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HEMISPHERIC ASYMMETRIES FOR VISUAL PROCESSING OF FAMILIAR FIGURES IN NORMAL MAN

There is extensive clinical and experimental evidence for left cerebral dominance for language and right cerebral dominance for spatial perception in man. The present experiment investigated the relative efficiencies of the left and right hemispheres in visually processing pairs of laterally presented, familiar geometric figures for sameness or difference, for a verbal reaction time response in 14 normal, right-handed males. Familiar figures can be named upon perception for verbal processing or can be processed spatially. The results of this experiment indicate that such figures were processed faster in the right hemisphere than the left, suggesting that they were processed spatially even though verbal qualities were present in the stimuli. Same responses were faster than different responses, giving support to an holistic processing mechanism for sameness detection and an analytic processing mechanism for difference detection. Pairs of figures presented to both left and right of fixation were processed nearly as fast as only one pair of figures presented unilaterally, implying that division of perceptual load between the hemispheres allows total output to be increased.

HEMISPHERIC ASYMMETRIES FOR VISUAL PROCESSING OF FAMILIAR FIGURES IN NORMAL MAN

A Thesis
Presented to the
Faculty of
California State
College, San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Psychology

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by
Charles M. Herndon
July 1974

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INTRODUCTION

One of the characteristic features of vertebrates, although not exclusive to the vertebrates, is the bilateral symmetry of their bodily structure. This bilateral symmetry is also represented in vertebrate brain structure, especially in the development of the cerebral hemispheres in mammals. Each side of the brain is one half of a set of matched pairs that are anatomically mirror images of each other. In animals phylogenetically lower than man, the two cerebral hemispheres also appear to be functionally equivalent (Gazzaniga, 1970; Geswind, 1970; Lenneberg, 1967; Sperry, 1961; Teuber, 1962; Young,1962). In man, however, there is extensive evidence from a variety of sources that the left and right cerebral hemispheres differ markedly in function, with each being highly specialized for certain tasks.

It has long been recognized that a left hemisphere dominance for speech and language exists in most humans, and evidence for a right hemisphere dominance for spatial perception and other non-verbal functions has recently been found (Milner, 1971). It is important to thoroughly investigate these functional differences for a number of reasons. In addition to the pure research value in further elucidating the laterality differences, there may be direct clinical application of such knowledge in rehabilitative strategies for unilateral brain lesions. Many clues to neural development in man have come from research in this area, and the potential is great for more comprehensive discoveries in the future. Also, there are many implications in the laterality findings for the proper human engineering of man-operated equipment.

Most of the original data indicating the lateralization of different cerebral functions came from studies of patients with unilateral brain damage or epilepsy or surgical lesioning of the brain for various disorders. Later studies on normal subjects have extended the initial findings and increased their generalizability to the normal population. It has become increasingly obvious that in most humans cerebral processing of a verbal nature occurs predominately in the left hemisphere and processing of distinctly non-verbal stimuli occurs predominately in the right hemisphere. However, there is a broadly overlapping area between stimuli which are strictly verbal or non-verbal, and this is an area of cerebral processing which has not been adequately investigated. It was the purpose of this research to compare the relative efficiencies of the left and right cerebral hemispheres in processing familiar geometric figures. Such figures may be classed as non-verbal, spatial stimuli, but due to their familiar names may also be processed verbally.

The reader may wish to skip the more comprehensive discussion of the literature on hemispheric specialization contained in the next section and go directly to the statement of the problem on page 9.

Language, Handedness, and Cerebral Dominance

The functional asymmetry between the cerebral hemispheres in man was first noted by Marc Dax (Penfield & Roberts, 1959) in 1836.

He found that loss of speech was associated with right hemiplegia and therefore was due to a lesion in the left hemisphere. This became widely publicized and studied following the publication in Paris of Paul Broca's (Penfield & Roberts, 1959) independently derived, similar findings in 1863. A correlation was made between the aphasia caused by left hemisphere damage and the right-handedness of the patients. When Broca found a left-handed aphasic patient with right hemisphere damage, the erroneous assumption was made that all left-handers had a right cerebral dominance for speech, just as right-handers had a left cerebral dominance for speech.

