, dripping, smoking...) objects (chair, glove, hammock...), geometric forms (square, triangle...) letters and numbers (7, 1936, 700...). In contrast, Goodglass et al (1966) found that objects were the most difficult category for aphasics to name and letters the easiest. In fact Broca's aphasics showed no significant difference between the various semantic classes in their naming proficiency while Wernicke's and amnesic aphasics showed superior letter naming and inferior object naming. It should be noted that frequency was not strictly equated across classes in this test and separation between actions and objects exhibited here, may in particular be a frequency effect (mean frequency of the actions is higher than that of the objects).

A metalinguistic semantic analysis of the errors on numerous naming tests reveals the following pattern. The vast majority of erroneous naming responses are semantic associates. In the following list the main types of (semantic) responses are listed accompanied by illustrative examples (the more frequent response types occur first).

1. Responses of the same semantic class as the stimulus: chicken -> "gorilla"; binoculars -> "goggles"; ship -> "submarine"; strawberries -> "peaches". It is clear that on most occasions R.S. is unaware that these equi-class responses are incorrect. Only rarely do we find: grapes -> "plum, I mean pea... I can't say it." The general impression here is one of semantically diffuse lexical entry retrieval mechanisms. 2. Definition or illustration by attribute or use: airplane -> "you fly in the air"; toothbrush -> "brush your teeth". The attribute may take the form of a characteristic subpart of the intended word (car -> "motor") or it may be egocentric (potato -> "I eat the skin"), idiocyncratic or incidental and highly concrete (ironing board -> "we have some"; teacher -> "sing") (R.S. especially enjoys her singing lessons at school); fork -> "spotless, can see myself". On other occasions a concrete though characteristic semantic elaboration occurs: signal -> "go, stop, caution". This class of naming responses differs from the rest in that they are in fact appropriate and accompanied by recognition of deficit. 3. Superordinates: writing -> "study"; buckle -> "watch". 4. Paradigmatic responses: saddle -> "horse; key -> "lock"; net -> "fishes". 5. Syntagmatic responses: comb -> "brushing". 6. Finally there are occasional nonverbal responses: vocal (caboose -> "choo choo"; bird in cage -> "he's tweet, tweet, tweet") or motor (pointing, and mimicking. Only 3 out of 50 responses were admissions of incapacity: "I can't say it" or "oh, I don't know". There is only one questionable case of error due to phonetic confusion: pencil sharpener -> "fishing pole".

<u>Cueing effects on naming</u>. As a rule R.S. can select from an aurally presented list the word she is trying to find. This may be considered a limit case of phonetic cueing and probably has the same significance, namely, facilitating the activation of the accoustic representation of the word. Direct data from the Rochford -Williams (1962) and comparative analysis of various speech tests indicate that cues can be listed in the following order of decreased effectiveness

in eliciting names: phonemic cueing (rhyming), sentence completion (especially in stereotypic phrases), definition or description by use, and spelling. Correspondingly there is progressively decreasing facility from repetition tasks through tasks requiring response to description by function or attribute, answering questions involving specific facts, to picture naming.

Responsive speech to verbal stimuli. In general the more pragmatically restricted or linguistically pre-specified is the response the more likely is R.S. to respond adequately to a given question. Her answers to simple questions (S.C.8) though usually in the form of incomplete sentences or phrases, nevertheless communicate satisfactory responses: "what do you eat with?" -- "a knife, fork, cup, hand". Performance is adequate since the questions used in this test are simple and short, they require a one-word response and supply a high strength association with the word to be elicited.

The word definition test, however, (S.C. 14) presents more difficulty. As a rule her responses were correct associations or egocentric examples but not definitions: apple -> "you eat"; bridge -> "cross over the bridge". There occurs then a spontaneous diffuse enrichment of the semantic context but an inability to narrow it down linguistically under normal communication constraints. When she does succeed in producing a sentence using a prescribed word, R.S. usually constrains herself by placing the stimulus word at the beginning of the sentence: "after" -> "after we bought clothes we take it home".

Further enrichment and complexity of the semantic domain aggravates rather than facilitates responsive speech. In response to a paragraph read to her about the nature of quicksand (S.C.15) R.S. responded with the following description: "Quicksand is ground...you can sink in it (correct)...you and me..." Neither is this simply a reflection of memory deficit since a similar deficiency occurs in describing a meaningful picture (S.C.12) in which the stimulus is constantly available.

Sentence completion and automatized sequences. Sentence completion as measured by (S.C.7) is virtually intact. It must be attributed not only to the fact that the sentences provide frames in which the response to be elicited has a high probability of occurence, but also because the sentences constitute common and stereotyped patterns ("the grass is"...green; "please pass the salt and..." pepper). Furthermore, sentence completion, as opposed to, say, answering simple questions requires no sentential syntactic transformation from interrogative to declarative and hence is a little easier for aphasic subjects in general (Schuell, 1965).

Indeed automatized linguistic sequences are least impaired of all of R.S.'s language functions relative to the aphasic population of Goodglass (1972). Her performance was perfect, in fact superior to D.W.'s (the case of nondominant hemispherectomy), on tests of counting aloud to 20 (S.C.5; G.III.B.3), naming the days of the week (S.C.6; G.III.B.1), reciting the alphabet (G.III.B.4) and (with one omission) reciting the months of the year (G.III.B.2). The association of automatized language competence with the right hemisphere was, of course, first espoused by Jackson and has since been confirmed (Smith, 1966).

Another context which facilitates speech is introduced by recitation of nursery rhymes initiated by the examiner (G.III.C.1 - perfect score). Likewise singing facilitates articulatory speech dramatically for the same material which could not be elicited in normal speech. Singing ability has long been associated with the right hemisphere (Gordon, 1972) and the selective preservation of words with song was also noted in Smith following dominant hemispherectomy (1966). In this isolated respect R.S. is much like a transcortical aphasic (Brown, 1972). The ability to repeat rhythms, on the other hand, is impaired in R.S. but not in D.W. thus supporting the dissociation between melody and rhythm with right and bilateral specialization respectively (Gordon, 1972). Perseverations were particularly frequent in the form of appendages to the correct patterns.

Like repetition, the ability to recite a memorized sequence represents the operation of an elementary sensori-motor skill of spoken language with minimal semantic components -- receptive or expressive. Stereotypes and expletives which are also associated with right hemisphere language capacity involve strong and ontogenically primitive affective semantic components.

Repetition. Repetition of monosyllables (S.C.B) in R.S. is perfect and of words in general (G.III.D)-virtually intact. Repetition of short common phrases, none longer than three words with mean of 3.5 syllables per phrase, is still very good (S.C.4). The words used in this monosyllabic repetition task are phonetically edited and the data show no articulation disability due to a gross speech musculature defect. Successful performance on the short phrases demonstrates that disintegrated articulation is not the cause of speech non-fluency. However, when the phrases increase in length and difficulty R.S.'s performance deteriorates (G.III.E).

The phrase repetition test in the Boston Examination is divided into two separately scored sets of sentences, differing in vocabulary difficulty and predictability of the verbal content and refered to as "high probability", and "low probability" sentences. R.S.'s performance disintegrates on low probability sentences containing 4 or more words, and on high probability sentences containing 6 or more words. More words were recalled correctly in repeating high probability than low probability sentences (46% vs. 25% respectively). Simple omission errors (especially of final and initial segments of the stimulus sentence) in the easier sentences give way to increasing semantic confusions in the more difficult sentence: "near the table in the dining room" -> "near the dining room"; "I stopped at his front door and rang the bell" -> "I knocked on the front door"; "The barn swallow captured a plump worm" ->"I like worms". In general the responses form a semantic unit which is itself associated but not identical with the meaning of the original sentence.

Consistent findings emerge from a syntactically diagnostic repetition task (Boston Examination Supplementary Language Tests) of conditional sentences and of alternately indicative and interrogative sentential forms. Occasional syntactic errors occur ("Stay home if it rains" -> "Stay home if <u>its</u> rains"; "He sells cars" -> "He sells ca<u>r</u>") although considerable number of sentences are also repeated correctly.

But the most common response consists in a complete or partial semantic reaction to the sentence instead of repetition. This can not be attributed to failure to comprehend the nature of the task since such semantic perseverations are interspersed with correct repetitions or trail a complete or partial correct repetition of the stimulus sentence: "He is very rich" -> "He is very rich, money"; "she ought to go" -> "she ought to go; where, any place?"; "If she cries, feed her" -> "If he feeds her, let her feed her". In the last example the semantic paraphasia is superimposed on a severe agrammatic distortion. Repetition is replaced completely by a semantic reaction in the following sentence: "If it rains, stay home" -> "That's right stay home". Semantic perseveration from previous sentences occurs as well. Thus following a sentence "If he moves shoot" which R.S. repeated correctly, she responded to "Feed her if she cries" by "Feed her if she dies...I mean, feed her if..."

Clearly there is a deficit in R.S.'s ability to manipulate sentences on a metalinguistic level (i.e. immitate from a modal with disregard for meaning) together with a strong propensity to react semantically to the sentence, while presupposing a natural communicative context. Following Goldstein (1948) it is possible to regard the syndrome as failure of the abstract attitute. Alternatively, Luria might attribute it to failure of the regulative function of speech (1970). But the theoretical account postulated here instead, interprets the behavior as characteristic right hemisphere language competence rather than as evidence of pathology.

Variability and improvement in naming and speech responses. Short term test-retest reliability in aphasics is notoriously low.

And so it is in R.S. In response to the question "what do you do with a razor?" for example (S.C.8), R.S. said "raise your hand" which may be regarded as a receptive (inverse) neologism. But exactly the same question occurs also in another test (G.III.G) administered a month later. This time R.S. could not ellicit the name but like the classical anomic made shaving motions with her hand next to her cheek.

Naming responses of R.S. are variable from session to session and are apparently very sensitive to the subtle aspects of the task, especially to its pragmatic context. She had scored only 1 out of 8 errors on Schuell's Answering Simple Questions test (S.C.8: "what do you do with...") but 4 out of 10 errors in the apparently equivalent Responsive Naming test (G.III.G). More errors occured on items of the form "what do you (V) a (N) with?" (what do you cut a paper with?") than on the apparently less difficult form "what do you do with a (N)?" ("what do you do with a scissors?")

In phrase repetition (G.III.E), the response deficit, on the other hand, is not semantically sensitive but seems to reflect pre-motor sentence structuration and short term verbal memory. Here, therefore, the disintegration occurs at remarkably stable limits of phrase length (5 words). Thus the same breakdown point occured at three different testing occasions on 8-72, 10-72 and 2-73.

By contrast a gradual <u>long term</u> improvement in the speech responses of R.S. is noticeable. A retest of the Naming Pictures test (S.C.13) on 2-8-73, six months following the original administration, shows a 50% reduction in the number of errors. There is a clear trend for acquisition of naming on items with higher frequency. In fact all the errors which persisted on retest have also occured originally and are all limited to the lowest frequency category (words occuring among the 5 through 10 thousand most commonly used words in the English language according to the Thorndike-Lorge count, 1944). Even the errors, however, show an improvement in the form of narrowing of the semantic domain. For example, the picture of a horseshoe which had originally ellicited the response "cow" has on retest given way to the response "donkey". This indicates continuing acquisition of speech by the right hemisphere.

Even more impressive is the improvement in the ability to produce sentences containing words of various syntactic classes. On 2-8-73 R.S. was able to produce 4 out of 6 sentences correctly as compared with 1 out of 6 on 9-17-72. Nevertheless, there is still a tendency to produce phrases rather than complete sentences and there is a persisting semantic perseveration.

Similarly the Word Definition test (S.C.14) score improved from 3 to 5½ points out of ten (Table 1). Again there is a consistent improvement in the semantic "distance" of the response across the items in an otherwise surprisingly consistent response pattern from test to retest. For example the word robin which triggered the response "robin hood" on September '72 ellicited the correct response "bird" on February '73; "history" yielded "read science" at first and "you're studying" later; "material" yielded "you iron" which gave way to "yarn". In particular there occurs a progression from equiclass semantic associates to examples of attributes, and from description by attribute to naming of specific examples, as well as general elaboration and sharpening of the responses.

Table 1

Responses to the Minnesota Word Definition Test (S.C.14)

item	response on Test 9-18-72	response on Retest 2-8-73
Robin	Robin hood	bird
Apple	you ate	apple a day keeps the doctor away
Return	you give it back to me	return it back
Different	-	like your face (?)
Bridge	cross over the bridge	cross the bridge
Continue	continue on	continue on
History	read science	you're studying
Material	you iron	yarn
Decide	decide on it	I decide if you're going
Opinion	you'll see	("I don't know")

R.S.'s ability to use appropriate syntactic constructions in self-initiated speech has been improving gradually in the past 2-3 years. Some recent examples are, "Mother, put me to bed. My legs hurt very much"; "Is dinner ready?"; "I am looking at the catalog"; "Hi Sheri, how are you?"; "say 'excuse me'"; "you wanted it"; "what are we having for dinner?" (February, 1973). It will be noted that these are mainly common or stereotyped expressions.

READING, WRITING AND ARITHMETIC

Reading. Reading and writing are the least developed language functions in R.S. But it is not clear to what extent the loss is congenital or acquired. Prior to initial surgery at age 8 R.S. is said to have been able to read and write. But learning retardation had apparently necessitated her repeating first grade. Following the left-intraventricular tumor removal and before hemispherectomy R.S. is also said to have maintained reading and writing abilities with some spelling difficulty which responded to phonetic cueing. At any rate her reading level prior to hemidecortication can be assumed to have been at the second grade level at best. Her current level is substantially lower. More significantly, however, she has lost phonetic spelling and her limited reading vocabulary consists of words she recognizes on sight, gestalt-fashion. This change in competence as well as in response to cueing strategies is attributable to postsurgical right hemisphere takeover of reading functions before the maturation of phonetic reading strategies.

R.S. can match letters (S.B.2) as well as geometric forms (S.B.1) without error, but must do so by pattern matching since she is in general unable to match the same letters in upper and lower case (G.IV.A). Both on matching words to pictures (S.B.3) and matching printed to spoken words (S.B.4) auditory confusions predominate over visual ones. This is in contrast to D.W. whose visual errors predominate. Furthermore, R.S. scored 14 out of 32 errors (16 = chance) on matching words to pictures but only 8 out of 32 errors on matching printed to spoken words.

Thus it would tentatively seem that the auditory pattern facilitates reading in R.S. better than the corresponding picture. R.S. is similarly deficient on a task of word-picture matching (G.IV.C 4 out of 10 correct). A plausible explanation is that in R.S. the aural word as a rule evokes pictorial images and thus the availability of the acoustic pattern introduces additional cues which are otherwise lacking in the word-picture paradigm due to expressive aphasia. It is also possible that the association of visual spelling pattern with lexical item was learned in the context of spoken words rather than pictures of the referents which in turn tend to be manipulated nonverbally in the minor hemisphere. At any rate a phonetic mediation in reading is indicated! This does not extend to oral spelling and "no" is the only word so identified by R.S. (G.IV.2).

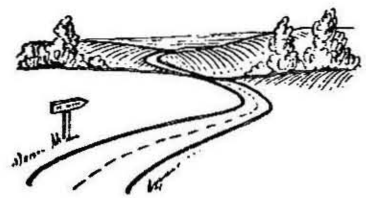
R.S. can not read sentences or paragraphs (S.B.5, S.B.7; G.IV.D). In summary, then, it would seem that R.S. has an extremely limited and somewhat idiocyncratic sight vocabulary which is associated with the acoustic image of the word but not with its detailed phonetic structure.

Contrast of reading in R.S. with reading in the disconnected right hemisphere. The virtually complete alexia in R.S. is in contrast to a substantial (though selective) reading vocabulary in the right hemisphere of N.G. and L.B. For example, on the Minnesota Matching-Words-To-Pictures Test (S.B.3) N.G. scored 27 out of 32 items correct and L.B. scored all 32 items correct in LVF-L/h CLVP (figure 3). Each item includes a picture with two words under it (figure 8a) and the patient is required to point to the correct word. Thus the stimuli are completely lateralized. Curiously enough of the five errors made by N.G. three were auditory ones (e.g. "buy" for "lie") and one was semantic ("street" for "road") but none were visual (as between "house" and "horse").

Rather unexpectly, the performance of both commissurotomy patients in LVF-L/h CLVP on a test of matching printed to spoken words (S.C. 4; figure 8b) was inferior to the picture matching one in contrast to the pattern in R.S. The same word pairs were used in both tests. This time N.G. scored 7 out of 32 errors (with 2 semantic errors, two auditory confusions and three visual ones!) and L.B. 5 errors out of 32 (one auditory confusion, one irrelevant response and three visual confusions). Relatively inferior right hemisphere performance on the visual-aural word match task may be attributable to left hemisphere interference invoked by the access it had to the auditory stimulus. A more intriguing possibility is that the disconnected right hemisphere mediates its linguistic functions by pictorial representations and thus invokes one less step in the visual-visual match than in the visual-aural match; namely, the step of decoding the aural word into a picture. Visual confusions are natural but auditory ones which also occur in R.S. indicate that right hemisphere reading may involve a pre-vocal phonetic component. But the reversal of error patterns on matching printed to spoken words between N.G. and L.B. and between R.S. suggests different strategies; R.S.'s being the less stable and systematic one.

b. write light store stone

a.



hear bear road street

Figure 8

Sample items from the Minnesota Matching Words to Pictures Test (a), and Matching Printed to Spoken Words Test (b). The two top items illustrate potential auditory (left) and visual (right) confusions; the two bottom ones represent visual (left) and semantic (right) confusions.

The disconnected right hemisphere can also match letters and words in various scripts (upper and lower case, block letters, script in various styles etc.) (G.IV.A; N.G. 8 out of 10 correct, L.B. 9 out of 10 correct) resisting incorrect perceptual similarities.

When required to point out one of 5 lateralized printed words corresponding to the one given orally by the examiner (G.IV.B) the right hemisphere of both N.G. (5 out of 8) and L.B. (5 correct out of 8) has more difficulty than in choosing one of a pair of such words (S.C.4 above) thus exhibiting a limited processing capacity well below left hemisphere reading. Similarly, the word-picture matching task in the Boston Examination (G.IV.C) yields lower scores (N.G. 3 out of 10 correct; L.B. 8 out of 10 correct) than the corresponding test in the Minnesota battery since the number of possible alternative solutions (pictures) is much larger.

Indeed the visual displays in the Boston Word-Picture matching task consists of three semantic categories including 6 items each, all grouped on one card and having no further relationship to each other. Consequently it seems that the need to choose between all the disconnected alternatives presents difficulty to the right hemisphere. On the other hand when the right hemisphere is required to match a printed word with the corresponding object in semantically complex but meaningful picture (returning-home scene items II.6 - II.10 in the Sklar Aphasia Scale) its performance is near perfect. Both N.G. and L.B. could also select from three printed alternatives the antonym to a given printed word (man-woman; happy-sad; good-bad; white-black; deep-shallow; Sklar's Opposites Test). Thus the disconnected right hemisphere has the ability to form sophisticated semantic transformations of completely lateralized printed lexical items.

N.G. and L.B. could also match some but not all printed verbs with a picture of the corresponding action. Thus N.G. could consistently read "smile", "sleep", "chop" and "squeeze" but not "wave", "spray", "bend" or "blow". L.B. could match with the correct picture the verbs "snap" "blow", "smile" and "sleep" as well as "break", "cut", "spray" and "blow" but not "wave", "squeeze", and "frown" nor "chop" and "bend". L.B. could also perform an action in response to a printed verb such as "tap", "point", "grin" and "rub" without being able to verbalize it correctly. On many other occasions he could verbalize the verb only after he performed the action, reportedly using kinesthetic feedback, and on still others he traced the letters with his left index finger and then verbalized the verbs. The precise limit of the capacity to comprehend and perform actions in response to verbs is still not known; neither is it clear that deficits when they occur are due to the nature of verbs qua verbs.

Finally, neither N.G. nor L.B. show evidence for a systematic ability to read sentences (G.IV.D). L.B., however, can read various short sentences and even perform actions in response to them. But the limits and nature of this capacity also remain to be found.

The above findings were described in some detail since they extend and revise previously established limits on the reading ability of the right hemisphere (Sperry, Gazzaniga and Bogen, 1969). The reading superiority of the disconnected right hemisphere in N.G. and L.B. to the isolated right hemisphere in R.S. suggests that the right hemisphere cannot acquire reading skills by itself but that it can learn to read a substantial vocabulary when allowed free interhemispheric communication with the left during and/or after reading acquisition. Furthermore, severe dyslexia in a boy who had undergone nondominant hemispherectomy at age 7 (D.W.) but not in a case of an adult nondominant hemispherectomy (G.E., see Part III of the thesis) suggests that the right hemisphere may play an active role in reading acquisition in the intact brain.

Writing. R.S. can reproduce letters quite well both in lower and upper case (S.D.4) (figure 9, p.78) but she can not reliably write letters to dictation (S.D.5; G.V.2a) (figure 10). Errors are mostly bizzare: t for h, w for c, u for b, a for r, etc. R.S. could not write the complete alphabet although she could recite it (G.V.B1) (see figure 12). She copies sentences laboriously and with great difficulty. Frequent false starts and omissions occur (G.V.A3) (figure 11c). Copying her house address is only slightly superior to spontaneous writing of it. Writing to dictation fails already at the lexical level. But the bizzare errors (key -> mole; chair -> denl; girl -> mou; letter -> mile; learn -> wina, etc.) verify that there is no phonetic element in her spelling. The few lexical items which can be read correctly are in fact, memorized as visual patterns. Consequently we find the rare writing of "DAD" for man. Thus, on a letter naming task (G.III.H) R.S. read "love" for L and "go" for G, and she responded orally with "spells my words (name)" to "R" and with "Joan Francine Sturges" to "S" or "Billy Goat" for "G". Thus even the distinction between written lexical

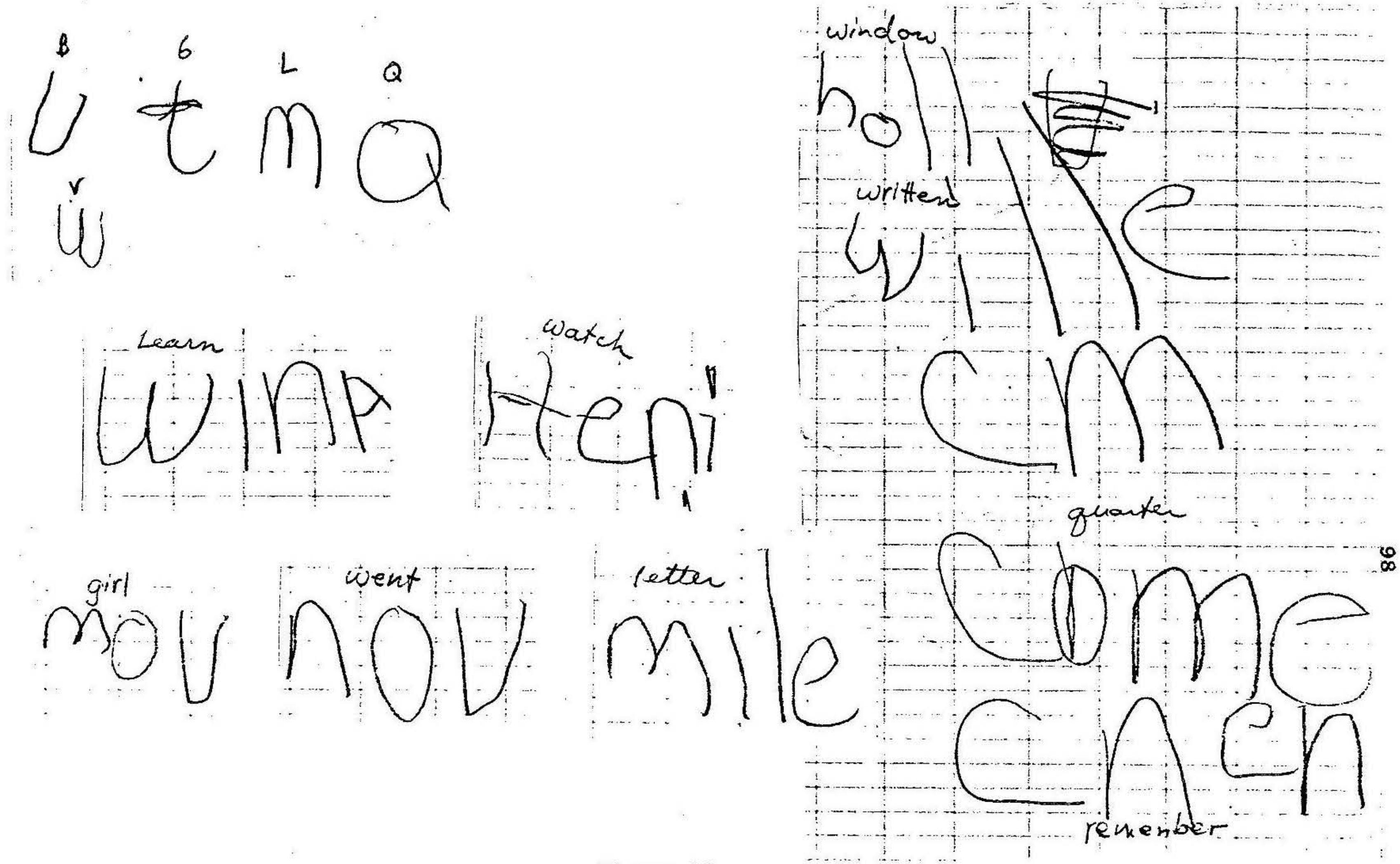


Figure 10
Letters and words spelled to dictation by R.S. Aural stimuli indicated above responses.

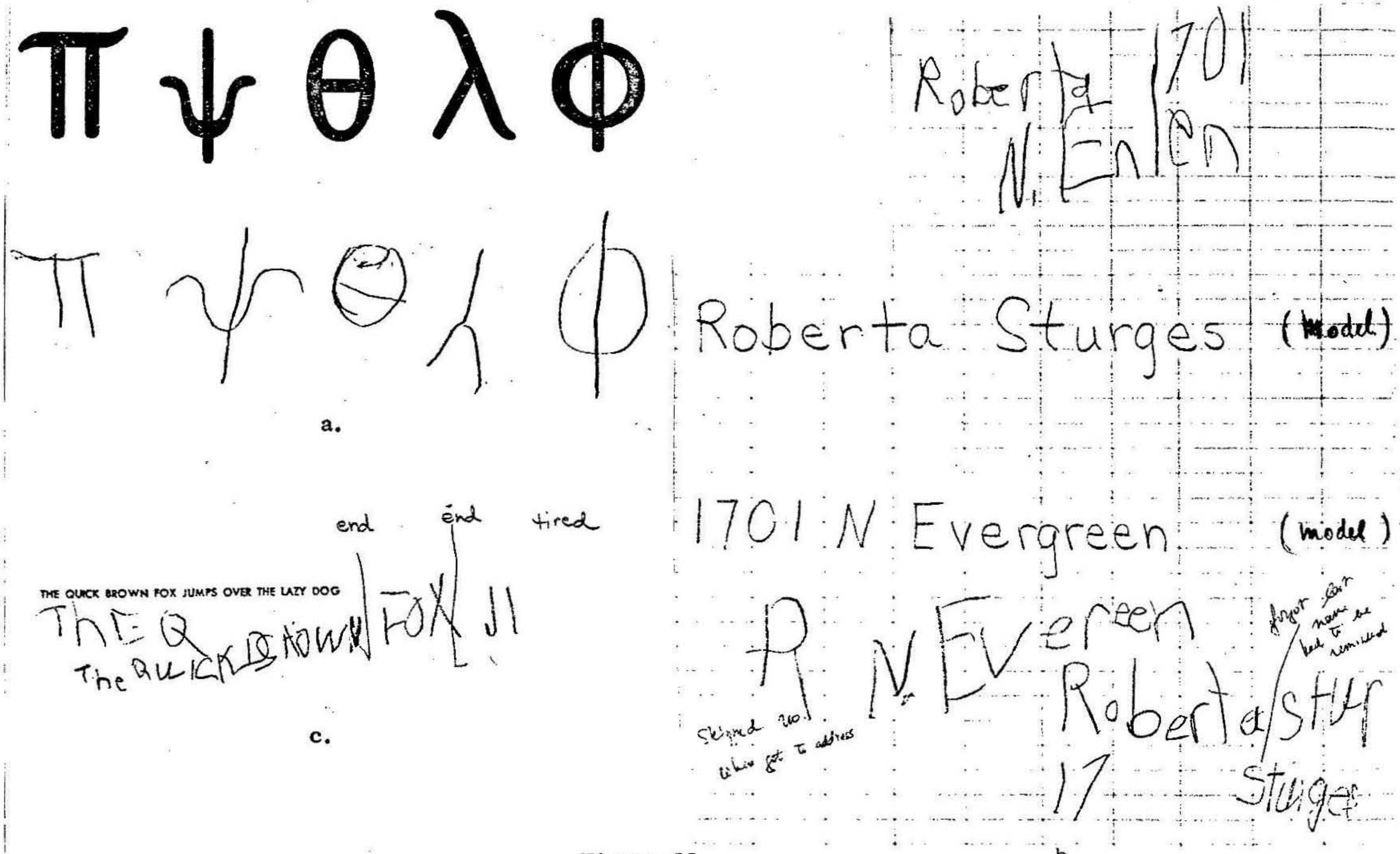


Figure 11

Sample writings of R.S. a. copying greek letters from model (top). b. writing her name and address spontaneously (top) and copying from model (bottom). c. copying a sentence.

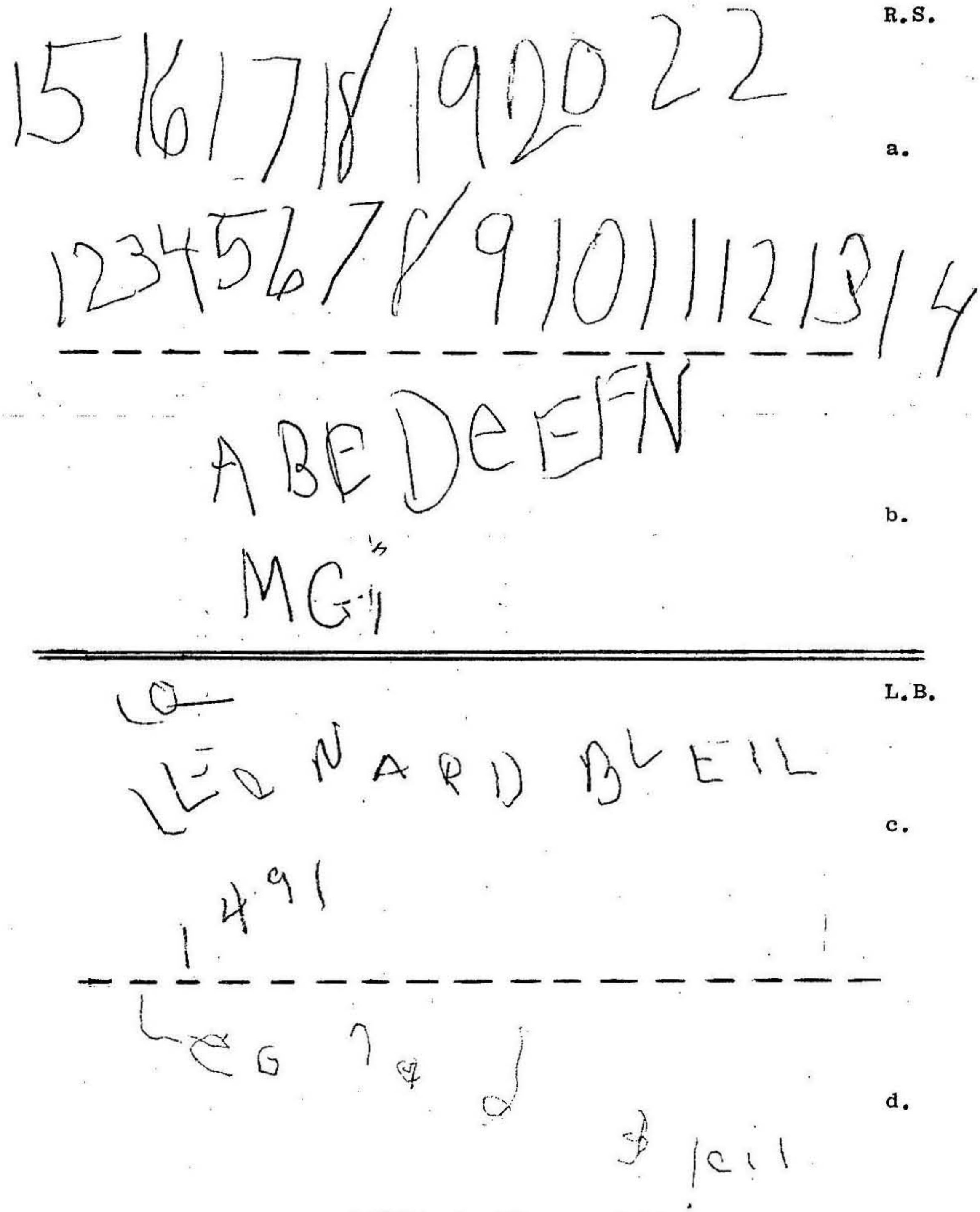


Figure 12. a. R.S.'s response to "write the numbers from 1 to 21"; b. R.S.'s response to "write the alphabet; c. L.B.'s copy of his name and address in LVF-L/h CLVP; d. L.B.'s spontaneous writing of his name in response to printed instruction "write your name and address" in LVF-L/h CLVP.

items and graphemes is not present in as much the letters are simply clues to the visual pattern of the words.

Sentence copying ability is comparable in R.S. and in N.G. and L.B. in LVF-L/h CLVP. Writing ability in the disconnected right hemisphere of L.B. -- although not in N.G. -- is far superior to that of R.S. In LVF-L/h CLVP L.B. can write the names of a variety of objects, actions, as well as concepts (e.g. "running") presented pictorially. He can even write short sentences (e.g. "The boat in the water") and figure 12d illustrates his correct written response to the lateralized written instruction "Write your name and address" which he could not verbalize either during or following his response. Figure 12c illustrates L.B.'s copy of his name and address from a lateralized model in LVF-L/h CLVP. He could not verbalize his own copied name until after spelling his last name which he then recognized through kinesthetic feedback. Spontaneous writing controlled by L.B.'s right hemisphere occurs both in capitals and lower case letters.

Number concepts. In spite of extensive tutoring at school R.S. can only add some small numbers under 10 (3+2; 5+5) by counting, usually on her fingers, and she seems to have grasped the rules for addition (11+8=19, but not 14+13). But even for digits under 10 she sometimes assigns the wrong notation to an intended verbal numerical referent as in consistently writing 7 for 8. She could not subtract 8-5, 8-3 or 7-4 (S.E.3) and apparently has no conception of the meaning or procedures of multiplication and division. There is a small residual ability to point to aurally presented numbers by choosing one out of six alternatives presented visually and simultaneously (G.II.A). Even though all aurally presented numbers were matched with the correct picture category (numbers as opposed to objects, letters, geometric forms, actions and colors) only "7", "42" and "7000" were correctly identified out of "7", "42", "700", "1936", "15" and "7000". In an analogous naming test using the same pictorial stimuli R.S. could not name any one of the numbers (G.III.H); she could only ellicit "one,five" to 15. Neither could she write any of the same numbers to dictation (G.V.B.2.6). Thus in response to "193" presented aurally she wrote 151; for 1865 she wrote 1414; for 42 she wrote 005; and for 7 she wrote 123.

R.S. can recite the numbers from 1 to 21 faultlessly (G.III.B3) and even write them (1-20) down correctly in sequence (S.D.2). But this must be regarded as an automatized sequence learning with no functional significance. R.S. can recite her address and phone number but does not retain facts about dates (S.C.9) or time information beyond highly stereotyped patterns (sleep time, etc.). She can not designate prescribed times on a clock face (S.E.2; Boston Examination Supplementary Nonlanguage Tests) and she can not be counted on to make change reliably for any but the simplest combinations (change for a dime, quarter vs. coins S.E.1).

Finger agnosia. Table 1 shows the performance of R.S. on an extensive finger agnosia battery included in the Boston Examination Supplementary Nonlanguage Tests. The data record a finger agnosia deficit centering on but not limited to the linguistic labeling component. The verbal part includes both comprehension and naming tasks and as is to be expected the naming deficit is particularly severe.

Table 1

Finger Agnosia in R.S. (Boston Examination- Suppl. Non Language)

		# correct (max. score)	% correct	weighted
A. Verbal	1. Comprehension a. picture hand	20(32)	62.5	51.25%
	b. own hand	10(16)	62.5	
	2. Finger Naming	11(32)	35.93	
B. Visual-Visual				61.18%
	1. paired fingers identif.	12(20)	60	70%
	2. matching 2 finger positions	16(20)	80	81.25
C. Tactile-Visual		24(32)	75	75%

Finger agnosia (especially bilateral) most commonly follows left hemisphere lesions. Benton (1959) does not recognize a direct relation between the finger schema and the dominant hemisphere; the great importance of left lesions in performance of finger identification is due, according to him, solely to the relation which exists between the major hemisphere and symbolization. This is supported by the results obtained here especially if symbolization is interpreted strictly to mean linguistic labeling. Indeed D.W.'s performance on the same task is strikingly superior to R.S.'s at 97% correct responses if left (hemiplegic) hand score is not included (the two single errors occuring on the visual-visual task!) or 91% even if left hand performance is included.

THEORETICAL APHASIOLOGICAL ANALYSIS

R.S. as an anomic aphasic. The word finding difficulty of R.S. resembles in part a relatively mild form of classical anomia. Typically the anomic aphasic like R.S. will recognize immediately the name which he had been unable to produce. Similarly the anomia is modality non-specific, and in spontaneous speech it is not confined to the names of physical stimuli but also involves abstract nouns and adjectives and other parts of speech (Wepman et al, 1956).

However, word finding difficulties in spontaneous speech of anomics is extreme for substantive words as against grammatical words while the reverse is correct for R.S. Indeed, word finding difficulty in R.S. is not selective, it is not limited to low frequency high information words. In fact during ongoing speech characteristic responses consist of semantically specific, highly informative substantives. Similarly, in marked contrast to classical anomia the spontaneous speech production of R.S. is not fluent and paraphasic. There is no trace of neologistic distortion or literal paraphasia and verbal paraphasia is extremely rare ("the water is floating"). Running speech includes no English or neologistic jargon.

R.S. does not deny her naming difficulty as some anomics do. She recognizes her inability and usually says "I can't say it" -- or "I know it but I can't say it" and concurrently she would often exhibit strained facial and postural efforts as if trying to ellicit the name by physical force. Since errors are most often "semantically appropriate" there is none of the standard excuses that the classical anomic offers for his errors. This may illustrate a significant component of right hemisphere cognition, namely, the recognition of errors. It was noted by McFie and Piercey (1952) that right frontal lesions impair the ability to correct errors in the face of contradictory information and it has been demonstrated repeatedly that the commissurotomy patients were able to recognize their own erroneous responses when tested with CLVP under left visual field exposure.

There is, however, a curious aspect to R.S.'s self awareness. Her parents report that following surgery and during acute illness she would tend to identify herself with her sister. Today she still confuses her name with her sister's occasionally. But she will then eventually realize her mistake and go on to correct herself. Furthermore she will never respond when her sister is called.

A relatively strong deficit in color naming in R.S. suggests analogy with left posterior lesions and yet the less severe impairment of object names than of body parts argues against an analogy with posterior localization (Nielsen, 1946). Similarly, relative superiority on object vs. action naming varies within the anomic aphasics themselves and thus has no special diagnostic localizationist significance.

Absence of paraphasia. In terms of differential diagnosis and localization analogies the semantic naming response pattern of R.S. comes closest to a posterior anomia. Yet, according to Kaplan (1970, cited in Brown, 1972, p. 23) occasional verbal paraphasias occur in the naming responses of both temporal and parietal anomics which remain in the appropriate semantic "field" and are accepted or rejected by the patient according to their closeness to the target word. The pattern here is not consistent with R.S.'s naming responses. In fact, the absence of paraphasia in responsive and ongoing speech is precisely what distinguishes R.S.'s symptoms from classical anomia.

Luria (1970, p. 293) accounts for verbal paraphasia in terms of an unstable or diffuse auditory image of the word. But the naming responses of R.S. are as a rule semantic associates rather than phonemic distortions or neologistic jargon. They also often occur as semantic perseverations. Certainly, perception of the accoustic signal is stable enough to interpret correctly the meaning of input messages. Indeed auditory-phonetic cues (rhyming) do facilitate naming. Thus the disorder in R.S. may be interpreted as a one way dissociation of the semantic and auditory representations of the lexical item so that the semantic reference is not able to ellicit the name.

R.S. as a Broca's aphasic. The presenting symptoms of ongoing speech in R.S. resemble a mild to moderate form of Broca's aphasia. Responses tend to the one-word utterances: "yes", "no", or a substantive noun. When longer phrases are produced they are "telegraphic", fragmentary and include many syntactic simplifications and occasional dropping of inflections. Unsolicited nominalizations, also occur and there is a sparsity of function words. The tendency of R.S. to simplify sentences to holophrastic utterances of the subject-verb-object type, to omit or substitute articles, prepositions and personal pronouns, and to omit subordinate clauses is characteristic of agrammatism as described by Goodglass (1968). Yet in contrast to motor aphasia, in which loss of the predicative aspect of speech underlies the majority of errors, one does not observe in R.S. the reduction of sentences to strings of unrelated nouns. Instead, from a syntactic point of view there is confusion of similar grammatical constructions and, in general, simplification of grammatical sentence structure. Indeed, R.S. occasionally includes function words of various classes in her phrases and unlike the typical agrammatic patient her intonation and melody are excellent.

In connection with the nominative function of the speech of motor sphasics Luria (1970, p. 294) notes that only in cases involving massive lesions or in the early phases of cases involving efferent motor (Broca's) aphasia is the spontaneous recall of names apt to be more difficult than simply repeating the same words presented orally. Yet this is the case in R.S. three years postoperatively.

CONCLUSION

On the basis of the preceding data it seems that while structures for semantic analysis of input speech signals by the isolated right hemisphere of R.S. are superior to structures for the syntactic formulation of output speech, it is still true that comprehension of complex linguistic material is severely impaired.

The speech deficit is in pre-motor sentence programming rather than in articulation. But there is no evidence for an intra-hemispheric disconnection syndrome between variously localized language processing centers (Gott, 1973), even if such a questionable connectionist model of neurolinguistic functions (Geschwind, 1965) were tenable. Rather, the dataare consistent with hypothesizing functionally undeveloped speech programming mechanisms.

Too little is known about the actual stages of neurolinguistic processing during the speech act to be able to pinpoint the impaired stages of speech synthesis in R.S. But intact, automatized speech sequencing and well articulated singing with words lead to the conjecture that the deficit is in a pre-articulatory phase and involves at least two subsequent processing stages: (i) weak lexical unit retrieval mechanisms and (ii) incompetence of syntactic sentence structuration which is circumvented only by using stylized expressions or multiple cueing of the various components of the response. The representation at these stages is probably pre-acoustic as there occur no phonetic paraphrasias in speech and phonetic cueing is less useful than sentence completion; it is strongly semantic since it most frequently eventuates in semantic errors.

The failure of the presenting symptoms of R.S. to coincide with unitary classical aphasic syndromes supports the following conclusion: The right hemisphere -- when disconnected or isolated (after infancy) -- internalizes a unique set of linguistic mechanism quite different from those of the left hemisphere of either a child or an adult. These linguistic mechanisms, are based in turn on the perceptuo-cognitive structures which characterize right hemisphere mentation in normal states of cerebral dominance. Here, it is quite likely that semantic information is represented pictorially or by some other perceptually-based structures. The right hemisphere undoubtedly has extensive ability to manipulate meanings, especially through nonlinguistic channels, by a characteristically fast and diffuse parallel-like process. The right hemisphere would seem to possess limited, afferent peripheral motor control and its "natural" communication may be largely sensory and intercortical or transcortical rather than motor.

The time course of the speech deficit in R.S. therefore reflects the gradual acquisition of expressive capacities, i.e. the construction of newly developed speech functions, on the basis of old and established, largely receptive ones. In any case there is an obvious need for a longitudenal study of the pattern of improvement of speech functions in R.S.

As we would expect some metalinguistic variables such as frequency show the same effects on the speech of R.S. as on that of left hemisphere aphasics (in both cases word finding difficulty increases for low frequency words) or children. This does not refute the hypothesis that the underlying linguistic structures are different in both cases. At any rate a frequency dependency of the speech of R.S. is consistent with a perceptually organized semantic structure in the right hemisphere.

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III. LATERALITY EFFECTS IN PSYCHOLINGUISTIC ABILITIES - OUTLINE

III. LATERALITY EFFECTS IN PSYCHOLINGUISTIC ABILITIES

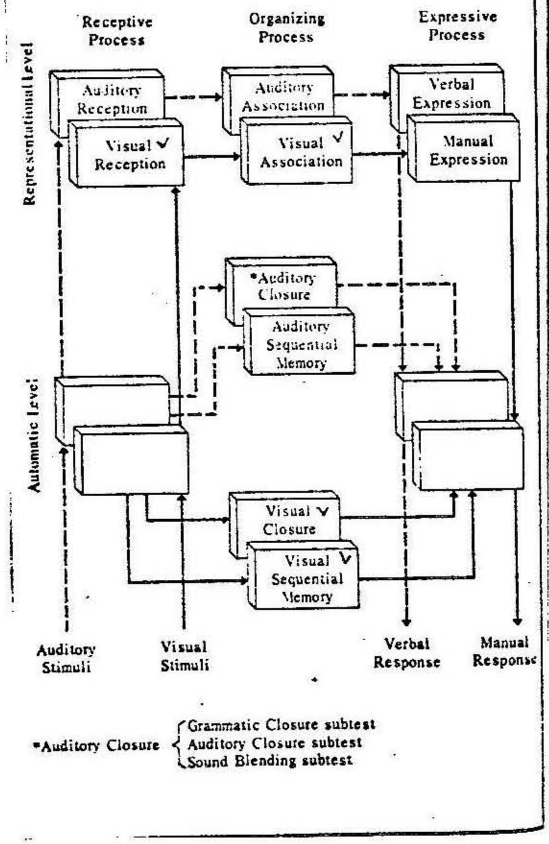
1. INTRODUCTION TO THE ILLINOIS TEST OF PSYCHOLINGUISTIC ABILITIES

The Illinois Test of Psycholinguistic Abilities (ITPA) was originally designed as a comprehensive diagnostic test of language and related perceptual abilities for children.

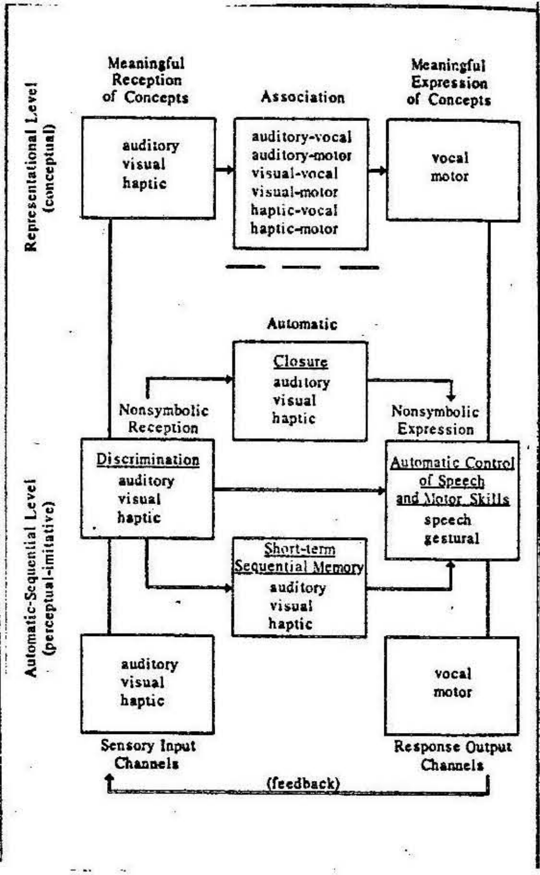
THE ITPA MODEL

Figure 1 illustrates the communication model presupposed by the ITPA (Kirk and Kirk, 1972). It includes three dimensions. Two input-output modalities define the channels of communication: the visual-motor vs. the auditory-vocal. Three main processes are considered in analyzing language acquisition and use. First, the receptive processes; second, a central organizing process; and third, the expressive process. Finally two levels of organization of communication habits are postulated. The representational level involves complex mediating processes of using symbols which carry meaning. The automatic level, on the other hand, includes communication behavior requiring less voluntary but highly organized and integrated patterns.

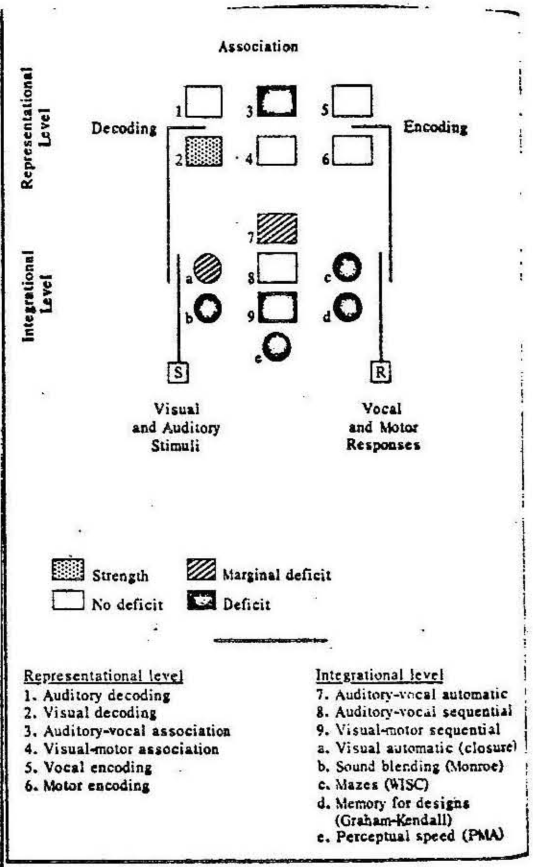
Level analysis as postulated by the ITPA model is rather tenuous and problematic. In particular, the automatic level functions of the ITPA include a much bigger constructive component than tests considered automatic in standardized aphasia batteries. The ITPA model was directly influenced by C. Osgood's behavioral model of the



Clinical model of the ITPA



Clinical model of the communication process



Clinical model of reading processes

Figure 1 Models of the ITPA

communication process which hypothesized the same 3-dimensions: processes (decoding, association and encoding); levels of organization (projection, integration and representation); and channals of communication (Osgood, 1957a, 1957b).

It should be pointed out that the ITPA is applicable to children whose mental levels are between two and a half and nine and a half years of age,not children over the chronological age of ten. However, since the mean psycholinguistic age of all the patients except L.B. falls under 10 it is valid to compare the distribution of subtest scores in the same individual or group of individuals.

The subsequent analysis of unilateral hemispheric performance in the form of the ITPA profile provides a direct test of the developmental hypothesis of right hemisphere language competence -- the analog of the regression hypothesis in aphasia. In its strict form the hypothesis predicts that the level of linguistic competence of the right hemisphere is equivalent to that of an average child of a certain age. On the contrary the profiles of disabilities of the hemispherectomy as well as commissurotomy patients (in unilateral as well as in bilateral performance) indicates a non uniform age score distribution due to modality and process specific deficits relative to the model of the ITPA. Further refutation of weaker forms of the thesis (e.g. one which recognizes speech incompetence in the right hemisphere but applies the thesis to receptive language functions alone) will emerge from the results of part IV of the thesis.

SCORING AND INTERPRETATION OF ITPA PROFILES

In administering the various ITPA subtests each item of each test was sampled consecutively without assuming any basal or ceiling. Scoring was done in the usual way.

The raw score of each patient on each test is assigned a psycholinguistic age (PLA) determined by norms derived from the responses of approximately 1000 average children between the ages of two and ten. A patient's composite psycholinguistic age (CPLA) indicates the age of an average child who achieves the same total raw score on the ITPA. Given a patient's composite psycholinguistic age, a scaled score for each of his tests is obtained. The scaled scores are transformations of raw scores such that at each age and for each of the 12 subtests the mean performance of the referral group is equal to a score of 36 with a standard deviation of 6. Thus the scaled scores profile of a patient permits a versatile means of comparing statistically the patient's performance from subtest to subtest. Differences between a subtest ss and the mean ss of $\pm$ 6 is not statistically significant; difference of $\pm$ 7, $\pm$8, or $\pm$ 9 is considered borderline discrepency and of $\pm$ 10 is considered a substantial discrepency. Finally, an estimated Stanford Binet Mental age is provided in each profile, which is based on the normative group.

2. SUBJECTS

Commissurotomy patients.

N.G.: This right handed patient, a housewife, was born at least two months prematurely on June 29, 1933. Her development was considered normal until the age of eighteen when epileptic seizures began. Those worsened progressively (reaching status epilepticus) and since no clear epileptogenic focus was determined she was admitted for cerebral commissurotomy. Preoperative skull X-ray showed a calcification in the right cortex and EEG tracings revealed left temporal slowing. In addition a right carotid angiogram proved negative and a pneumoencephalagram showed bilateral though minimal ventricular dilation. Surgery was performed by Drs. P.J. Vogel and J.E. Bogen on September 5, 1963. The operation was a single stage one and involved a midline section of the corpus callosum, hippocampal and anterior commissures as well as the massa intermedia. The right fornix was sectioned as well. For 9 years following surgery the patient had no major seizures. Her postoperative Full Scale IQ is 77, Verbal IQ 83, and Performance IQ 83 as measured on August 13, 1968 by Dr. Jerre Levy.

L.B.: Born two weeks prematurely and delivered by cesearean section, this right handed patient was cynotic and remained in an Isolette for eight days. His development was considered normal until the age of 3 when epileptic seizures occured. Despite intensive medication his seizures became progressively more severe until cerebral commissurotomy was undertaken at age 13. Pre-operative neurologic examinations, skull X-ray, brain scan, air study and bilateral carotid angiogram all proved negative. The operation was also performed by Drs. P.J. Vogel and J.E. Bogen in a single stage as with N.G. involved sectioning of the corpus callosum, hippocampal and anterior commisures (the massa intermedia was absent). His recovery was unusually rapid as compared with the other commissurotomy patients -- he spoke on the first postoperative day and was moving and well oriented by the fifth day. The few seizures following surgery suggested the presence of a lesion in the right hemisphere. His Full Scale IQ is 106, Verbal IQ 110, and Performance IQ 100 as measured on May 28, 1968 also by Dr. Jerre Levy.

Hemispherectomy patients.

R.S.: Case history detailed in part II of the thesis.

D.W.: This teenage boy, born 2-9-56, developed normally until the age of 5½ when temper tantrums began followed a few months later by severe convulsions. EEG studies showed multiple right hemisphere foci and pneumoencephalography disclosed extensive right hemisphere atrophy. Although the boy was left handed (as are two of his siblings) carotid amytal injection showed left hemisphere lateralization of speech. Right hemispherectomy was performed by Dr. J. Green on 11-6-63 sparing the basal ganglia and thalamus and subsequent histology revealed chronic encephalitis in the removed cells. Following surgery seizures ceased and EEG tracings 3 years postoperatively showed no abnormality from the left hemisphere. D.W. is ambulatory but his left hemisparesis necessitates the use of his right hand alone. He is alert and his speech is fluent though with minor slurring. On the other hand extensive tests administered by the author showed that he is severely alexic, agraphic, and acalculic. At age 3 years and 6 months his Stanford-Binet IQ was 125 but on 10-16-64 it was only 84. On 12-4-69 his postoperative WISC Full Scale IQ was 64, Verbal IQ 77, and Performance IQ 51.

G.E. (born 2-15-38): A right hemispherectomy was performed on this patient because of a malignant glioma by Dr. E. Beehler on May 14, 1966. The basal ganglia was partially spared. When tested she had paralysis of the left extremeties and used a wheel-chair for ambulation. Her use of the right hand and arm were unimpaired. She is an alert, sociable and highly articulate 35 year old woman. Her education includes 3 years of Liberal Arts education in college where she majored in music.

3. GENERAL PATTERNS OF PERFORMANCE IN FREE VISION

DISPERSION OF SUBTEST SCORES

The first observation (figures 2- 8) is that with one exception (L.B.) all the patients show a generalized language deficit indicated by their low composite psycholinguistic ages (see figures 1-6). Two explanations for this are possible. First the generalized language deficit may be due to a reduced intellectual status following diffuse brain damage and reflected in I.Q., M.Q., etc. (Piercy, 1964). Another explanation is that the general performance deficit on these tests is due to specific lack of interhemispheric interaction in all these patients and especially, perhaps, the lack of interaction between linguistic processes originating in the left hemisphere and pictorial-imagerial processes from the right hemisphere. At the present time it is impossible to decide between these possibilities since the critical test which consists of comparing the ITPA performance of a matched population of brain damaged patients with diffuse lesions to that of a group s with left and right localized lesions, respectively, was not done.

Furthermore, the profiles are highly irregular with very wide dispersions of subtest scores. They indicate instability or imbalance of psycholinguistic functions. In particular there is a highly significant superiority of the auditory-vocal channel tests over the visual-motor channel tests in the two cases of right hemispherectomy but not in the case of dominant hemispherectomy. This is consistent with the

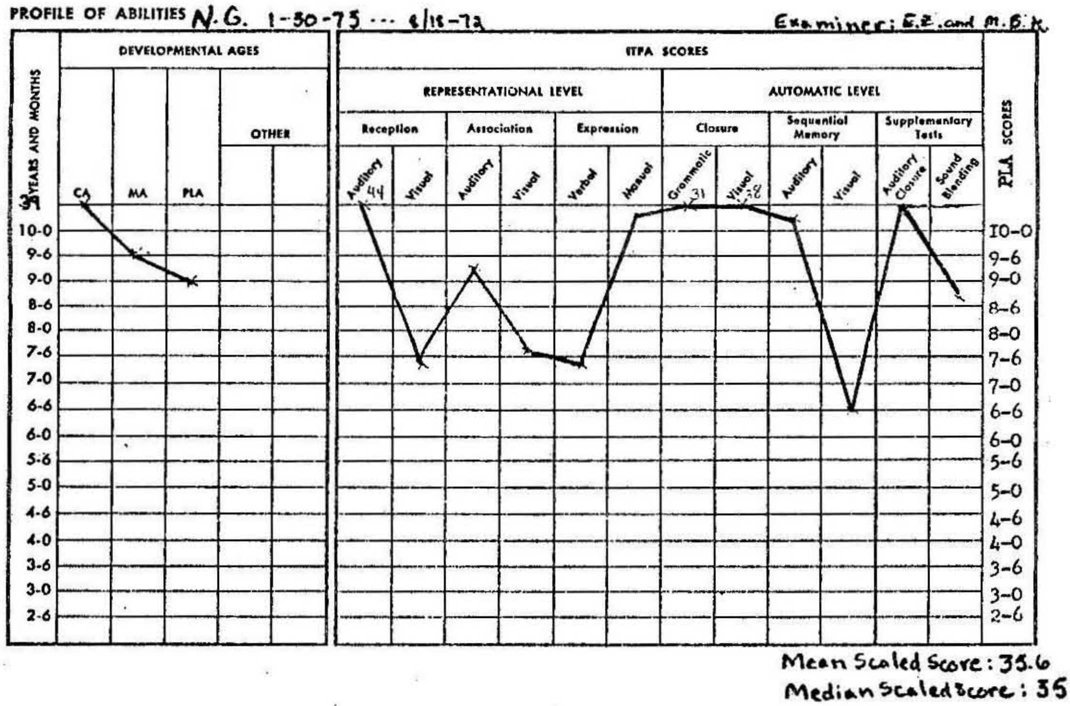
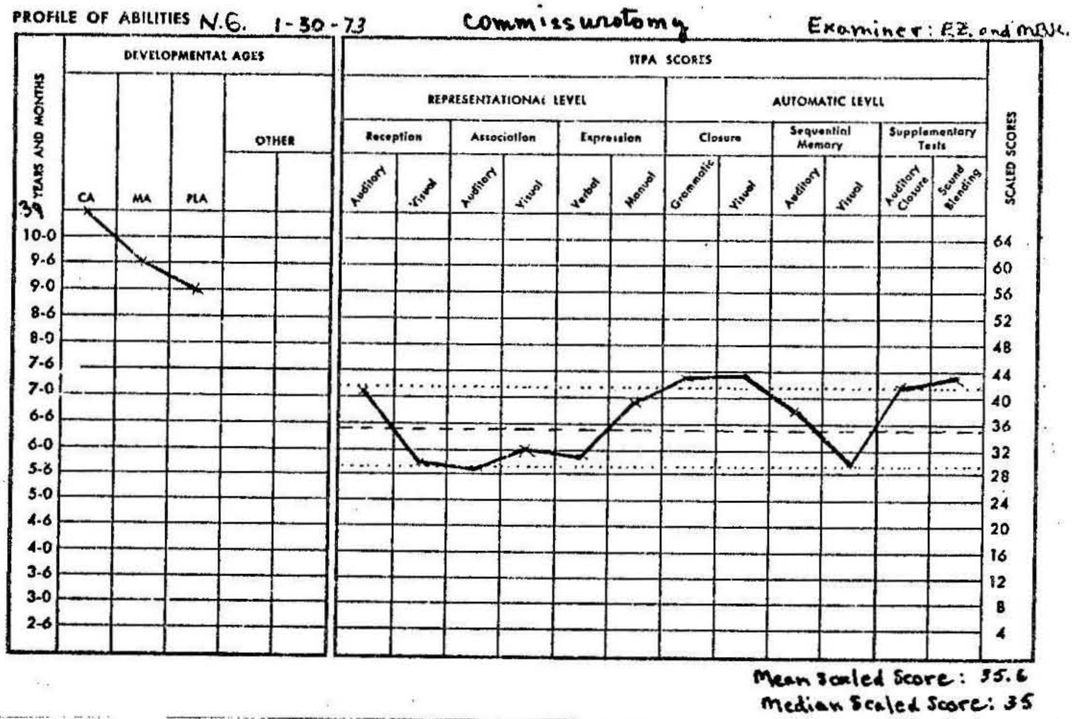
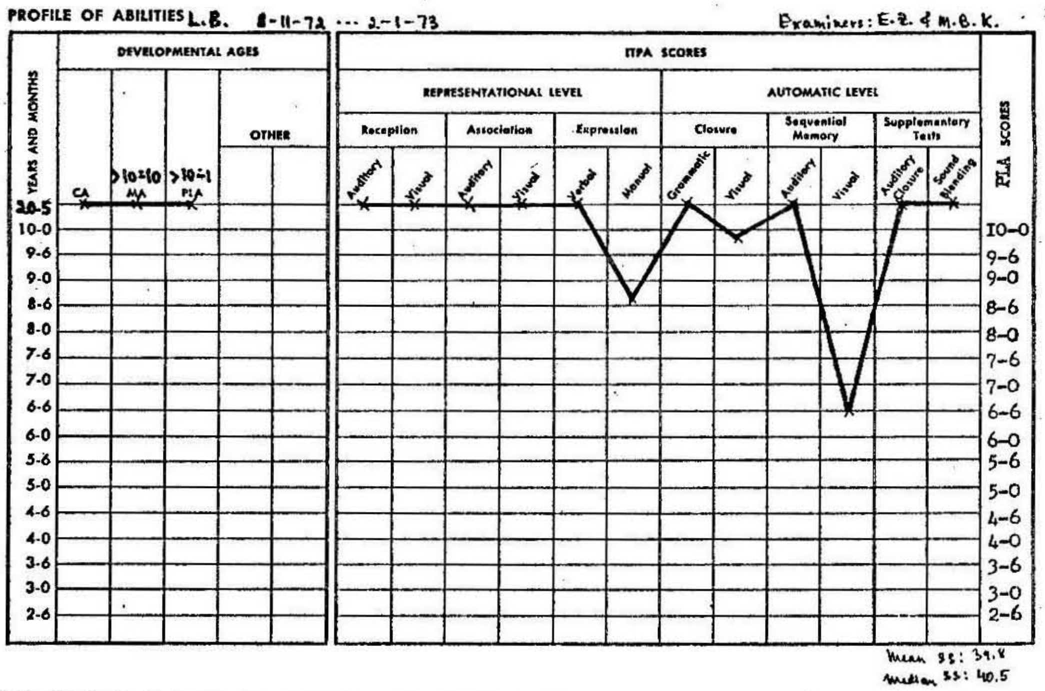


Figure 2



Figures 2 - 6: ITPA age and Scaled Score profiles for the commissurotomy and hemispherectomy patients based on free vision performance.


PROFILE OF ABILITIES L.B. 8-11-72 --- 2-1-73
Examiners: E.Z. & M.B.K.
DEVELOPMENTAL AGES
ITPA SCORES
REPRESENTATIONAL LEVEL
AUTOMATIC LEVEL
YEARS AND MONTHS
OTHER
Reception
Association
Expression
Closure
Sequential Memory
Supplementary Tests
Auditory
Visual
Verbal
Manual
Grammatic
Auditory Closure
Sound Blending
CA
MA
PLA
>10-10
>10-1
PLA SCORES
10-5
10-0
9-6
9-0
8-6
8-0
7-6
7-0
6-6
6-0
5-6
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4-6
4-0
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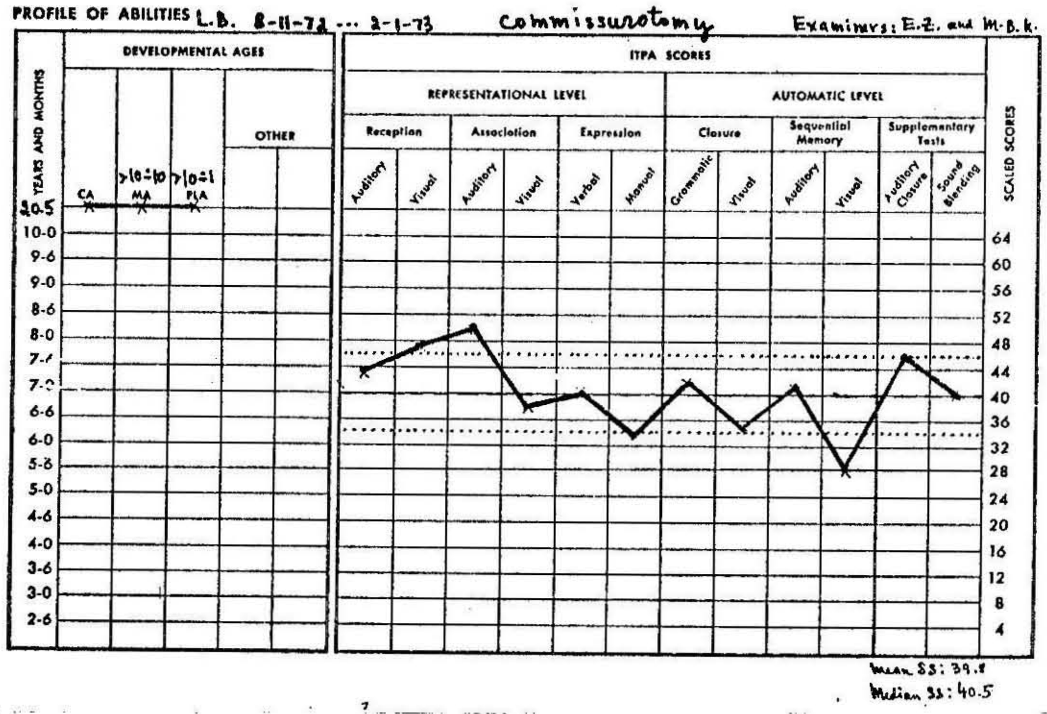
2-6
Mean SS: 39.8
Median SS: 40.5

Figure 3


PROFILE OF ABILITIES L.B. 8-11-72 --- 2-1-73
Commissurotomy
Examiners: E.Z. and M.B.K.
DEVELOPMENTAL AGES
ITPA SCORES
REPRESENTATIONAL LEVEL
AUTOMATIC LEVEL
YEARS AND MONTHS
OTHER
Reception
Association
Expression
Closure
Sequential Memory
Supplementary Tests
Auditory
Visual
Verbal
Manual
Grammatic
Auditory Closure
Sound Blending
CA
MA
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>10-10
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SCALED SCORES
10.5
10-0
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8-6
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6-6
6-0
5-0
4-6
4-0
3-6
3-0
2-6
64
60
56
52
48
44
40
36
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28
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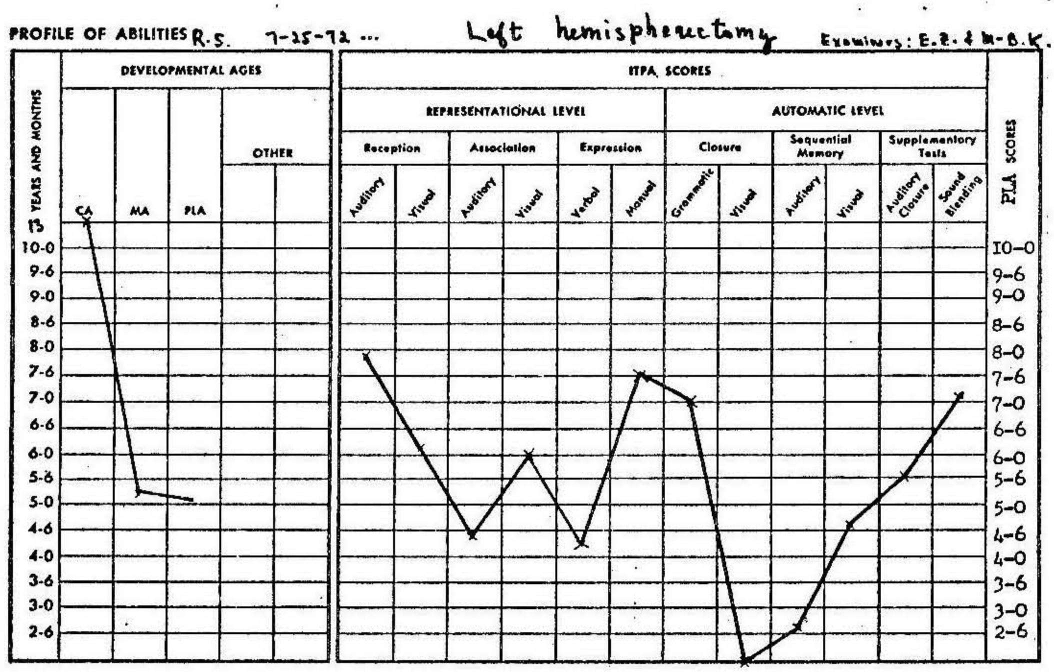
16
12
8
4
Mean SS: 39.8
Median SS: 40.5


PROFILE OF ABILITIES R.S. 7-25-72
Left hemispherectomy
Examiners: E.Z. & M.B.K.
DEVELOPMENTAL AGES
CA
MA
PLA
OTHER
ITPA SCORES
REPRESENTATIONAL LEVEL
AUTOMATIC LEVEL
Reception
Association
Expression
Closure
Sequential Memory
Supplementary Tests
Auditory
Visual
Verbal
Manual
Grammatic
Auditory Closure
Sound Blending
YEARS AND MONTHS
PLA SCORES
13
10-0
9-6
9-0
8-6
8-0
7-6
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6-0
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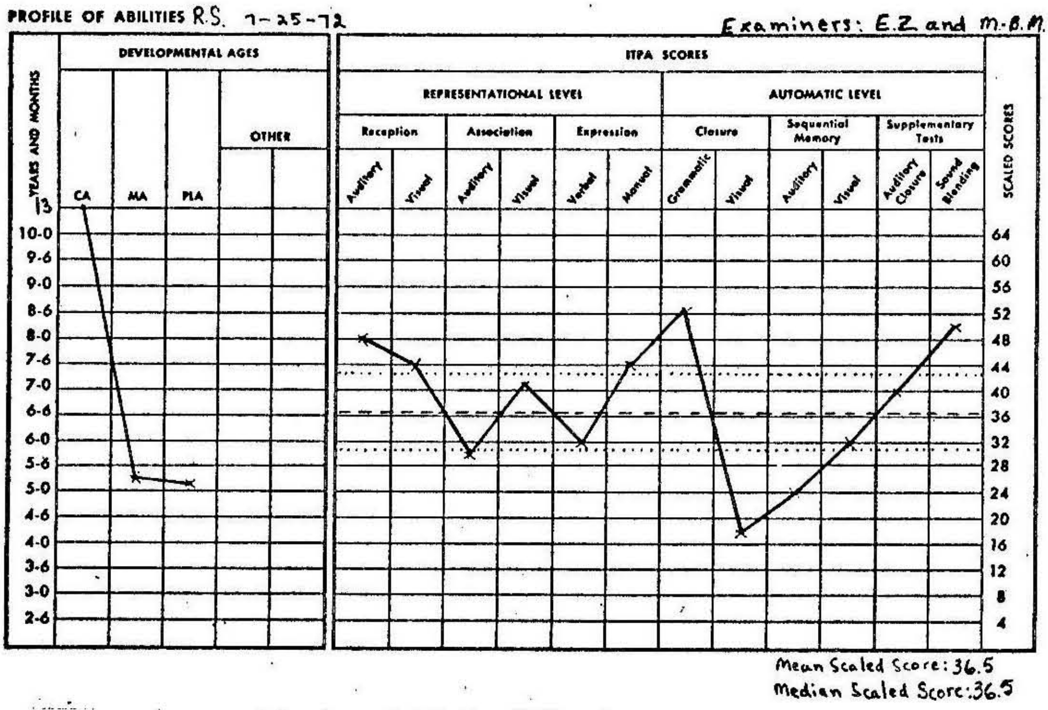
3-6
3-0
2-6

Figure 4


PROFILE OF ABILITIES R.S. 7-25-72
Examiners: E.Z and M.B.M.
DEVELOPMENTAL AGES
CA
MA
PLA
OTHER
ITPA SCORES
REPRESENTATIONAL LEVEL
AUTOMATIC LEVEL
Reception
Association
Expression
Closure
Sequential Memory
Supplementary Tests
Auditory
Visual
Verbal
Manual
Grammatic
Auditory Closure
Sound Blending
YEARS AND MONTHS
SCALED SCORES
13
10-0
9-6
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8-6
8-0
7-6
7-0
6-6
6-0
5-6
5-0
4-6
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3-6
3-0
2-6
64
60
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52
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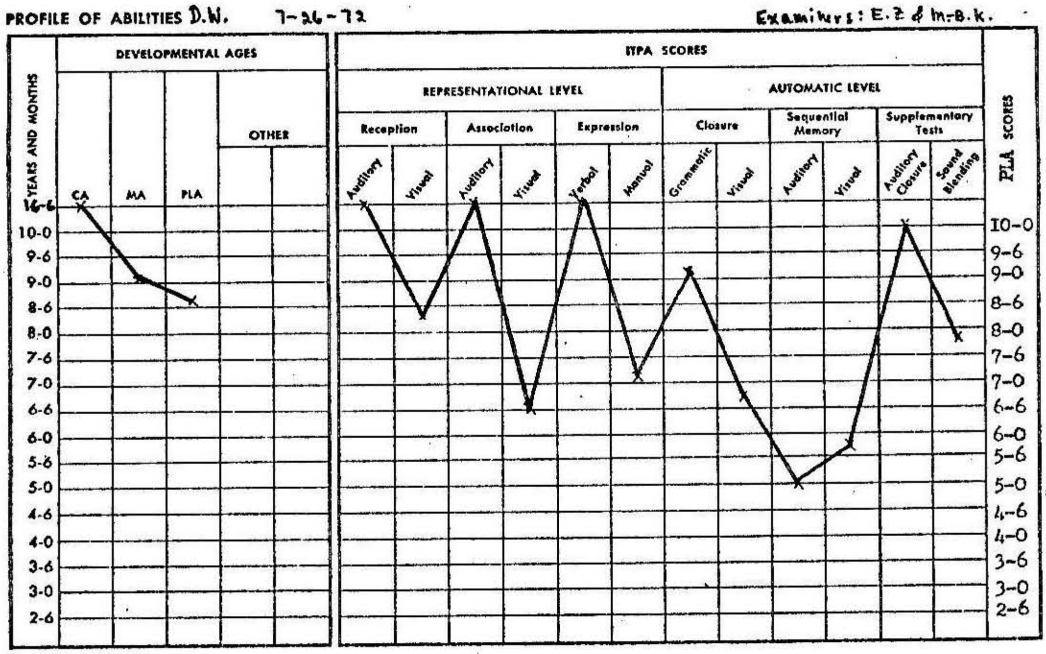
4
Mean Scaled Score: 36.5
Median Scaled Score: 36.5


PROFILE OF ABILITIES D.W. 7-26-72
Examiners: E.Z & M-B.K.
DEVELOPMENTAL AGES
ITPA SCORES
REPRESENTATIONAL LEVEL
AUTOMATIC LEVEL
YEARS AND MONTHS
OTHER
Reception
Association
Expression
Closure
Sequential Memory
Supplementary Tests
PLA SCORES
CA
MA
PLA
Auditory
Visual
Auditory
Visual
Verbal
Manual
Grammatic
Visual
Auditory
Visual
Auditory Closure
Sound Blending
16-6
10-0
9-6
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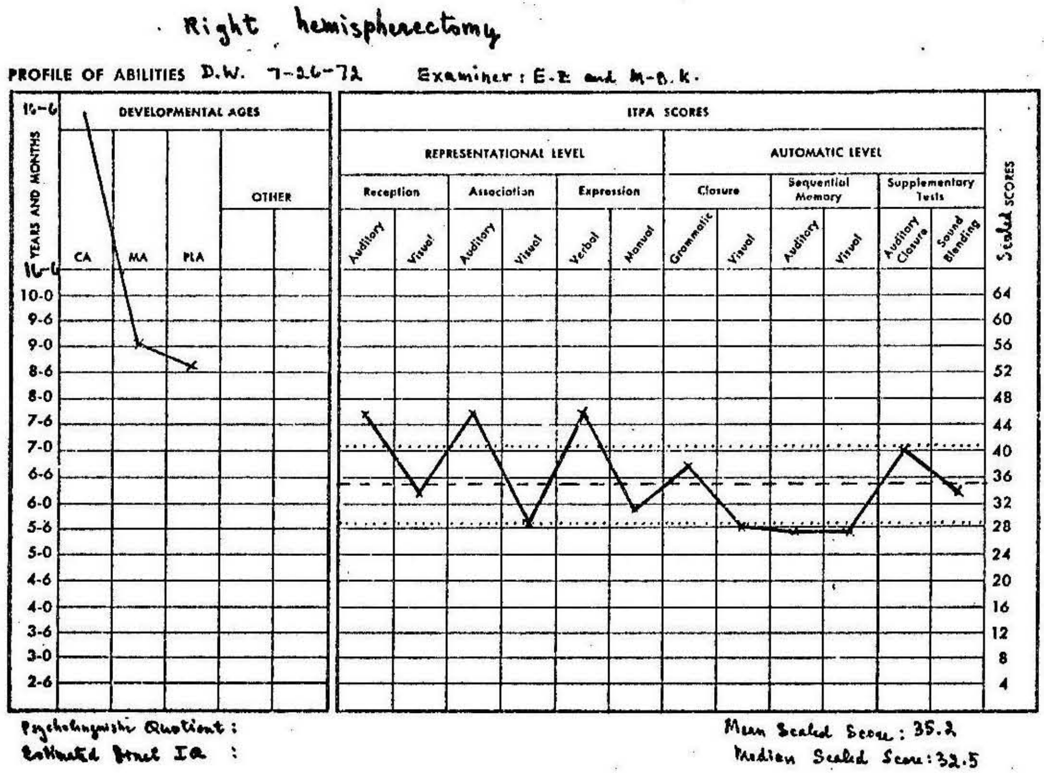
2-6

Figure 5


Right hemispherectomy
PROFILE OF ABILITIES D.W. 7-26-72
Examiner: E.Z and M-B.K.
DEVELOPMENTAL AGES
ITPA SCORES
REPRESENTATIONAL LEVEL
AUTOMATIC LEVEL
YEARS AND MONTHS
OTHER
Reception
Association
Expression
Closure
Sequential Memory
Supplementary Tests
Scaled SCORES
CA
MA
PLA
Auditory
Visual
Auditory
Visual
Verbal
Manual
Grammatic
Visual
Auditory
Visual
Auditory Closure
Sound Blending
16-6
10-0
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8-6
8-0
7-6
7-0
6-6
6-0
5-6
5-0
4-6
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3-6
3-0
2-6
64
60
56
52
48
44
40
36
32
28
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12
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4
Psycholinguistic Quotient:
Estimated Binet IQ :
Mean Scaled Score: 35.2
Median Scaled Score: 32.5

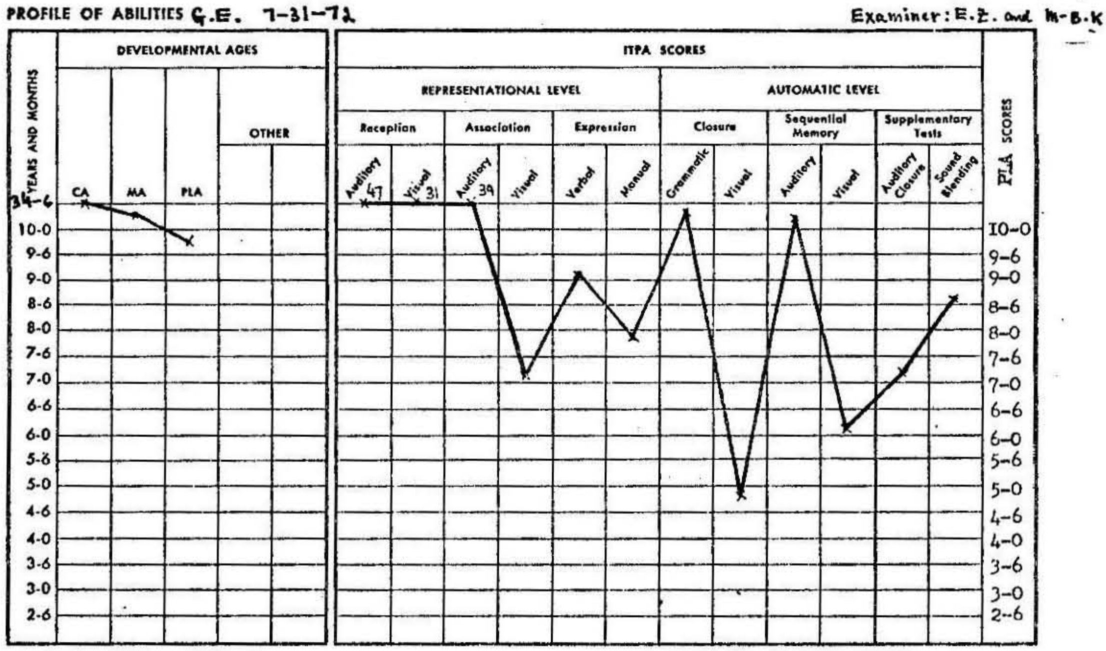
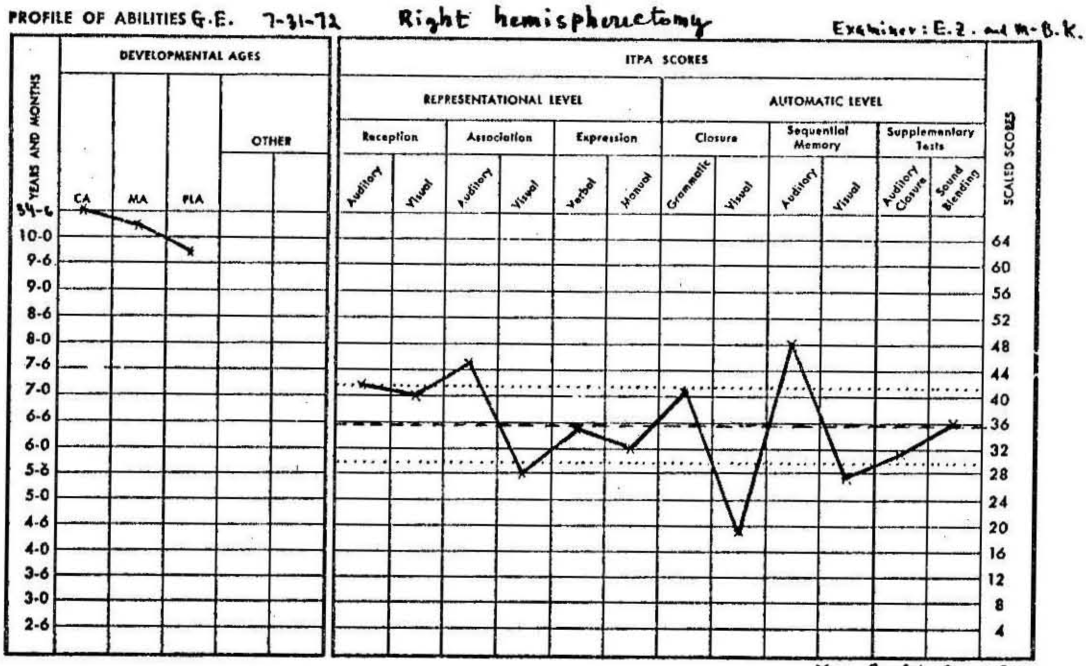


Figure 6



Mean Scaled Score: 35.7
Median S.S : 37.5

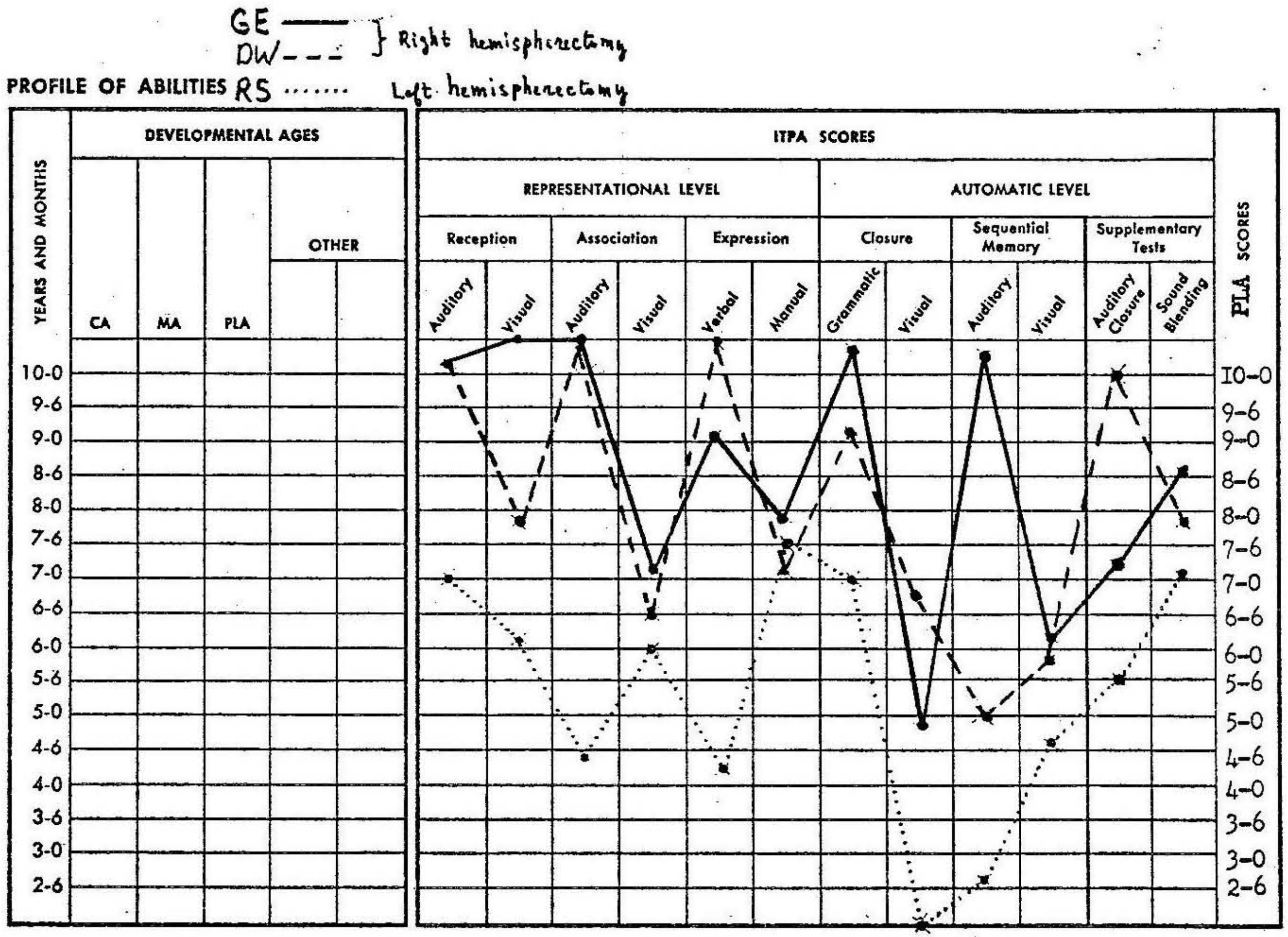


Figure 7: Comparison of the ITPA psycholinguistic age profiles of three hemispherectomy patients.

idea that the left hemisphere is inferior to the right on visuo-spatial tasks.