This assumption was widely held until numerous studies within the past 25 years found that most left-handers had a left hemisphere dominance for speech (Geswind, 1970; Hécaen, 1962; Humphrey & Zangwill, 1952; Lenneberg, 1967; Milner, 1971; Milner, Branch, & Rasmussen, 1964; Penfield & Roberts, 1959). The major differences between right-handers and left-handers in cerebral organization of speech were found to be the degree of lateralization and the incidence of right hemisphere dominance for speech. The overwhelming majority (well over 90%) of right-handers were found to have left cerebral dominance for speech, with a very small percentage having right dominance or bilateral representation of speech. Although most left-handers also evidenced left cerebral dominance for speech, many more left-handers than right-handers were found with right dominance and bilateral representation.

Due to the preponderance of left hemisphere language dominance, further discussion of hemispheric differences will refer to the majority of right-handers and left-handers with speech representation solely in the left hemisphere.

In order to have a more reliable measure of handedness than self-report, Crovitz and Zener (1962) devised a questionnaire which required the subject to visualize himself performing 14 different manual tasks and to state which hand is used to perform them. For each question, a score of one was given for a purely right-handed response, a score of five was given for a purely left-handed response, and responses that fell between those extremes, i.e., "used either hand", were scored from two to four. Pure right-handedness scored a minimum of 14 total, and pure left-handedness scored a maximum of 70 total. Of 1059 subjects to whom the test was administered, the range of scores of those reporting themselves as right-handed was from 14 to 44 with the mean being close to 18, while the range for those reporting themselves as left-handed was from 23 to 70 with the mean being close to 50. It is evident from these data that the wide range of self-reported left-handers' scores, which considerably overlapped the scores of those self-labeled as right-handed, indicated a lower degree of lateralization of motor control in the left-hander.

As the evidence for left cerebral dominanance for speech accumulated, the right hemisphere became known as the "minor" hemisphere and the only functions ascribed to it were elementary sensory and motor functions for the left side of the body. This traditional view of left hemisphere dominance has now been largely rejected, as it has become increasingly evident that the right hemisphere plays a major role in many non-verbal cognitive functions, and particularly in the perception of spatial relations. This was first revealed by clinical studies of patients with well-lateralized brain lesions, who showed more severe spatial and other perceptual disorders after right-sided lesions than after left (Milner, 1962, 1971; Shankweiler, 1966; Teuber, 1962).

The availability of a small series of patients with surgical interruption of the corpus callosum and other interhemispheric commissures has permitted the direct comparison of how different kinds of information are processed by the left and right hemispheres of the same individual (Gazzaniga, 1967, 1970; Sperry, 1968). The patients underwent commissurotomy to control major epileptic seizures. Appropriate procedures were used to confine sensory input to one side or other of the brain. Although speaking and writing ability were restricted to the left hemisphere, the right hemisphere demonstrated the ability to comprehend simple verbal and written sentences and could perform elementary arithmetic calculations. All task performances requiring spatial perception or three-dimensional visualization were superior in the right hemisphere or could only be performed by the right hemisphere (Gazzaniga, 1967, 1970; Milner, 1971; Nebes, 1973).

Studies of Hemispheric Specialization in Normal Man

Work with normal subjects has provided much indirect evidence for differential specialization of the two sides of the brain. Studies have been done in hearing, with dichotic listening procedures, and in vision, with tachistoscopic presentation in right and left visual fields.

Dichotic listening studies in which competing stimuli are channelled to the two ears simultaneously have revealed a consistent right ear (left hemisphere) advantage for such verbal material as digits (Kimura, 1964) and words (Broadbent & Gregory, 1964). Conversely, a left ear (right hemisphere) advantage is seen for the recognition of non-verbal melodies (Kimura, 1964) and two-click thresholds (Murphy & Venables, 1970). These experiments showing right hemisphere specialization for the recognition of non-verbal auditory patterns are consistent with the clinical finding of an impairment in the discrimination of tonal patterns and timbre after right anterior temporal lobectomy but not after left (Milner, 1962; Shankweiler, 1966).