R.S. (left hemispherectomy) also shows a statistically significant process advantage in the reception as against the association subtests, but, surprisingly, no relative deficit on the expression subtests.

CLOSURE DEFICITS AND PAUCITY OF OTHER ITPA MODEL-SPECIFIC LATERALITY EFFECTS

Four of the ITPA subtests assess the subject's ability to fill in the missing parts of an incomplete picture or verbal expression or the ability to integrate discrete units into a whole. One of these is the Grammatic Closure subtest which assesses the ability to make use of the redundancies of oral language in acquiring automatic habits for handling syntax and grammatic inflections. The responses consist of sentence completions, "here is a dog; here are two ____", and each item is pictorially illustrated. The second is the Auditory Closure subtest in which the child has to fill in missing parts of an auditorily presented word and to produce the complete word, e.g. "airpla__", or "__ype__iter". In the test of Sound Blending the sounds of a word are spoken singly at half-second intervals and the subject is asked to tell what the word is. This requires synthesis of the separate parts into an integrated whole. Finally the Visual Closure subtest requires the subject to identify a common object from an incomplete visual presentation. There are four scenes, presented separately, each containing 14 or 15 examples of a specified object. The objects are seen in varying degrees of concealment. The subject is asked to locate and point to all examples of a particular object within 30 seconds for each scene.

No laterality effects on the closure tests as a whole is indicated by the mean scaled scores in Table 1. R.S., however, shows significantly high scaled scores on the linguistic closure tests. (Grammatic closure, Auditory closure, and Sound blending). All closure tests are classified at the automatic level and R.S.'s relative superiority here is consistent with her facility with automatized linguistic sequences (part II) and with the right hemisphere's propensity for pattern completion -- even in the linguistic domain!

No further consistent organizational level-specific, process or channel-specific laterality effects emerge from the data.

Table 1. ITPA dimensional score analysis.

	Levels of Organization				Channels				Processes							
	Represent.		Automatic		Auditor-Vocal		Visuo-Motor		Reception		Associatn.		Exprsn.		Closure	
	PLA	SS	PLA	SS	PLA	SS	PLA	SS	PLA	SS	PLA	SS	PLA	SS	PLA	SS
Hemispherec.																
R. S.	5:11	40.7	4:1	31.5	5:3	38.5	4:8	33.7	6:7	46	5:2	36	5:10	38	5:5	40
D. W.	9:0	38.7	6:8	30.0	9:3	40.6	6:11	29.8	9:3	40	8:8	37.5	9:0	38.5	9:2	35
G. E.	9:4	37	7:11	33.75	10:2	42.2	7:5	29.2	10:6	41	9:1	36.5	8:6	33.5	7:9	21.7
Commissurot.																
N. G.	8:6	32.7	9:3	38.5	9:6	36.4	8:4	34.8	8:1	35.5	8:4	30.5	8:7	35	9:10	42.75
L. B.	10:3	42	12:3	36.5	10:6	43.2	9:3	36.4	10:6	45	10:7	44	9:9	37	9:8	40.75

PLA = Psycholinguistic Age

SS = Scaled Score

4. LATERALITY EFFECTS IN VISUAL CHANNEL SUBTESTS

INTRODUCTION

Tests and administration. Four subtests were selected for unilateral presentation to N.G. and L.B. in CLVP. The four subtests are Visual Reception (representational level, reception process), Visual Association (representational level, association process), Visual Closure (automatic level, closure functions), and Visual Sequential Memory (automatic level, sequential memory functions). In this way both of the theoretical levels and each of the three processes of the psycholinguistic model were sampled on a single channel, namely, the visual-motor one. The four subtests exhaust, in fact, the visual channel tests of the ITPA. This modality combination lends itself to unilateral presentation since it tests semantic, perceptual and memory functions without requiring any language input-output.

Lenient scoring. One feature of the ITPA is that scoring some of the subtests allows a subject a second chance if he fails a test item on the first attempt. It was found here that the same scoring procedure was useful in comparing the abilities of the two hemispheres to correct erroneous initial guesses. Second right hemisphere may also be interpreted to represent weak right hemisphere signals (perhaps because of doubt or uncertainty) insufficient to inhibit random left hemisphere interference of left sided guesses on the basis of very limited information. An error on the first attempt, however, so the interpretation goes, would raise the threshold of left hemisphere responses and permit right hemisphere expression. Accordingly, not only the Visual Sequential Memory but the Visual Reception and Association as well were administered so as to permit a second attempt to answer. Correspondingly, the Visual Reception and Visual Association subtests each carries two scores: a standard and a "lenient" score. In the case of "Visual Closure" lenient score means imposing no time limit (as opposed to the standard 30 seconds), thus allowing the patient to continue until he could find no more hidden figures (typically totaling from one to two minutes per strip) in order to counteract possible occasional loss of focus.

General patterns of impairment in lateralized performance on the ITPA Visual channel tests. Table 2 permits a detailed analysis of CLVP scores of the two hemispheres of N.G. and L.B., and Figure 8 illustrates the corresponding psycholinguistic age scores in comparison to free vision performance. Two particularly suggestive patterns of deficits emerge. First there is the pattern, common to both commissurotomy patients, of low performance in lateralized stimulation of either visual field in contrast to relatively high performance in free vision. Such a pattern suggests that interhemispheric communication in certain free vision tasks may take place in spite of the disconnected commissures. This pattern occurs most prominantly in the Visual Closure subtest. The hemispherectomy data (figure 8) supports this interpretation: all three patients, dominant and nondominant hemispherectomy cases alike, perform deficiently on this test. Indeed, evidence will be presented in section 4 of this part (Visual Closure tests) to show

Table 2. Summary of lateralized performance by N.G. and L.B. on the ITPA Visual Channel subtests.

	N.G.		L.B.	
	LVF-L/h	RVF-R/h	LVF-L/h	RVF-R/h
Visual Reception Score	17	10	13	27
Psycholinguistic age	5:10	4:4	5:0	8:5
total # correct	21	15	19	35
total % correct	50%	37.5%	47.5%	87.5%
ceiling % correct	71%	83%	87%	93%
ceiling	#24	#12	#15	#29
Lenient score	24	22	22	39
len. psycholing. age	7:4	6:10	6:10	10:11
total len. # correct	25	27	27	39
total len. % correct	60%	67.5%	67.5%	97.5%
ceiling len. % correct	77%	81%	79%	97.5%
len. ceiling	#31	#27	#28	#40
Visual Assoc. Score	17	16	18	29
Psycholinguistic age	5:3	5:0	5:6	9:4
total # correct	21	17	24	29
total % correct	50%	40%	57%	69%
ceiling % correct	85%	67%	64%	76%
ceiling	#20	#24	#28	#38
Lenient score	27	31	23	39
len. psycholing. age	8:5	10:3	6:10	>10:3
total len. # correct	30	31	32	39
total len. % correct	71%	79%	76%	93%
ceiling len. % correct	75%	79%	82%	97.5%
len. ceiling	#36	#39	#28	#40
Visual Sequence Memory Score	10	17	18	35
Psycholinguistic age	4:4	6:2	6:6	>10:5
Visual Closure Score	8	13	4	13
Psycholinguistic age	3:10	4:10	2:6	4:10
Lenient(no time limit)Score	18	20	11	28
len. psycholing. age	5:10	6:1	4:6	8:3

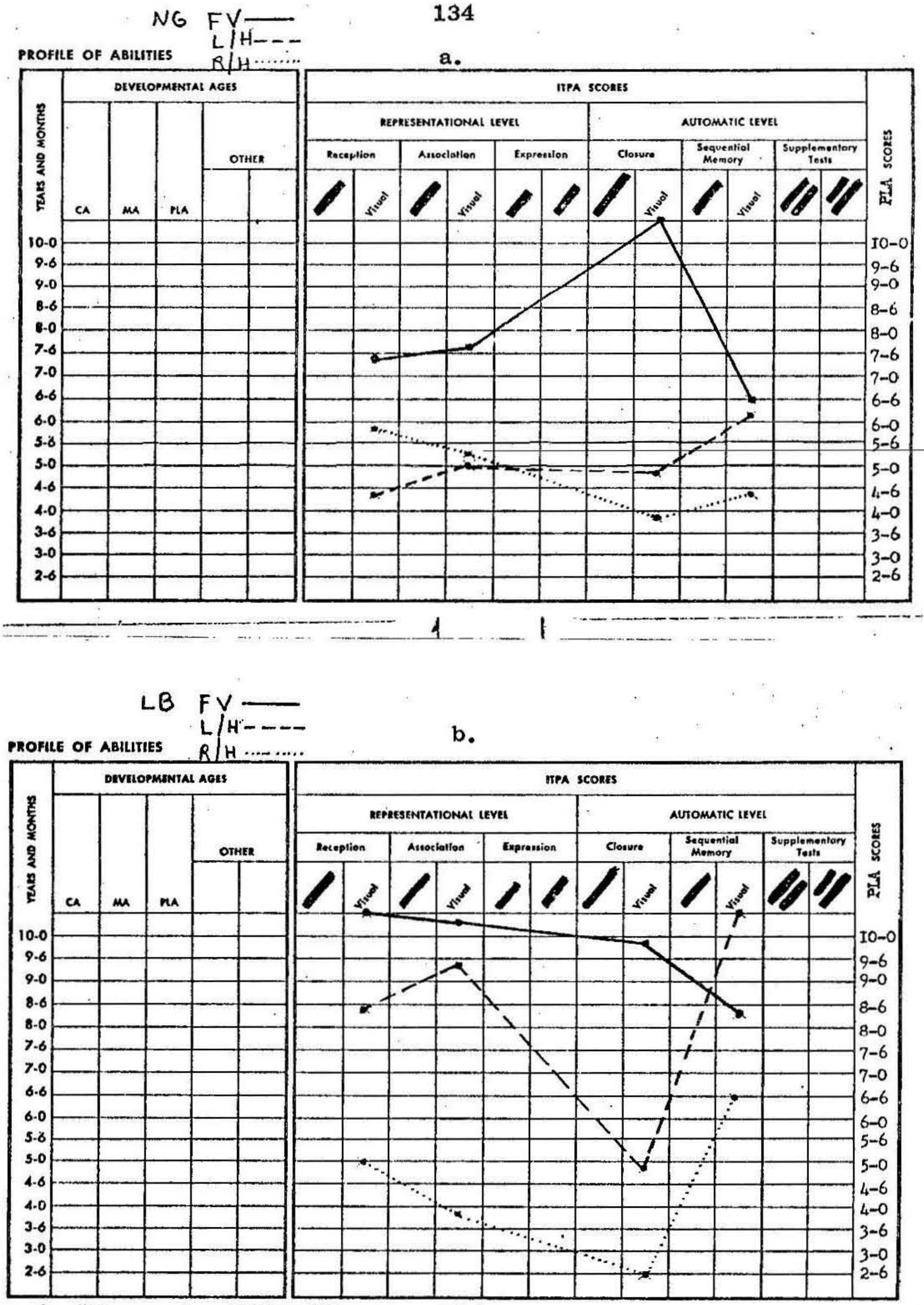


Figure 8

Lateralized vs. free vision scores of the two commissurotomy patients on the visual channel subtests of the ITPA.

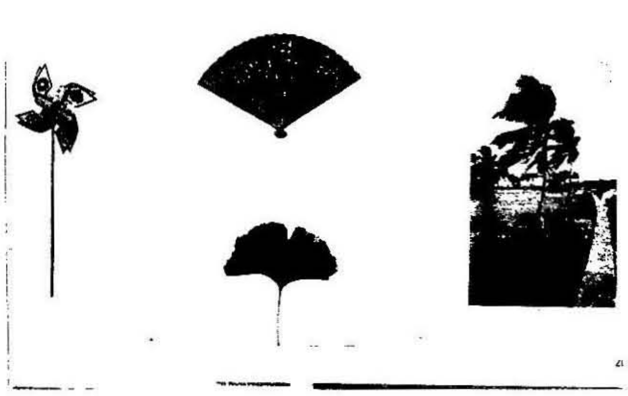
that the ITPA subtest activates distinct left (figure-ground separation) and right (figure completion) hemisphere processes.

The second pattern of deficits occurs when free vision and lateralized performance alike show relatively low scores as in the Visual Sequential Memory. In this case hemispheric interaction in the intact brain is suggested, which, in contrast to the first pattern, is disturbed following interruption of the callosal fibers. Each of the four visual channel subtests will now be discussed in more detail.

VISUAL RECEPTION

Test. The Visual Reception Subtest is comprised of 40 picture items, each consisting of a stimulus picture on one page and four option response pictures on the second page (figure 9). The subject is shown the stimulus picture which is subsequently removed; he is then shown the response picture, from which he must select, by pointing, the option that is conceptually most similar to the stimulus. Thus a definite component of short term memory is involved.

Results and discussion. The primary question which CLVP administration of the ITPA Visual Reception subtest was intended to answer concerns the limit in the ability of right hemisphere to extract semantic information from pictorial input. Left hemisphere and free vision performances by the same commissurotomy subjects then serve as a base line for comparison and control for assessing right hemisphere capacity. As table 3 shows, in no case was the score of the right hemisphere lower than that achieved by a 5 year old child. Since the test measures the subject's ability to recognize different pictorial representations of the same semantic concept, it follows that the right hemisphere possesses extensive central capacity for the representation of meaning which is in some sense independent of any particular representation. Such a semantic net could play an important role in an input processor which interprets sensory data and converts it to some central storage representation as in memory.



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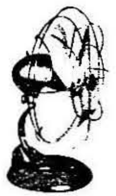

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Figure 9. Sample items from the Illinois Test of Psycholinguistic Abilities Visual Reception Subtest. The stimulus (bottom: "See this?") is replaced by four choices (top: "find one here").

Table 3a. Visual Reception Scores (maximum score = 40) by the three hemispherectomy patients and by the two commissurotomy patients in CLVP and free vision.

Patients	RS	PLA	CPLA	SS	# correct
Hemispherc.					
R.S.	19	6:2	5:2	44	*
D.W.	25	7:9	8:8	34	*
G.E.	31	10:10	9:9	40	*
Commissurot.					
N.G.	24	7:4	9:0	30	24
L.B.	36	> 10:10	> 10:1	47	36
CLVP					
N.G. R/H	17	5:10	-	-	21
L/H	10	4:4	-	-	15
L.B. R/H	13	5:0	-	-	19
L/H	27	8:5	-	-	35
Lenient CLVP					
N.G. R/H	24	7:4	-	-	25
L/H	22	6:10	-	-	27
L.B. R/H	22	6:10	-	-	27
L/H	39	10:11	-	-	39

* score not available

RS = Raw Score

PLA = Psycholinguistic Age

CPLA = Composite Psycholinguistic Age

SS = Scaled Score

Table 3b. Statistical analysis of difference in Visual Reception # correct scores and raw scores (one-tailed t-test for correlated means).

	R/H	vs.	L/H	t	p	Significant
Raw Score	R.S.		D.W.	1.77	<.05	+
	R.S.		D.W. + G.E.	2.97	<.005	+
	N.G.		N.G.	-2.48	<.01	+
	L.B.		L.B.	4.58	<.0005	+
Lenient Raw Score	N.G.		N.G.	-.53	>.10	-
	L.B.		L.B.	4.89	<.0005	+
# correct	N.G.		N.G.	1.64	>.05	-
	L.B.		L.B.	5.10	<.0005	+
Lenient # correct	N.G.		N.G.	.24	>.10	-
	L.B.		L.B.	3.67	<.0005	+
	Free Vision	vs.	L/H			
Raw Score	N.G.		N.G.	4.58	<.0005	+
	L.B.		L.B.	3.36	<.005	+
Lenient	N.G.		N.G.	.57	>.10	-
	L.B.		L.B.	-1.4	>.05	-
# correct	L.B.		L.B.	.44	>.10	-
Lenient # corr.	L.B.		L.B.	-1.36	>.05	-

When we compare unilateral performance of N.G. and L.B. (Table 3) a most unexpected result emerges. While L.B.'s right visual field-right hand (RVF-R/h) performance is consistently and significantly superior to the corresponding performance of N.G., the situation is reversed for the left visual field-left hand (LVF-L/h) mode where N.G.'s right hemisphere performance is superior to L.B.'s. Moreover, N.G.'s right hemisphere performance surpasses her own left hemisphere performance during continuous lateralized visual presentations. Indeed N.G.'s LVF-L/h score is identical to her free vision score, thus suggesting right hemisphere control on this task. In the case of L.B., on the other hand, it is the left hemisphere which is superior to the right and his free vision score is virtually identical to his RVF-R/h mode in CLVP. Even in R.S. whose performance is slightly superior to the right hemisphere performance of both N.G. and L.B., but inferior to the left hemisphere performance of all but N.G., the score on the visual reception subtest is relatively high.

The exhibited right hemispheric superiority on the ITPA Visual Reception subtest gains in significance when we recall that N.G. is said to have right central hemisphere damage (calcification by X-ray diagnosis). Nevertheless left temporal damage is also indicated by preoperative EEG tracings which showed for a while left temporal epileptoform activity. (One possible explanation to N.G.'s exceptional superiority is that left hemisphere interference in the case of L.B. is stronger and results in more frequent attempts by the left hemisphere to direct the responses perhaps on the basis of the very limited information relayed through the uncrossed visual system mentioned before (part 1). If this is so then left hemisphere interference may attenuate when a second attempt at an answer is encouraged following an erroneous response.

However, the trends showed by the lenient score are identical with those observed above. In fact the relative gain in L.B.'s left hemisphere performance surpasses the relative gain in the right hemisphere performance and so the interference hypothesis for explaining L.B.'s relatively low right hemisphere score is not verified by lenient score data. Instead, there is some reason to believe that impaired visual acuity was especially detrimental to RVF-R/h CLVP in L.B.

Linguistic interpretation. In effect the Visual Reception subtest requires to match two exemplars of the same semantic concept or relation or of a propositional function in general, even when they are perceptually disimilar or unrelated and even while some of the option response pictures are related to the stimulus by a semantic relation other than being members of the extension of a single concept. All of the concepts possess a natural linguistic label such as "bridge", "net", "windy" or "blowing" or "breeze", "revery", "visual magnification instruments", "antenna", and "reflections", etc.

In this sense the test studies a single elementary but fundamental semantic relation, namely that of "hyponymy" or inclusion (Lyons, 1967; e.g. the meaning of tulip is said to be "included" in the meaning of flower). Our data show that the right hemisphere is able at least to construct or "synthesize" the meaning of the more general superordinate concept from exemplars or co-hyponyms of it; the data do not show that the right hemisphere can also "analyse" the meaning of the superordinate concept into its exemplars or hyponyms but this is almost certainly true. The Visual Association subtest described next extends the study to a variety of other semantic relations. Success on the Visual Reception test presupposes, of course, adequate perceptual discrimination in addition to semantic interpretation of pictures; in this sense the data verify that the right hemisphere has good gnostic abilities. It is hard to conceive a-priori of a strategy to solve such semantic analogy problems without verbal mediation. Some preliminary evidence for verbal mediation in the Visual Reception subtest comes from the ability of L.B. to write down the name of the common association with his left hand without being able to verbalize it. But such writing is laborious and was not sampled systematically, nor does its occurence rule out a non-verbally mediated right hemisphere performance on the original task. It is conceivable, in fact likely, that the organization of semantic information in the right hemisphere is conceptual and its representation non-verbal, possibly pictorial. This whole question is in need of further research.

Perceptual versus semantic associations in the right hemisphere. Incorrect choice items in the Visual Reception Subtest include pictures of objects with varying degrees of superficial or structural (rather than functional) similarity, or pictures which are merely associated with the stimulus or with the acceptable choice. Item difficulty level is increased by making the option pictures physically but not conceptually similar to each other or to the stimulus picture, and by requiring the choice of an item which is widely different in superficial appearance but serving the same function as the stimulus picture. Thus the ability of the right hemisphere to perform well above chance, in fact above the level of five years of psycholinguistic age, revises previous conception of strictly structural (perceptual) as opposed to functional (semantic) right hemisphere competence for visual processing (Levy, 1971; Levy, Trevarthen and Sperry, in preparation). The failure of the right hemisphere to exhibit similar competence in the study of Levy et al must be attributed to the weakness of the semantic associations used in their study or the short duration of visual exposure. Weaker or less explicit task requirements may also be a contributing factor. As usual, both N.G. and L.B. were unable to name left visual half field stimuli and L.B. reported that he is choosing items by perceptual similarity (of shape). In fact, however, most of his responses were semantically correct although perceptually distant from the stimulus. His report must therefore be interpreted as indicative of an attempt by the left hemisphere interference with right hemisphere processing on the basis of the incomplete information, consisting largely of meaningless patterns, which is available to it, or as post hoc inaccurate rationalization of what really happened. Thus we may assume that some of the errors at least are due to left hemisphere interference.

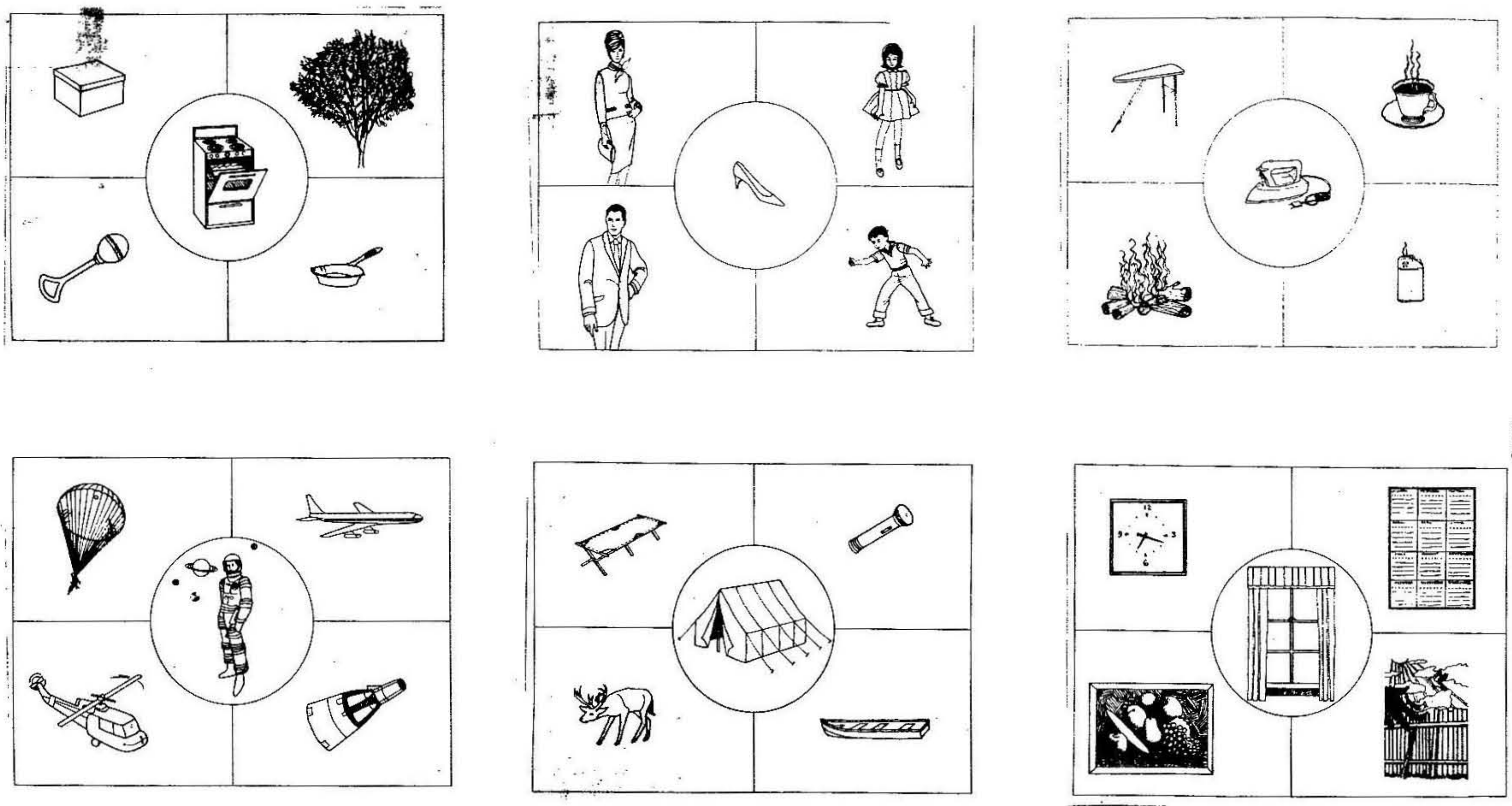
Effects of visual acuity. The Visual Reception and Visual Association subtests do not manipulate the pictorial complexity of the stimuli for differential diagnosis and consequently furnish no data on laterality differences in the ability to extract semantic information from pictorial stimuli graded for complexity. The picture stimuli for the Visual Reception subtest are photographic reproductions. Although color complexity was minimized through the use of black and white photographs, the contrast in some of them is weak and the complexity of detail great. Here, therefore, a question arises concerning the effect of reduced visual acuity on this test, especially since the continuous lateralized visual presentations technique occludes between one and two degrees of the fovea on the stimulated visual half field.

In a study conducted by Bateman (1963) on 131 children enrolled in twenty classes for the partially seeing in Illinois, she found that those children who had visual acuity greater than 20/200 showed no significant inferiority on the tests utilizing the visual-motor channel as compared with their auditory-vocal abilities. Bateman concluded that with mild and moderate visual handicaps, the ITPA measures central rather than peripheral processes, and that mild visual defects do not affect scores on ITPA subtests using the visual modality. Nevertheless both of the commissurotomy patients are particularly sensitive to low acuity with right visual half-field presentations -- more so, as far as we can tell than with left visual half-field stimulation even though approximately equal parts of the fovea past the midline are occluded in both cases. If true this would be consistent with a view which attributes to the right hemisphere mechanisms for global feature extraction from the enviornment which utilize low acuity information.

VISUAL ASSOCIATION

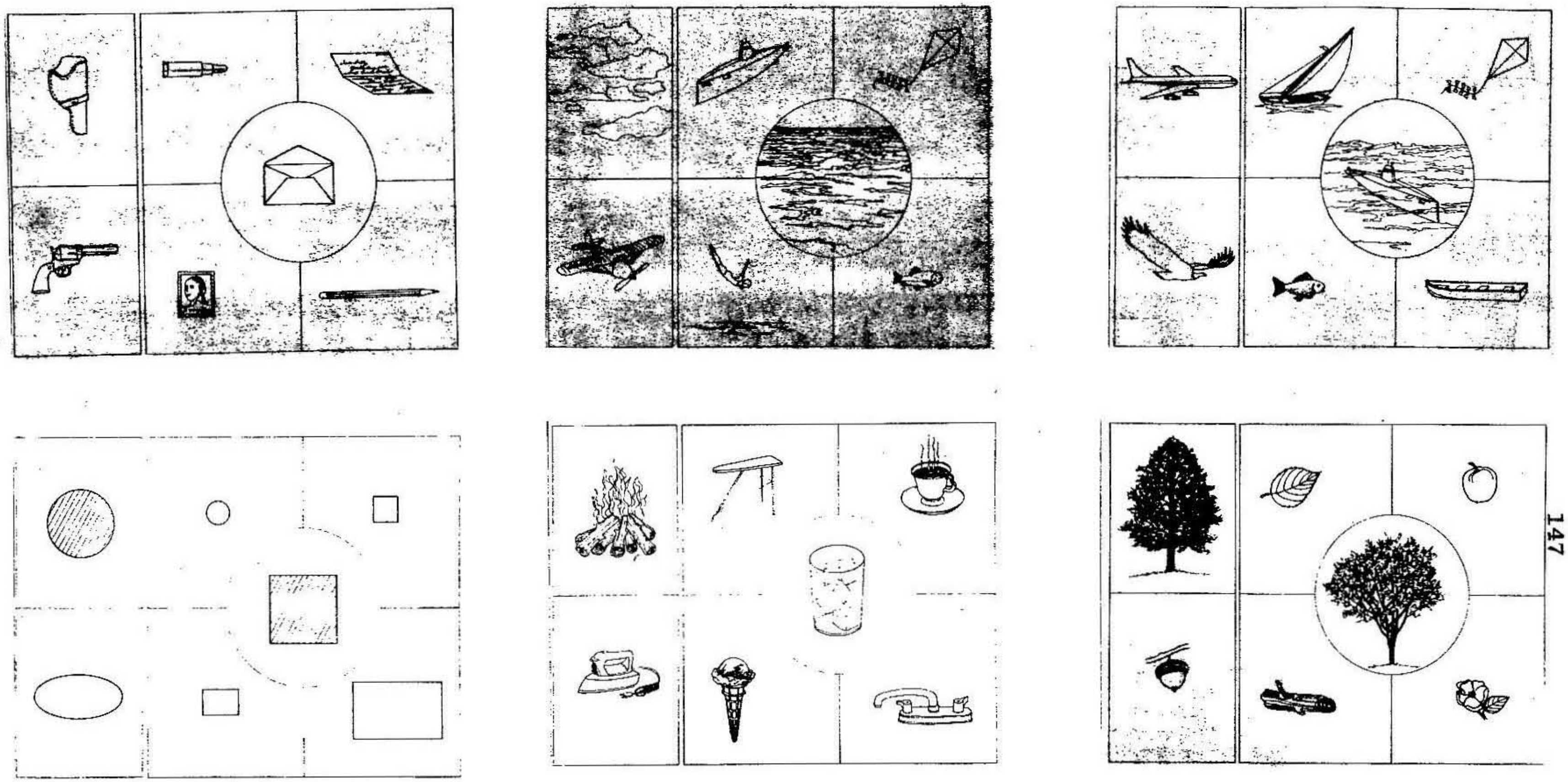
Test. The Visual Association Subtest of the ITPA incorporates two types of tasks. The lower level of the test comprises 20 items in each of which the subject is required to select from among four pictures the one which most meaningfully relates to a control stimulus picture (figure 10). The upper level of the test consists of 22 visual analogies. In each of these pictures two objects having a certain relationship are shown to the subject, who must then locate from among four pictures the one which relates similarly to a given object. Here then is an abstract concept formation test (figure 11).

An effort was made in designing the Visual Association subtest to reduce the contribution of the receptive process to score variance through the use of line-drawing pictures of association. Indeed verbal reports to right visual field CLVP presentation indicates a smaller number of perceptual confusions than during the corresponding presentation of the Visual Reception subtest. The requisite in the visual association as contrasted with visual reception seems to be a second order of comprehension derived from visual impressions. In a first order of comprehensions, a patient may comprehend picture of a hammer and a picture of a carpenter but not recognize the second-order relationship of tool and user. He must see that a needle and a thimble have a relationship to each other in that they are used together in sewing. As in the Visual Reception test there is also, of course, the requirement to evaluate and discard alternative solutions which possess



Sample items from the ITPA Visual Association Test - part I
(from left to right, top to bottom: #3,6,9,11,19,20)

Figure 10



Sample items from the ITPA Visual Association Test, part II (left to right and top to bottom: 21,26,28,33,37,39). Denote: as in * - "If '1' goes with '2' which one of A,B,C,D goes with "0"?"

*:

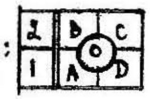


Figure 11

weaker or non-unique semantic associations.

Results and discussion. Table 4 summarizes the results on the Visual Association subtest. The usual scoring method was used to obtain equivalent developmental psycholinguistic ratings. Again in CLVP lenient scoring was computed in addition to the regular score taking into account correct second attempts at answers. Comparison of right and left hemisphere performance in CLVP, however, was based on the total percent of correct responses. Age estimates for right hemisphere competence a gain of five years and above. In view of the left hemisphere scores as compared to free vision performance, it is possible that the figure of five years is an underestimate. As in the case of Visual Reception N.G.'s right hemisphere performance is superior to her left hemisphere performance and for both subjects free vision scores are higher than the isolated left hemisphere performance thus suggesting some normal right hemisphere contribution to task performance. The hemispherectomy cases as well show very similar scores resulting from a relatively superior performance by R.S. and relatively inferior performances by D.W. and G.E.! It is evident that both hemispheres seem to be necessary here and that right hemisphere contribution is especially important. Lenient scoring improves the scores of both hemispheres significantly. Perhaps the right hemisphere overcomes some left hemisphere interference while the left gains from improved acuity and has better facility in formulating alternative solutions and utilizing error information. Further evidence for a relatively greater left hemisphere ability to gradually improve its performance or gain facility in a series of graded consecutive problems, was noted (Zaidel and Sperry, 1973) on the Raven's Colored Progressive Matrices Test.

Table 4a. Visual Association Scores (maximum score = 42) by the three hemispherectomy patients and the two commissurotomy patients in free vision and CLVP.

Patients	RS	PLA	CPLA	SS	# corr.	RS p.1	RS p.2
Hemispherec.							
R.S.	20	6:0	5:2	41	*	17	3
D.W.	22	6:6	8:8	29	*	20	2
G.E.	24	7:2	9:9	28	*	17	7
Commissurot.							
N.G.	24	7:2	9:0	32	24	19	5
L.B.	32	>10:3	>10:1	38	40	20	20
CLVP							
N.G. R/H	17	5:3	-	-	20	17	3
L/H	16	5:0	-	-	17	13	4
L.B. R/H	18	5:6	-	-	24	13	11
L/H	29	9:4	-	-	29	18	11
Lenient CLVP							
N.G. R/H	27	8:5	-	-	30	17	13
L/H	31	10:3	-	-	31	20	11
L.B. R/H	23	6:10	-	-	32	18	14
L/H	39	>10:3	-	-	39	20	19

* score not available

RS = Raw Score

PLA = Psycholinguistic Age

CPLA = Composite Psycholinguistic Age

RS p.1 = Raw Score first part, maximum score=20.

RS p.2 = Raw Score second part, maximum score=22.

corr. = number correct

Table 4b. Statistical analysis of differences in Visual Association # correct scores (raw scores in hemispherectomy cases) using one-tailed t-test for correlated means.

	R/H	vs.	L/H	t	p	Significant
Standard						
Total	R.S.		D.W.+G.E.	1.289	$>.1$	-
part 1	R.S.		D.W.+G.E.	1.15	$>.1$	-
part 2	R.S.		D.W.+G.E.	.9	$>.1$	-
Total	N.G.		N.G.	-.829	$>.1$	-
part 1	N.G.		N.G.	-1.449	$>.05$	-
part 2	N.G.		N.G.	.44	$>.1$	-
Total	L.B.		L.B.	1.4031	$>.1$	-
part 1	L.B.		L.B.	1.751	$<.05$	+
part 2	L.B.		L.B.	2.6175	$<.05$	+
Lenient						
Total	N.G.		N.G.	.298	$>.2$	-
part 1	N.G.		N.G.	1.83	$>.05$	-
part 2	N.G.		N.G.	-.699	$>.2$	-
Total	L.B.		L.B.	2.6107	$<.05$	+
part 1	L.B.		L.B.	1.452	$>.05$	-
part 2	L.B.		L.B.	2.0175	$<.05$	+
	Free Vision	vs.	L/H			
Total	N.G.		N.G.	-2.471	$<.01$	+
part 1	N.G.		N.G.	-1.00	$>.1$	-
part 2	N.G.		N.G.	-2.324	$<.05$	+
Total	L.B.		L.B.	3.816	$<.001$	+
part 1	L.B.		L.B.	1.4524	$>.05$	-
part 2	L.B.		L.B.	3.8133	$<.001$	+

Lenient scoring effects. A comparison between standard and lenient scores in unilateral presentations is theoretically important for two possible reasons. First, it is often the case in right hemisphere CLVP performance that left hemisphere interference prevents the expression of "weak" responses especially in linguistic tasks when the auditory message and hence partial information is available to the left. Under those circumstances it may occur that a second attempt at an answer following erroneous responses will improve right hemisphere scores considerably and may be more representative of its potential capacity. Secondly, lenient scoring reflects the differential ability of the two hemispheres to correct errors and act in uncertainty.

Table 5 compares the statistical significance of difference from chance of the patient's correct versus lenient scores on the Visual Reception and on the Visual Association subtests. Although the number of correct identifications improve considerably in both right and left visual field presentations, the lenient scores are generally less significantly different from chance since the probability of guessing increases from .25 to .5. In fact equivalent z-scores, obtained by approximating the binomial guessing distribution with a normal curve, show an increase in significance from number correct to lenient score only in left hemisphere performance! In the rest of the cases the drop in significance of the difference from chance is similar in both hemispheres. Thus the hypothesis that lenient scores will reflect a selective increase in the significance of right hemisphere scores due to increased freedom from left hemisphere interference, is not supported. On the other hand, there is evidence that the left

Table 5. z-score equivalents of # correct and lenient scores in lateralized presentation of the Visual Reception and Visual Association tests(based on # correct, not raw scores).

	Standard Scores			Lenient Scores		
	# correct	z-score	signif.	# correct	z-score	signif.
Visual Reception (max.40)						
N.G. L/H	15	1.8258	-	27	2.2152*	+
R/H	21	4.0167	+	26	1.8987	+
L.B. L/H	35	9.1288	+	39	6.0127	+
R/H	19	3.2864	+	27	2.2152	+
Visual Association (max.42)						
Commissurotomy						
Total						
N.G. L/H	17	2.3165	+	31	3.0864*	+
R/H	20	3.3856	+	30	2.7778	+
L.B. L/H	29	6.5930	+	39	5.5556	+
R/H	24	4.8111	+	32	3.3951	+
Part 1 (max. 20)						
N.G. L/H	13	4.1322	+	20	4.4723*	+
R/H	17	6.1984	+	17	3.1306	+
L.B. L/H	18	6.7149	+	20	4.4723	+
R/H	13	4.1322	+	18	3.5778	+
Part 2 (max. 22)						
N.G. L/H	4	.3748	-	11	0	-
R/H	3	.6247	-	13	.8528	-
L.B. L/H	11	1.3743	-	19	3.4115*	+
R/H	11	1.3743	-	14	1.2793	-
Hemispherectomy						
Total						
R.S.	20	3.3856	+			
D.W.	22	4.0984	+			
G.E.	24	4.8111	+			
Part 1						
R.S.	17	6.1984	+			
D.W.	20	7.7479	+			
G.E.	17	6.1984	+			
Part 2						
R.S.	3	-.6247	-			
D.W.	2	-.8616	-			
G.E.	7	.3692	-			

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* cases in which lenient score is more significantly different from chance than # correct. Note: All occur in the left hemisphere and all but one in N.G.

hemisphere is better able than the right to utilize error information and evaluate alternative solutions under conditions of uncertainty.

Conclusion to Visual Reception and Association. It is commonly assumed but has never been verified systematically that the disconnected right hemisphere is able to ellicit semantic information (meaning) from pictures. In fact some of the tests in subsequent parts of the thesis presuppose such competence and proceed to investigate the lateralization of certain language functions by limiting the pictorial information to one visual field and conditioning the response on the ability to extract the meaning of the pictures even though partial information, e.g. auditory linguistic messages, is available to both hemispheres. Unilateral right hemisphere performance of the commissurotomy patients on the Visual Reception and Visual Association subtests of the ITPA verifies that the assumption is indeed correct and that the right hemisphere has the capacity to form conceptually rather complex semantic associations which may even surpass the ability of the left hemisphere at least under certain conditions of extrafoveal or borderline foveal perception.