In the visual modality, laterality studies have utilized stimuli presented to either the left or the right visual hemifield in order to produce cortically lateralized presentations. The structure of the human visual system is such that the initial projection of stimuli presented to the right of fixation is solely to the left cerebral hemisphere, while that of stimuli presented to the left of fixation is to the right cortex (Gazzaniga, 1967, 1970). A right visual field (RVF) superiority is consistently found for the perception of alphabetical material and other verbal stimuli, while a left visual field (LVF) superiority is found for face recognition, form perception, discriminating the slope of lines, and other non-verbal perceptual tasks (Cohen, 1972; Durnford & Kimura, 1971;

Fontenot & Benton, 1972; Geffen, Bradshaw, & Nettleton, 1972; Geffen, Bradshaw, & Wallace, 1971; Gross, 1972; McKeever & Huling, 1970; Rizzolatti, Umiltá, & Berlucci, 1971; White, 1972). Durnford and Kimura (1971) also showed that the threshold for binocular depth perception, using Julesz figures (Julesz, 1964), is lower in the LVF than in the RVF.

Tachistoscopic studies of laterality differences initially used accuracy of response as the measure of processing efficiency. However, this measure proved to lack sensitivity and reliability due to the probability that uncontrolled and undetected transmissions of information occurred across the corpus callosum. A reaction time (RT) measure was eventually adapted which not only provided a means for comparing the processing time of the two hemispheres, but also gave an indication of the callosal crossing time when coupled with a verbal response which must be initiated in the left hemisphere.

Direct physiological measures of transcallosal transmission time have shown that excitation originating exclusively in one hemisphere takes approximately 10 msec (primary positive wave) to 35 msec (secondary negative wave) to cross the callosum and its related synapses to the opposite hemisphere (Bremer, 1958; Grafsstein, 1959; Teitelbaum, Sharpless, & Byck, 1968). Behavioral studies using tachistoscopic techniques with a verbal response in order to measure interhemispheric crossing time have corresponded well with the electrophysiological determinations (Filbey & Gazzaniga, 1969; Moscovitch, 1972; Moscovitch & Catlin, 1970).

Many of the tachistoscopic studies using the RT paradigm with verbal and/or manual responses have discussed the observed latency differences as supporting a model of hemispheric specialization for information processing, with the left hemisphere specialized for verbal tasks and the right hemisphere specialized for spatial tasks (Cohen, 1972; Geffen et al., 1972; Geffen et al., 1971; Gibson, Filbey, & Gazzaniga, 1970; Gross, 1972; Rizzolatti et al., 1971). Gross (1972) interprets the evidence from studies comparing verbal and spatial hemispheric processing as supporting the view that all or part of the processing of verbal stimuli must take place in the left cerebral hemisphere, while all or part of the processing of spatial stimuli must take place in the right cerebral hemisphere.

The terms "verbal" and "spatial" or "non-verbal" remain undefined throughout these studies. White (1972) criticizes studies which use familiar figures in a spatial perception task and then label the task as non-verbal, since the language hemisphere could name the figures as they were perceived and then process the names. If this criticism is valid, familiar figures could be processed in either hemisphere rather than depending solely on the right hemisphere. Most of the previously mentioned studies did not use familiar figures for just this reason. Complex matrices or unfamiliar faces were used to minimize the possibility of a naming strategy in performing a same-different task in the spatial or non-verbal portion of the experiment. The finding of a LFV advantage in such a task is therefore reliable evidence for a right hemisphere superiority in processing spatial or non-verbal stimuli.

Few, if any, studies have specifically addressed the problem of hemispheric differences in cerebral processing of stimuli deliberately chosen for both spatial and verbal qualities. Such stimuli are interesting because they include such a large number of commonly encountered items, such as geometric figures or familiar faces. The purpose of the present experiment was to study the relative efficiencies of the left and right cerebral hemispheres in visually processing pairs of familiar geometric figures for sameness or difference.

Statement of the Problem

Triangles and squares are familiar geometric figures which, when drawn, are spatial and non-verbal in the nature of their construction, i.e., no linguistic labels present. However, in the perception of such figures there is a natural tendency to name them. Thus, squares and triangles are both spatial and, at least potentially, verbal stimuli.

Pairs of triangles and squares in same and different combinations presented to the left or right of a visual fixation point for a verbal RT response, offers an objective and sensitive method for introducing the stimuli to one hemisphere at a time and comparing the latencies of response of the two hemispheres. A verbal response must be initiated in the left hemisphere. If the pair of figures were named as they were perceived in the left hemisphere and the names processed for sameness or difference, then the left hemisphere could perform the task without need for a callosal transmission to the right hemisphere, which is specialized for spatial perception, and back again for the verbal response. This should result in reduced response latencies for RVF (left hemisphere) presentation compared with response latencies for LVF (right hemisphere) presentation which requires a callosal transmission from right to left hemisphere for the verbal response.

As a check of the above hypothesis, if pairs of figures were presented to both LVF and RVF simultaneously with sameness or difference being between fields rather than within fields, a minimum of one callosal transmission would be required to perform the task, that from the right hemisphere to the left. Therefore, response latencies for figures presented to both visual fields (BVF) should be greater than those for RVF presentation and close to those for LVF presentation for the hypothesis to hold.

The experimental design used was a randomized block factorial design (Kirk, 1968), which partitioned out the individual variation in RT.

METHOD

Subjects

The Ss were 14 male college graduates between the ages of 24 and 28, who were unpaid volunteers. All Ss were selected on the basis of three selection criteria; (a) having normal or corrected vision of at least 20/20 in each eye, as measured with a Snellen chart (American Optical No. 1930) at 20 ft, with an acuity difference no greater than one step between eyes (e.g., 20/15 and 20/20), (b) being right-handed as defined by self-label, by the hand with which they wrote when filling out the experimental questionnaire, and by the Crovitz and Zener (1962) handedness scale, (c) having no history of neurological disorder or speech defect. The 14 Ss scored an average of 18.4 on the Crovitz and Zener (1962) scale, with scores ranging from 14 to 25.

Apparatus

A 3-channel tachistoscope (Scientific Prototype Model GB) with a viewing distance of 122 cm was used to present stimuli to Ss who were seated in a darkened, soundproofed isolation box. A black fixation dot of 1-mm diameter was centered in the blank field. The stimuli consisted of 12 white cards on which were drawn pairs of geometric figures with 1 mm-thick black lines. Combinations of squares and triangles were used, with squares being 1.3 cm per side and equilateral triangles being 1.9 cm per side, both having approximately the same area. The various combinations of square and triangle pairs which were used on the stimulus cards are shown in Figure 1.

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The figures were drawn either to the right or left of center with the closest edge no less than 4.4 cm from the center, giving a minimum angle of 2^{0} at the closest approach to the center fixation point. Each pair of figures was drawn one above the other with 1 cm between figures. A pair of figures subtended a visual angle of 1.7^{0} -2.0^{0} at a viewing distance of 122 cm. A single figure subtended a visual angle of 0.6^{0}-0.8^{0}. The luminance of the fixation field and the test field was approximately 2.0 log fL.

A millisecond timer (Lafayette Instrument Co. Model 54419) was stopped by a verbal response into a microphone that activated a voice relay (Lafayette Instrument Co. Model 6602A).

Procedure

The Ss were instructed by written instructions to maintain visual focus on the black fixation dot which was always displayed except when test stimuli were being presented. Test onset was signaled by the fixation dot being flashed off and on once, followed 900 msec later by presentation of the test stimulus. Stimulus duration was 150 msec to preclude shifts in fixation. Each S verbally responded "tat-same" to stimuli consisting of one type of geometric figure and "tat-different" to stimuli consisting of both types of figures, regardless of visual field of presentation. The first part of the response ensured a standard cut-off point for the voice relay, while the second part indicated the S's perception of the category of the stimulus. It was necessary for the S to say the verbal response as one word, with no pause between parts, in order to prevent him from saying "tat" as the stimulus was flashed and then "same" or "different" a short time later after processing was complete. The Ss were instructed to respond as quickly as possible, consistent with accuracy. The timer was activated simultaneously with the warning flash of the fixation dot and was stopped by S's response, the time between warning flash and stimulus onset being subtracted out later.