VISUAL SEQUENTIAL MEMORY

Test and administration. The ITPA includes two memory subtests at the automatic level. These are the visual and the auditory sequential memory tests. Visual sequential memory is described as a "short term memory for a visual sequence". (Kirk and Kirk, 1972). "it assesses the subjects ability to reproduce sequences of nonmeaningful (underlining mine) figures from memory." (Paraskevopoulos and Kirk, 1969). The subject is allowed two trials on each sequence when the first attempt is unsuccessful. The sequence increases in length from two to eight figures (figure 13). The visual stimuli are presented simultaneously, they are arranged horizontally, and they appear close together in order to approximate the physical characteristics of written English words. Abstract and novel figures were chosen in order to counteract the tendency to label the figures and therefore recall them through auditory and kinesthetic rehearsal as well as to avoid specific age effects (Paraskevopoulos and Kirk, 1969). Still, Kirk and Kirk (1972) acknowledge that "the task is sometimes facilitated or circumvented by using mnemonic devices involving meaning or by verbalizing so as to use auditory memory" (p. 116).

The Visual Sequential Memory figures thus satisfy the characteristics of right hemisphere material specificity as described by the McGill group (Kimura, 1963; Milner, 1962,1967,1968).

The test was administered in the standard manner to N.G. and L.B. in CLVP. Left visual half field presentation with left hand responses was followed, about a week later, by right visual half field presentation with the right hand rearranging the chips.

Results and discussion. As Table 6 indicates, left hemisphere performance was, in fact, superior and the material specific prediction is refuted. This difference is statistically significant ($p<.01$ for N.G.; $p<.05$ for L.B.). N.G. still shows bilateral memory deficit with a psycholinguistic age score of 4:4 for her right

Table 6a: ITPA Visual Sequential Memory scores by all patients in free vision and by the two commissurotomy patients in CLVP and in lateralized tactile testing

	RS	PLA	CPLA	SS
Visual				
Hemispherectomy				
R.S.	11	4:7	5:2	32
D.W.	16	5:10	8:8	27
G.E.	17	6:2	9:9	29
Commissurotomy				
N.G.	18	6:6	9:0	30
L.B.	18	6:6	> 10:1	28
CLVP				
N.G. R/H	10	4:4	-	-
L/H	18	6:6	-	-
L.B. R/H	18	6:6	-	-
L/H	35	> 10:5	-	-
Tactile				
N.G. R/h	9	-	-	-
L/h	8	-	-	-
L.B. R/h	16	-	-	-
L/h	15	-	-	-

RS = Raw Score

PLA = Psycholinguistic Age

CPLA = Composite Psycholinguistic Age

SS = Scaled Score

Table 6b: Statistical significance of difference in Sequential Memory scores between hemispheres and between modalities.

	R/H	vs.	L/H	t	p	Significant
Visual						
Hemispherectomy						
	R.S.		D.W.	1.948	.10	-
Commissurotomy						
	N.G.		N.G.	3.618	.01	+
	L.B.		L.B.	2.167	.05	+
Free	Vision	vs.	L/H			
	N.G.		N.G.	0		-
	L.B.		L.B.	3.644	.001	+
Tactile						
	L/h	vs.	R/h			
	N.G.		N.G.	.3781	.20	-
	L.B.		L.B.	.5780	.20	-
tactile	L/H	vs.	vis. L/H			
	N.G.		N.G.	2.689	.05	+
	L.B.		L.B.	4.663	.001	+
tactile	R/H	vs.	vis.R/H			
	N.G.		N.G.	.913	.2	-
	L.B.		L.B.	2.030	.01	+

hemisphere performance and 6:2 for her left hemisphere performance. In fact, N.G.'s right hemisphere psycholinguistic age score is essentially the same as R.S.'s (4:7). Similarly, both cases of right hemispherectomy, D.W. (5:10) and G.E. (6:2), although themselves deficient, are superior to R.S.

It should be noted in comparing R.S. to other patients that of all the ITPA subtests the lowest correlation with I.Q. and M.A. (mental age) in normal children occur in Auditory and Visual Sequential Memory (Paraskevopoulos and Kirk, 1969). Hence the comparison of scores seem particularly valid here without regard to R.S.'s generally lower intelligence. Thus it can be concluded on the basis of right hemisphere performance on the Visual Sequential Memory test that the right hemisphere has a poor capacity for recalling specific sequential order information of meaningless visual patterns, even when applied to spatial as opposed to temporal configurations. It remains to be seen whether the same deficit applies to recognition as to recall.

L.B.'s scores show a highly significant left hemisphere superiority and his RVF-F/h score surprisingly surpasses even his earlier free vision performance. The reason for this became clear during the test itself as L.B. used verbal codes to represent the various figures by employing a loose perceptual similarity and so rehearse the sequence verbally during the delay (5 seconds). Thus for him "" was an antenna, "" a figure eight, "" a star, "" an I, "" an equals sign, "" a circle and "" a curlique. In this way he has substituded an effecient left hemisphere verbal short term store for a more limited left hemisphere short term store for visual patterns. In fact L.B. was able to reconstruct correctly figure sequences up to 7 chips long and the longest auditory digit sequence which he could repeat correctly on the ITPA Auditory Sequential Memory test also contained precisely seven digits. Thus the observed and reported strategy of visual-verbal encoding is verified. Furthermore, the limitation of 7 bits of information in short term verbal store coincides with George Miller's famous magical number 7 (Miller, 1956). The right hemisphere, on the other hand, using most probably a complete pattern template matching recall strategy, was successful only with pattern-sequences up to five items long. This is a nice example of the efficiency tradeoffs involved in visual to auditory verbal encoding in memory and in left vs. right hemisphere strategies relative to a given task.

Two questions arise. First, why did L.B. fail to use the same verbal encoding strategy in his free vision performance which he used to such an advantage under RVF-R/h CLVP? A particularly intriguing possibility is that in free vision performance the left hemisphere is hampered by right hemisphere interference due to the nature of the stimuli. Indeed L.B.'s free vision score (18) is exactly the same as his LVF-L/h in CLVP, thus suggesting right hemisphere control of motor performance in free vision on this task (cf. Levy, Trevarthen and Sperry, 1972). However, the same can not be said of N.G. whose superior left hemisphere performance in CLVP is essentially the same as her free vision performance (raw score = 18). Consequently the pattern of performance in L.B. can not be said to represent the general disconnection syndrome on this test.

A more speculative extention of the thesis of unilateral depression of bilateral competence applies to N.G. It is possible to argue that the unexpected superiority of N.G.'s right hemisphere on the Visual Reception and Association subtests over her left hemisphere stems partly from a failure by the left hemisphere to inhibit or depress performance on this task just as with LVF-L/h CLVP performances on the Visual Sequential Memory. In general, informal observation supports the contention that N.G.'s right hemisphere performance on typical right hemisphere tasks tends to suffer less interference from the left hemisphere and thus performs more optimally than L.B.'s right hemisphere (even though N.G.'s right hemisphere is consistently inferior to L.B.'s) and this may be attributable to a left hemisphere lesion in N.G. (Levy, 1969).

The second question now arises: what characteristics of the task make it favor the left hemisphere? More specifically, is the left hemisphere superior in recognizing the figures or figure patterns? Alternatively, is it better able to identify the particular sequences presented due to a specialized competence in the perception of sequential order (Efron, 1963; Carmon and Nachshon, 1971; Hirsh, 1967); or does it use to advantage the strategy of verbal encoding in spite of the visually abstract nature of the figures? Regardless of the answer, the finding of left hemisphere superiority on the Visual Sequential Memory weakens the material specifity hypothesis in that it must either be rejected outright or be made secondary to other stimulus characteristics as a determinant of laterality effects or a component of hemispheric specialization.

Visual Sequential Memory error analysis reveals that the right hemisphere tends consistently to produce slightly more errors in which the whole sequence is reversed or in which just one chip is out of place, than the left hemisphere does. The higher systematic reversal rate may be attributed to its failure to register detailed order information. Similarly, the left hemisphere was more precise in aligning the figures in precisely the correct orientation even though the patients were aware that no credit was lost for unfaithful reproduction of figure orientation.

Visual Sequence Memory and reading ability. Kirk and Kirk (1972) believe that the ability measured by the visual sequential memory "is of vital importance in learning to read and spell" due especially to the sequential (-spatial) factor (p. 181). Indeed studies by Macione (1969) and Hirshcoren (1969) indicate that retarded readers have poorer visual sequential memory than children with similar intelligence who are good readers. Poor visual sequential memory ability is also consistent with a deficient STVM which is postulated to explain the pattern of dyslexia in D.W. As table 4 indicates, D.W.'s score on the visual sequential memory is in fact low and corresponds to normal performance of children aged five years and ten months old. Indeed an analysis of D.W.'s spelling error patterns (E. Zaidel, in preparation) showed that he uses a visual retrieval strategy characteristic of kindergarteners and first graders, who are of approximately the same psycholinguistic age as D.W.'s (5:10) as far as his performance on the Visual Sequential Memory is concerned.

D.W. also presents a lower mean score on the automatic ITPA subtests (mean psycholinguistic age equivalent 7:11) than on the representation subtests (9:4) as predicted by Macione (1969). But then so do all three hemispherectomy cases. G.E. who reads fluently has a psycholinguistic age equivalent of only 6:2 on this test, and N.G.'s right hemispheric equivalent psycholinguistic age on this test is 4:4 even though she can read selectively certain lexical items on the level of a first or second grader. Thus the functions measured by the visual sequential memory are not necessary for good reading ability.

Modality Specificity in Sequential Memory. Although a high positive correlation has been found between visual and auditory modes of presentation on short term memory tasks in normal adults (Kelly, 1954) the hemispherectomy data indicate that the right hemisphere performs better on a visual short term sequential memory task for non-meaningful figures than on an auditory short term sequential memory digit repetition task and the converse is true for the left hemisphere. To further ellucidate the issue of laterality effect in modality vs. function or material specificity in short term sequential recall tasks, a tactile version of the Visual Sequential Memory test was prepared and administered to the two commissurotomy patients, N.G. and L.B.

Materials. The original ITPA Visual Sequential Memory figures were photographed and enlarged by a factor of two and then etched photochemically to form raised patterns on zinc surface. The metal plates were then mounted on wooden blocks approximately 2X2X½" with the raised contours averaging approximately 2mm in width and .06" in height, as compared with the original 1x1x1/8" plastic chips. Administration was out of vision behind a screen to one hand at a time. Left hand testing was followed by right hand testing about two weeks later. The blocks were arranged in a horizontal row behind an opaque curtain and the subject was instructed to feel them consecutively from left to right. The patients took as long as necessary to explore the raised contours with their fingers for an average of approximately 10 seconds per item in the sequence. They were then required to rearrange the blocks in the same order presented to them following a 5 second delay. Pretest training on tactile pattern matching to sample at zero delay showed virtually complete success on all shapes, thus excluding somatosensory recognition deficit as a factor in poor performance on the test. The usual intertrial interval of 5 seconds was used but compared to the length of time the patients spent palpating the stimulus sequence this is negligible.

The lateralized somesthetic sequential memory test introduces a temporal factor into the task which according to brain lesion literature (e.g. Efron, 1963, Carmon and Nachshon, 1971) may favor the left hemisphere.

Results. The results in Table 6 show that the right hand is still inferior to the left hand in both N.G. and L.B. but that the difference is no longer statistically significant as it was on the visual version of the test. In spite of the added temporal factor, in fact the left hemisphere dropped in performance from a raw score of 17 and 35 (in N.G. and L.B., respectively) in CLVP to 9 and 16, respectively, in lateralized somesthesis, i.e. a drop of 69% and 54% respectively.

The right hemisphere score, on the other hand, dropped from 10 and 18 in CLVP to 8 and 15 in the tactile version (N.G. and L.B., respectively), or a respective drop of 20% and 17%. Indeed the drop in left hemisphere scores is significant (t=2.689 p .05 for N.G., t=4.663 p .001 for L.B.).

Thus the following conclusion emerges. Given a task within the competence of both hemispheres, left hemisphere superiority on a visually lateralized form of the task is likely to be diminished or even reversed on a somesthetically lateralized form of the same task. This is consistent with recent findings on right hemisphere superiority in part-whole relations and figural unification tasks (Nebes, 1971) as well as on the apprehension of 2-dimensional representations of 3-dimensional wooden blocks (Levy, 1969) in which the lateralized input was presented somesthetically (and which I have failed, in a pilot study, to duplicate in continuous lateralized <u>visual</u> presentation).

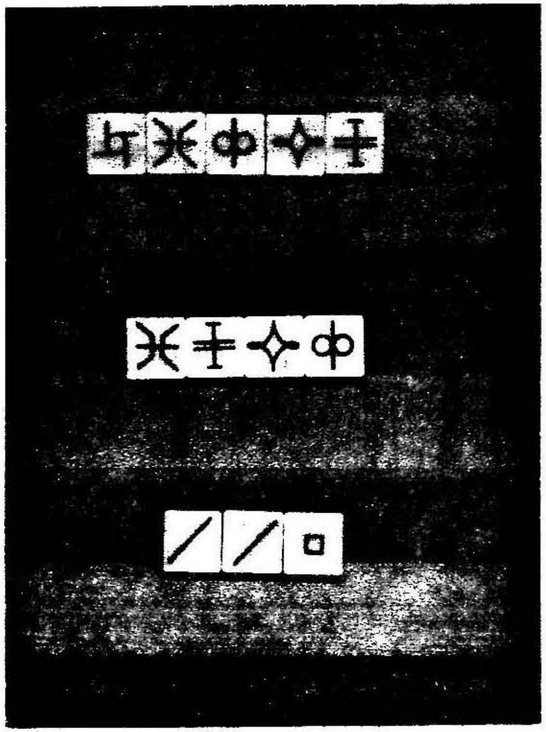
The tendency of unilateral somesthetic presentations to show a relative right hemisphere bias may be due to the diffuse, incomplete and imprecise nature of the information which reaches the cortex by tactile palpation. Such information may favor right hemisphere capacity diffuse for pattern completion while putting the left hemisphere with its reliance on specific, detailed, analyzable information at a disadvantage. Such modality dependent laterality effects deserve further study.

An alternative account for the somesthetic data could argue that the change from continuous lateralized vision to lateralized somesthesis may be attributed to an ipsilateral kinesthetic feedback and motor control between the left hand and left cortex. In that case left hand performance in the somesthetic case is attributed to left hemisphere competence. But this explanation is refuted by the inability of the commissurotomy patients to verbalize the details of their left hand performance.

VISUAL CLOSURE FACTORS

1. The ITPA Visual Closure Subtest

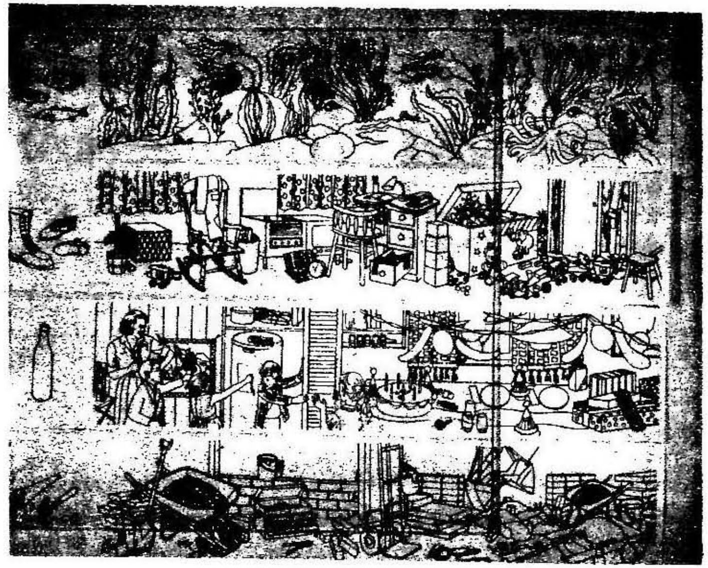
Test characteristics. The test was described in section 3.2 of this part. With the specified time limit condition the Visual Closure Test (figure 13) is primarily a test of perceptual speed. It is also important to note that in perceiving the visually incomplete forms the subject makes use of his previous everyday experience with visual stimuli. Three samples of the concealed objects are in view to the left of the scene but the concealed objects vary from these and from each other in size and orientation as well as in the degree of concealment. Thus form and size consistancy apprehension is necessary for success. Parakevopoulos and Kirk (1969) assert that the test incorporates several factors, such as recognition of out-of-focus pictures, completion of incomplete figures of animals and common objects, or of parts into a whole, or selecting the appropriate piece to complete a picture (pp. 42-43). In fact the test also involves the ability to distinguish a figure from a gestalt-binding surround. This study investigates the relationship of each of these factors and the test as a whole to hemispheric lateralization of function.



Sample items from the ITPA Visual Sequential Memory Test. Top to bottom: items no. 12,10,4.

Figure 12

1.
2.
3.
4.



The four stimuli for the ITPA Visual Sequential Memory Test. "Find hidden figures like the samples on the left".
Each of four scenes (fish, shoes, bottles, tools) is presented separately.

Figure 13

It may be argued that on the WISC both objects assembly and block designs probably involve considerable visual closure ability as does the coding test. Finding missing parts as in the picture completion test of the WISC may be also related in that the child must identify the incomplete picture. The manikin subtest of the WISC is also said to involve visual closure (Kirk and Kirk, 1972, p. 114). Thus it is important to assess directly the contribution of this factor to laterality differences.

Administration. The Visual Closure subtest was administered in the usual manner to the three hemispherectomy patients and to the two commissurotomy patients. The test was also administered to N.G. and L.B. in CLVP with one week intervals between LVF-L/h and RVF-R/h presentations. CLVP administrations were preceded by bilateral demonstration through the lens system with full verbal explanation and corrections. During continuous lateralized visual presentations the two subjects were encouraged to scan the scene (measuring 43.8 by 9.5 cm) and often this involved moving it from side to side on the platform in the subject's lap.

In CLVP the patients were instructed to work as fast as possible and their scores after the usual 30 seconds have been recorded. However the patients were allowed to continue searching for hidden figures as long as necessary until no new figures were identified (never longer than two minutes per scene). In this way possible interference of the lens system with scanning patterns of the eye or with visual search strategies were minimized and assessment of performance independently of speed was made possible.

Results. As table 7 indicates there is a consistent and statistically significant left hemisphere superiority on the visual closure subtest in all patients.

It turned out that performance with no time limit was substantially superior to standard performance in both hemispheres even though there is evidence from verbal reports during RVF CLVP that acuity was quite good. It follows that unilateral continuous lateralized visual presentations performance is characterized by reduced visual scanning efficiency. But it is not possible to say with certainty at this time whether the cause is the limitations introduced by the lens system or whether it is associated with an inherent unilateral visual scanning deficiency in either hemisphere.

Even with lenient scoring RVF-R/h performance is significantly inferior to free vision performance. Thus it would seem that some interhemispheric interaction is responsible for superior free vision score. Such interaction could occur thorough constant interchange in unilateral oculomotor control.

Absence of unilateral neglect of space. All patients fail to exhibit unilateral neglect of space with unilateral visual presentation (free vision in the case of hemispherectomy patients, R.S., D.W. and G.E.). Since the concealed figures are quite evenly distributed along each scene it is possible to score the number of correct identifications for the left and right half of the scene separately. As figure 14

Table 7a: ITPA Visual Closure subtest scores by the three hemispherectomy and two commissurotomy patients in free vision and in CLVP.

Patients	RS	SS	PLA
Hemispherec.			
R.S.	2	0	< 2:2
D.W.	22	28	6:9
G.E.	17	19	4:10
Commissurot.			
N.G.	38	43	> 10:6
L.B.	33	35	9:10
CLVP			
N.G. R/H	8	-	3:10
L/H	13	-	4:10
L.B. R/H	4	-	2:6
L/H	13	-	4:10
Lenient CLVP			
N.G. R/H	18	-	5:10
L/H	20	-	6:1
L.B. R/H	11	-	4:6
L/H	28	-	8:1

RS = Raw Score
SS = Scaled Score
PLA = Psycholinguistic Age

Table 7b: Significance of difference between right hemisphere and left hemisphere scores on the ITPA Visual Closure (t-test for correlated means).

L/H vs.	R/H	t	p	Significant
R.S.	G.E.	4.104	< .001	+
L.B.	L.B.	2.88	< .01	+
N.G.	N.G.	.62	> .2	-
N.G.+L.B.	N.G.+L.B.	2.28	< .05	+
Lenient				
L.B.	L.B.	3.6796	< .001	+
N.G.+L.B.	N.G.+L.B.	2.3587	< .05	+
Free Vision vs.	L/H			
L.B.	L.B.	5.479	< .001	+
N.G.	N.G.	6.357	< .001	+
Lenient				
L.B.	L.B.	1.517	> .1	-
N.G.	N.G.	4.1336	< .001	+

indicates there is a consistent left half scene preference for all patients during unilateral presentation. The data may be attributed to habitual scanning (reading) habits as well as enforced left to right scanning by instruction since the model figures appear exposed to the left of the scene. The results of figure 14 conflict with data of De Renzi, Faglioni, and Scotti (1970) from populations with unilateral brain damage who tend to perform worse on the side of the display contralateral to the side of lesion during a visual search test. The authors interpret this as pathological unilateral neglect of space. The tasks are not comparable but unilateral neglect in localized lesions may be attributed to an active inhibition effect which disappears with collosal interruption or equally with hemidecortication.

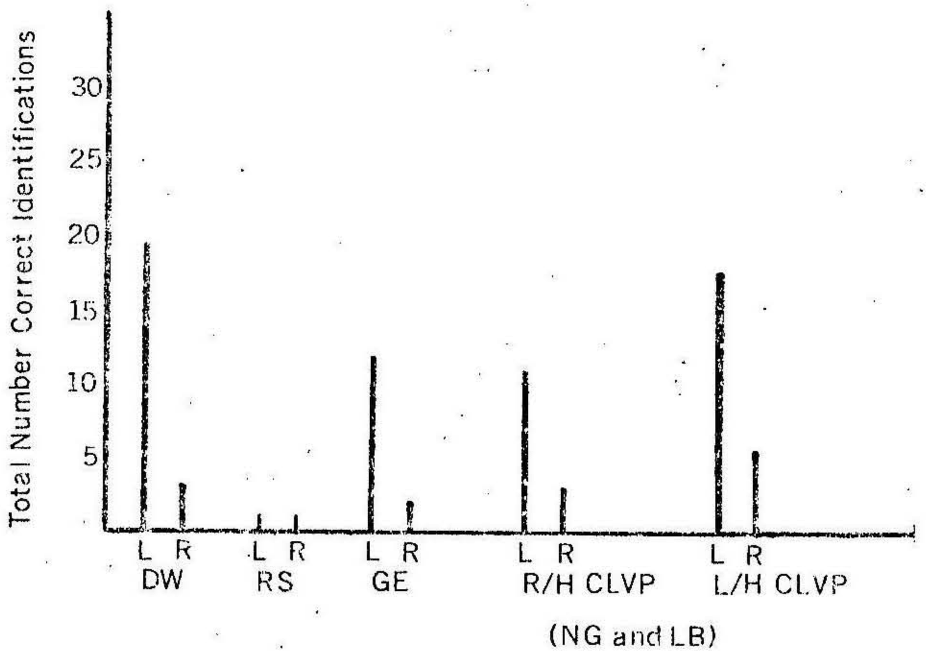


Figure 14
Total number of correct identifications in left (L) versus right (R) side of the scenes in the ITPA Visual Closure subtests.

Visual closure and reading. Since intersaccadic fixations during effecient reading expose only part of the phrase to foveal vision, it is clear that some visual closure must occur during reading. Observations of eye movements during reading indicate that an average reader in the fourth or fifth grade has three or four fixations per line whereas an average reader in the first grade has eight to twelve fixations. Thus it may be meaningful to correlate visual closure with reading ability and ask whether D.W. shows a selective deficit in visual closure which may be associated with his dyslexia. However, as table 7 indicates, evidence is fairly strong against such a correlation. D.W. has a higher visual closure score than G.E. who reads fluently! Indeed, closure in reading must be largely contexual semantic rather than visual perceptual. That is, phrases and words are "closed" or completed by reference to meaning and established linguistic usage rather than as a purely visual pattern matching. It may be argued that visual closure is necessary for reading acquisition, as in D.W., but not for maintenance of the already established overlearned reading skill as in G.E. where extra perceptual linguistic factors compensate for impaired closure ability. But D.W.'s performance matches the norm for a child 6 years and 9 months old whose reading ability would be far superior to D.W.'s. Consequently, D.W.'s reading disability can not be attributed to a visual closure deficit. Nevertheless the posibility that a visual closure impairment in D.W. is a contributing factor to his dyslexia, can not be ruled out.

Semantic effects. One of the scenes includes semantic cues which may be helpful in identifying some of the concealed figure.

Thus, the scene which conceals bottles depicts a mother and two children holding bottles in their hands. It is therefore interesting to compare the relative ability of the two hemispheres to utilize such cues by comparing their performance on these items relative to the rest in the same scene. Surprisingly, it turned out that the right hemisphere is not only inferior to the left in the utilization of such cues but also that it tended to make relatively more errors on the semantically cued than other items even though the former all appear on the left hand side of the scene which is invariably the starting scanning position for both hemispheres. Nevertheless, very few items are involved and the results may not be representative.

Was left hemisphere superiority in completing and disembedding figure form distracting ground due in whole or in part to the semantic nature of the material? Would the same advantage emerge when nonverbalizable geometric shapes replace familiar objects (fish, bottles, shoes, hammer and saw) as concealed figures? In order to answer that question an embedded figures test was administered to the hemispherectomy and commissurotomy patients in free vision and to N.G. and L.B. unilaterally in CLVP.

2. An Embedded Figures Test

Witkin's Embedded Figures Test. Form A of the adult version of Witkin's Embedded Figures Test (EFT; Witkin's et al, 1971) was administered to the two hemispherectomy patients, R.S. and D.W. The figures which make up the EFT are modifications of some of the geometric patterns used by Gottschaldt (1926) but their difficulty and variety were increased by introducing partial coloring into the complex figures and incorporating a memory component into the task. The final score is the mean solution time per item. Testing disclosed immediately that the test was too difficult for either patient. R.S. took inordinately long to understand the practice item and could not get any of the test figures. Both border outlines and colored subsections of the complex figure were found distracting and performance was not aided by putting the simple figure in view next to the complex one. D.W. was successful on items 2,7,10 and his score was 138 seconds per item. The norm score, x, and standard deviations, S.D., for ages 13 and 15, respectively, are: x=73.5, S.D.=37.9 and x=34.6; S.D.=30.5. D.W.'s score falls within the range of scores for 10 year olds (x=117.9, S.D.=32.9). It was concluded that this test was too difficult and the Benton and Spreen Embedded Figures Test administered instead. Nevertheless the results indicate bilateral deficit but a left hemisphere superiority.

Benton and Spreen's Embedded Figures Test

Test and administration. Form A of the Embedded Figures Test of Benton and Spreen (1969) was administered to all the patients under all conditions. The simple and complex figures are again relatively unfamiliar geometric patterns of broken line drawings that are hard to verbalize but the complex patterns are much simpler than in Witkin's test and both are presented side by side on the same sheet so that no memory component is involved. The subjects are required to search for and trace the stimulus figure in the embedded design using a black marker. For the two cases of right hemispherectomy and for right visual field CLVP a version for right handers was used where the simple figure appears to the left of the complex one. This is reversed in the left-handers version which was used for the right hemispherectomy patient and for LVF-L/h presentation to the two commissurotomy patients in CLVP. One credit point is given for every design correctly completed within 30 seconds. One additional credit point is given if the design is completed within 20 seconds. Maximum credit score for all 16 items is 32 points. Norms for children aged 6 to 12 as well as preliminary norms for adults including brain damaged patients are available.

About a week separated consecutive administrations of the test to the commissurotomy patients (LVF-L/h, RVF-R/h, free vision). For continuous lateralized visual presentations the demonstration items were presented in bilaterally exposed vision through the lens.

Results and discussion. A significant left hemisphere advantage is apparent in comparing left to right hemisphere performance in each of the two commissurotomy patients with CLVP (Table 8). A learning transfer effect from left visual field to right visual field presentation is unlikely since following LVF-L/h testing, L.B., for example, could not verbalize or draw with his right hand any of the patterns he had just traced in CLVP, and he instead confabulated about patterns experienced by the right visual field previously to the Embedded Figures test. When encouraged to draw with his left hand some of these patterns and "let his left hand draw what it wants" he indeed eventually traced two of the simple figures of the Embedded Figures test, his verbal reaction

Table 8a: Performance on the Embedded Figures Test by the three hemispherectomy cases and the two commissurotomy patients in free vision and in CLVP.

Patients	Score (max.=32)	# correct (max.=16)	Overtime	Equal to mean score at age....	Equal to mean # correct at age.....
Hemispherec.					
R.S.	3	3	1	<6	6
D.W.	10	5	2	6	<6
G.E.	12	8	2	6	<7, and>6
Commissurot.					
N.G.	14	8	0	< 7,and>6	<7, and>6
L.B.	31	16	0	>12	>12
CLVP					
N.G. R/H	2	1	0	<6	<6
L/H	8	4	0	<6	<7, and>6
L.B. R/H	15	9	2	< 7,and>6	<7, and>6
L/H	28	15	0	11	12

Normal controls mean score = 30.83; brain damaged mean score = 21.04
mean IQ = 117 mean IQ = 89

Table 8b: Results of statistical analysis of the difference between right and left hemisphere scores and between free vision and lateralized left hemisphere scores (one-tailed t-test for correlated means).

R/H vs.	L/H	t	p	Significant
R.S.	D.W.	1.5175	>.05	-
R.S.	D.W.+G.E.	1.9357	<.05	+
N.G.	N.G.	1.3787	>.05	-
L.B.	L.B.	3.895	<.01	+
Free Vision vs.	CLVP			
L.B.	L.B. L/H	1.8564	<.05	+
N.G.	N.G. L/H	1.3787	>.05	-

being one of surprise. Due to the generally low scores the difference in performance between R.S. and between D.W. and G.E. just reaches statistical significance ($p < .05$ on a one tailed test). It is interesting to note that all the three successful responses of R.S. were to items failed by D.W. and only one of them was performed successfully by G.E. Characteristically, R.S. would start tracing the correct part of the complex figure but eventually be distracted to add spurious lines (figure 15). The superior performance of L.B. with respect to N.G. in both hemispheres is consistent with higher intelligence and known individual differences.

The scores of all three hemispherectomy patients are significantly inferior to those of normal children and adults of the same ages, all of them falling on or below the mean score norms for 6 year old children. This result coincides with the findings of Teuber and Weinstein (1956) that men with wounds of entrance into any lobe but without aphasia showed about equal degree of impairment on such hidden figures tasks. Only men with aphasia showed selectively greater impairment than the rest of the brain injured population, who in turn fell significantly below the performance level of the control group with peripheral nerve injuries. Indeed, R.S., the case of dominant hemispherectomy who is aphasic has the lowest score of the whole population.

The two commissurotomy patients also show improvement of performance in free vision as compared with RVF-R/h in CLVP. One explanation may be that the CLVP restricts scanning patterns of the eye.

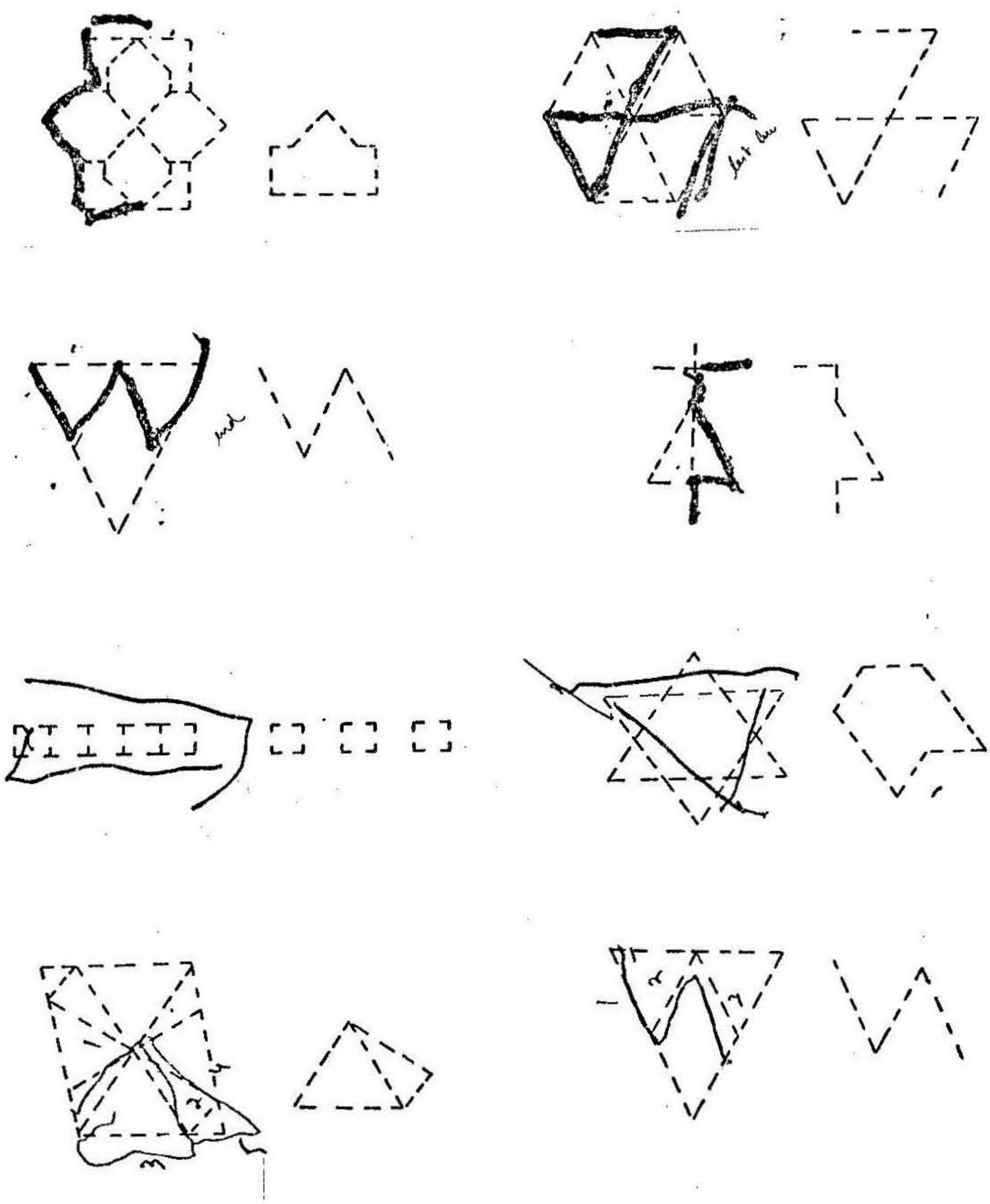


Figure 15. Some sample right hemisphere responses on Benton and Spreen's Embedded Figures Test. Responses 1-4 are by R.S., 5,6 are by N.G. and 7,8 are by L.B. Note perseverations in items 3,5.

Yet, the erroneous responses tend to show spurious rather than restricted or incomplete tracing and there is never any doubt that both the simple and complex patterns are adequately perceived. Furthermore, the data of Teuber and Weinstein (1956) shows that the impairment on the hidden figures task was clearly independent of the presence or absence of visual field defects and the authors concluded that the deficit can not be equated with agnosia in the usual sense of this term.

On the basis of the preceding data it is possible to conjecture that the embedded figures task involves two independent factors. The primary factor is highly correlated with language competence in the left hemisphere, while a secondary factor involves the right hemisphere -- perhaps through a synthetic pattern completion component which is intermediate in the processing of the task. On this hypothesis the improved free vision performance of N.G. and L.B. must be attributed to partial interhemispheric interaction probably mediated by brain stem pathways. It should be noted, however, that since the free vision administration was given within seven days of RVF-R/h CLVP a learning effect is quite likely. The conjecture advanced here is consistent with Teuber and Weinstein's results. In fact Russo and Vignolo's (1967) have proposed a similar two-abilities model to explain their data which virtually replicates Teuber and Weinstein's.

3. Summary: laterality effects in the two visual factors

Thurstone (1944, pp. 78-80) has identified two visual closure factors in perception. The first closure factor he described as the ability to perceive an apparently disorganized or unrelated group of parts as a meaningful whole, i.e., the capacity to construct a whole picture from incomplete or limited material. This basic perceptual capacity may manifest itself at a more general level as the conceptual ability to grasp and unify a complex situation. The first visual factor is labeled by Guilford (1968) CFU-V: cognition of visual figural units, and in certain forms it is referred to as "perceptual speed". Various tests, notably by Street (1934), Thurstone's Closure Speed (1966), Hooper (1958), Gollin (1960), and Mooney (1954) measure this factor.

Thurstone's second closure factor is the ability to hold a configuration in mind despite distraction, i.e., the capacity to see a given configuration (diagram, drawing or figure) which is "hidden" or embedded in a larger, more complex pattern. Guilford labels the factor NFT: convergent production of figural transformations, and Witkin refers to a corresponding cognitive style of field independence (differentiation) which is correlated with personality factors. Poppelreuter's (1917) and Ghent's (1956) Overlapping Figures, Gottschaldt's Hidden Figures (1926), Thurstone's Gestalt (Closure) Flexibility (Pemberton, 1952), and Witkin's Embedded Figures Test (Witkin et al, 1971) measure this factor. Witkin refers to this factor as the ability to break up or analyze a perceived visual structure. Guilford objects to the term "analysis" in this connection since the reinterpretation of the lines of the hidden figures does not lead from apprehension of the part to understanding of the totality.

Right hemisphere superiority on tests involving the first visual factor has been reported often in the neuropsychological literature (De Renzi and Spinnler, 1966 on the Street test; Nebes, 1971 on tests for part-whole apprehension and figure unification; Lansdell, 1968 on the Mooney faces). The picture is more complicated in the case of the second visual factor. De Renzi and Spinnler (1966) present data to the effect that the right hemisphere is superior to the left on Ghent's Overlapping Figures test but Teuber et al (1960) and Russo and Vignolo (1967) conclude from patients with penetrating missile wounds and cerebro-vascular lesions, respectively, that the left hemisphere is superior to the right on Gottschaldt's embedded figures although both studies hypothesize independent right and left hemisphere component processes which contribute to the task. Cohen et al (in press) have shown strong left hemisphere involvement in and right hemisphere suppression of performance on Witkin's Rod and Frame test which is highly correlated with the Embedded Figures test.

In the way of summary, we are now in a position to provide a fairly detailed analysis of laterality effects in visual closure tasks. There is substantial evidence from unilateral brain lesion studies (De Renzi and Spinnler, 1966; Lansdell, 1968; Warrington and James, 1967) as well as from commissurotomy patients (Nebes, 1971) that the right hemisphere is superior to the left on the first closure factor, namely, pattern or gestalt completion from partial, incomplete or fragmented information. On the other hand bigger left hemisphere contribution to the second closure factor, i.e. freedom from distracting background gestalt, emerges from populations with lateralized cerebral damage (Teuber et al 1960; Russo and Vignolo 1967; Cohen et al, 1973) and this is extended by our results on the Embedded Figures Test to the commissurotomy and hemispherectomy patients. When both factors are present at once as in the ITPA Visual Closure subtest, gestalt distraction incapacitates the right hemisphere and proves to have a strong inhibiting effect on its pattern completion ability. Furthermore, left hemisphere superiority on the second closure factor is not material specific (i.e. not only for familiar, verbalizable items as in the ITPA Visual Closure subtest) since it occurs just as dramatically in the Embedded Figures test with non-verbalizable geometric patterns.

A more general interpretation of the left-right hemispheric dissociation on the Visual Closure and Embedded Figures tests is possible. The crucial factor which creates a bigger right hemisphere deficit may be the inability to change sets or reorient attention to different aspects of a complex visual stimulus which are univocally specified. This has been demonstrated here for the inertness of strong initial interpretations as in concealed or overlapping figures. It remains to be shown for figure-ground combinations in unstable equilibrium as in the Rubin figures. In effect this reinterprets Luria's frontal syndrome (1966) as a laterality effect at least in double dissociation (left-right and front-back). The hypothesis is consistent with prevailing intuitive notions about right hemisphere perception being fast and "simultaneous" as well as with the data submitted above on differential effects in the abilities of the two hemispheres to improve their performance in repeated trials following corrections -- the left hemisphere being superior.

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IV. ASPECTS OF RIGHT HEMISPHERE AUDITORY LANGUAGE COMPREHENSION

INTRODUCTION: AURAL VOCABULARY IN THE RIGHT HEMISPHERE

Previous studies of language in the right hemisphere of commissurotomy patients have consistently reported extensive comprehension of nouns but limited comprehension of verbs (e.g. Gazzaniga, 1970). But none of these studies was systematic either in its sampling selecting or in controlling for frequency of usage, abstraction or meaningfulness of the words sampled. Further sampling restrictions were imposed by the tachistoscopic presentation. Thus inspite of a general agreement about the ability of the right hemisphere to comprehend lexical items, the precise scope of this ability has never been assessed.

Two commonly used picture vocabulary tests were administered in CLVP to N.G. and L.B. and in free vision to all patients. Table 1 summarizes the results on the Peabody Picture Vocabulary Test and on Ammon's Full Range Picture Vocabulary Test. Mental age and IQ estimates based on raw scores are included as well. IQ and percentile ranks for the patients over 18 years old on the Peabody test were computed by assuming the maximum standardized age of 18:5. As can be seen, the scores are surprisingly high and show a selectively superior aural vocabulary in the right hemisphere as compared with other language functions.

The results of an attempt to reveal any part-of-speech effect in the comprehension vocabulary of the right hemisphere of N.G. and L.B.

are illustrated in Figure 1. Percent of correct responses by the combined left hemispheres and combined right hemispheres of N.G. and L.B. are plotted for each part of speech (nouns, verbs, and adjectives) pooled from responses to the Peabody and Ammon tests. A slight superiority of the comprehension of nouns as against verbs is apparent. Rather surprisingly the comprehension of both nouns and verbs was inferior to that of adjectives. But, more significantly, both left and right hemispheres show exactly the same trend throughout! The reason for this effect became clear when the number of occurences in the tests of each part of speech was plotted against age of acquisition (Figure 2). It turns out that while nouns and verbs are sampled more or less uniformly at all levels of difficulty (mean ages of acquisition), this is not the case for adjectives which predominate among the difficult items. Indeed, these picture vocabulary tests were not designed to compare performance on various parts of speech and previous investigations of the vocabulary in the right hemisphere of the commissurotomy patients must have suffered from the same shortcomings.