Each S served in four sessions lasting approximately 10 min each, in which the 12 stimuli were presented a total of 5 times each in a random order. The first session was a practice session, while the last 3 sessions were test sessions. All Ss were run between late morning and early afternoon with 10 min rest periods between the test sessions.

RESULTS

The RTs of Ss to the 12 stimuli were averaged over the 3 test sessions. The mean RTs to the individual stimuli were then reduced by averaging into same and different RTs for stimuli presented in the LVF, RVF, and BVF. These data are displayed in Table 1.

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These means excluded error trials, however the error rate for all Ss was low and did not seem to differ with regard to visual field of presentation or same-different category of response. The mean error rate was 2%; the range over Ss was 0% to 8% with half the Ss having 0% error rates. In addition, extreme RTs were dropped. The drop rule used entailed the averaging of all RTs for a particular stimulus and then eliminating those RTs which exceeded two standard deviations from that mean. The dropped RTs did not differ with respect to side of presentation.

A logarithmic data transformation (Kirk, 1968) was carried out on these mean RTs and an analysis of variance was then performed. A significant difference was found between RTs to same and different stimuli, $F(1,65) = 25.00$, $p < .01$, with mean RT to same stimuli of 485 msec and to different stimuli of 502 msec. A significant visual field effect was found, $F(2,65) = 5.50$, $p < .01$, and a pairwise comparison between the visual field means revealed a significant difference only between mean RTs to LVF presentation and to BVF presentation, $t(65) = 2.2637$, $p < .05$. The analysis of variance summary table is presented in Table 2.

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DISCUSSION

The visual field differences in mean RT were found to be in precisely the opposite direction to those hypothesized. Since LVF pairs were projected to the right hemisphere (and vice versa), the data would seem to indicate that the right hemisphere is superior to the left in processing familiar geometric figures for sameness or difference. This finding can be interpreted in one of two ways. Due to the right hemisphere specialization for spatial perception, it may routinely receive all inputs which can be spatially processed, regardless of secondary verbal qualities. Alternately, the left hemisphere may be able to perform the differentiation without the aid of the right hemisphere, but required longer processing time due to its lack of specialization for the task.

In support of the first interpretation, split-brain studies of humans have found the left hemisphere almost totally inept at three-dimensional perception (Gazzaniga, 1967, 1970; Levy-Agresti & Sperry, 1968; Milner, 1971; Sperry, 1968). Although in this experiment only two-dimensional perception was required, the task was made more difficult by the rapid presentation of stimuli and the small size of the figures. The rapid presentation time may have reduced the tendency to name the figures and encouraged an holistic or gestalt processing. Levy-Agresti and Sperry (1968) suggest that the right hemisphere apprehends events in a gestalt fashion whereas the left carries out a sequential analytic procedure. Thus, the right hemisphere may have been required to perform the discrimination in this experiment.

If, on the other hand, the left hemisphere did perform the differentiation without the aid of the right hemisphere, it obviously required longer processing time, since mean RT for RVF presentation was larger, although not significantly, than mean RT for LVF presentation; and the right hemisphere had the disadvantage of having to make a callosal transmission. A callosal transmission requires at least 10 msec (Moscovitch & Catlin, 1970; Teitelbaum et al., 1968) and if both hemispheres could process the stimuli equally fast, a RVF superiority would be expected due to the necessity for left hemispheric initiation of the verbal response, but this was not found.

It is of considerable interest that same responses were significantly faster than different responses. Egeth and Epstein (1972) discuss evidence that the mechanism underlying the perception of sameness is sensitive to holistic, configurational properties of stimuli, while the mechanism underlying the perception of difference is analytic and sensitive to parts and features of stimuli. It has been proposed that, compared to the sameness detector, the difference detector is "relentless in its examination of the features of the stimuli under investigation [Egeth & Blecker, 1971, p. 325]". The results of this experiment are consistent with such a description of the mechanisms of sameness and difference detection. A decision based upon an overall or holistic perception of the two or four stimulus figures would be expected to take less time than one based on an individual analysis of each figure.