In fact, as Figure 3 illustrates, when percent of correct responses is plotted against frequency of accurence of items (Thorndike and Lorge, 1944) both hemispheres show the <u>same</u> frequency effect (which also parallels that of children as well as normal and aphasic adults -- Howes, 1964), even though the right hemisphere is consistently inferior to the left.

The right hemisphere shows good comprehension of words of diverse semantic classes. No difference could be found in its ability to identify pictures which correspond to actions, affective states, or

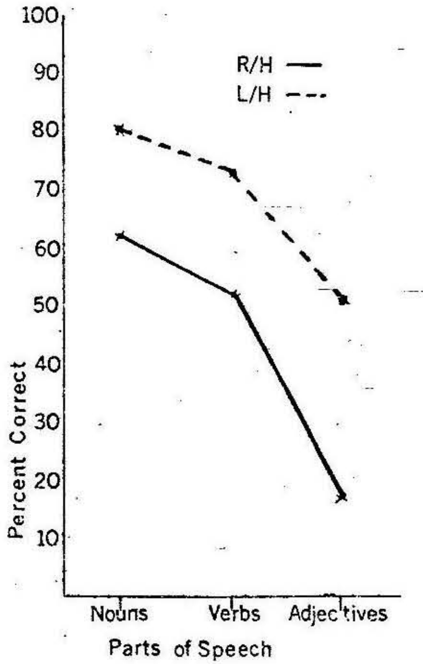

Figure 1

Combined percent of correct unilateral (CLVP) responses as a function of part of speech by N.G. and L.B. on Peabody's and Ammon's Picture Vocabulary Tests.

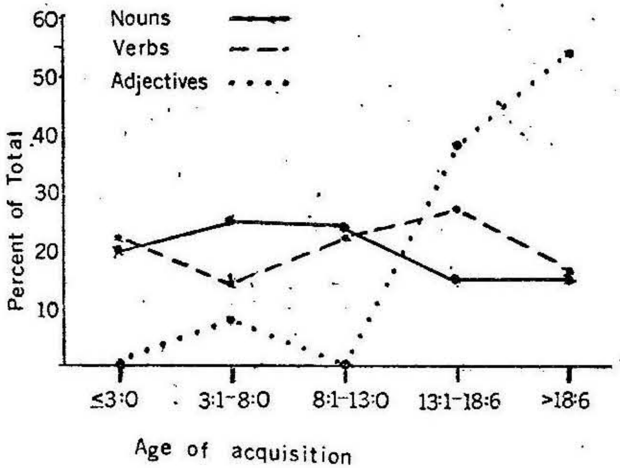

Figure 2

Percent of nouns, verbs and adjectives out of total number of words in each age category in Peabody's and Ammon's Picture Vocabulary Tests.

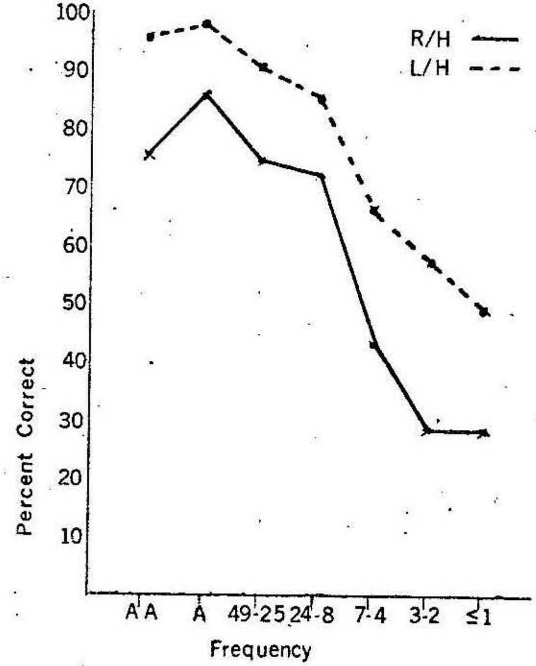

Figure 3

Percent of correct unilateral (CLVP) responses as a function of word frequency by N.G. and L.B. on Peabody's and Ammon's Picture Vocabulary Tests.

highly abstract words such as "discipline" (picture of a mother spanking a child), "mastery" (picture of mountaineer) or "reminder" (tap on the shoulder).

	L.B. LVF-L/h	L.B. RVF-R/h	L.B. FV	N.G. LVF-L/h	N.G. RVF-R/h	N.G. FV	R.S.	D.W.	G.E.
Peabody									
RS	103	115	130	82	87	91	66	92	108
MA	16:3	>18	>18	11:0	12:5	13:2	8:1	13:7	17:9
IQ	94(18:5)	106(18:5)	121(18:5)	71(18:5)	78(18:5)	82(18:5)	68	86	99(18:5)
%ile	34(18:5)	66(18:5)	89(18:5)	2(18:5)	8(18:5)	14(18:5)	<1	18	47(18:5)
Ammon									
RS	53	69	73	40	58	63	42	61	76
MA	13:5	16:5	Adult	10:0	14:6	15:4	10:6	15:2	Adult
IQ	73	98	105	52	81	89	75	75	110
adult %ile	3	47	60	<1	13	25			73

RS=raw score; MA=mental age

Table 1

Performances by the patients on the Peabody Picture Vocabulary Test and Ammon's Full-Range Picture Vocabulary Test. IQ and %ile estimates on the Peabody scores obtained by assuming the maximum chronological age of 18:5 (indicated in parentheses).

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SYNTAX IN UNILATERAL AUDITORY LANGUAGE COMPREHENSION

SYNTAX IN UNILATERAL AUDITORY LANGUAGE COMPREHENSION

GENERAL

Introduction. As late as 1972 in his review of recent research on asymmetry of cerebral hemispheric function O. Zangwill (1972) concluded in connection with commissurotomy studies on language that "there is still little or no evidence to suggest that the minor hemisphere can appreciate syntax or the meaning of a proposition" (p. 443). He supports this conclusion by references to Gazzaniga (1970) and Gazzaniga and Hillyard (1971).

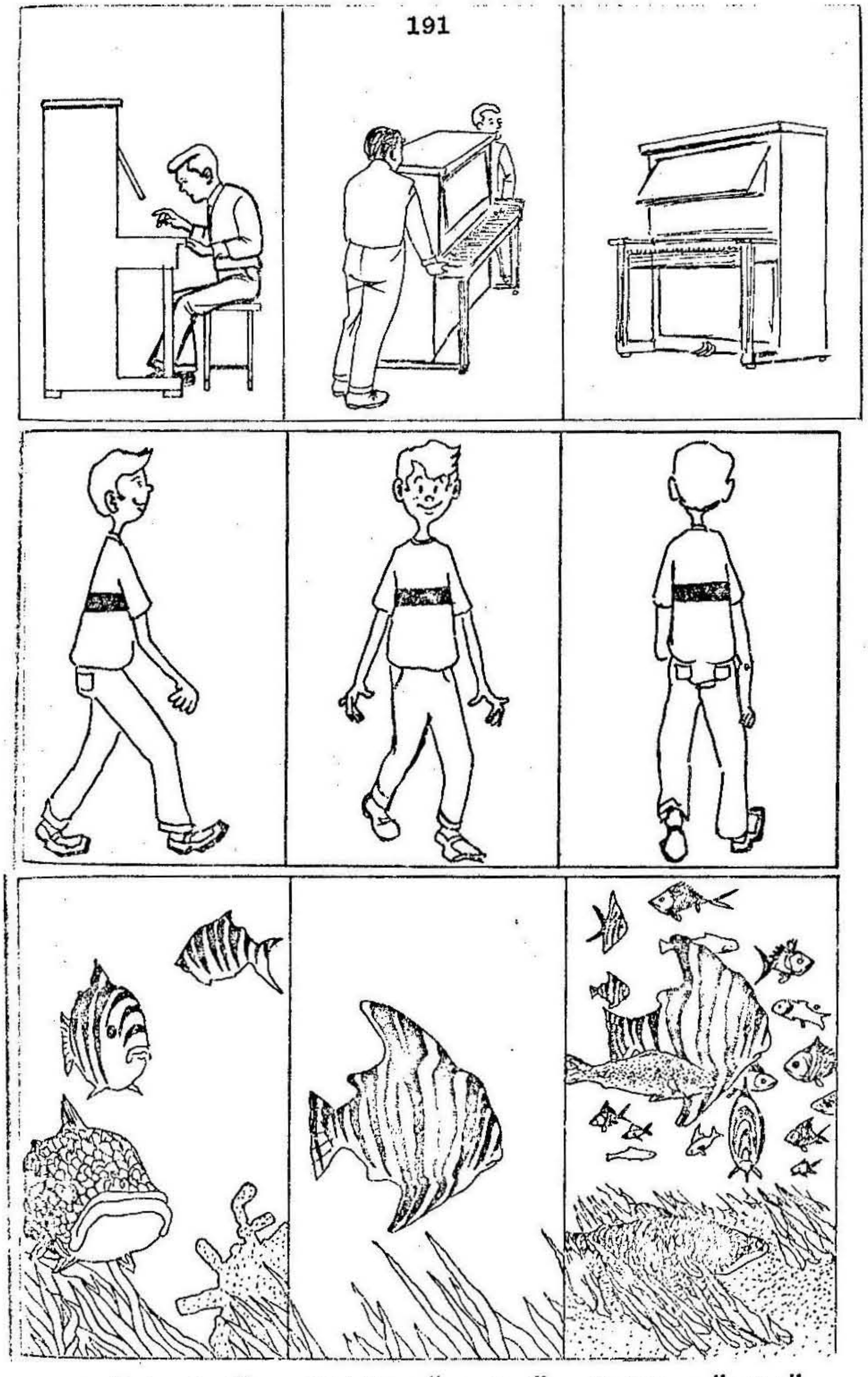
In his introductory text (1970) the developmental psycholinguist David McNeill concludes on the basis of Gazzaniga and Sperry summary (1967) that "there is no evidence that the right hemisphere can comprehend syntax, although one might plausibly expect it to do so in view of the fact that language acquisition is underway long before lateralization is complete" (pp. 140-141).

As it turns out, Gazzaniga and Sperry's 1967 summary can now be revised and extended considerably and the negative results in Gazzaniga and Hillyard's 1971 conclusions must be rejected as inaccurate. McNeill's expectation turns out to be substantially correct as informal observations of the "split-brain" patients during right hemisphere testing have suggested for some time. For, appropriate, even when poor, right hemisphere performance on numerous tests indicates that it has comprehended task requirements which have usually been explained verbally.

Materials and Administration. Four tests for evaluating comprehension of syntactic structures were administered to N.G. and L.B. in CLVP and to all patients in free vision. The tests are slightly modified versions of the comprehension test described by Fraser, Bellugi and Brown (henceforth: FBB) (1963), Lea's Northwestern Syntax Screening Test (NSST), Carrow's extensive Auditory Test for Language Comprehension (1968, 1969) and Shewan and Canter's Sentence Comprehension Test (1971) (henceforth: SC). The first three were designed for and used with children, the last for and with aphasics. As administered here, all tests employ the same paradigm. Pairs of syntactic contrasts are presented separately in aural sentences along with an array of 3-4 pictures which differ from each other in precisely one dimension involved in the contrast (figure 1). The subject has to point to the one picture which best corresponds to the stimulus message -- word, phrase or sentence.

FBB's comprehension test was redesigned to present 4 picture choice arrays instead of two and in administering it as well as the NSST contrast pairs were not both read before one of them was repeated, nor were they sampled consecutively. Otherwise, scoring and administration follows standard procedures.

Results and discussion. As Table 1 indicates, with only one exception (N.G. on the Shewan-Canter Test) the right hemisphere is able to comprehend syntactic structures as measured by the four tests well above chance. As expected, the left hemisphere is superior to



Top: "pianist". Middle: "coming". Bottom: "many".

Figure 1

Three sample items from Carrow's test.

Table 1a :Summary of raw scores and Z-scores (difference from chance) on the syntax tests.

Test (max. score)	N.G.			L.B.			R.S.	D.W.	G.E.
	R/H	L/H	FV	R/H	L/H	FV			
Shewan (42)									
raw score	13	16	30	24	31	37	24	32	35
Z-score	.8909 N.S.	1.9599	6.9489	4.8108	7.3053	9.4434	4.8108	7.6616	8.7307
Brown (52)									
raw score	33	48	45	37	48	52	44	48	50
Z-score	6.4051	11.209	16.2482	7.6861	11.209	12.49	9.9279	6.1016	6.6563
Lea (38)									
raw score	22	28	29	18	36	37	25	30	34
Z-score	4.6829	6.9307	7.3053	3.1844	9.9277	10.3023	5.8068	7.6799	9.1784
Carrow (106 or 112)									
raw score	87	95	100	86	108	110	83	104	99
Z-score	12.8748	14.6205	15.7116	13.3465	17.4573	17.8938	12.6736	16.5834	16.2625

N.S. = not significantly different from chance, $p > .05$

$Z = 1.96$: $p < .05$; $Z = 2.576$: $p < .01$; $Z = 3.291$: $p < .001$ (two-tailed)

Table 1b: Statistical significance (one-tailed, t-statistic for difference between correlated means) of right vs. left hemisphere performance on the four syntax tests.

	N.G. R/H vs. L/H			L.B. R/H vs. L/H			R.S. vs. D.W.		
	t	p	signif.	t	p	signif.	t	p	signif.
Shewan	1.2205	>.1	-	1.7383	<.05	+	1.6343	>.05	-
Brown	3.8881	<.001	+	2.5804	<.005	+	1.1599	>.10	-
Lea	1.638	>.05	-	5.2285	<.0005	+	1.3030	>.10	-
Carrow	1.6376	>.05	-	3.6563	<.0005	+	3.6563	<.0005	+

the right on these tasks, although the difference is not always statistically significant. In general lenient scoring which allows second guesses following incorrect first answers results in higher scores but statistically less significant difference from chance (the probability of guessing correctly increases from .25 to .5 in changing from standard to lenient scoring). The only exception to this rule is in N.G.'s left and right hemisphere performance on Shewan-Canter's test for sentence comprehension (see below). Furthermore, the difference in Z-scores between the left and right hemispheres are invariably smaller for lenient than for standard scores (even though the left hemisphere's Z-scores are consistently higher). In fact, the left hemisphere gain in performance due to lenient scoring is numerically smaller than the gain by the right hemisphere. But this results from the already high left hemisphere raw scores which can only gain a few more points, but lose much in significance relative to chance by lenient scoring.

The following cumulative difficulty ranking of syntactic structures for the right hemisphere (Table 2) which combines results on the four tests is often based on relatively few samples and not all grammatical categories were sampled equally often. Neither were they sampled under uniform conditions (the results combining as they do four different tests) nor do they always use the identical grammatical contrast pairs. Consequently, error scores for particular syntactic structures are not always reliable and only gross features of difficulty rank ordering will be discussed in relation to the cumulative data. In particular, the error scores obtained here underestimate the capacity of the right hemisphere to comprehend the corresponding syntactic constructions in the context of a normal, semantically redundant, conversation and in the absence of the stringent perception-cognitive task the requirements imposed by the formal paradigm used here.

Combined right hemisphere percent error scores from the four tests on selected grammatical constructions are presented in Table 2. Proportion error scores are obtained by dividing the combined (across patients and across tests) number of incorrect responses to a given grammatical construction by the total number of times the construction was administered.

There occur very few failures by the right hemisphere to recognize individual nouns and verbs and the same words are used to construct subsequent sentences (Carrow's test). In contrast to previous reports (Sperry, Gazzaniga and Bogen, 1969; Gazzaniga and Hillyard, 1971) and in agreement with the general trend in R.S. (Part II of the thesis) results here indicate no difference in the right hemisphere's capacity to comprehend nouns and verbs. In fact none of the three patients failed to perform any of six actions (imperatives)

Table 2

Error scores of the right hemisphere on selected grammatical categories combining tests and subjects.

grammatical category	proportion error	percent error	rank order
Lexemes by part of speech			
nouns	4/90	4	3
verbs	1/18	6	5
adjectives			
qualitative contrasts (little/ big)	1/21	5	4
colors	1/9	11	6
number, relative quantity, quantifier (two, some, more, fourth...)	8/24	30	15
Spatial			
adjectives (left/right)	1/3	33	16.5
adverbs (up/down)	0/3	0	1.5
prepositions (on, in, between)	8/24	33	16.5
coming / going	3/6	50	21.5
demonstratives (this, these/that, those)	2/12	17	8
Pronouns	17/48	35	18
Nominative case (he, she, they)	4/18	22	
Objective case (him, her, them)	3/3	100	
Possessive case (his, her, their)	7/21	33	
Reflexive case (himself...)	3/6	50	
Morphological constructions			
Possessive inflection 's' (mother's cat/ mother cat)	3/6	50	21.5
Number, noun: inflectional singular/ plural	7/27	26	11
Predication, noun-verb, member agreement:	5/18	28	12.5
Inflectional, present-indicative-singular/plural (the cat plays/ the cats play)			
Suffixes	7/24	29	14
noun+derivative suffix "er" (farm/farmer)	1/6	17	
verb+derivative suffix "er" (catch/catcher)	1/6	17	
comparative:adj.+deriv. suff. "er" (tall/taller)	3/6	50	
noun+deriv. suff. "ist" (piano/ pianist)	3/6	50	

Table 2 (continued)

grammatical category	proportion error	percent error	rank order
Tense, verb: present indicative, present progressive, future, past	15/54	28	12.5
Sentential transformations			
Interrogatives	9/12	75	24
Auxiliary "is" (Is the dog in the box?)	4/6	67	
Auxiliary "have" (Has daddy finished his dinner?)	5/6	83	
Negation ("The girl is/is not running")	5/30	17	8
neither-nor	0/3	0	1.5
Voice, Subject-object, active voice ("The boy pushes the girl")	11/24	46	20
subject-object, passive voice ("The dog is chased by the boy")	8/18	44	19
Complementation, direct/indirect object	15/21	71	23
Noun vs. prepositional phrase ("The tea cup"/"the tea in the cup")	2/12	13	8

included in Carrow's test and incorporating dependent adjectival or conditional clauses ("mark the car that is on the street"). The reason for this becomes clear when one notes the age group at which 60% of the children in Carrow's population (1968) comprehend each linguistic item. In fact the mean age group of the nouns used is 3:2 and of the verbs 3:6 with bigger standard deviation in the verbs. Thus the difficulty levels of the items in the two groups is comparable and the right hemisphere again shows a typical dependency of the responses on the age of acquisition of lexical items (though not, as will become evident shortly, for syntactic structures) which is equally characteristic of left hemisphere and aphasic responses.

As far as sentential transformations are concerned (Chomsky, 1965) it turns out the interrogative sentences employing auxiliary verbs ("Has daddy finished his dinner?") are more difficult than either active, passive or negative sentences. Somewhat surprisingly, the comprehension of passive sentences was not more difficult (impaired) than active constructions. The active and passive sentences are not directly comparable to the negative ones since they are longer and involve the identification of subject and object ("The dog is chased by the boy" - boy = subject; dog = object, vs. "The boy is chased by the dog"). Indeed the most important parameters in producing right hemisphere deficit would seem to be length and word order, especially in tasks with nonredundant subject/object and direct/indirect object relations, perhaps because of the demand that such tasks impose on detailed analysis and classification and on short term verbal memory. This is in contrast to the finding of Goodglass (1968) that the best retained signal of grammatical relationships in aphasics is word order. Thus the right hemisphere is sensitive, in general, to the perceptuo-cognitive complexity of the identification task than to the syntactic function of a given grammatical structure.

For example, the difficulty of morphological constructions is highly variable even though uninflected forms are usually more readily comprehended by the right hemisphere than inflected ones. It seems that the plural s and the third person s are easier for the right hemisphere than the possessive inflection s. This is in accord with a transformational grammatical account (Chomsky, 1965) which invokes sentence structure changes in the possessive transformation (from "John has a hat" to "John's hat") but not in the other two. The relative difficulty of the possessive construction has parallels in the work of Bellugi (1964) on children and of Goodglass (1968) on aphasics. On the other hand the failure of the third person singular inflection to show a higher error rate is at odds with developmental psycholinguistic as well as aphasic data. The fact that the right hemisphere is more de - ficient in distinguishing "is" from "are" than the plural inflection from the third person singular shows that the prominence of the syntactic one is not a crucial factor.

At any rate, the contention that "there is no ability (in the right hemisphere) to recognize either the relations between subject, verb, and object, the future versus the present tense, or the singular versus the plural case" (Gazzaniga and Hillyard, 1971) must be rejected and attributed to limitations in the experimental technique (tachistoscopic presentations) and for unbalanced design (failure to equate for frequency, etc.). It would seem to follow that semantic interaction occurs and affects the level of right hemisphere performance. Notable in this regard is the relatively high error rate of the right hemisphere on lexical items involving numbers, adjectives of relative quantity and quantifiers (four, many, middle). The foregoing is not intended to deny that normal sentence comprehension is sensitive to contextual meaning as well, but one is impressed that this is particularly strong in the case of the right hemisphere.

Parisi and Pizzamiglio have administered a similarly designed test for syntactic comprehension to a group of 60 Italian aphasics and compared their performance to that of 144 3 to 6 year old Italian children.

They found the difficulty rank order correlation between the aphasics and children to be highly significant as was the correlation between the subgroups of Broca's and Wernicke's aphasics and between two unclassified aphasic groups at the two opposite ends of the severity rating scale distribution. Table 3 compares right hemisphere difficulty rank ordering to that of Broca's and Wernicke's aphasics as well as to that of children. Right hemisphere scores are pooled from relevant items in all four syntax tests and extra care was expended to match tasks as closely as possible. For that reason 6 of the grammatical contrasts used by Parisi and Pizzamiglio were omitted from the analysis since they did not have matching tasks that were similar enough to the tests administered to the commissurotomy and hemispherectomy patients, on linguistic as well as cognitive grounds. Even so, the compared tasks are not identical especially since syntactic structures in Italian are different from English (e.g. Italian requires more morphological changes and inflections than English to denote the same grammatical contrasts) and may be acquired at different ages and in a different way than in English.

Spearman's rank order correlation coefficient between the right hemisphere and the total aphasic population is significant beyond the .05 level ($r_{R/H\text{-}Aph.} = .5667$) as are the correlations between the right hemisphere and the Broca aphasics ($r_{R/H\text{-}Bro.} = .5998$) and the Wernicke aphasics ($r_{R/H\text{-}Wer.} = .6035$). The correlation between the right hemisphere and the children, however, ($r_{R/H\text{-}child.} = .4498$) fails to reach statistical significance ($p > .05$). The conclusion, if it is valid, that the pattern of right hemisphere errors resembles that of Wernicke's

Table 3 : Rank of difficulty of some of Parisi and Pizzamilio's (1970) grammatical contrasts for the right hemisphere (R/H) and for a total group of aphasics, a Broca subgroup, a Wernicke subgroup, and children.

Contrast type	R/H	Aphasics total group	Broca's	Wernicke's	Children
1 on vs. under	9	10	14	8.5	14
2 behind vs. in front of	6.5	13	13	10	10
6 beside (by) vs. behind	11.5	8	8	8.5	7
7 between vs. beside (by)	13.5	9	12	12	9
8 up vs. down	13.5	14	10	13.5	12
10 subject-object (active voice)	3	4	4	3.5	6
11 subject-object (passive voice)	4	2	2	3.5	5
12 direct object-indirect object*	1	1	1	1	1
15 singular plural*	5	12	9	13.5	11
16 affirmative-negative	11.5	11	11	11	13
17 present tense-past tense	8	3	3	2	4
18 present tense-future tense	10	5	5	5.5	3
19 reflexive pronouns	2	6	6	7	8
20 his-their	6.5	7	7	5.5	2

*Weak English-Italian equivalence: In both cases the Italian distinction is easier (multiple cues by inflections, pronouns, etc.)

aphasics more than any other group is of considerable theoretical importance. It argues against a simplistic identification between language competence in the right hemisphere and between the diagnostic pattern of language impairment in Broca's aphasia only because in both cases language reception surpasses language production. In fact, auditory language comprehension in the minor hemisphere is inferior to the left and its structure may be profitably analyzed by comparison with similar breakdowns in receptive aphasics.

It is important to note that the standard paradigm used in the lateralized tests for syntax in auditory comprehension almost certainly invokes a strong bias against the right hemisphere. The formal reference task introduced by the need to choose between similar pictures which differ only in a few details makes it necessary for the right hemisphere to recognize and assess each alternative in turn and perhaps also to compare several alternatives at the same time. In fact, previous lateralized tactual tests of the right hemisphere of commissurotomy patients (Nebes, 1971; D. Zaidel and Sperry, 1973) have employed only 3 choices since careful preliminary observations revealed a reduced ability by the disconnected right hemisphere to deal with more than that number of choice alternatives. Thus the right hemisphere seems inferior to the left in precisely tasks which require the assessment of details (cf. for example, McFie & Zangwill, 1960), the interpretative performance of rule governed behavior , the comprehension of nonredundant linguistic messages and the serial account of several options simultaneously through analytic cross reference (cf. Levy, 1969). Yet in spite of these biases right hemisphere performance on the syntax tests is well above chance and thus previous estimates of right hemisphere competence, especially in the comprehension of linguistic input including both syntactic and semantic structures, must now be revised and considerably upgraded.

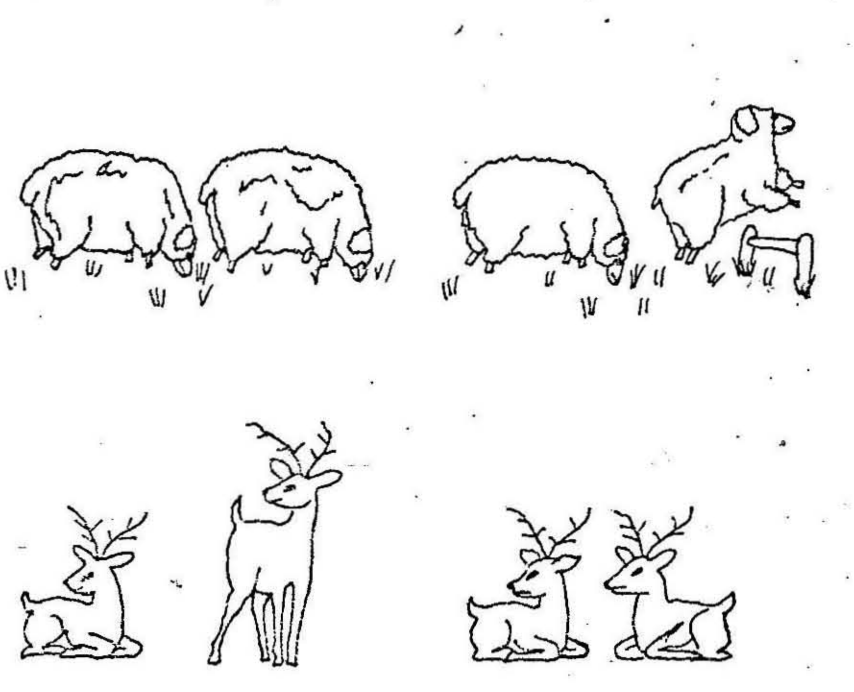
The relatively weak correlations of right hemisphere competence with aphasics and especially with children's performances indicates that the study of syntax may be more useful to characterize the unique aspects and limitations of right hemisphere language competence than it has been in characterizing differences between aphasic groups or aphasics and children (Parisi and Pizzamiglio, 1970). In particular, formal similarities between the structure of the lexicon in children and in the right hemisphere all but disappear due to syntactic effects. A more precise comparison of the syntactic capacity of the right hemisphere with that of children and aphasics is afforded by analyzing results on the individual tests (BBF, NSST and SC).

INDIVIDUAL TESTS

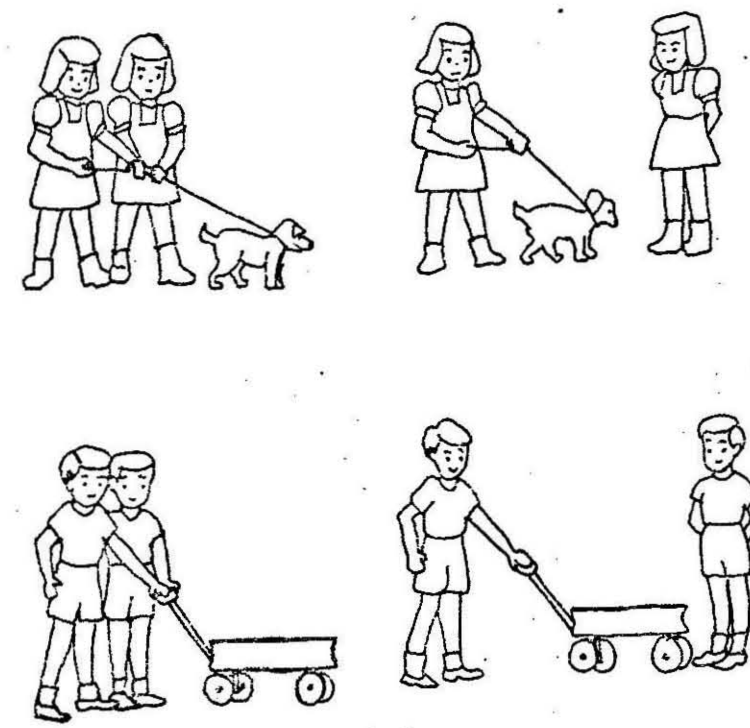
FRASER, BELLUGI AND BROWN'S TEST (FBB)

Material. The test used here is a revised and slightly extended version of part of the one used by Fraser, Bellugi and Brown (1963) to assess children's ability to repeat, comprehend and produce contrasting grammatical sentences. Only the comprehension test was administered here and the version available contained four equally long sentence pairs for each linguistic contrast. In the "mass noun" / "count noun" contrast the nonsense syllables used by Fraser et al were replaced by words that accepted either grammatical form, e.g. "a string/some string"; "some chicken/a chicken". In addition to the structures contrasted in the original test two new grammatical contrasts were added involving the use of adjective modifiers in sentences with two noun phrases: "The dish on the round table" / "The round dish on the table". The other contrasts prepositional with noun phrases: "the tea cup"/ "the tea in the cup". As usual words familiar to young children and the right hemisphere were used and two line drawings identical in every respect except the one coded by the grammatical contrast illustrated each sentence pairs.

Task and administration. The procedure differed from the comprehension test of Fraser et al. First, instead of the examiner pronouncing both utterances of each contrast before repeating the sentence to which the subject had to point, each sentence was read aloud only once in order to minimize the information available to the left hemisphere during LVF-L/h CLVP. Secondly, the pictures were presented two pairs at a time in arrays of four (reduced to fit a 6x7 inch format for all four -- Figure 2). Thus every array was presented twice at different times to test each of the two contrasting sentences illustrated in it. Since the two sentence pairs sometimes differ in their referents (e.g. "the sheep are eating"/"the sheep is eating" and "the *deer* is resting"/"the *deer* are resting") and assuming that the right hemisphere can distinguish them independently of the grammatical contrast, it follows that the guessing probability in each trial is in general $.25 \leq p. < .5$. These differences make the test as used here harder. But even though absolute scores may not be comparable, it is reasonable to



Top: "The sheep are eating"/"The sheep is eating."
Bottom: "The deer is resting"/"The deer are resting."



Top: " Their dog"/"her dog."
Bottom: " Their wagon"/"his wagon".

Figure 2

Sample visual arrays used in the adaptation of Fraser, Bellugi and Brown's syntax comprehension test.

expect the error patterns between the various grammatical categories to remain the same across the two forms of the comprehension test.

Results and discussion. Table 4 summarizes the performance of the right hemisphere -- N.G. and L.B. in LVF-L/h CLVP and R.S. in free vision. The maximum score for each grammatical structure is 12 (three patients on four sentence pairs each) and it is compared with the performance of the twelve children 37 to 43 months old (mean age 3:4) tested by Fraser et al. Ranks of difficulty of the various syntactic structures are indicated in each case. The Spearman rank order correlation coefficient for the difficulty of problems between the children and the right hemisphere, however, is $r = .3867$ with $p > .05$, so that the pattern of syntactic competence in right hemisphere auditory comprehension does not parallel that of first language acquisition, as the comparison above with Parisi and Pizzamiglio's results has already suggested.

The mean right hemisphere score is higher than the proportional scores of Fraser et al's children subjects on each of the ten syntactic categories in the comprehension test reported in their paper (1963). The data reported by Fraser et al show that the mean percent correct of the twelve children in their population (mean four years) on the comprehension test is 50% while the mean percent correct score of the right hemisphere is 73%. The authors argue, not very convincingly, that the children respond independently to the two sentences in the same contrast pair and conclude that the probability of chance success for these subjects is .025 or .11 (!?) rather than .5. However that may be, in the current administration the two contrasting sentences which are actually

Table 4
Comparison of right hemisphere and children's performance on Fraser, Bellugi and Brown's syntax comprehension test

Contrast	mean no. correct R/H by grammatical structure	mean no. correct R/H (max=12)	mean no. correct Children+ (max=12)	R/H rank order*	children rank order
Mass nouns (count nouns		12	6.5	1	5.5
A (N)	6				
Some (N)	6				
Inflectional single/plural		10	3.5	3	8.5
The (N)-s (V)	5				
The (N) (V)-s	5				
Singular/plural marked by <u>is</u> and <u>are</u>		7	6	8	7
The (N) is (V)-ing	3				
The (N) are (V)-ing	4				
Past/present progressive tense		10	6.5	3	5.5
The (N) (V)-ed	4				
The (N) is (V)-ing	6				
Future/present progressive tense		10	8	3	2.5
The (N) will (V)	5				
The (N) is (V)-ing	5				
Negative/affirmative		9	8.5	5.5	1
The (N) is not (V)-ing	5				
The (N) is (V)-ing	4				
Subject/object in passive voice	5	5	3.5	10	8.5
The (N_1) is (V)-ed by the (N_2)					
The (N_2) is (V)-ed by the (N_1)					
Indirect object/direct object	6	6	2.5	9	10
The (N_1) (V)'s the (N_2) the (N_3)					
The (N_1) (V)'s the (N_3) the (N_2)					

Table 4 (cont.)

Contrast	mean no. correct R/H by grammatical structure	mean no. correct R/H (max=12)	mean no. correct children+ (max=12)	R/H rank order*	children rank order
Singular/plural of third person possessive		9	7.5	5.5	4
pronouns (her, his) (N)	5				
Their (N)	4				
Subject/object in active voice	8	8	8	7	2.5
The (N_1) (V)-s the (N_2)					
The (N_2) (V)-s the (N_1)					
- - - - - -	- - -	- - -	- - -	- - -	- - -
Adjectival modifier		9			
The (N_1) (Prep) the (Adj) (N_2)	4				
The (Adj) (N_1) (Prep) the (N_2)	5			Spearman's rank order correlation coefficient	
Prepositional phrase/noun phrase		10			
The (N_1) (Prep) (N_2)	5				
The (N_1) (N_2)	5			$r_{R/H\text{-child.}} = .3867$	

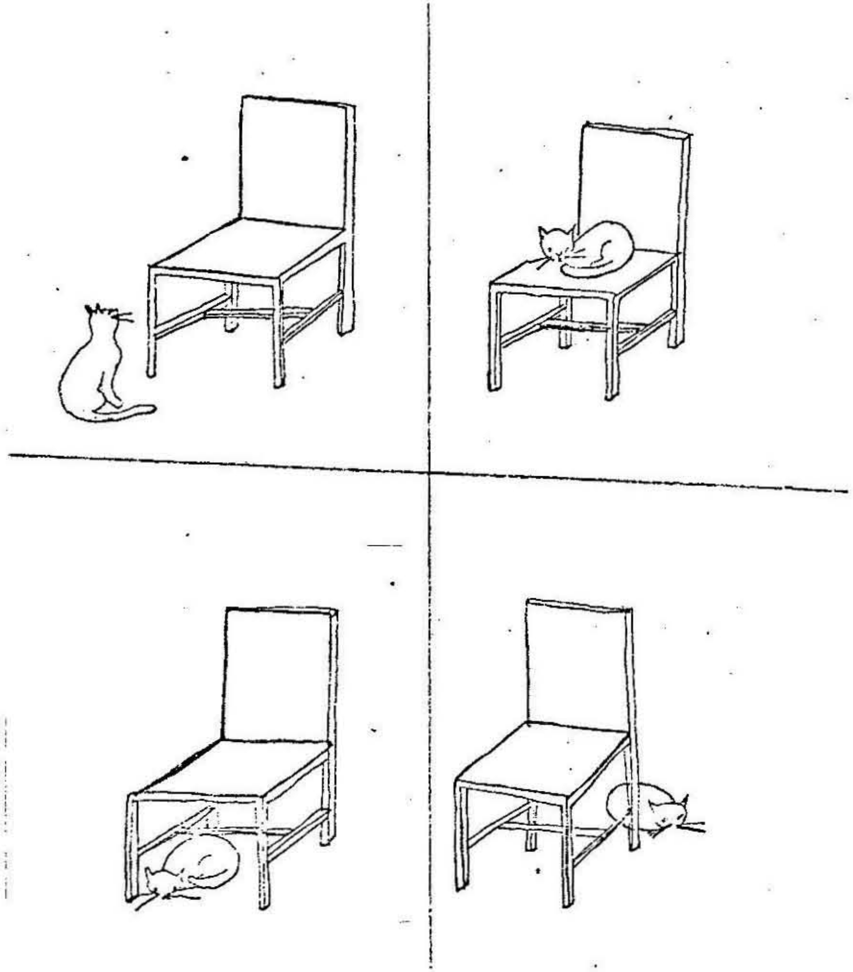
* The first ten syntactic structures only were sampled by Fraser, Bellugi and Brown.

+ Adapted from Fraser et al (1963) to fraction out of 12 read by the examiner to assess a given grammatical contrast belong to different contrast pairs and hence also to a different illustration pair (even though both pairs test the same syntactic structure) and further more they are not administered consecutively. Consequently the responses to each sentence in the pair of a given syntactic contrast are truly independent of each other. Thus it is not possible to attribute the superiority of the mean right hemisphere scores over the mean children's score to a different guessing probability resulting from different procedures of administration.

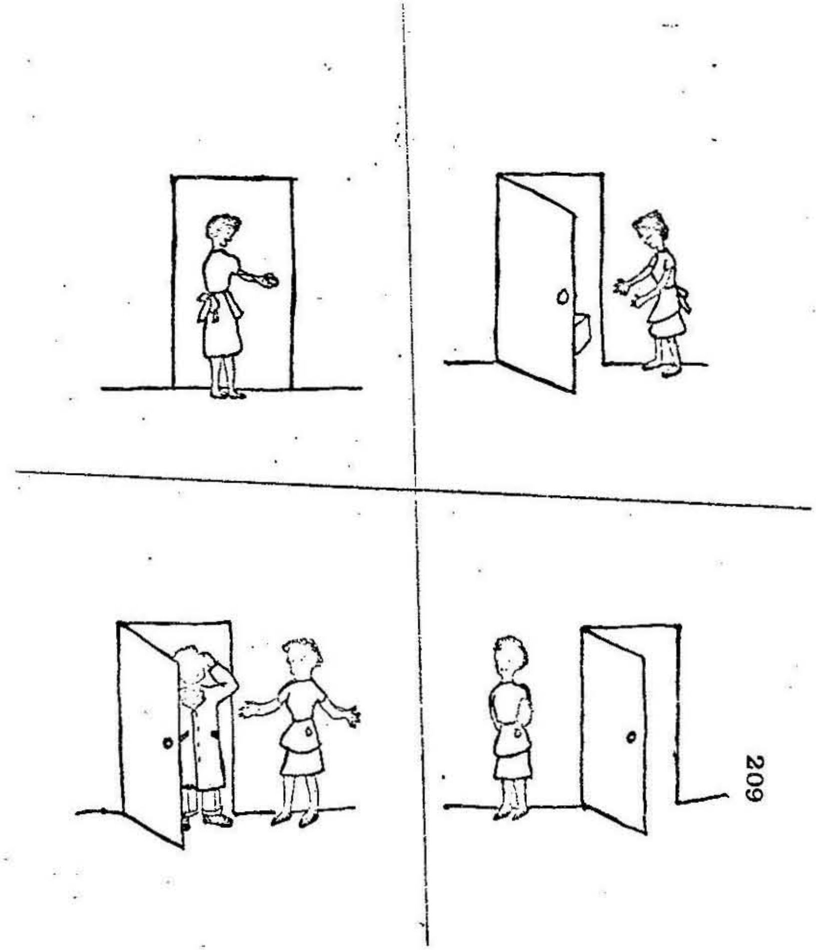
NORTHWESTERN SYNTAX SCREENING TEST (NSST)

Materials and administration. This test was developed in the department of Communicative Disorders at Northwestern University under the direction of Laura L. Lea and was inspired by Fraser, Bellugi, and Brown (1963). It includes a separate receptive and expressive test but only the receptive test was given to the patients here (figure 3). The test includes 40 items (of which only 38 were administered) and it expands the items in FBB to include spatial prepositions, personal pronouns in the nominative case, reflexive pronouns, wh- questions, yes-no questions (with the auxiliaries "be" and "have"), as well as the demonstratives "this" and "that". The test includes norms obtained from 344 middle class children between the ages of 3:0 and 7:11 and the sentence pairs have been arranged in order of increasing difficulty according to the children's performance (Lea, 1970).

However, as in the FBB test, the administration procedure used here differs from the standard one in the following important way.



"The cat is behind/under the chair".



Mother says, "Look who/what is here".

Figure 3
Two visual arrays from the comprehension NSST, each illustrating two contrasting sentences administered separately.

In the standard NSST children were required first to listen to the examiner say two grammatically contrasting sentences (e.g. "This is mother's cat"/"This is a mother cat") and then point to the picture named, one at a time, as the examiner repeats the sentences. In the present study, however, the test was administered in two passes with only one sentence at a time read (once) to the patient who was then asked to point to the corresponding picture. Clearly this task is more difficult than the standard one and the children norms are therefore not directly comparable to the patient's scores. The fact that the patients scores are really lower than they would most probably have been on a standard administration of the test should be born in mind when consulting figure 4 in which the age equivalents of the patients' scores (determined by the 50th percentile of a given age group) are indicated after adjustments from 38 to 40 items.

Results and discussion (Table 1). The results reveal first that the right hemisphere performs well above chance on this test ($p < .005$). Second and at the same time, the left hemisphere is significantly superior in N.G. ($p < .05$ one-tailed) and L.B. ($P < .005$) as well as between R.S. and G.E. ($p < .005$) although the difference between R.S. and D.W. falls short of statistical significance ($.05 < p < .1$). Furthermore, R.S. scored significantly higher on this test than either L.B.'s or N.G.'s right hemisphere ($p < .02$, two-tailed t test). This difference may have been due to restrictions imposed by the contact lens technique on scanning patterns of the eye which are especially important in distinguishing the correct from the three decoy pictures. N.G.'s low free vision score verifies that performance on the test is sensitive to intellectual level but it is impossible to conclude from this or on the basis of the deficit in G.E.'s and D.W.'s performance alone that the right hemisphere contributes to normal test performance.

Since the original test is arranged in order of increasing difficulty it is interesting to compare the left-right hemisphere performance differential on the first and second halves of the test. Somewhat surprisingly the difference is slightly bigger on the first half of the test (Table 5).

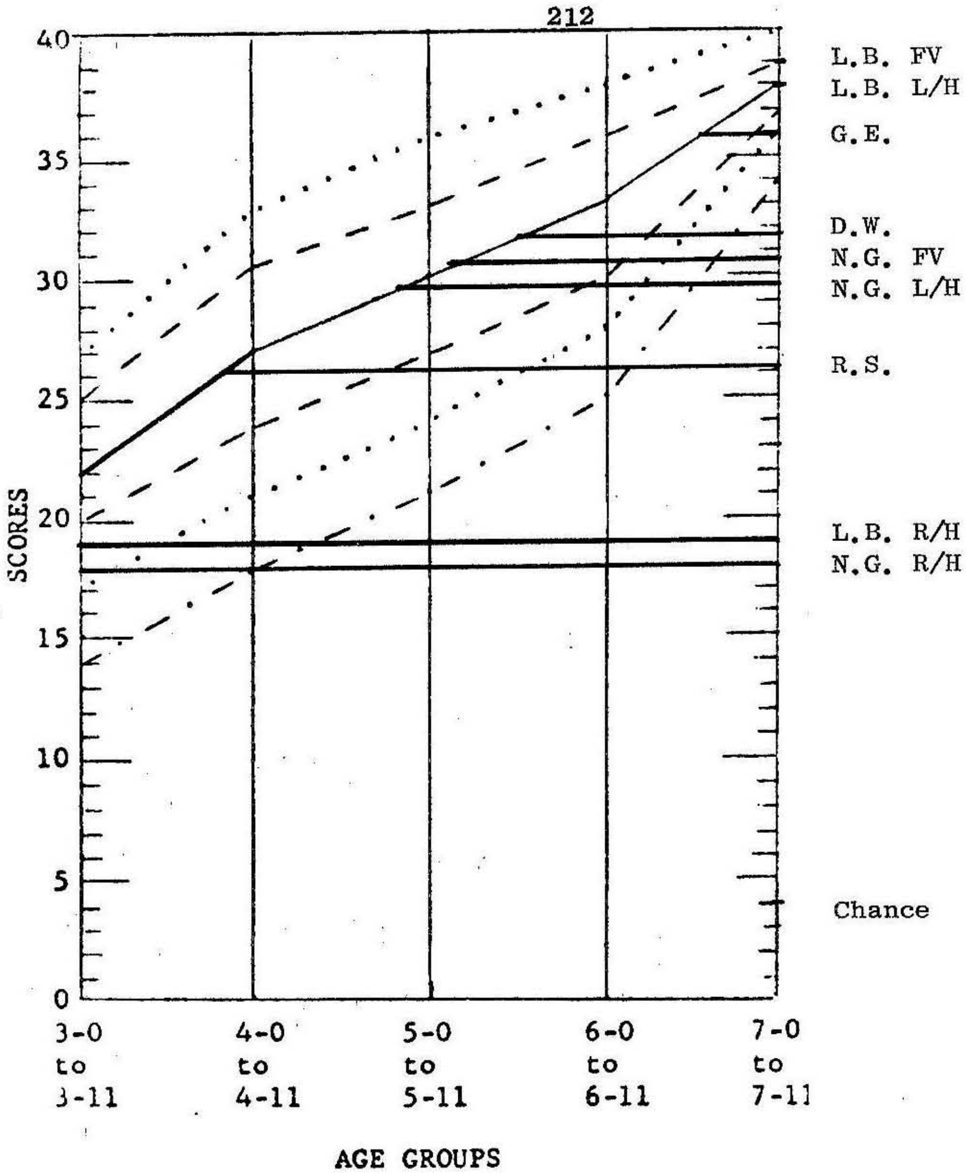
Table 5

Left minus right hemisphere scores on first and last halves of the NSST.

	N.G. L/H-R/H	L.B. L/H-R/H	D.W.-R.S.
First	6	9	3
Last	5	9	2

This suggests again that developmental level of syntactic difficulty (in terms of age of acquisition) is not a sensitive parameter of right hemisphere performance on this test.

From figure 4 it can be seen that the mean score for 3:6 year old children on the comprehension test NSST is 22 or 55% correct. This datum is somewhat higher than Fraser et al's (1963) results which indicate 50% correct responses for twelve children with mean age 3:4 even though the comprehension test of the NSST is more difficult since it contains four, often subtly different, alternative answers instead of only two as in the original FBB test. Yet mean right hemisphere percent correct score on the NSST is only 53% while it was 73% on the FBB test (figure 5). The



NSST Percentiles

... 90th
--- 75th
—— 50th
--- 25th
... 10th

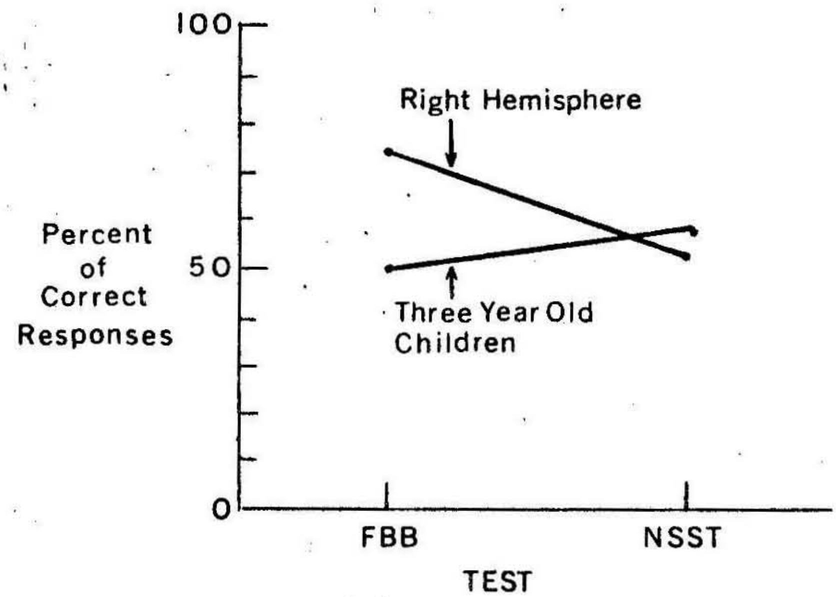
-.- second SD below mean

Figure 4. Patients' adjusted scores and median age comparison (50th percentile) on the receptive NSST (superimposed on percentiles of NSST scores of 344 children).

L/H = Left Hemisphere
R/H = Right Hemisphere
FV = Free Vision

conclusion must be that the FBB test includes syntactic structures and/or contrasting sentences which are more difficult for the right hemisphere. Further evidence is therefore lent to the conclusion that right hemisphere performance on this task is quite dissociable from rules governing the pattern of acquisition of syntax in children.

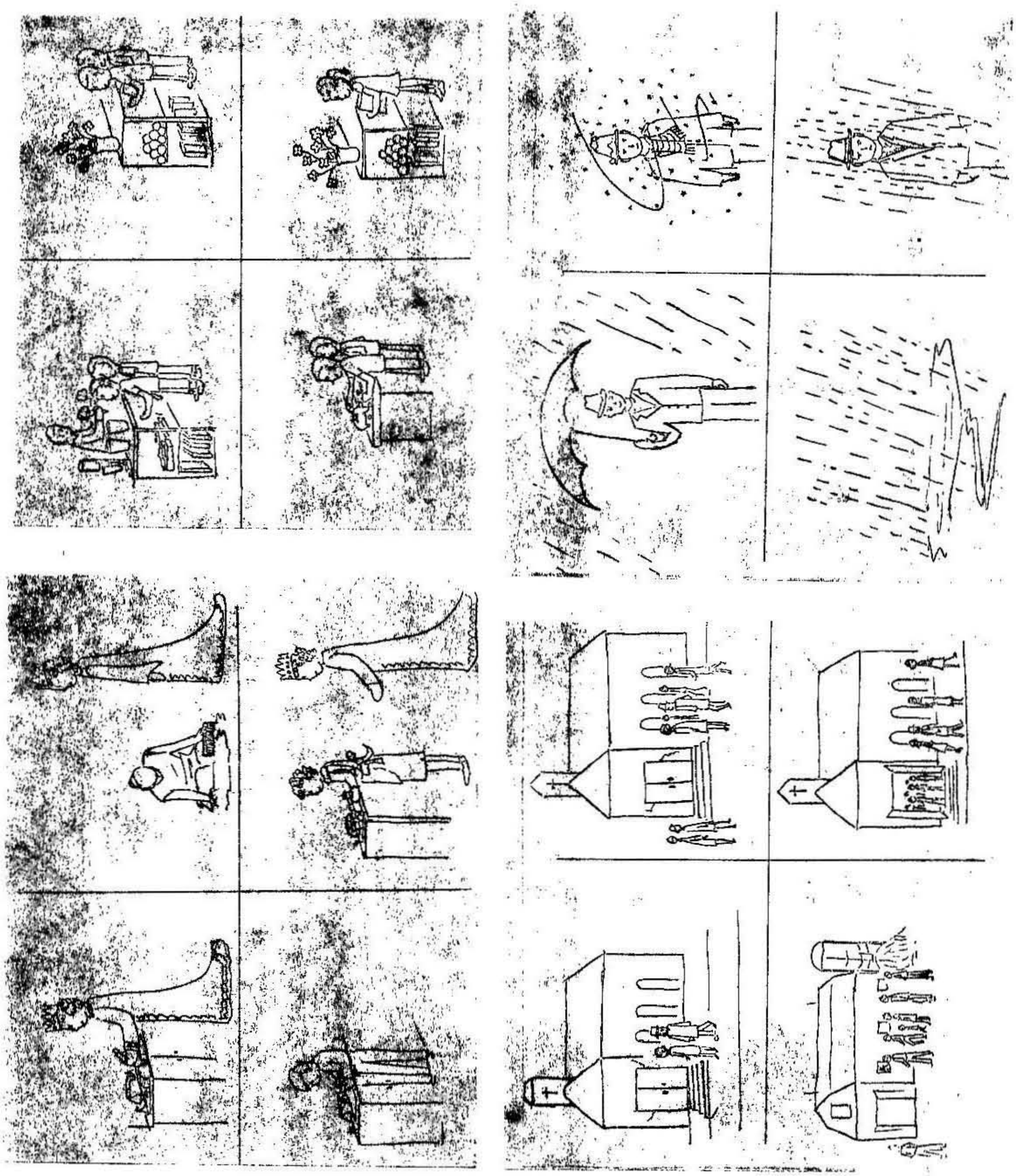
Figure 5



Percent of correct responses of the right hemisphere and three year old children on the Fraser-Bellugi-Brown test and on Lea's NSST.

SHEWAN AND CANTER'S TEST (SC)

Materials and administration. Shewan and Canter (1971) have used the same sentence-pictures paradigm to design a test of auditory comprehension for sentences (figure 6). The test sentences constructed varied systematically in the parameters of length, vocabulary difficulty, and syntactic complexity. Three levels of difficulty were defined for each parameter. Length was controlled for number of



31

2

6

39

Figure 6

Figure 6. Sample items from Shewan and Canter's test for sentence comprehension.

6: "Dishes are not washed by queens".

31: "The young boys are spending their money on flowers, balls and books".

39: "A large crowd is gathering at the old church".

2: "The deluge soaked his raiment".

"critical items" or essential contentive words as well as for total number of syllables. The three levels of length, designated as L_1, L_2, L_3 are shown in Table 6.

Table 6

Length, in number of critical items and total number of syllables, for the three levels of sentence length.

Level	No. of critical items	No. of syllables
L_1	3	7
L_2	5	11
L_3	7	15

Three levels of vocabulary difficulty V_1, V_2, V_3, were defined in terms of frequency of word usage and difficulty of vocabulary. Level 1 words were selected from the 1000 most frequent words in the general count of Thorndike and Lorge (1944). Level 2 words had frequencies of 25 to 35 occurences per million and age equivalents between 6.5 and 8.5 years. Level 3 words had frequencies of 24 or fewer per million and difficulty levels of 10 years or above on vocabulary tests.

Of the three levels of syntactic complexity S_1, S_2, and S_3, level 1 sentences were simple active declarative with no optional transformations. Level 2 sentences contained one transformation, either the negative or the passive. Level 3 sentences contained two transformations, both the negative and the passive.

Seven sentence types occur with only one parameter permitted to vary from level 1 at any type. Six sentences of each type were included, for a total of 42.

Subjects had to point to one of four line drawings (figure 6) in response to each picture. As usual "dummy" items differed on one critical item so as to represent all possible confusions. But the quality of the drawings is often poor and critical items are often illustrated inconspicuously (for example old in the sentence "A large crowd is gathering at the old church" is represented by two small lines denoting cracks (figure 6)) especially in the CLVP condition.

Shewan and Canter compared the performance of adult aphasics (Broca's, Wernicke's and amnesic) and a group of normal control subjects on the auditory comprehension test for sentences. The authors concluded that all the aphasic groups performed in a manner qualitatively similar but quantitatively inferior to normals. In particular, no difference in parameter effects among the aphasic groups were observed. We seek here to compare right hemisphere performance and especially breakdown pattern with that of aphasics.

Results and discussion. The aphasic population studied by Shewan and Canter was first screened for minimal language comprehension by having to pass two out of five sentences of type A. All our patients have reached or surpassed this criterion in all conditions. Table 7 summarizes the performance of the patients on the test proper, and the

Table 7. Items correct out of six on each sentence type in the auditory language comprehension test for sentences.

		N.G.			L.B.			R.S.	DW.	G.E.	Mean	Mean	Mean
Sentence Type		R/H	L/H	FV	R/H	L/H	FV				R/H	L/H	FV
A	$L_1\ V_1\ S_1$	3	6	6	3	6	6	5	5	6	3.7	5.75	6
B	$L_2\ V_1\ S_1$	1	2	5	2	5	5	3	3	6	2	4	5
C	$L_3\ V_1\ S_1$	0	1	5	4	4	4	4	5	4	2.7	3.5	4.5
D	$L_1\ V_2\ S_1$	4	1	5	2	3	6	2	5	6	2.7	3.75	5.5
E	$L_1\ V_3\ S_1$	3	2	2	4	4	6	3	5	4	3.3	3.75	4
F	$L_1\ V_1\ S_2$	0	2	2	4	4	5	5	2	4	3	3	3.5
G	$L_1\ V_1\ S_3$	2	2	2	5	5	5	2	6	5	3	4.5	3.5
	Total	13	16	27	24	31	37	24	31	35	20.4	28.25	32

R/H = Right hemisphere of NG, LB, RS

L/H = Left hemisphere of NG, LB, DW, GE

FV = Free vision NG and LB

Table 8. Mean total scores of various populations on the SC test. (Max=42)

Commis. & Hemisph. FV	R/H	L/H	Wernicke's Aphasics	Broca's Aphasics	Amnesic Aphasics	Normal Controls
32	20.3	28.5	21.78	27.44	30.89	36

mean total scores on the complete scores are compared with those reported for aphasics in Table 8. Again, mean right hemisphere score is closer to that of Wernicke aphasics than to any other group.

Table 9 presents (and figure 7 illustrates) the percentage of correct responses (left half entry) and mean number correct items out of six (right half entry) for the three levels of difficulty on the SC test by patient group. As is expected all patients under all conditions found type A sentences easiest.

Unexpectedly, mean left hemisphere performance was similar to that of aphasics. Another surprising result is that both the right hemisphere and the left hemisphere found the moderate items slightly more difficult than the hard ones in contrast to the aphasics. In fact, however, the difference between aphasics' performance on moderate as compared with hard items was found to be not statistically significant (Shewan and Canter, 1971).

Nevertheless it is logically consistent with the data to hypothesize that different factors are responsible for the errors in LVF-L/h presentation (classification and abstract discrimination between the subtle semantic similarities of the four pictures) and RVF-R/h presentation (poor visual discrimination of the information in the pictures).

A comparison between standard and lenient scores on the sentence comprehension test (Table 1) supports the hypothesis of poor acuity as a factor in low CLVP performance especially in LVF-L/h testing. In both N.G. and L.B. and in contrast to all other tests lenient scores of right

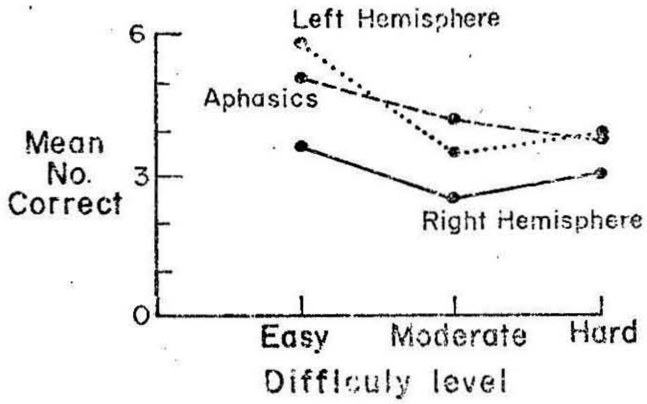


Figure 7. Mean number of correct responses (out of six) of the right hemisphere (N.G., L.B. and R.S.), the left hemisphere (N.G., L.B., D.W. and G.E.) and aphasics on the SC test by level of difficulty.

Table 9

Percent correct and mean number correct out of six on the three difficulty levels

	Easy		Moderate		Hard	
	% correct	mean no. correct	% correct	mean no. correct	% correct	mean no. correct
R/H	61%	3.7	43%	2.6	50%	3.
Aphasics	85%	5.1	69%	4.2	64%	3.8
L/H	96%	5.75	60%	3.6	65%	3.9
FV	100%	6.	78%	4.7	67%	4.

R/H = right hemisphere (N.G., L.B. and R.S.)
L/H = left hemisphere (N.G., L.B., D.W. and G.E.)
FV = free vision (N.G. and L.B.)

hemisphere performance are statistically more significantly different from chance than the standard scores even though the guessing probability increases from .25 to .5. In other words there is a large increase in right hemisphere score if a second guess is allowed and this is most probably because the hemisphere could not discriminate adequately between the two alternatives. On all the other syntax tests, lenient scores are statistically less significant than standard scores (Table 1). The increase in significance of lenient score applies also to N.G.'s left hemisphere but not to L.B. Since his LVF-L/h standard score is already high, "extralinguistic" cognitive factors are most probably involved in this task.

A dissociation between the right and left hemispheres as well as between the right hemisphere and the aphasics emerges, however, when the differential effect on performance of vocabulary, length, and syntactic complexity is assessed (Table 10 and figure 8) by summing across all subjects the number of sentences correct for difficulty level 2 and 3 in each parameter. The negative and passive sentence transformations are easiest for the right hemisphere which surpasses the aphasics for whom in turn syntactic complexity is most difficult. And the converse applies to the effects of length. Left hemisphere scores, in contrast, do not show parameter interaction. Apparently the right hemisphere can not retain long sentences. Thus the data corroborate once again the hypothesis of short term verbal memory deficit which may be especially crucial in this task in order to eliminate wrong alternative solutions.

Table 10

Mean total scores for parameter complexity. Maximum score x=12.

	Syntax	Vocabulary	Length
R/H	6	6	4.6
Aphasics	4.5	8.2	8.4
L/H	7.5	7.5	7.5
FV	7	9.5	9.5

R/H= right hemisphere; L/H = left hemisphere; FV = free vision

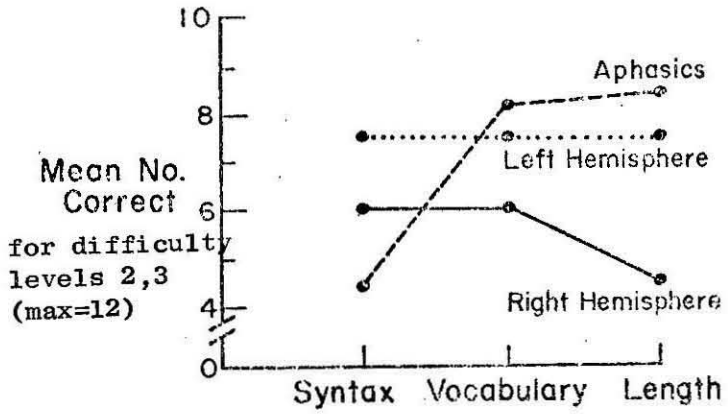


Figure 8. Comparison of the effects of parameter complexity on the performance of the "combined right hemisphere", "combined left hemisphere" and aphasics, in the SC test.

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LATERALITY EFFECTS IN AURAL LINGUISTIC REFERENCE -- THE TOKEN TEST

LATERALITY EFFECTS IN AURAL LINGUISTIC REFERENCE -- THE TOKEN TEST*

INTRODUCTION

Reference is perhaps the most fundamental aspect of the semantics of ordinary language. Thus reference is a particularly fundamental instance of the meaning of a word, i.e. its ostensive definition (as by pointing). References put words in "correspondence with features of the physical world" (Lyons,1968,p.425) i.e. they presuppose physical existence either directly or by extension.

Reference is the relationship which holds between words and things, events, actions and qualities (their referents); words refer to things. Phrases and sentences can refer to similar things and then the referent of the sentence is a more or less complex function of the meaning of its constituents. The Token Test instructions are a special case in that the adjectival modifiers and the nouns all consist of

* The word "token" in "Token Test" refers to the chips used in the visual display. This is an unfortunate misnomer. For, the originators of the test, De Renzi and Vignolo (1962), consider the abstract nature of the linguistic references used in this test (e.g. square and circle instead of common household objects, say) as essential to its power in identifying aphasics. But the technical philosophical sense of the word token is that of a concrete specified utterance or exemplar of a given linguistic expression or a written utterance of it (i.e. the series of ink marks or sounds made on some occasion) as opposed to an expression type -- the meaning which is entirely abstracted from all actual and potential occurences of the linguistic expression. Thus the emphasis in the test is on abstracted generic attributes while in the name of the test, it is on concrete instances of occurence.

lexical items which are references in their own right and whose individual referents are several and present in the immediate perceptual environment.

Given the right hemisphere's ability to identify by pointing to a choice array the referents of simple lexical items from the semantic categories of colors, geometric shapes and adjectives of size, the question arises as to whether it will also be able to handle the added complexity of reference phrases with multiple adjective modifiers constructed from the same lexical items when these phrases refer to items in a nonredundant and abstract visual display. In order to answer this question a version of De Renzi and Vignolo's token test originally used to detect mild receptive disorders in aphasia was adapted for use with lateralized visual presentations (De Renzi and Vignolo, 1962).

In designing this test De Renzi and Vignolo attempted to produce a sensitive diagnostic tool uncontaminated by "extralinguistic" intellectual factors**, especially memory and attention. The test involves merely pointing responses to a visual array of from 10 to 20 colored chips, in response to aural instructions of progressively increased complexity. Since only simple motor responses are required and no speech is involved, the test is suitable for lateralized presentations to the separated hemispheres in CLVP.

**For the purpose of this paper the question whether extralinguistic intellectual functions really exist will be ignored. For the sake of the neuropsychological argument suffice it to identify these operationally with higher functional tasks which are difficult for organic brain patients including those who are free from defects in the language area.

Linguistic aspects. The visual display consists of 10 or 20 different chips of two shapes (rectangular or circular), in two sizes (large and small), and in one of five colors (white, red, yellow, blue, green). The instructions include referential phrases of the type "large green rectangle" or "small white circle". In the last section an attempt was made to sample various additional constructions, verbs: pick up, put, touch, move, use(-ing); prepositions: on, behind, before (in front of), beside, between, away from; conjunctions: and, or, then, when, with, without, except, instead; quantifiers: all, one; adverbs: slowly, quickly; the inflectional plural "s"; the pronouns "I" and "you"; and finally a few subordinate clauses in various sentence positions (instructions no. 9, 12, 20, 22 in De Renzi and Vignolo's version, Appendix 2). But with the exception of the color, size and shape references none of the other constructions is sampled systematically to allow syntactic analysis of performance.

The following will focus on the adjectival modifiers of the form adjective+adjective+noun, which constitute the references in the Token Test instructions. These are classified as endocentric subordinative noun phrases by distributional analysis (Lyons 1968, p. 232). Noun modification in an endocentric construction is the most typical function of the adjective (e.g. "sad boy"). The reference task must be considered formal or non-naturalistic since the references are strictly semantically nonredundant and since the visual referents are abstract, i.e. context-free, and vary from each other only in a small number of explicitly specified perceptual dimensions.

The original test was administered in Italian (De Renzi and Vignolo, 1962; Boller and Vignolo, 1966). A validation study and further research were conducted with a German version (Orgass and Poeck, 1966; Poeck and Kerschensteiner, 1972). A Dutch translation was administered by Van Dongen and Van Harskamp (1972). Clinical studies in English were conducted by Swisher and Sarno (1969) and Needham and Swisher (1971) using De Renzi and Vignolo's original translation (1962) and by Spreen and Benton (1969) using a revised version. The relative and absolute difficulty of the various items can not be assumed to be the same in all those languages and developmental norms are urgently needed to permit precise cross-language comparisons of results. Some norms for American children aged 5:10 to 11:11 are now available in Whitaker and Noll (1972). Whitaker and Noll have also attempted a deep structure linguistic analysis of the verbs involved in the Token Test commands but, as it turns out perhaps surprisingly, the right hemisphere of N.G. and L.B. in CLVP as well as of R.S. in free vision encounters more difficulty in interpreting the references than in performing the correct action.

<u>Cognitive Aspects</u>. The gnostic and practic components of the test are relatively simple but by no means clear. In CLVP studies during LVF-L/h testing the correct execution of motor components of the instructions may often be attributed to the ipsilateral left hemisphere motor control of the left hand in the commissurotomized patients since the auditory input reaches both hemispheres.

But even the reference components of the instructions involve a complex interaction of visual perception and scanning with short term memory in which the references are encoded and stored. Thus it is misleading to consider the test "purely verbal". Previous data reported in this thesis indicate good gnostic capacity and adequate practic facility within the right hemisphere to locate and point to an item which is described verbally in a visual display lateralized to the LVF. At the same time there is suggestive evidence for a right hemisphere deficiency in carrying out more complex commands (Gazzaniga and Sperry, 1967; see also part IV of the thesis) and mounting data on severe short term memory limitations auditory as well as visual -- for certain materials in the right hemisphere. In fact, De Renzi's contention that the Token Test involves no memory constraints, can not be taken at face value. Of particular interest here is the interaction of verbal versus pictorial representations in storing the references and processing the search for a match.

<u>Clinical data</u>. As we would expect, all aphasics who show clear disturbances in the understanding of speech on a normal examination of aphasia also have serious difficulty in performance on the Token Test (De Renzi and Vignolo, 1962). But it turns out that all aphasics, irrespective of type, are significantly impaired on the test compared to normal controls and non-aphasic brain damaged patients, focal (Boller and Vignolo, 1966) as well as diffuse, (Orgass and Poeck, 1966). This applies to motor aphasics (Boller and Vignolo, 1966) including anarthritics (De Renzi and Vignolo, 1962) as well as sensory aphasics (Orgass and

Poeck, 1966) even at a stage of very good regression of the symptoms (De Renzi and Vignolo, 1962), and amnesic aphasics (Orgass and Poeck, 1966). In fact, Poeck, Kerschensteiner and Hartje (1972) have compared the Token Test performance of non-fluent and fluent aphasics, and found that impairment was equal in both subgroups on each part of the test and in total score. Token Test scores of aphasics were found to be largely independent of age, sex and educational level and to be corre - lated with the degree of severity of aphasia (Orgass and Poeck, 1966) although Van Dongen and Van Harskamp (1972) demonstrated a definite influence of intelligence on Token Test pass-fail scores contradicting the finding by Boller and Vignolo (1966).

Boller and Vignolo (1966) addressed themselves to the differen- tial impairment on the Token Test with focal hemisphere damage. Within the non aphasic group, it was performed significantly worse by left than by right brain damaged patients. Orgass and Poeck (1966) report that the performance of an unselected group of non-aphasic brain damaged patients (including demented patients with diffuse cerebral involvement) was not significantly different from that of the normal control group. Swisher and Sarno (1969), on the other hand, report that part 5 and especially part 4 of the test differentiated the right brain damaged non-aphasics from the control patients. This con - tradicts Orgass and Poeck's finding but is attributed by the authors to the fact that English requires fewer morphological changes than either German (used in the Orgass and Poeck study) or Italian (used in the De Renzi and Vignolo, and Boller and Vignolo studies), and therefore provides fewer cues and imposes greater dependence on understanding each lexical item. More likely, however, the difference is attributable to the different scoring systems employed.

The test appears to discriminate well between non-aphasic and aphasic brain damaged patients and to have about the same discrimination power in a Dutch population of neurological patients (88%) as in German (90%) and English (86%) ones. Boller and Vignolo (1966) recorded pass-fail scores and noted that the number of aphasics who performed at normal level was found to decrease progressively from part 1 to part 5. In fact part 5 was as sensitive as the entire test in discriminating among the experimental groups. De Renzi and Vignolo (1962) used weighted scores and found particular deficits in parts 4 and 5 of the test. Error count of performances on the first four parts of the test suggested a selective deficit of aphasics on nouns (circle, rectangle) as against the size and color adjectives. On the fifth part particles were effected more than nouns with the spatial prepositions (on, under, before, behind) and the logical connectives (or, no, if) being the weakest.

Spellacy and Spreen have administered to a group of non-aphasic brain damaged patients and a group of aphasic patients with no distinction as to type of aphasia, a shorter version of the Den Renzi-Vignolo test (see below). They found this version and even a shorter form of it to discriminate the aphasic from the non-aphasic population as well as the weighted-scored De Renzi-Vignolo version did for Orgass and Poeck (1966). It was noted that items containing prepositional adjectives and items with high information (hence memory) load tended to present the most serious difficulty for aphasic patients. In contrast, right hemisphere performance (described below) was affected mainly by the length of the component phrases.

METHOD

Versions of the test. In the present study three versions were used. The first is Boller and Vignolo's (1966) minor revision (table 1, Appendix 2) of the original test (De Renzi and Vignolo, 1962). Hereafter this version will be denoted DVV since De Renzi and Vignolo's test differed from this one only in that it does not contain instruction no. 11 in part 5 (Appendix 2), and in that in parts 1-4 the subject was asked to "pick up" the chip defined by the examiner rather than merely "touch it". The fixed display of chips -- regular with respect to size and shape but not color -- was not adopted. The weighted scoring system used by De Renzi and Vignolo (1962) whereby correct handling of each informational item is scored a point separately, yields a maximum score of 280 points but leaves some ambiguities in scoring. Boller and Vignolo, however, employ a pass-fail scoring system for a maximum of 62.

The second version administered to each patient and denoted SBV is due to Spreen and Benton (1969) who have standardized a shorter selection of 39 out of the 62 original instructions (Table 2, Appendix 2). A plastic square is used instead of a rectangle. The first 15 instructions start with "show me the..." and the next 8 with "take the...". But verbs are scored only in the last 16 instructions (part

F). Partial (weighted) scoring is used with a maximum scoring of 163. Nevertheless some ambiguities or inconsistencies in scoring may occur. The preposition "before" is replaced by "in front". Part F is analogous to part 5 in De Renzi and Vignolo's version.

In this study all instructions have been sampled consecutively, regardless of failure on previous ones. The fixed arrangement of the chips called for by the manual of instructions was not used here.

For the same test using pass-fail scoring the reliability was 92. Items no. 31, 32, 36, 38, 39 (conditional sentences) are easiest and are answered correctly by more than 50% of the aphasic subjects.

All three versions were administered in order to permit maximum interface with results in the literature as well as to assess the value of each for studying laterality differences.

Spellacy and Spreen (1969) have evaluated a shorter version (SSV) of the Spreen-Benton test by performing an item analysis of the SBV scores of 37 nonaphasic and 67 aphasic patients. In fact this procedure is questionable since the results may differ from a separate administration of the selected items alone in so far as practice, set, motivation and attention may vary greatly in the latter case. This version was administered to the patients as well.

The short form consists of 16 items -- at least one from each of the 6 parts of the test -- with high item-total correlations and a large mean difference between aphasic and non-aphasic groups (items check marked in Table 2). Most of the relational terms were retained because of their relative difficulty level. The reliability for the 16 item version using weighted scores was .92. Reliability for pass-fail scoring was .87.

Administration. In all versions tokens of 2 different shapes, 2 different sizes and 5 different colors are arranged on the table in front of the patient, who is then given progressively more complex oral commands. In response to these orders the patient must perform very simple manual tasks with the tokens. Before administration the subjects were given control tests and practice tutoring in free vision and lateralized token identification and naming. The same control tests were administered again following the test. The commands were read in a slow neutral intonation, with no special prosodic emphasis. Instructions were repeated once upon request before first response or if no response was forthcoming, but this was rare. At no time was an instruction repeated in the middle of performance or more than once before it was scored.

Each of the hemispherectomy patients was administered first the DVV and then the SBV of the test in free vision with at least one month elapsed in between. During the session in which the SBV was administered in free vision and immediately following a short rest period the shorter SSV was administered as well. Each of the two commissurotomy patients was administered the following tests in the given order in intervals of at least one week: LVF-L/h CLVP of the SBV; free vision presentation of SBV and immediately thereafter the SSV in free vision. About one month later each patient was administered the DVV in LVF-L/h

CLVP and following a brief rest period the same test in free vision.

The following deviations from standard administration procedures occured. First, in all versions a random arrangement of display of chips was affected for each part of the test. This was done to prevent left hemispheric learning and hence participation during right hemisphere processing by using from the ipsilateral visual half field the auditory message and direct (uncrossed) visual cues. In addition the chips manipulated last were repositioned in order to avoid perseveration or learning effects. Secondly, specially laminated (clear) plastic frame of fixed size contained each of the chips used in CLVP in order to prevent kinesthetic feedback from the ipsilateral hand to the homolateral non-active hemisphere.

Scoring procedures. Three scoring systems were adopted. On a pass-fail (P-F) system each instruction receives one point if performed correctly and zero otherwise; on a weighted scoring system (WS) each item capitalized in table 1 or typed in heavy print in Table 2 of Appendix 2 scores 1 point if manipulated correctly; and on a restricted weighted scoring system (RWS) each and only color and size adjectives and shape nouns score as 1 point -- these items are underlined in the tables. Partial scoring on the Spreen-Benton version (SBV) is as specified in that test; in the De Renzi-Vignolo version (DVV) it is inferred.

In scoring partial credits the general principle of lenient maximum scoring was applied. That is, responses were assigned to instructions in such a way as to maximize scores unless the context indicated otherwise. For example, if the patient picked the large yellow circle and the small red square (in that order) in response to "large white square and small yellow circle", then the "small yellow circle" of the stimulus was matched with the large yellow circle in the response for a score of 3 out of 6 credits instead of only 2 credits if order was strictly enforced. When more than one assignment yielded the same score, assignment by order was applied. Furthermore, interpretations of the verb "touch with" as "put on" and of "touch" as "pick up" (but not the converse) were accepted as correct. Any reasonable interpretation of "beside" (next to but not above or under) and of "behind" (under; next to and farther away; next to and closer; sometimes even 'to the left' and 'to the right')is accepted. In scoring responses to the instruction "pick up all squares except the yellow one" the connective "all" receives credit when either all circles, all squares or all chips are manipulated; the word "one" is scored correctly if only one item of the class manipulated is excluded. Whenever possible verification of choices was ellicited from the patient to identify his responses, but with lateralized left visual field presentations this often led to confabulations and unreliable responses (with respect to both command and response).

It was found during LVF-L/h CLVP to the commissurotomy patients that very few errors occured in the correct practic interpretation of the verbs, spatial prepositions and conjunctions and this was generally attributed to left hemisphere interaction through ipsilateral motor control since all the instructions reached both hemispheres. Consequently an additional (restricted) weighted score (RWS) was calculated for each patient on each test, which considers only the size and color adjectives and the shape nouns as scorable items.

The following additional scoring conventions were applied in calculating the restricted weighted scores. Perseverations or manipulations of additional items to those specified by the instruction were scored as errors in the pass-fail system but as complete credit for weighted scores. In the SBV the inclusive interpretation of the logical connective "or" receives more credit than the usual exclusive interpretation even though in general it may signify erroneous "and" interpretations. In contrast, the same weighted score credit was assigned here for both correct exclusive and inclusive "or" interpretations, and for inclusive interpretations with one correct referent even though these are scored "fail" on the pass-fail system. Only performance on the manipulated items are given a restricted weighted score in conditional instructions like "if there is a black circle pick up the red square". In contrast to the SBV on the instruction "put the red circle between the yellow square and green square" each of the underlined items counts as one point in the restricted weighted scoring system. Further details on the RWS system are included in Table 2, Appendix 2, where each underlined item scores as 1 point in that system.

RESULTS

In each case, the patients performed correctly on color, shape and size matching tasks before testing proper began. With the possible occasional exception of R.S. they could all identify correctly the referents of the words "circle", "rectangle" (or "square"), "large" and "small", "red", "blue", "green", "yellow" and "white". Table 1 presents the data on LVF-L/H CLVP testing of N.G. and L.B. and free vision testing of N.G., L.B., R.S., D.W. and G.E. on De Renzi and Vignolo's version of the Token Test. Both pass-fail and weighted scores are recorded in absolute numbers as well as percent of correct responses for each part of the test and for the test as a whole. The data for part 5 and total test scores includes also the restricted weighted score (in parentheses) for size, color and shape items as described above. Table 2 presents the same data for both LVF-L/h and RVF-R/h CLVP to N.G. and L.B. on the Spreen-Benton version of the Token Test. Also data for Free vision performance of N.G., L.B., R.S. and D.W. is included. Scores for the shorter form of the Spreen-Benton version test are reported as well in Table 3 in order to compare its efficacy in elliciting representative right hemisphere performance. In Tables 1, 2 and 3 the results of statistical analysis are indicated. Right and left hemisphere performances have been compared using a one tailed t-statistic for correlated means.

In general the results show that right hemisphere performance is significantly above chance but significantly inferior to left hemisphere performance. The separation between the left and the right hemisphere is larger in terms of pass-fail score than of weighted score and higher in terms of restricted weighted score than of standard weighted score. The difference between right and left hemisphere performance in N.G. and L.B. and between R.S. and D.W. is already significant on the last part of the short form of the SSV (with the exception of the difference in restricted weighted score between L.B.'s right and left hemisphere in that section).

Table 1

Summary of scores on De Renzi and Vignolo's Token Test

	N.G.				L.B.				R.S.		D.W.		G.E.		Max.	
	R/H		FV		R/H		FV									
Part	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)
1	7	16	10	20	7	17	10	20	6	14	10	20	10	20	10	20
2	2	17	10	30	3	18	10	30	2	18	10	30	10	30	10	30
3	2	27	9	38	3	29	10	40	1	27	7	35	10	40	10	40
4	0	36	8	58	2	42	10	60	0	39	7	55	10	60	10	60
5	+ 4	+ 95 +(55)	18	126 (77)	+ 9	+ 103 +(57)	22	130 (80)	+ 2	+ 76 +(48)	18	125 (77)	20	126 (78)	22	130 (80)
Total	+ 15	+ 186 +(150)	55	272 (223)	+ 24	+ 209 +(163)	62	278 (230)	+ 11	+ 174 +(145)	52	265 (217)	60	276 (228)	62	280 (230)

+= $p < .005$ in a one-tailed t-statistic for the difference between right hemisphere and free vision scores.

Table 2
Summary of scores on Spreen-Benton's version of the Token Test

	N.G.						L.B.						R.S.		D.W.		Max. score	
	L/H		R/H		FV		L/H		R/H		FV							
Part	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)
A	7	7	7	7	7	7	7	7	5	5	7	7	5	5	7	7	7	7
B	4	8	4	8	4	8	4	8	3	7	4	8	2	6	4	8	4	8
C	2	10	1	7	4	12	4	12	3	11	4	12	2	10	4	12	4	12
D	4	16	1	11	4	16	4	16	0	9	4	16	0	8	4	16	4	16
E	3	23	0	18	4	24	4	24	1	20	4	24	0	12	3	23	4	24
F	12	90 (52)	+ 4	+ 69 +(37)	14	94 (51)	14	94 (49)	+ 5	+ 79 +(37)	14	94 (50)	+ 0	+ 36 +(21)	14	94 (50)	16	96 (52)
Total	32	154 (116)	17	+ 120 +(88)	37	161 (118)	37	161 (116)	+ 16	+ 131 +(89)	37	161 (117)	+ 9	+ 77 +(62)	36	160 (116)	39	163 (119)

+ = p<.005 in a one-tailed t-statistic on the difference between the corresponding left hemisphere scores (R.S. is compared to D.W.).

P-F = pass-fail scores
WS = weighted scores
RWS = restricted weighted scores

Table 3

Summary of scores on Spellacy and Spreen's short version of the Token Test

Part	L/H P-F	L/H WS (RWS)	N.G. R/H P-F	N.G. R/H WS (RWS)	FV P-F	FV WS (RWS)	L/H P-F	L/H WS (RWS)	L.B. R/H P-F	L.B. R/H WS (RWS)	FV P-F	FV WS (RWS)	R.S. P-F	R.S. WS (RWS)	D.W. P-F	D.W. WS (RWS)	Max score P-F	Max score WS (RWS)
A	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1
B	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
C	1	3	0	2	1	3	1	3	1	3	1	3	1	3	1	3	1	3
D	3	12	0	7	3	12	3	12	0	7	3	12	0	6	3	12	3	12
E	3	23	0	18	4	24	4	24	1	20	4	24	0	12	1	21	4	24
F	5	35 (26)	2	28 (20)	6	36 (26)	4	34 (23)	+1	+27 (17)	6	36 (26)	+0	21 (14)	4	32 (22)	6	36 (26)
Total	14	76 (67)	4	+58 +(50)	16	78 (68)	14	76 (65)	+5	+60 +(50)	16	78 (68)	+2	+44 +(37)	11	71 (61)	16	78 (68)

+ = significantly different from corresponding left hemisphere score.

Figures 1-3 illustrate the total number of correct responses of N.G., L.B., R.S. and D.W. on the various versions of the Token Test and on their last parts using pass-fail scoring. Right hemisphere scores are highly above chance level but cluster significantly below left hemisphere and free vision scores, with R.S. consistently performing poorest and L.B.'s LVF-L/h performance consistently the best. N.G.'s scores are probably most representative of the disconnection syndrome.

As Figure 3 shows, the shortest form of the test i.e. the Spreen-Spellacy version is just as good in discriminating left from right hemisphere performance as the original 39 item form.