There was no significant interaction between visual field of presentation and same-different category of stimuli. This would seem to indicate that the perception of both sameness and difference in the stimuli used in this experiment was superior in the right hemisphere compared with the left. This is in conflict with the conclusions of Egeth and Epstein (1972) that the left hemisphere is superior at sameness detection and the right hemisphere is superior at difference detection. However, they used pairs of letters in their experiment and admit to the possibility that in sameness detection their Ss were basing their decision on the names of the letters rather than on their physical characteristics.

It was noted that the difference between mean RT to RVF presentation and to BVF presentation was not significant. The difference between mean RT to LVF presentation and to BVF presentation was significant, being 15 msec in magnitude. This is on the order of one callosal transmission and is consistent with the view that the difference represents two callosal transmissions for BVF presentation compared to only one transmission for LVF presentation.

The closeness in RTs of BVF presentation to unilateral presentation implies that with proper lateralization of visual input, twice as much stimulus material of a certain type can be processed in only slightly longer time than the lesser amount of non-lateralized input. Strong support for this argument is given by a series of experiments (Dimond, 1970; Dimond & Beaumont, 1971, 1972) which suggest that the division of perceptual load between the hemispheres allows total output to be increased and that there is no apparent disadvantage that stimuli to be compared should arrive for analysis by two separate channels.

This finding may seem to lack importance, since most tasks are little affected by millisecond differences in performance times. However, in the human engineering of an instrument panel for an aircraft or space vehicle, which often travel well in excess of 1000 ft/sec, such factors may become very important. Under conditions of reduced outside visibility, the pilot must devote most of his attention to the attitude indicator, which hopefully is centrally located. Typically, pitch and bank are controlled by a "stick" held in the right hand and forward velocity is controlled by a throttle held in the left hand. While focus is maintained on the attitude indicator, instruments to the left of focus are perceived in the right hemisphere, which has primary control over the throttle hand, and instruments to the right of focus are perceived in the left hemisphere, which has primary control over the "stick" hand. Therefore, instruments which primarily affect pitch and bank, e.g., vertical velocity and turn-and-bank indicators, should be located to the right of the attitude indicator and instruments which primarily affect velocity, e.g., air speed and mach indicators, should be located to the left of the attitude indicator. This arrangement is partially followed in some aircraft, but the fact that it is not standard is indicative of a need for greater consideration for the hemispheric specializations in man in the design of human-operated equipment.

SUMMARY

Pairs of triangles and squares in same and different combinations were presented to the left or right of a visual fixation point for a verbal RT response. It was hypothesized that pairs of familiar geometric figures could be processed verbally or spatially, and since verbal responses must be initiated in the left hemisphere, a reduced response latency for RVF presentation should be observed compared with response latency for LVF presentation, which requires a callosal transmission from right to left hemisphere for the verbal response. However, the observed visual field differences in mean RT were found to be in precisely the opposite direction to those hypothesized. The data seem to indicate that the right hemisphere is superior to the left in processing familiar geometric figures for sameness or difference, therefore implying that spatial processing occurred rather than verbal processing.

Same responses were faster than different responses, giving support for an holistic or gestalt processing mechanism for sameness detection and a sequential or analytic processing mechanism for difference detection.

Pairs of figures presented to both left and right of fixation were processed nearly as fast as only one pair of figures presented unilaterally, implying that division of perceptual load between the hemispheres allows total output to be increased.

REFERENCES

Bremer, F. Physiology of the corpus callosum. Research Publications of the Association for Nervous and Mental Diseases, 1958, 36, 424-448.

Broadbent, D. E., & Gregory, M. Accuracy of recognition for speech presented to the right and left ears. Quarterly Journal of Experimental Psychology, 1964, 16, 359-360.

Cohen, G. Hemispheric differences in a letter classification task. Perception & Psychophysics, 1972, 11, 139-142.

Crovitz, H. F., & Zener, K. A group test for assessing hand and eye dominance. American Journal of Psychology, 1962, 75, 271-276.

Dimond, S. J. Hemispheric refractoriness and control of reaction time. Quarterly Journal of Experimental Psychology, 1970, 22, 610-617.

Dimond, S. J., & Beaumont, J. G. The use of two cerebral hemispheres to increase brain capacity. Nature, 1971, 232, 270-271.

Dimond, S. J., & Beaumont, J. G. Processing in perceptual integration between and within the cerebral hemispheres. British Journal of Psychology, 1972, 63, 509-515.

Durnford, M., & Kimura, D. Right hemisphere specialization for depth perception reflected in visual field differences. Nature, 1971, 231, 394-395.

Egeth, H., & Blecker, D. Differential effects of familiarity on judgements of sameness and difference. Perception & Psychophsics, 1971, 9, 321-326.

Egeth, H., & Epstein, J. Differential specialization of the cerebral hemispheres for the perception of sameness and difference. Perception & Psychophysics, 1972, 12, 218-220.

Filbey, R. A., & Gazzaniga, M. S. Splitting the normal brain with reaction time. Psychonomic Science, 1969, 17, 335-336.

Fontenot, D. J., & Benton, A. L. Perception of direction in the right and left visual fields. Neuropsychologia, 1972, 10, 447-452.

Gazzaniga, M. S. The split-brain in man. Scientific American, 1967, 217 (2), 24-29.

Gazzaniga, M. S. The bisected brain. New York: Appleton-Century-Crofts, 1970.

Geffen, G., Bradshaw, J. L., & Nettleton, N. C. Hemispheric asymmetry: Verbal and spatial encoding of visual stimuli. Journal of Experimental Psychology, 1972, 95, 25-31.

Geffen, G., Bradshaw, J. L., & Wallace, G. Interhemispheric effects on reaction time to verbal and nonverbal visual stimuli. Journal of Experimental Psychology, 1971, 87, 415-422.

Geswind, N. The organization of language and the brain. Science, 1970, 170, 940-944.

Gibson, A. R., Filbey, R., & Gazzaniga, M. S. Hemispheric differences as reflected by reaction time. Federation Proceedings, 1970, 29, 658. (Abstract)

Grafsstein, B. Organization of callosal connections in supra-sylvian gyrus of cat. Journal of Neurophysiology, 1959, 22, 504-515.

Gross, M. M. Hemispheric specialization for processing of visually presented verbal and spatial stimuli. Perception & Psychophysics, 1972, 12, 357-363.

Hécaen, H. Clinical symptomatology in right and left hemispheric lesions. In V. B. Mountcastle (Ed.) Interhemispheric relations and cerebral dominance. Baltimore: Johns Hopkins Press, 1962.

Humphrey, M. E., & Zangwill, O. L. Dysphasia in left-handed patients with unilateral brain lesions. Journal of Neurology, Neurosurgery, and Psychiatry, 1952, 15, 184-193.

Julesz, D. J. Binocular depth perception without familiarity cues. Science, 1964, 145, 356-362.

Kimura, D. Left-right differences in the perception of melodies. Quarterly Journal of Experimental Psychology, 1964, 16, 355-358.

Kirk, R. E. Experimental design: Procedures for the behavioral sciences. Belmont, Ca.: Wadsworth Publishing Co., 1968.

Lenneberg, E. H. Biological foundations of language. New York: John Wiley & Sons, 1967.

McKeever, W. F., & Huling, M. D. Left-cerebral hemisphere superiority in tachistoscopic word-recognition performances. Perceptual and Motor Skills, 1970, 30, 763-766.

Levy-Agresti, J., & Sperry, R. W. Differential perceptual capacities in major and minor hemispheres. Proceedings of the National Academy of Science, 1968, 61, 1151.

Milner, B. Laterality effects in audition. In V. B. Mountcastle (Ed.) Interhemispheric relations and cerebral dominance. Baltimore: Johns Hopkins Press, 1962.

Milner, B. Interhemispheric differences in the localization of psychological processes in man. British Medical Bulletin, 1971, 27, 272-277.