In Figure 4 the pass-fail scores of the patient population are compared with those of a brain damaged population (Swisher and Sarno, 1969) on the De Renzi-Vignolo version of the test and on each of its parts separately. Swisher and Sarno used 22 non brain damaged control patients, 22 left brain damaged aphasics and 22 right brain damaged non-aphasics. While the non brain damaged population score is slightly lower than the right hemisphere scores on the first part of the test, this trend is reversed on all subsequent parts. There is one exception in part 5 where L.B.'s LVF-L/h score is higher than the mean aphasic score perhaps due to left hemisphere interaction in comprehending and performing the manual tasks.

Furthermore, in contrast to the aphasic population which is most deficient in part 5, the "right hemispheres" are worst on part 4 of the test in which more chips are displayed and in which longer referent phrases are used. This is inconsistent with Swisher and

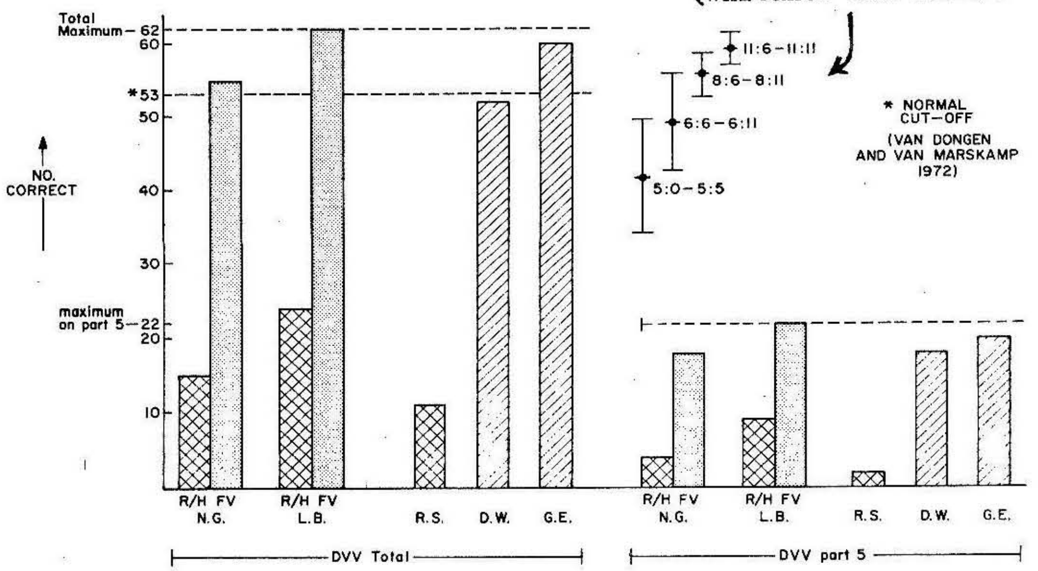
Sarno's finding (1969) that part 4 discriminated best between right brain damaged non aphasics and control subjects presumably because the right hemisphere contributes to efficient scanning of the bigger display. Since the bigger display is also used in part 2 with better right hemisphere performance than on part 4, the phrase length effect postulated here seems incontrovertible. Nevertheless visual scanning deficit or increased difficulty in perceptual identification by the right hemisphere when more chips are presented, can not be ruled out.

Figures 5, 6 and 7 illustrate the percent correct of weighted scores of the patients on all versions of the test and compare their performance to various aphasic populations reported in the literature. Figure 5 records the total weighted scores and itemized right hemisphere scores by part LVF-L/h in CLVP for N.G. and L.B.; free vision for R.S. The salient feature of Figures 5-7 is that the difference between right and left hemisphere weighted scores is smaller than pass-fail scoring would suggest (Figures 1-3).

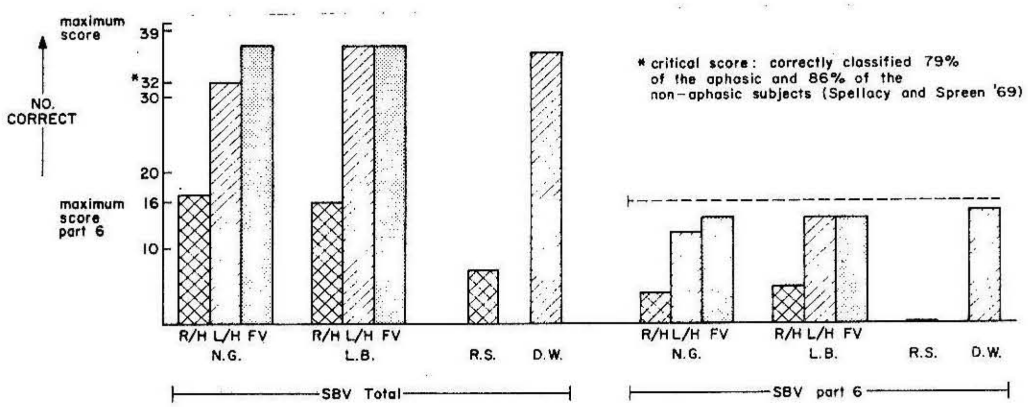
In Figure 5 right hemisphere scores on the DVV are compared with those of matched populations of fluent vs. nonfluent aphasics studied by Orgass and Poeck (1966). Again in N.G. and L.B. parts 2 and 4 of the test show most impairment. Part 2 also discriminates best the aphasic populations from the three "right hemispheres". While the right hemisphere of N.G. and L.B. is inferior to the mean aphasic performance on part 2, it is superior on part 5. But the total performance of the right hemisphere, especially of R.S. and N.G., is quite comparable to the mean of both aphasic populations.

Children's scores at various ages

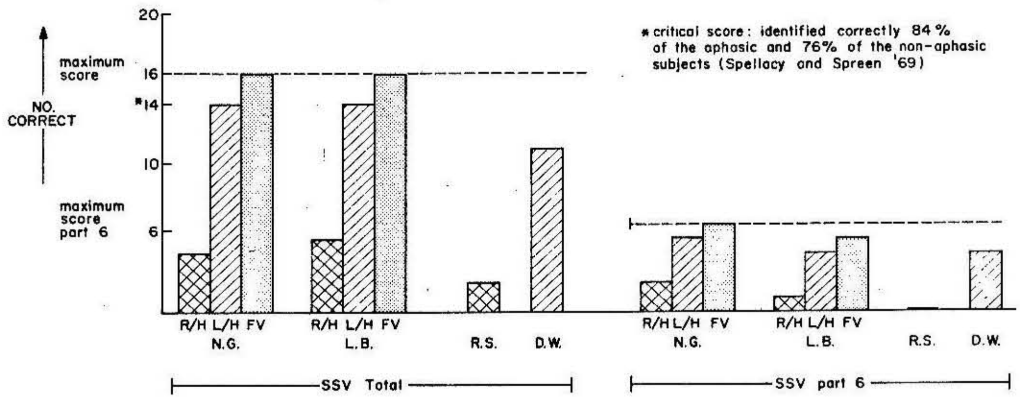
(Whitaker and Noll).



Pass-fail scores on De Renzi-Vignolo's Token Test



Pass-fail scores on Spreen-Benton's Token Test

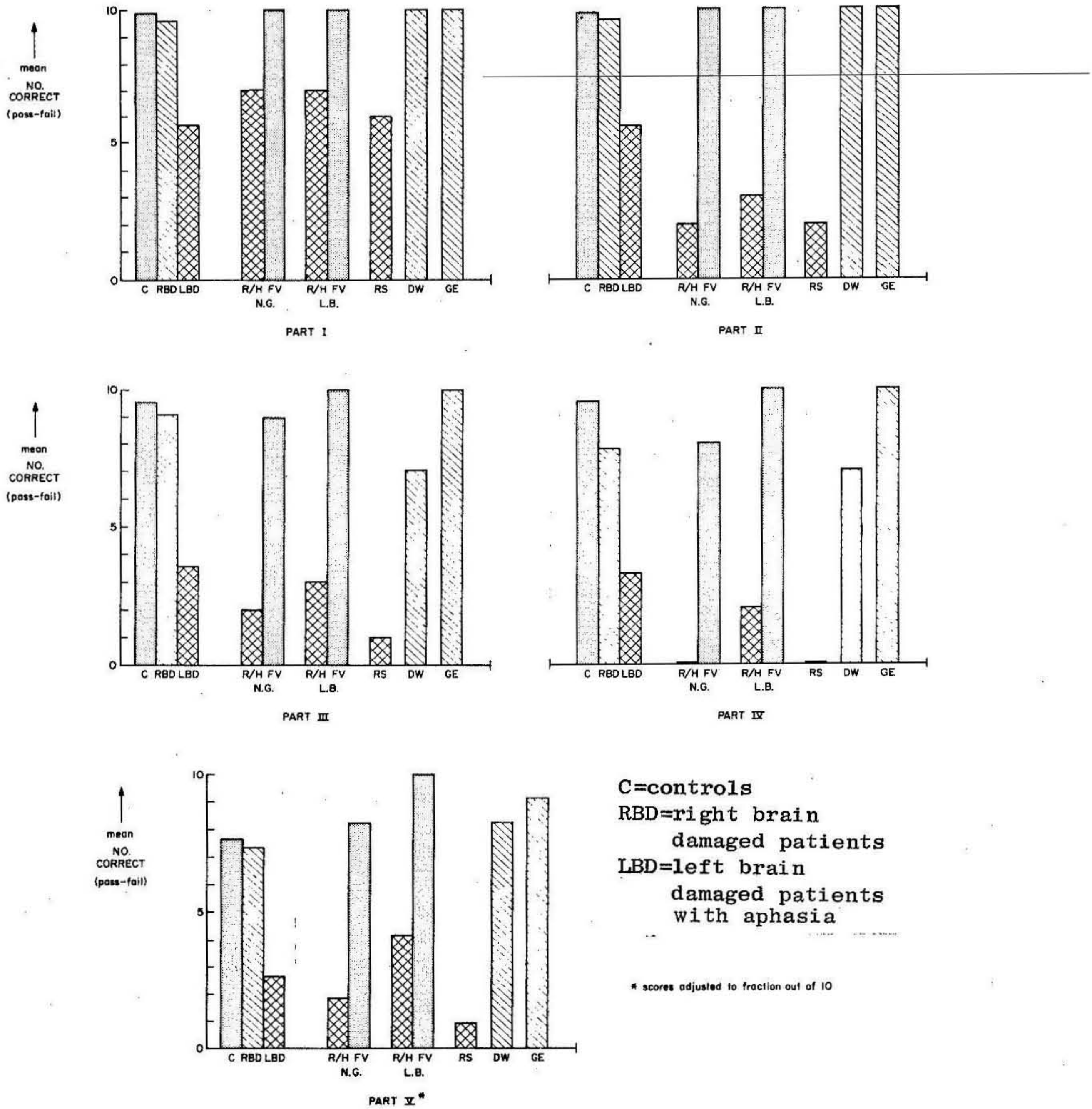


Pass-fail scores on Spellacy-Spreen's Token Test

Figures 1-3

Figure 4

Comparison of right hemisphere pass-fail scores by part on De-Renzi-Vignolo's Test with a brain-damaged population (Swisher and Sarno, 1969).



F= fluent aphasics; NF = non fluent aphasics

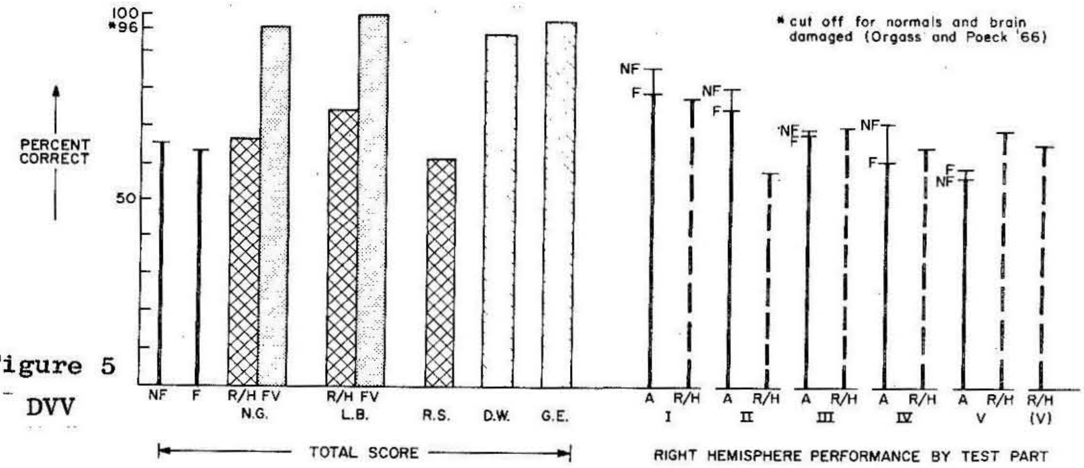


Figure 5

DVV

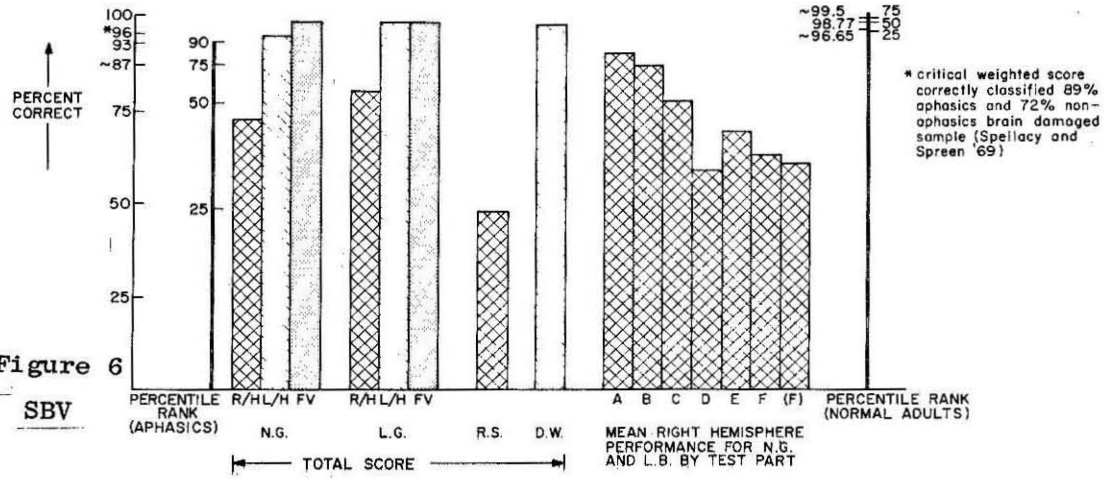


Figure 6

SBV

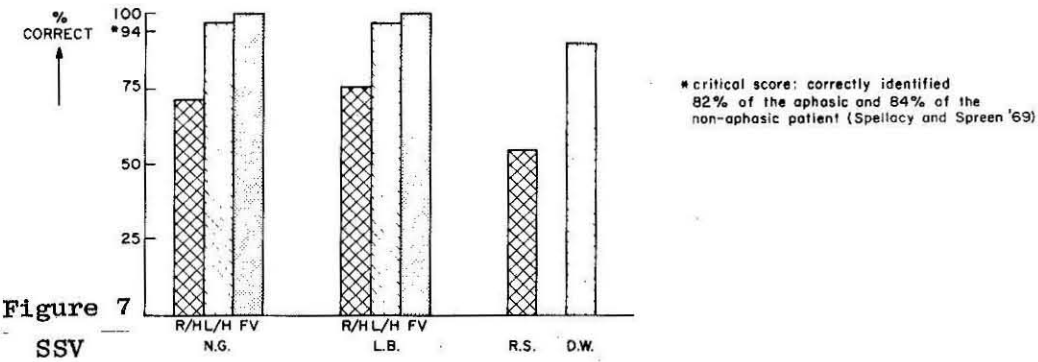


Figure 7

SSV

Figures 5-7

Percent correct weighted scores on the Token Tests.

Finally Figure 6 illustrates the performance of the patients on the Spreen-Benton version for which general aphasic population norms exist and are recorded in percentile ranks. With the exception of part F, all previous parts of this test are too short to provide reliable weighted score breakdown by part. It can be seen that R.S. ranks near the 28th percentile while N.G.'s and L.B.'s right hemisphere rank near the 50th percentile. As expected, left hemisphere performances are all above the 90th percentile.

Analysis of right hemisphere errors by semantic class. The left hemisphere has erred too rarely to provide error analysis by part of speech. Table 4 presents the number and percent of errors by the right hemisphere on size adjectives, color adjectives and shape nouns on the De Renzi-Vignolo version and the Spreen-Benton version of the Token Test. The three word classes are not equally frequent and in the context of the Token Test the probability of guessing the correct word differs from size to shape to color. Chips come in only 2 sizes and 2 shapes so that the long term probability of pointing to the correct one by chance is 50%. The colors, however, occur in a set of 5 (red, green, blue, yellow, white) and each is likely to be picked up correctly by chance 20% of the time. The syntactic difference between these words (adjective vs. noun) is not essential and the results are interpreted semantically.

The first observation is that all three classes were interpreted correctly well above chance level. Size adjective errors (large, small) occur relatively (and absolutely) least frequently. This is probably due to the early stage of acquisition of these words in the

Table 4
Analysis by size, color and shape of right hemisphere errors on the De Renzi-Vignolo and Spreen-Benton Versions of the Token Test

		N.G. (R/H)						L.B. (R/H)						R.S.								
		# Errors			% Errors			# Errors			% Errors			# Errors			% Errors			Max # Errors		
		Sz.	Col.	Shp.	Sz.	Col.	Shp.	Sz.	Col.	Shp.	Sz.	Col.	Shp.	Sz.	Col.	Shp.	Sz.	Col.	Shp.	Sz.	Col.	Shp.
DVV	Part 1	-	2	2	-	20	20	-	2	1	-	20	10	-	4	2	-	40	20	-	10	10
	2	1	5	7	10	50	70	1	4	4	10	40	40	1	4	5	10	40	50	10	10	10
	3	-	8	5	-	40	25	-	4	8	-	11	2	-	11	2	-	55	10	-	20	20
	4	3	10	11	15	50	55	-	9	9	0	45	47	6	12	3	30	60	15	20	20	20
	5	-	13	13	-	36.1	36.2	-	7	16	-	19.4	42.1	-	19	15	-	52.8	39.5	-	37	39
	Sub-total	4	38	38	13.3	39.1	38.4	1	26	38	3.3	27.1	38.8	7	50	27	23.3	52.1	22.55	30	97	99
SBV	Part A	-	0	0	-	0	0	-	2	0	-	40	0	-	2	0	-	40	0	-	5	2
	B	-	0	0	-	0	0	-	1	0	-	25	0	-	1	1	-	25	25	-	4	4
	C	1	1	3	25	25	75	0	1	0	0	25	0	0	2	0	0	50	0	4	4	4
	D	-	3	1	-	37.5	12.5	-	3	47	-	37.5	50	-	6	2	-	75	25	-	8	8
	E	1	2	3	12.5	25	37.5	0	2	2	0	25	25	3	5	4	37.5	62.5	50	8	8	8
	F	-	4	12	-	15.4	42.9	-	7	8	-	27	28.6	-	19	14	-	67.0	50	-	26	28
	Sub-total	2	10	19	16.7	18.2	35.2	0	10	14	0	29.1	25.9	3	35	21	25	63.6	38.9	12	55	54
DVV+SBV	Sum total	6	48	57	14.3	31.6	37.2	1	42	52	2.4	27.6	34	10	85	48	23.8	55.9	31.4	42	152	153

child's language (comprehension lexicon) and their common use thereafter.

However, while R.S. shows a consistently and significantly more inferior performance on color adjectives than on shape nouns (circle, rectangle), this trend is reversed in the total right hemisphere performance of both N.G. and L.B. This result is significant in view of the higher guessing probability of shape nouns.

The pattern of higher error rate by N.G.'s and L.B.'s right hemisphere on shape nouns than either size or color adjectives coincides with the results obtained by De Renzi and Vignolo (1962) on their mild receptive aphasics. These authors attribute the deficit to the semantic abstraction of the nouns "circle" and "rectangle" and its later acquisition by children. Yet R.S. who is the youngest of the patients shows a selectively severe deficit on color names. Accordingly, her deficit must be interpreted as a specific color anomia and may in turn be due to a particular reliance of the acquisition of color names on bilateral hemispheric integration.

Fixed display effect. In order to learn the effects of a fixed visual display of the chips (as used by De Renzi and Vignolo and in the Spreen-Benton version), on right hemisphere performance, the SBV has been administered once to L.B. with a fixed order as prescribed in Spreen and Benton (1969). This arrangement is different from the order used in De Renzi and Vignolo although in both cases the chips are arranged in rows with constant size and shape. The results (Table 5) show a reversal of the error trend observed on testing with a random display. This time, color adjective errors exceed shape noun errors by 2 to 1 even though the percentage of color errors remains the same as during testing with variable display. Thus the reduction in number of shape noun errors may be due to the added display information implicit in the regular arrangement of the chips by size and shape rather than by color.

Again it is impossible to determine on the basis of the present data whether the right hemisphere utilized the increase in information provided by the fixed display or whether it is the left hemisphere which was then able to ascertain the shape (though not the size) of the chips with better reliability on the basis of incomplete visual information transmitted uncrossed from the left visual field to the left cortex. Relevant results on laterality effects in form vs. color dominance supporting the latter interpretation will be presented in a forthcoming paper (E. Zaidel in preparation).

It should also be noted that the data show no consistent primary or recency effect in recalling the first vs. the second part of symmetric instruction (e.g. "pick up the red circle and the yellow square") in the performance of the right hemisphere either within or across subjects.

Instruction repetition effect. Repetition of the instructions following erroneous responses should not significantly effect the chance of obtaining completely correct responses (pass-fail scoring) or even a higher weighted score since the subject does not know which part of the instruction was incorrect. On the other hand repetition

Table 6. Comparison of N.G.'s right hemisphere weighted score with and without repetition of the Token Test (De Renzi-Vignolo version) instructions.

	First Formulation N.G. - R/H				Repetition N.G. -R/H			
	# Correct		% Correct		# Correct		% Correct	
DVV	P-F	WS (RWS)*	P-F	WS (RWS)	P-F	WS (RWS)	P-F	WS (RWS)
Part I	7	16	70	80	9	19	90	95
II	2	17	20	56.7	3	19	30	63.3
III	2	27	20	67.5	4	32	40	80
IV	0	36	0	60	0	40	0	66.7
V	4	90 (55)	18.2	69.2 (68.7)	7	96 (54)	31.8	73.8 (68.7)
total	15	186 (151)	24.2	66.9 (65.4)	23	206 (164)	37.1	74.1 (71.3)

*WS = weighted score

(RWS) = restricted weighted score

Table 5. Size, color and shape errors by L.B. in LVF-L/h CLVP of the SBV using a fixed display of chips.

# Errors			% Errors		
Sz.	Col.	Shp.	Sz.	Col.	Shp.
-	0	0	-	0	0
-	2	2	-	50	50
1	2	1	25	50	25
-	3	1	-	37.5	12.5
1	2	1	12.5	25	12.5
-	6	2	-	23.1	7.1
2	15	7	16.7	27.3	13

may improve memory and facilitate attention. Repetition invariably improves an already high left hemisphere score to a perfect one. Table 6 illustrates the representative effect of repetition on the performance of the right hemisphere of N.G. in the De Renzi-Vignolo version of the test. A moderate improvement in performance is evident. Qualitative observations of the patients' behavior suggests that the score increase is due to facilitation of verbal memory rather than improved motivation or attention. Consequently, in contrast to Boller and Vignolo's (1966) improvement with repetition is attributable to task specific verbal factors.

Analysis of right hemisphere errors on verbs vs. prepositions, conjunctions and adverbs. The last parts of both the De Renzi-Vignolo version and Spreen-Benton version of the Token Test include instructions containing several verbs (put, touch, pick up, take, move), and various prepositions, conjunctions and adverbs (on, behind, between, under, with, no, and, or, if, when, except, without, instead, together, one, all) and a few adverbs (quickly, slowly). Table 7 summarizes right hemisphere's performance on verbs vs. prepositions, conjunctions and adverbs (PCA's). Both R.S. and N.G. in LVF-L/h CLVP show an expected bigger deficit on PCA's if only because there are fewer alternative verbs than other grammatical units. In contrast there is only a minute deficit in either verbs or prepositions, conjunctions and adverbs in L.B.'s right hemisphere performance and this must be attributed, at least in part, to left hemisphere interaction in practic control using the ipsilateral motor pathways. Evidence for better left than right hemisphere ipsilateral motor control comes from other studies of the

Table 7

Analysis of verbs (V) vs. prepositions, conjunctions and adjectives (PCA) errors in right hemisphere performance on the last part of the Token Test.

	V		PCA	
	# err.	% err.	# err.	% err.
DVV part V	5	20	8	32
SBV part E	2	12.5	8	52.4
total	7	17.1	16	41.3

a. N.G. - R/H

V		PCA	
# err.	% err.	# err.	% err.
3	12	0	0
0	0	1	4.8
3	7.3	1	2.2

b. L.B. - R/H

	V		PCA	
	# err.	% err.	# err.	% err.
DVV part V	5	20	15	60
SBV part E	4	25	8	38.1
total	9	21.9	23	50

c. R.S.

# items in test	
V	PCA
25	25
16	21
41	46

commissurotomy patients (A.A. in Nebes, 1971; L.B. in D. Zaidel and R.W. Sperry, 1973, in preparation).

Only N.G. has occasionally exhibited a classical motor disconnection syndrome as when she was not "verbally aware" of the action just completed incorrectly by her left hand. Thus when instructed to "put the white circle on the blue rectangle" she would instead touch the two chips with her left hand. When questioned about this she appeared surprised that her left hand did not in fact put one chip on top of the other and exclaimed "But I thought I did that, didn't it (the left hand) do it? There's something wrong with these (chips), they are stuck to the (testing) board."

Both R.S. and N.G. have slightly more mistakes on particles than on nouns + adjectives in part 5 of DVV similar to De Renzi and Vignolo's aphasic patients. But neither demonstrates particular weakness on spatial prepositions as did the aphasics. On the other hand like De Renzi and Vignolo's patients R.S. did find the logical connectives "no" and "if" as used in the Token Test especially difficult most probably due to perseveration or to what Luria calls deficient dynamic regulation of action by speech (1961).

Cross cueing in L.B. Given enough time, L.B. was able to name colors presented to the left visual field with good accuracy. Two processes may have contributed to this ability and in turn to left hemisphere participation in the Token Test, especially during trials in which responses were not immediate but slow and labored. These are due to information transfer from the right to the left hemisphere or from the

LVF to the left hemisphere directly. Consequently the recorded performance of the right hemisphere on the Token Test should be regarded as an upper bound on its capacity, at least in L.B. Still, the logical possibility that left hemisphere participation in the task may in fact cause interference and reduce the effectiveness of performance can not be excluded. At any rate tasks in which the right hemisphere is proficient are not prone to interference and one is justified in maintaining the conclusion that the right hemisphere is deficient on the Token Test.

There is evidence from CLVP testing that L.B. can tell which of two colors presented in the left visual half field is brighter or darker (value) than the other and which is more intense (Chroma), at least when the differences are gross (cf. also Trevarthen and Sperry, 1973). The patients can also say whether two such colors are the same or different. Alternatively, of course, this capacity may reflect information transfer from the right hemisphere to the speech centers in the left perhaps through midbrain mechanisms. In particular the color "white" is most frequently correctly named in left visual field presentations. L.B. reports that when he is required to verbalize the name of a color exposed to the left visual field he will spell with his left hand or subvocally name one by one the initial letters of the primary colors until he will reach the correct one -- i.e. presumably until the right hemisphere recognizes and somehow signals the correct color. It is also possible that the writing originates from the right hemisphere. These subjective reports seem to be supported by overt signs of left hand letter tracing and subvocal mouthing of words as well as by the time elapsed between stimulus onset and naming response. There was no evidence of any other behavioral cross cueing.

Color confusion. One may study the pattern of confusions of colors during right hemisphere performance of the Token Test. It should be remembered that such a confusion matrix reflects mainly limitations in short term verbal memory. Furthermore, since the patients original intention in assigning responses to multi phrase stimulus combinations can never be completely verified and since some ambiguity in scoring responses persists (here the principle of maximum scoring was arbitrarily invoked) the results are only suggestive. In the case of the commissurotomy patients and especially L.B., the confusion may also partially reflect left hemisphere guesses on the basis of incomplete uncrossed visual information as well as cross cueing. In R.S., on the other hand, the confusion matrix reflects a genuine color anomia and deficient association of names with colors. At any rate, the confusion matrix for pointing identification of colors named by the examiner shows lower error scores, than the confusion matrix for naming responses to colors pointed at by the examiner in the LVF in CLVP; different error patterns also emerge, reflecting color name comprehension and left hemisphere awareness of left visual field color information, respectively. More on a comparison between the two confusion matrices will be presented in a forthcoming paper (E. Zaidel, in preparation).

Table 8 (a-d) presents the color confusion matrices of N.G. and L.B. during LVF-L/h CLVP and of R.S. in free vision, as well as a summary of the combined results in raw scores and in percentages of

Table 8

		Response color					
		white	red	yellow	green	blue	total
	white	96	1	1	2	1	101
stimulus	red	10	81	11	10	16	128
color	yellow	14	23	68	9	5	119
	green	6	11	8	79	17	121
	blue	4	19	10	19	89	141

a. Color confusions in N.G. and L.B. in LVF-L/h CLVP in terms of number of responses.

		Response color					
		white	red	yellow	green	blue	total
	white	95	1	1	2	1	100
	red	8	63	9	8	12	100
stimulus	yellow	12	19	57	8	4	100
color	green	5	9	7	65	14	100
	blue	3	13	7	14	63	100

b. Color confusions in N.G. and L.B. in LVF-L/h CLVP in terms of percent of stimulus color.

		Response color					
		white	red	yellow	green	blue	total
	white	20	2	1	3	1	27
	red	1	22	1	2	7	33
stimulus	yellow	2	7	5	7	4	25
color	green	7	6	2	10	6	31
	blue	2	6		10	16	34

c. Color confusions in R.S. in terms of number of responses.

		Response color					
		white	red	yellow	green	blue	total
	white	74	7	4	11	4	100
	red	3	67	3	6	21	100
stimulus	yellow	8	28	20	28	16	100
color	green	23	19	6	32	20	100
	blue	6	18		29	47	100

d. Color confusion in R.S. in terms of percent of stimulus colors.

Table 8 a-d. Color confusion matrices for right hemisphere performance on the Token Test.

stimulus colors. A clear tendency, which is significant and consistent across all these patients, is apparent for the color "white" to be least confused with other colors; "red", "green", "blue" and "yellow" occupy some intermmediate positions. Since the Token Test colors were not matched for intensity or brightness no further analysis of the confusion pattern will be attempted.

In Table 9 the percentage of correct color responses on the Token Test is compared with some preliminary data on comprehension of color names vs. naming of colors by R.S. and in LVF-L/h CLVP by N.G. Again it should be remembered that the Token Test confusion matrices are at best approximations to the actual errors and that they furthermore reflect memory limitations and confusion with other items (e.g. in perseverations), while either comprehension as tested by pointing, or naming do not involve memory and are susceptible only to left hemisphere interference. Nevertheless a typical trend emerges with pointing responses to aural color names being superior to Token Test performance and naming of indicated colors being inferior to it. The possibility that naming in N.G. originates in the right hemisphere is particularly strong. However, the counterargument in favor of naming due to visual information transfer from left visual field to left cortex or from the right to the left hemisphere is supported by the improvement in naming ability shown between pretest and post test controls in both N.G. and L.B.

	Percent of correct responses		
	Token Test identification	color names comp.	color naming
N.G.	65	94	40
R.S.	49	63	50

Table 9
Comparison of percent of correct color identification in the Token Test with the comprehension and naming of colors by R.S. and by N.G. in LVF CLVP.

DISCUSSION

Comparison with other tests of auditory language comprehension in the right hemisphere. As the preceding data indicate the Token Test reveals a more severe receptive language deficit in the right hemisphere than was apparent on some auditory language comprehension subtests of standardized aphasic batteries (Schuell and Goodglass) using a similar paradigm with aural-visual stimuli and pointing responses. Correspondingly, Needham and Swisher (1971) have shown that the Token Test revealed mild auditory comprehension deficits in aphasics more effectively than either the subjectively rated, informally administered and non-task-oriented comprehension category in the Functional Communication Profile (Sarno, 1969) or the task oriented comprehension section of a standard aphasia battery. Similarly, De Renzi and Vignolo (1962) and Boller and Vignolo (1966) noted the superior sensitivity of the Token Test in detecting latent sensory aphasia to Pierre Marie's Three Paper Test (as well as Ombredane's Cat-Chair Test). Both of these tests were administered to R.S. (Part II) and the results indeed indicate that her performance was poorest on the Token Test in the sense that she could more often perform the Three-Paper Test faultlessly than not. In this vague and generalized sense, then, an analogy can be made between the auditory language comprehension of the right hemisphere and that of a mild sensory or any expressive aphasic (see "clinical data" above).

At the same time the right hemisphere proved capable of extracting a significant amount of partial information from the aural instructions. Again such limited competence may not reflect even a corresponding performance in the intact brain. Thus the Token Test results neither support nor reject the thesis of a specific right hemisphere role in the mediation of high-level language functions (Critchley, 1962; Eisenson, 1962). The importance of the Token Test results lies, rather, in the fact that they indicate the limiting factors in right hemisphere auditory language comprehension.

A comparison with left hemisphere scores does not support the hypothesis of right hemisphere participation (interaction) in this task in normals. With the possible marginal exception of the pass-fail performance of D.W. on the De Renzi-Vignolo version there is no evidence of significant left hemisphere deficit on the Token Test. In particular, left hemisphere performance remains the same regardless of whether a fixed and regular or random arrangement of tokens was used. Thus, without denying a considerable right hemisphere competence in partially interpreting Token Test type instructions, the preceding data suggest that the deficit found by Swisher and Sarno on the performance of right hemisphere damaged patients is due to general mental deterioration involving decreased attention (Archibald and Wepman, 1968; Swisher and

Sarno, 1969) rather than to specific right hemisphere contributions as in visual scanning. Of course, performance of the separated or isolated hemispheres may vary from the normal functioning of each in the intact brain and the possibility of bilateral interaction on the Token Test in normals can not logically be excluded.

Right hemisphere performance on the Token Test has no localization significance by (symmetric) analogy with deficits due to left hemisphere lesions. For, it was repeatedly demonstrated that expressive aphasics (De Renzi and Vignolo, 1962; Boller and Vignolo, 1966) unselected aphasics-- sensory, amnesic and motor-amnesic -- (Orgass and Poeck, 1966), as well as latent sensory aphasics (De Renzi and Vignolo, 1962) are all about equally impaired in their Token Test performance. More specifically, Poeck et al (1972) found that both fluent (all sensory and most amnesic aphasics) and nonfluent (mainly motor aphasics) are equally impaired on the test, and Benson (1967) has demonstrated that fluent aphasia is related to anterior brain lesions within the language area while non-fluent aphasia is associated with a posterior localization of brain lesion in the language area.

<u>Short term verbal memory deficit.</u> The instructions in the Token Test are linguistically unique in that they are non-redundant and semantically context free, hence referentially abstract. Consequently, there is a heavy dependence on short term verbal memory and the subject's ability to rehearse in it. Thus perhaps the simplest and most natural "account" for the observed right hemisphere deficit on the Token Test is that it lacks a short term verbal memory and rehearsal buffer. Data in Parts II and III of the thesis already point to the same conclusion.

Indeed, analysis by part of weighted scores of right hemisphere performance on the De Renzi-Vignolo version discloses that the most severe relative deficits occur in parts 2 and 4 rather than 5, as found by Boller and Vignolo (1966) on aphasics and left hemisphere damaged patients. Even the argument that left hemisphere comprehension and execution of the practic components during right hemisphere processing of part 5 improves the performance of the left hand through ipsilateral motor control is incomplete since it does not apply to R.S. who shows the same rank ordering of success on the 5 parts of the test. Now, parts 2 and 4 are precisely the ones containing 3 word long referent phrases ("the small white circle") even though the items do not constitute the longest instructions in the test. It would seem that the right hemisphere is deficient in encoding and maintaining in memory as units references consisting of three or more items. In fact the auditory pointing span of the right hemisphere (subtest A.3 in Schuell's battery) which also measures the short term verbal retention span (by pointing to a visual display in response to an aural sequence of common nouns) was also found to be 3 in R.S. as well as in N.G. and L.B. (LVF-L/h CLVP. It is, in fact, natural to attribute the deficit in short term right hemisphere verbal memory to inadequate verbal rehearsal mechanisms due to undeveloped speech mechanisms.

A similar defect in speech production may be the cause of the deficit on the Token Test of the expressive aphasics of Boller and Vignolo (1966) or indeed of aphasics in general. So interpreted, the test is seen to rely on and measure productive as well as receptive language mechanisms. In view of the well known general expressive language involvement in all aphasic forms, one would also expect a deficient performance on the Token Test by any aphasic group. This is indeed what was found in the various studies (Boller and Vignolo, 1966; Orgass and Poeck, 1966; Poeck and Kerschensteiner and Harjig, 1972). Yet the interpretation of low Token Test performance in terms of verbal memory deficit associated with deficient verbal rehearsal mechanisms has been dismissed with surprisingly little attention by other investigators (e.g. De Renzi and Vignolo, Boller and Vignolo). The uncritical consensus, instead, has been that subtle receptive disorders are present in all aphasics.

Boller and Vignolo do entertain the hypothesis that receptive difficulties of expressive aphasics are due to a retroactive effect of the impaired expressive formulation (or implicit articulation) on comprehension, in the sense that the impossibility of "rehearsal" or internal reverbalization of complex audio-verbal messages prevents the patients from keeping them in mind long enough to make their decoding possible. In fact they verified this hypothesis by showing that aphasics whose oral expression was more widely affected performed Token Test (part 5) significantly worse than those with less impaired oral expression (pp. 327-828). Nevertheless the authors refrain from generalizing this finding, by attributing poor performance on the Token Test in general to latent speech deficits.

In fact data presented by Goodglass, Gleason, Bernholtz and Hyde (1972) show that a patient with Broca's aphasia and agrammatism finds it most difficult to ellicit syntactic constructions of the form

Adjective + Adjective + Noun which is the characteristic structure of the reference phrases in the Token Test instructions. It follows that the difficulty experienced by aphasics in the Token Test may be communication-channel non specific, expressive as well as receptive.

What can one infer from right hemisphere performance about its semantic referential capacity in general? It is clear that it substantially comprehends in isolation lexical items of each of the semantic classes included in the test, i.e. size adjectives, spatial prepositions and logical connectives (see section on syntactic structures and data on R.S. in Part II), as well as geometric shapes and color names (cf. Goodglass' Boston Diagnostic Aphasia Examination). Why then do phases of the type "Adjective + Adjective + Noun" consisting of the same lexical items fail to acquire the same referential significance? Aside from the hypothesized limitations in short term right hemisphere verbal memory there must exist a more fundamental limitation in the ability of the right hemisphere to form stable and precisely specified non-verbal, say pictorial or visual imagerial, representations in response to non-redundant abstract linguistic messages with poor associative value and no unifying semantic concept. We may say that the right hemisphere is adept at integrating novel or fragmented information only if a unified coherent meaning can thus be assigned to the integrated whole. In other words, the right hemisphere may be incompetent to classify or analyze the details of the input information (for example by cross comparing or correlating its constituent components). Yet the nature of the stimulus and visual display in the Token Test is precisely such that the components of the Adjective + Adjective + Noun phrases can not be integrated into a single higher precept since the meaning of the referent is simply the concatenation of the constitutent adjectives and nouns. Furthermore, the verbal decoding task is paralleled by the informational characteristics of the visual identification task. Again, the stimuli all resemble each other; they share all their dimensions with other chips and a relatively fine classificatory skill is necessary to select the correct one.

PROSPECTS

The preceding results suggest that the Token Test is a useful paradigm by which to study linguistic limitations in auditory language comprehension of the right hemisphere. The task is simple enough to permit a "micro" information processing analysis of the strategies used by either hemisphere in integrating the verbal message with visual search, -- by systematically varying the information in the display and in the instruction. One promising technique is the use of chronometric (reaction time) data for model building, especially in hemispherectomy patients and using a laterality research paradigm on normal subjects -- adults as well as children. For example the technique can disclose that the left hemisphere processes the reference phrases by comparing a stored abstract linguistic representation of it with that of a given chip in the display. The right hemisphere, on the other hand, may first recode the reference phrase as a visual image which is then matched visually with each chip in the display.

Detailed and early developmental norms and analysis of task performance in free vision as well as visually lateralized conditions by children is indispensable to interpreting the Token Test in the light of hemispheric specialization.

A reading version of the Test can be studied to advantage using the CLVP technique. In particular, results here may clarify the issue of left hemisphere interaction, since the total input will be restricted to the left hemisphere. At this time it is a mere theoretical exercise to analyze and interpret unilateral performance on the Token Test in terms of the transformational linguistic phrase structure of the instructions since the Chomskian model is mainly syntactic and fails to account systematically for semantic and pragmatic perceptuo-cognitive aspects of the context of the task, which, I believe, are at the crux of hemispheric differentiation in it.

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V. GENERAL CONCLUSION

The development of a new technique for continuous lateralization of visual input which permits eye scanning movements of an experimental arena made it possible to investigate systematically for the first time some limits to the disconnected right hemisphere's ability to manipulate meanings -- especially through language -- using a variety of standardized tests.

It was found that perceptuo-cognitive-mnestic functions in general and linguistic functions in particular, show a hierarchy of competence as reflected in widely varying age estimates of performance. For example, the highest age level of right hemisphere language performance is obtained on oral picture vocabulary tests (the range across R.S., N.G. and L.B. is from 8:1 to 16:3) and the lowest on tests of semantically abstract and syntactically complex references (as low as 3:0). Thus any attempt to characterize right hemisphere cognition uniformly as that of a child of a certain age is false on empirical grounds.

Furthermore, it is now evident that hemispheric specialization cannot be characterized in terms of linguistic versus visuo-spatial functions. Rather, the distinction is process-specific with the right hemisphere providing general, quick orientational responses obtained from redundant even fractionated semantic information in the sensory environment, processed in parallel by pattern matches without exhaustive analysis or enumeration. And this characterization applies equally to linguistic input as to visuo-spatial information.

The precise nature of the linguistic interaction between left and right in the intact brain remains to be found but there is evidence from this study that functional language in the right hemisphere depends on the integrity of the left during the acquisition stage of the corresponding skills (e.g. reading). It is possible that the right hemisphere provides some common supportive role to the left in the processing of linguistic material, perhaps through the activation of perceptually or affectively based representations of experience.

There is no doubt that the disconnected right hemisphere has access to highly complex systems for the symbolic representation of experience, including self reference. It can well extract meaning from line drawings of semantically complex scenes and especially from half-tone pictures under conditions of low acuity, but not when the figure and ground are in gestalt competition. Furthermore, the right hemisphere seems to possess adequate long term semantic memory but severely limited short term verbal memory.

Indeed the concept of left hemisphere specialization for language must be sharpened to the concept of left specialization of speech (with the usual provisions for crossed or mixed states of dominance). The mature right hemisphere presents little evidence for speech capacity but it possesses a considerable ability to comprehend spoken language: single words and (when semantic context is redundant enough) sentences and perhaps even connected discourse. And it is only for speech, therefore, that the dictum of pre-puberty laterlization should apply after which right hemisphere take-over of language functions is said to be impossible.

Data presented here lend new physiological support (by the right hemisphere) to the classical separation between the expressive (encoding) and receptive (decoding) components of language (cf. Weisenberg and McBridge, 1935; Goldstein, 1948; Luria, 1970) even though such a separation has recently come under much criticism by aphasiologists. It remains to be seen whether the data invalidate analysis-by-synthesis models of speech perception; whether it relegates them to left hemisphere processing exclusively; or whether a constructive motor theory of speech perception (as opposed to some synchronized parallel pattern matching) may even apply to the right hemisphere itself.

What can one conclude from these findings about right hemisphere participation in language processing in the intact brain? In particular, why have direct studies on populations with unilateral brain lesions failed to show either substantial language comprehension deficits following right sided focal lesions or substantial residual comprehension following focal left sided lesions with global or Wernicke's aphasia?

It is conjectured here that right hemisphere language competence exhibited by the disconnected (and isolated) right hemisphere reflects inherent capacities independent of brain damage of early onset. For it makes little teleological sense for the disconnected right hemisphere to acquire linguistic capacities unless it has functional need and basis for them in its normal states of cerebral dominance. The failure of many patients with reportedly unilateral (left) cerebral disease to show residual language functions, could be explained as due to pathological inhibition of the healthy by the damaged tissue (French et al, 1955; Smith, 1972; Sperry et al, 1969; Moscovitch, 1972). Nevertheless, the alternative explanation that the linguistic competence of the disconnected right hemisphere reflects the effects of early brain damage and thus represents an abnormal state of cerebral dominance, cannot be excluded.

Regardless of whether the linguistic competence exhibited by the right hemisphere of these patients is inherent or acquired after brain trauma it has profound clinical implications for the restoration of language functions following focal left brain damage. Results obtained here constrain both the limits of right hemisphere support of language functions and the techniques used to achieve it, namely, acquisition of extensive comprehension but limited speech, on the one hand, and utilization of certain semantically meaningful remedial pictorial materials to achieve it, on the other.

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APPENDICES

Appendix 1

Mean Percentage of Errors Over Modalities in the Minnesota Test

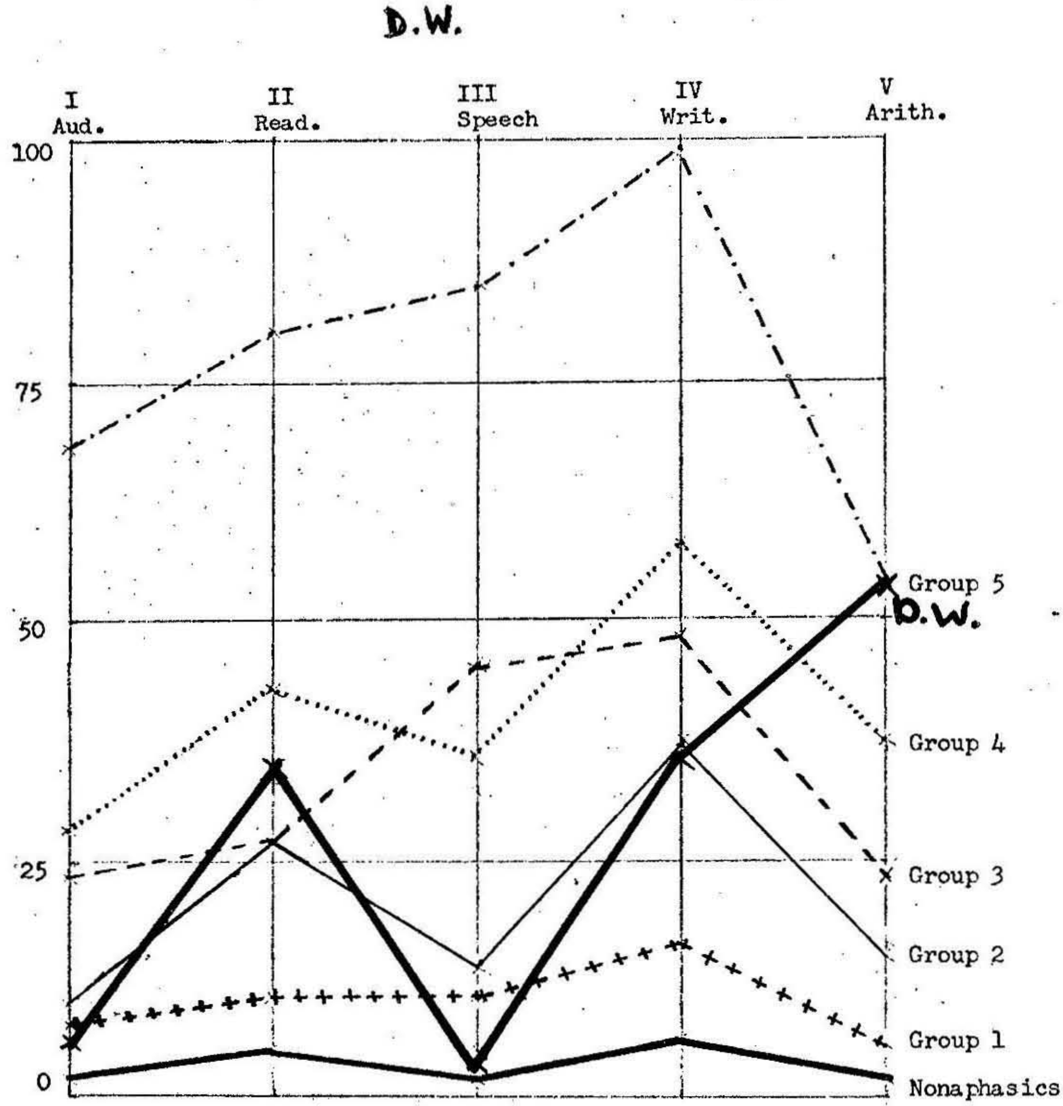


Figure 1

Patient's name: D.W.

Date of Testing: 1-9-73
Scored by: E. Z. and M.-B. K.

OVERALL PATTERN OF IMPAIRMENT ON THE MINNESOTA TEST

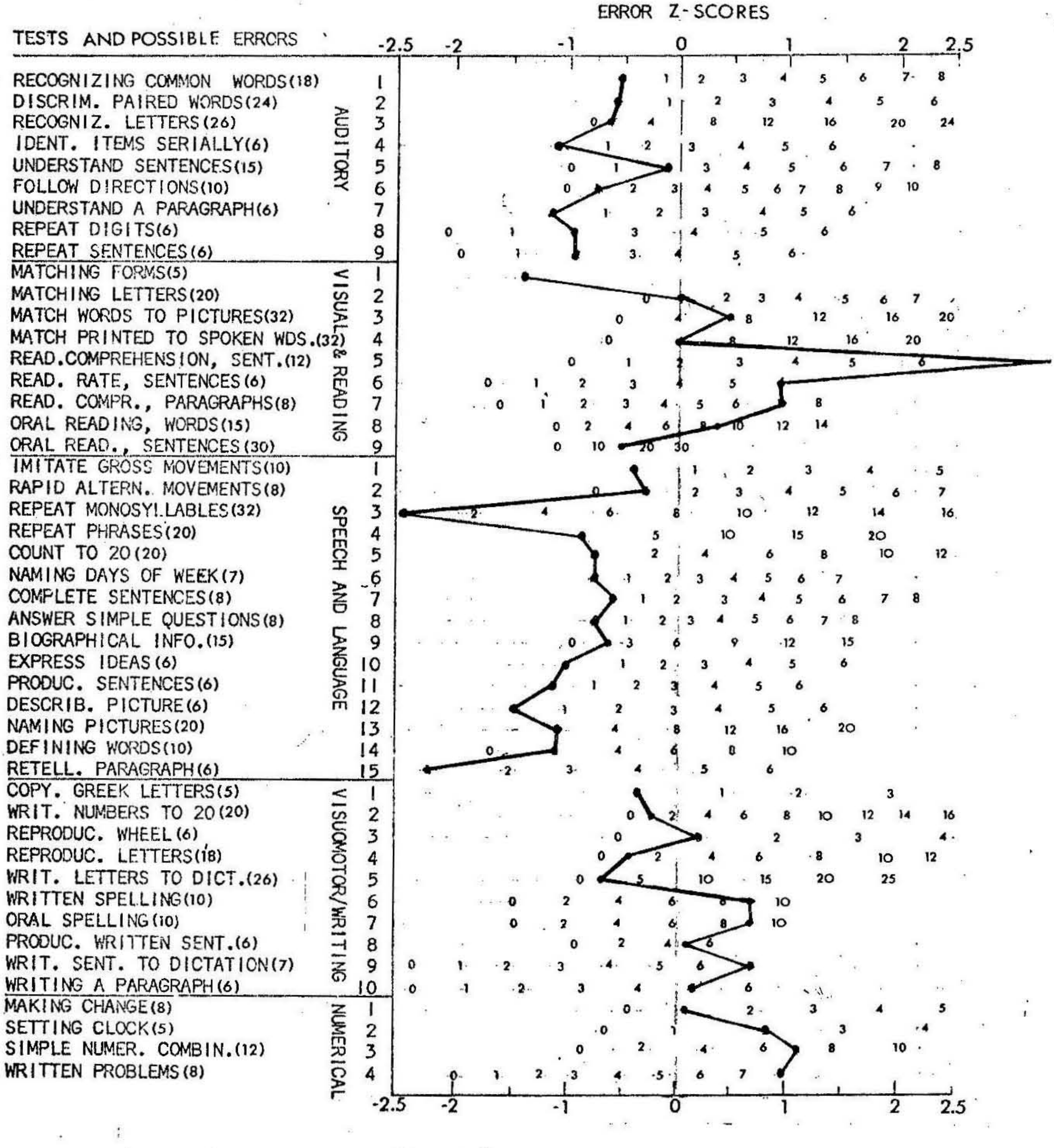


Figure 2

Patient's Name D.W. Date of rating 12/28/72 – 1/2/73

Rated by E.Z. and M.B.K

APHASIA SEVERITY RATING SCALE

0. No usable speech or auditory comprehension.

1. All communication is through fragmentary expression; great need for inference, questioning and guessing by the listener. The range of information which can be exchanged is limited, and the listener carries the burden of communication.

2. Conversation about familiar subjects is possible with help from the listener. There are frequent failures to convey the idea, but patient shares the burden of communication with the examiner.

3. The patient can discuss almost all everyday problems with little or no assistance. However, reduction of speech and/or comprehension make conversation about certain material difficult or impossible.

4. Some obvious loss of fluency in speech or facility of comprehension, without significant limitation on ideas expressed or form of expression.

5. Minimal discernible speech handicaps; patient may have subjective difficulties which are not apparent to listener.

RATING SCALE PROFILE OF SPEECH CHARACTERISTICS

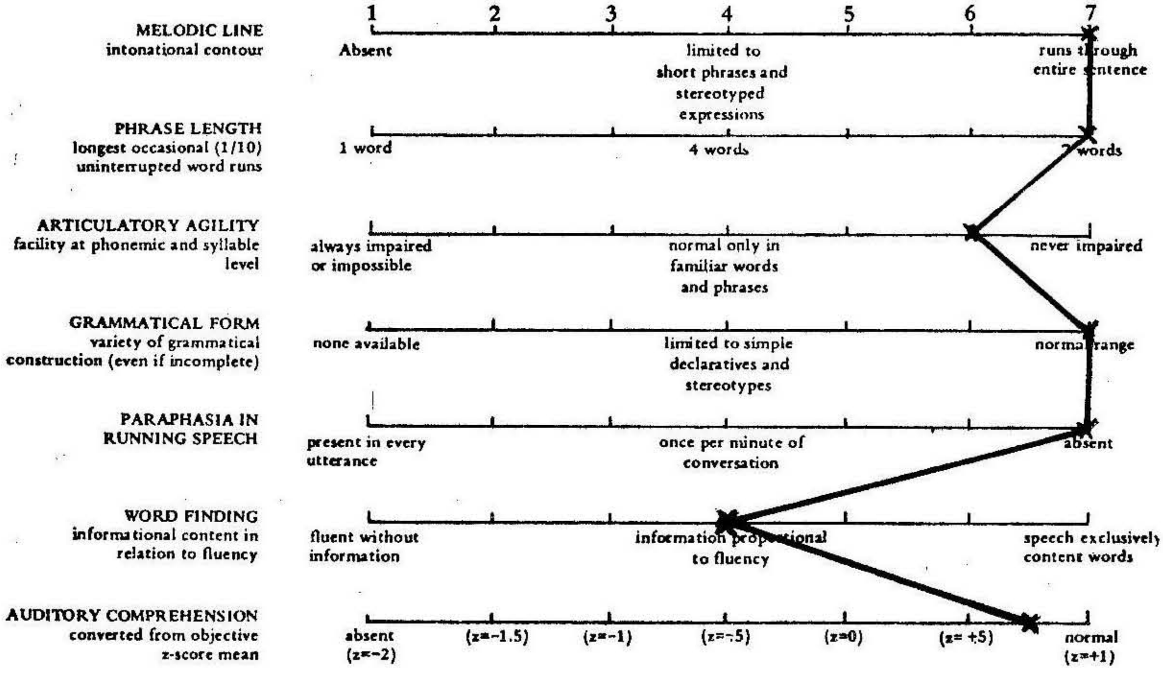


Figure 3

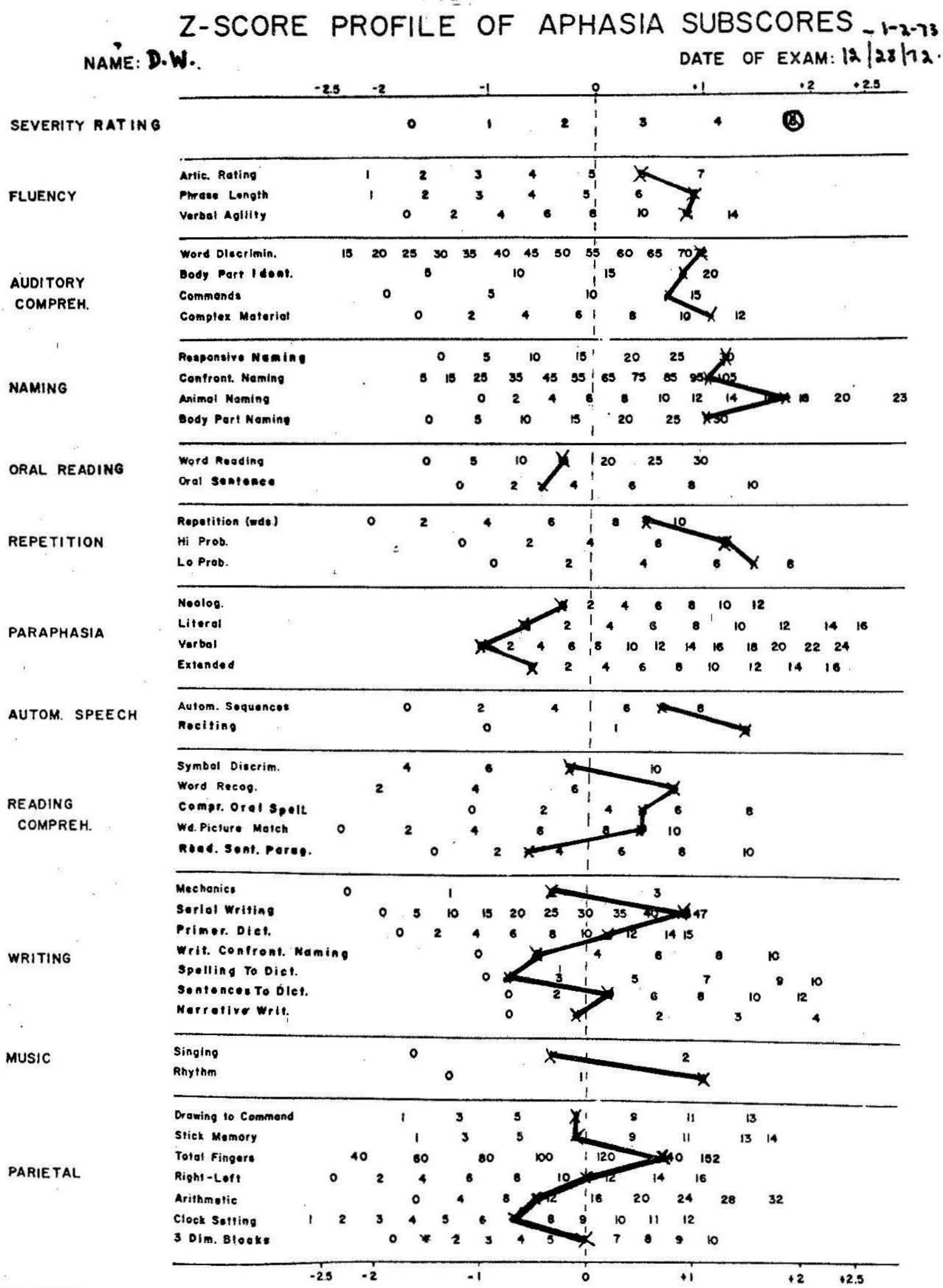

Z-SCORE PROFILE OF APHASIA SUBSCORES
1-2-73
NAME: D.W.
DATE OF EXAM: 12/28/72.
-2.5 -2 -1 0 +1 +2 +2.5
SEVERITY RATING
FLUENCY
Artic. Rating
Phrase Length
Verbal Agility
AUDITORY COMPREH.
Word Discrimin.
Body Part Ident.
Commands
Complex Material
NAMING
Responsive Naming
Confront. Naming
Animal Naming
Body Part Naming
ORAL READING
Word Reading
Oral Sentence
REPETITION
Repetition (wds)
Hi Prob.
Lo Prob.
PARAPHASIA
Neolog.
Literal
Verbal
Extended
AUTOM. SPEECH
Autom. Sequences
Reciting
READING COMPREH.
Symbol Discrim.
Word Recog.
Compr. Oral Spell.
Wd. Picture Match
Read. Sent. Parag.
WRITING
Mechanics
Serial Writing
Primer. Dict.
Writ. Confront. Naming
Spelling To Dict.
Sentences To Dict.
Narrative Writ.
MUSIC
Singing
Rhythm
PARIETAL
Drawing to Command
Stick Memory
Total Fingers
Right-Left
Arithmetic
Clock Setting
3 Dim. Blocks
-2.5 -2 -1 0 +1 +2 +2.5

Figure 4

Mean Percentage of Errors Over Modalities in the Minnesota Test

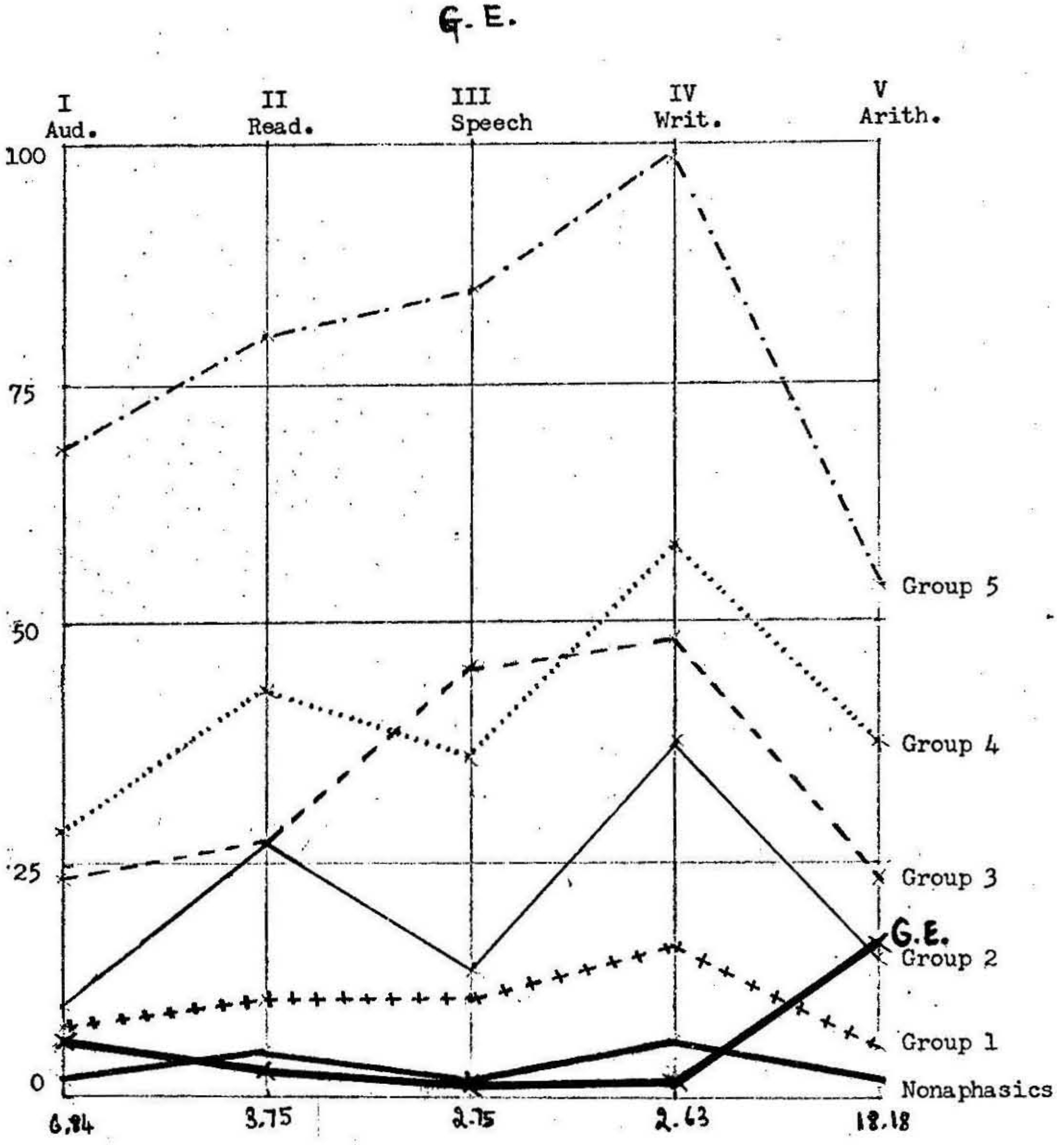


Figure 5

Patient's name: G.E.

Date of Testing: 1-12-73
Scored by: E.Z. and m.B.K

OVERALL PATTERN OF IMPAIRMENT ON THE MINNESOTA TEST

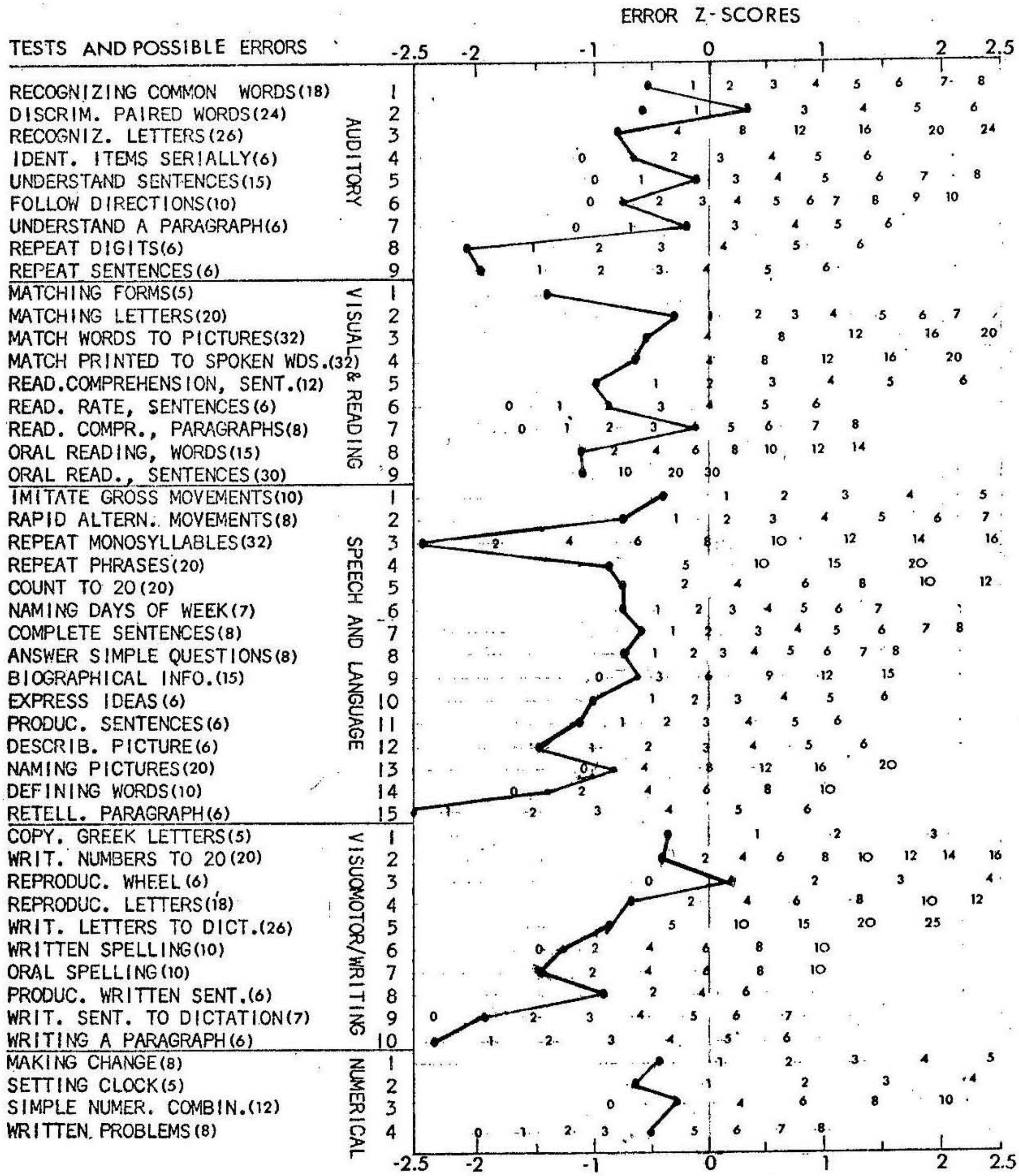


Figure 6

Patient's Name G. E. Date of rating 3-29-73

Rated by E. Z.

APHASIA SEVERITY RATING SCALE

0. No usable speech or auditory comprehension.

1. All communication is through fragmentary expression; great need for inference, questioning and guessing by the listener. The range of information which can be exchanged is limited, and the listener carries the burden of communication.

2. Conversation about familiar subjects is possible with help from the listener. There are frequent failures to convey the idea, but patient shares the burden of communication with the examiner.

3. The patient can discuss almost all everyday problems with little or no assistance. However, reduction of speech and/or comprehension make conversation about certain material difficult or impossible.

4. Some obvious loss of fluency in speech or facility of comprehension, without significant limitation on ideas expressed or form of expression.

(5.) Minimal discernible speech handicaps; patient may have subjective difficulties which are not apparent to listener.

RATING SCALE PROFILE OF SPEECH CHARACTERISTICS

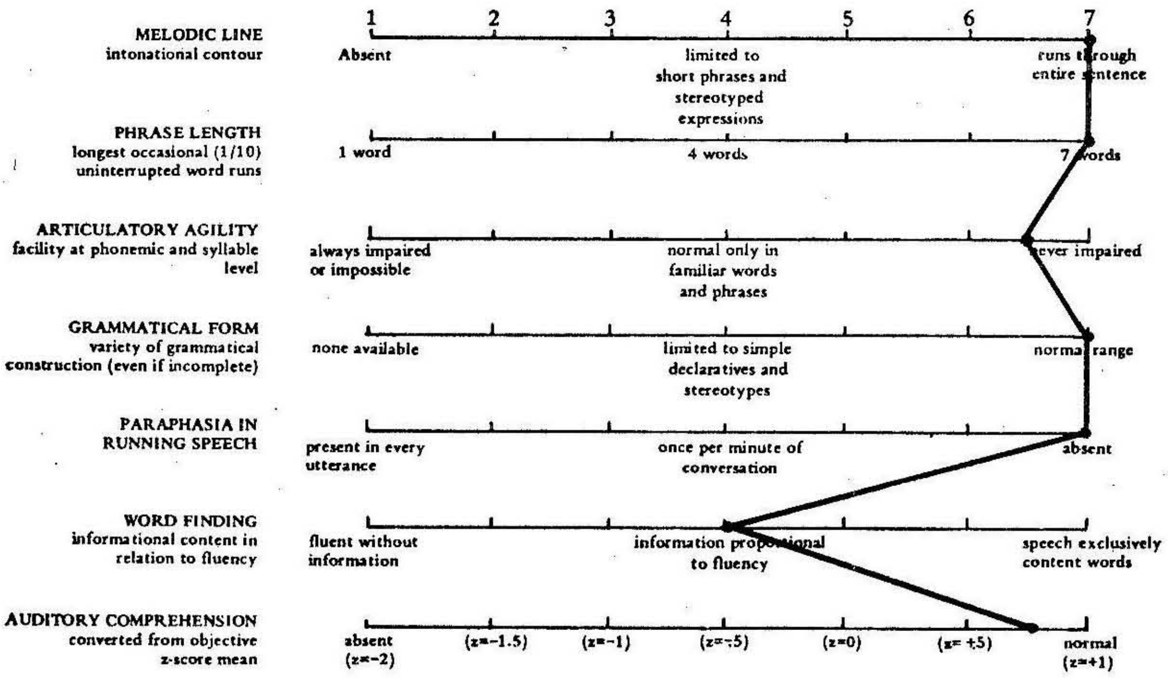
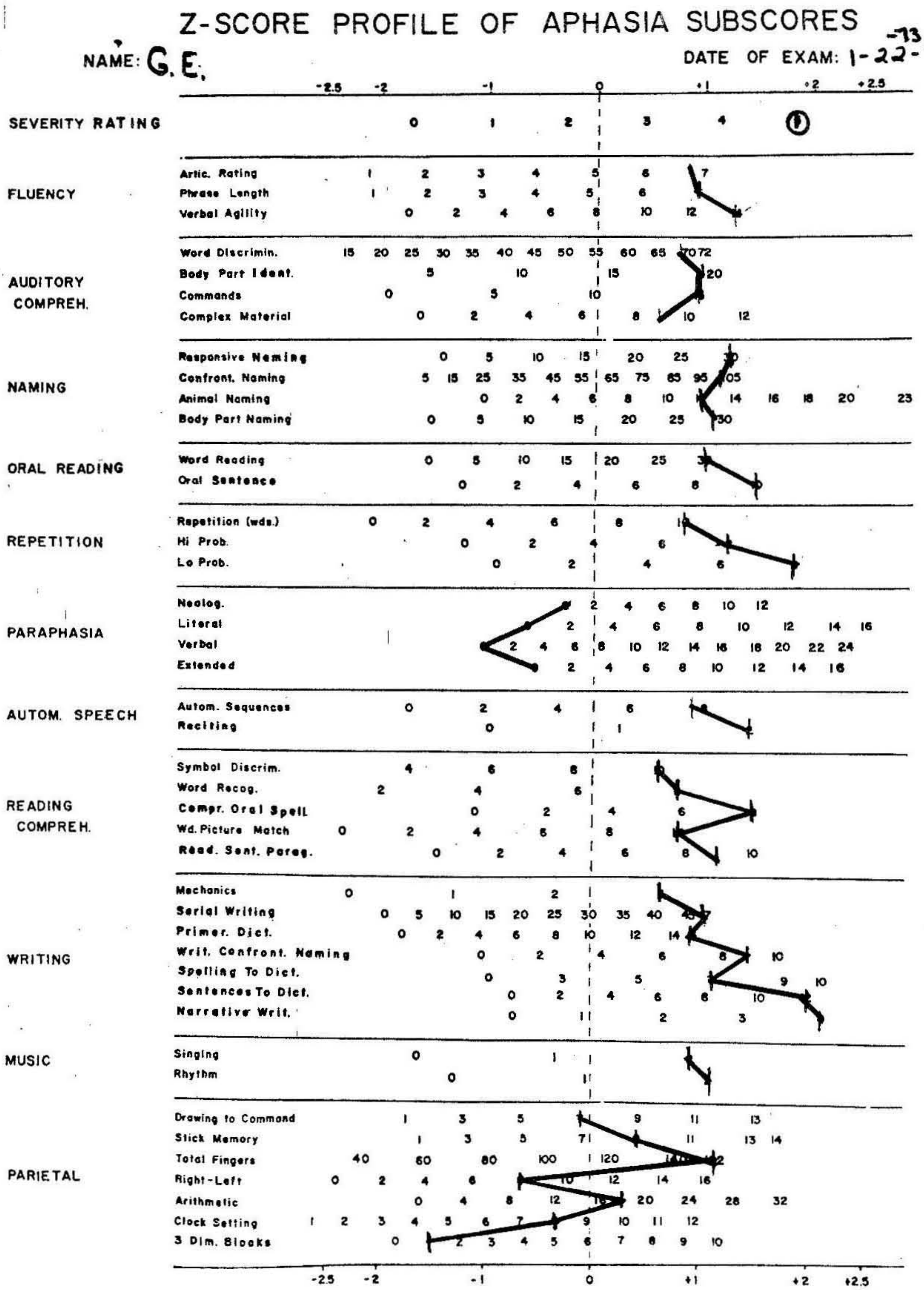


Figure 7



Z-SCORE PROFILE OF APHASIA SUBSCORES
NAME: G. E.
DATE OF EXAM: 1-22-73
-2.5 -2 -1 0 +1 +2 +2.5
SEVERITY RATING
FLUENCY
Artic. Rating
Phrase Length
Verbal Agility
AUDITORY COMPREH.
Word Discrimin.
Body Part Ident.
Commands
Complex Material
NAMING
Responsive Naming
Confront. Naming
Animal Naming
Body Part Naming
ORAL READING
Word Reading
Oral Sentence
REPETITION
Repetition (wds.)
Hi Prob.
Lo Prob.
PARAPHASIA
Neolog.
Literal
Verbal
Extended
AUTOM. SPEECH
Autom. Sequences
Reciting
READING COMPREH.
Symbol Discrim.
Word Recog.
Compr. Oral Spell
Wd. Picture Match
Read. Sent. Parag.
WRITING
Mechanics
Serial Writing
Primer. Dict.
Writ. Confront. Naming
Spelling To Dict.
Sentences To Dict.
Narrative Writ.
MUSIC
Singing
Rhythm
PARIETAL
Drawing to Command
Stick Memory
Total Fingers
Right-Left
Arithmetic
Clock Setting
3 Dim. Blocks

Figure 8

Appendix 2
Table 1

Boller and Vignolo's Token Test

Part 1 (Large rectangles and large circles only are on the table)

(1) Touch the RED CIRCLE +
(2) Touch the GREEN RECTANGLE
(3) Touch the RED RECTANGLE
(4) Touch the YELLOW CIRCLE
(5) Touch the BLUE CIRCLE
(6) Touch the GREEN CIRCLE
(7) Touch the YELLOW RECTANGLE
(8) Touch the WHITE CIRCLE
(9) Touch the BLUE RECTANGLE
(10) Touch the WHITE RECTANGLE

Part 2 (Large and small rectangles and circles are on the table)

(1) Touch the SMALL YELLOW CIRCLE
(2) Touch the LARGE GREEN CIRCLE
(3) Touch the LARGE YELLOW CIRCLE
(4) Touch the LARGE BLUE RECTANGLE
(5) Touch the SMALL GREEN CIRCLE
(6) Touch the LARGE RED CIRCLE
(7) Touch the LARGE WHITE RECTANGLE
(8) Touch the SMALL BLUE CIRCLE
(9) Touch the SMALL GREEN RECTANGLE
(10) Touch the LARGE BLUE CIRCLE

Part 3 (Large rectangles and large circles only)

(1) Touch the YELLOW CIRCLE and the RED RECTANGLE
(2) Touch the GREEN RECTANGLE and the BLUE CIRCLE
(3) Touch the BLUE RECTANGLE and the YELLOW RECTANGLE
(4) Touch the WHITE RECTANGLE and the RED RECTANGLE
(5) Touch the WHITE CIRCLE and the BLUE CIRCLE
(6) Touch the BLUE RECTANGLE and the WHITE RECTANGLE
(7) Touch the BLUE RECTANGLE and the WHITE CIRCLE
(8) Touch the GREEN RECTANGLE and the BLUE CIRCLE
(9) Touch the RED CIRCLE and the YELLOW RECTANGLE
(10) Touch the RED RECTANGLE and the WHITE CIRCLE

Part 4 (Large and small rectangles and circles)

(1) Touch the SMALL YELLOW CIRCLE and the LARGE GREEN RECTANGLE
(2) Touch the SMALL BLUE RECTANGLE and the SMALL GREEN CIRCLE
(3) Touch the LARGE WHITE RECTANGLE and the LARGE RED CIRCLE
(4) Touch the LARGE BLUE RECTANGLE and the LARGE RED RECTANGLE
(5) Touch the SMALL BLUE RECTANGLE and the SMALL YELLOW CIRCLE
(6) Touch the SMALL BLUE CIRCLE and the SMALL RED CIRCLE
(7) Touch the LARGE BLUE RECTANGLE and the LARGE GREEN RECTANGLE
(8) Touch the LARGE BLUE CIRCLE and the LARGE GREEN CIRCLE
(9) Touch the SMALL RED RECTANGLE and the SMALL YELLOW CIRCLE
(10) Touch the SMALL WHITE RECTANGLE and the LARGE RED RECTANGLE

+ In De Renzi - Vignolo's version the sentences in parts 1-4 begin with "pick up" instead of "touch".

Table 1 (cont.) 2

Part 5 (Large rectangles and large circles only)

(1) PUT the RED CIRCLE ON the GREEN RECTANGLE
(2) PUT the WHITE RECTANGLE BEHIND the YELLOW CIRCLE
(3) TOUCH the BLUE CIRCLE WITH the RED RECTANGLE
(4) TOUCH WITH the BLUE CIRCLE the RED RECTANGLE
(5) TOUCH the BLUE CIRCLE AND the RED RECTANGLE
(6) PICK UP the BLUE CIRCLE OR the RED RECTANGLE
(7) PUT the GREEN RECTANGLE AWAY FROM the YELLOW RECTANGLE
(8) PUT the WHITE CIRCLE BEFORE the BLUE RECTANGLE
(9) IF there is a BLACK CIRCLE PICK UP the RED RECTANGLE
(10) PICK UP the RECTANGLES EXCEPT the YELLOW ONE
(11) TOUCH the WHITE CIRCLE WITHOUT USING your right hand*
(12) WHEN I TOUCH the GREEN CIRCLE you TAKE the WHITE RECTANGLE
(13) PUT the GREEN RECTANGLE BESIDE the RED CIRCLE
(14) TOUCH the RECTANGLES SLOWLY and the CIRCLES QUICKLY
(15) PUT the RED CIRCLE BETWEEN the YELLOW RECTANGLE and the GREEN RECTANGLE
(16) EXCEPT for the GREEN ONE TOUCH the CIRCLES
(17) PICK UP the RED CIRCLE - NO! - the WHITE RECTANGLE
(18) INSTEAD OF the WHITE RECTANGLE TAKE the YELLOW CIRCLE
(19) TOGETHER WITH the YELLOW CIRCLE TAKE the BLUE CIRCLE
(20) AFTER PICKING UP the GREEN RECTANGLE, TOUCH the WHITE CIRCLE
(21) PUT the BLUE CIRCLE UNDER the WHITE RECTANGLE
(22) BEFORE TOUCHING the YELLOW CIRCLE PICK UP the RED RECTANGLE

* This sentence did not appear in the original De Renzi - Vignolo version

Maximum pass-fail score......62
Maximum weighted score.......278
Restricted weighted score
(sizes, colors, and shapes
only)....................230

Table 2

Test 11. IDENTIFICATION BY SENTENCE (TOKEN TEST)

Spreen and Benton's Version

	A. Present tokens as in Fig. 4.	Instructions may be repeated once	
	1. Show me a circle		
	2. Show me a square		
	3. Show me a yellow one		
	4. Show me a red one		
	5. Show me a blue one		
+	6. Show me a green one		
	7. Show me a white one		
		TOTAL A(7)	

	B. Present only large tokens.	Instructions may be repeated once	
	8. Show me the yellow square		
	9. Show me the blue circle		
+	10. Show me the green circle		
	11. Show me the white square		
		TOTAL B(8)	

	C. Present all tokens as in Fig. 4	Do not repeat instructions	
+	12. Show me the small white circle		
	13. Show me the large yellow square		
	14. Show me the large green square		
	15. Show me the small blue square		
		TOTAL C(12)	

	D. Present large tokens only.	Do not repeat instructions	
+	16. Take the red circle and the green square		
+	17. Take the yellow square and the blue square		
	18. Take the white square and the green circle		
+	19. Take the white circle and the red circle		
		TOTAL D(16)	

	E. Present all tokens as in Fig. 4.	Do not repeat instructions	
+	20. Take the large white circle and the small green square		
+	21. Take the small blue circle and the large yellow square		
+	22. Take the large green square and the large red square		
+	23. Take the large white square and the small green circle		
		TOTAL E(24)	

Table 2 (cont.)

Test 11. (continued)

	F. Present large tokens only. Do not repeat instructions.	
+	24. Put the red circle on the green square.	
	25. Put the white square behind the yellow circle.	
+	26. Touch the blue circle with the red square.	
+	27. Touch the blue circle and the red square.	
	28. Pick up the blue circle OR the red square.	
+	29. Move the green square away from the yellow square.	
	30. Put the white circle in front of the blue square.	
	31. If there is a black circle, pick up the red square.	
	32. Pick up all squares except the yellow one.	
+	33. Put the green square beside the red circle.	
	34. Touch the squares slowly and the circles quickly.	
+	35. Put the red circle between the yellow square and the green square.	
	36. Touch all circles, except the green one.	
	37. Pick up the red circle —no— the white square.	
	38. Instead of the white square, pick up the yellow circle.	
	39. Together with the yellow circle, pick up the blue circle.	

Maximum pass-fail score..........39	TOTAL F(96)	
Maximum weighted score...........163		
Restricted weighted score........119	TOTAL A-F (163)	