Milner, B., Branch C., & Rasmussen, T. Observations on cerebral dominance. In A. V. S. de Reuck & M. O'Connor (Eds.) Ciba Foundation symposium on disorders of language. London: Churchill, 1964.

Moscovitch, M. Choice reaction-time study assessing the verbal behavior of the minor hemisphere in normal adult humans. Journal of Comparative and Physiological Psychology, 1972, 80, 66-74.

Moscovitch, M., & Catlin, J. Interhemispheric transmission of information: Measurement in normal man. Psychonomic Science, 1970, 18, 211-213.

Murphy, E. H., & Venables, P. H. Ear asymmetry in the threshold of fusion of two clicks: A signal detection analysis. Quarterly Journal of Experimental Psychology, 1970, 22, 288-300.

Nebes, R. D. Perception of spatial relationships by the right and left hemispheres in commissurotomized man. Neuropsychologia, 1973, 11, 285-289.

Penfield, W., & Roberts, L. Speech and brain mechanisms. Princeton: Princeton University Press, 1959.

Rizzolatti, G., Umiltá, C., & Berlucci, G. Opposite superiorities of the right and left cerebral hemispheres in discriminative reaction time to physiognomical and alphabetical material. Brain, 1971, 94, 431-442.

Shankweiler, D. Effects of temporal lobe damage on perception of dichotically presented melodies. Journal of Comparative and Physiological Psychology, 1966, 62, 115-119.

Sperry, R. W. Cerebral organization and behavior. Science, 1961, 133, 1749-1757.

Sperry, R. W. Hemisphere deconnection and unity in conscious awareness. *American Psychologist*, 1968, *23*, 723-733.

Teitelbaum, H., Sharpless, S. K., & Byck, R. Role of somatosensory cortex in interhemispheric transfer of tactile habits. *Journal of Comparative and Physiological Psychology*, 1968, *66*, 623-632.

Teuber, H.-L. Effects of brain wounds implicating right or left hemisphere in man: Hemisphere differences and hemisphere interaction in vision, audition, and somesthesis. In V. B. Mountcastle (Ed.) *Interhemispheric relations and cerebral dominance*. Baltimore: Johns Hopkins Press, 1962.

White, M. J. Hemispheric asymmetries in tachistoscopic information-processing. *British Journal of Psychology*, 1972, *63*, 497-508.

Young, J. Z. Why do we have two brains? In V. B. Mountcastle (Ed.) *Interhemispheric relations and cerebral dominance*. Baltimore: Johns Hopkins Press, 1962.

TABLE 1

Mean Reaction Times to Presentation of Same and Different Stimuli in Left Visual Field (LVF), Right Visual Field (RVF), and Both Visual Fields (BVF), in Milliseconds

Subjects	Same			Different		
	LVF	RVF	BFV	LVF	RVF	BVF
S_1 +	624	618	654	636	684	622
S_2 –	702	711	684	722	730	774
S_3 –	446	462	500	503	480	484
S_4 +	548	506	537	536	550	530
S_5 +	516	506	521	514	527	558
S_6 -	254	266	258	260	270	254
S_7 –	590	628	627	617	621	627
S_8 –	441	493	507	492	506	554
S_9 +	428	418	407	416	422	428
S_{10} –	464	477	472	470	504	510
S_{11} –	486	491	520	490	494	504
S_{12} +	420	380	420	435	434	434
S_{13} 0	449	449	462	476	492	466
S_{14} –	492	516	510	523	532	540
Means Over Ss	490	494	506	506	518	520

496.7 514.7

2.4 2.71

TABLE 2

Analysis of Variance Summary

Source	*SS*	*df*	*MS*	*F*
1. Blocks	0.8365	13	0.0643	321.73*
2. Treatments	0.0073	5		
3. A (Same-Different)	0.0050	1	0.0050	25.00**
4. B(LVF, RVF, BVF)	0.0022	2	0.0011	5.50**
5. A x B	0.0001	2	0.00005	0.25
6. Residual	0.0132	65	0.0002	

$^*p < .001$ $\quad$ $^{**}p < .01$

FIGURE CAPTION

Fig. 1. Stimuli used in tachistoscopic presentation (not drawn to scale).