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DIFFERENTIATION OF PERCEPTUAL CLOSURE: IMPLICATIONS FOR
RIGHT HEMISPHERE FUNCTIONING

City University of New York

PH.D.

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DIFFERENTIATION OF PERCEPTUAL CLOSURE:
IMPLICATIONS FOR RIGHT HEMISPHERE FUNCTIONING

by

JEANETTE WASSERSTEIN

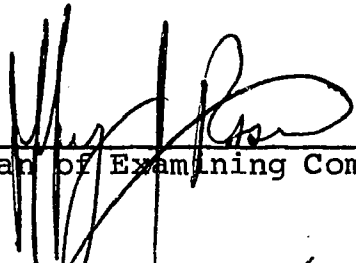
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Abstract

Differentiation of Perceptual Closure: Implications for Right Hemisphere Functions

by

Jeanette Wasserstein

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Level of functioning on perceptual closure tasks has been associated with degree of right hemisphere integrity. Closure ability has been assessed by different Gestalt Completion Tests (GCTs). Users of these instruments have assumed that a unitary process, common to each test, underlies identification of pictures despite the fact that 1) considerable ambiguity exists in the Gestalt literature on the meaning of 'closure', and 2) the degree of interrelationship among the several GCTs has yet to be determined.

The tacit assumption of a unitary process was subjected to empirical analysis in the first experiment of this study. A collection of GCTs and Milner facial recognition stimuli (another test of right hemisphere visual-perceptual

processing) were group administered to normal subjects (N=70). Findings demonstrated that traditional Street figures as well as competing versions of GCTs, although partially overlapping, could not be defined by a unitary set of characteristics. Further, facial memory and whatever was measured by these closure tasks appeared to be separate functions.

A second experiment with unilaterally focal brain-lesioned subjects (N=23) isolated a subset of closure items which were maximally sensitive to RH pathology and shared a common underlying perceptual process, as defined by a concurrent measure. These findings indicated that the ability to appreciate subjective contour illusions characterizes the right hemisphere capacity required by GCTs. Further, the dissociation between two right hemisphere sensitive visual-perceptual tasks implied by the first experiment was corroborated, and related to the visual discrimination rather than the memory aspect of the original facial memory task. Case-by-case analysis suggested the existence of site-by-task specificity and reciprocal interactions within the right hemisphere for those dissociated processes. Finally, left brain-damaged subjects were found to perform better than normals on several dimensions of the closure tests. Findings are discussed in relation to 1) underlying right hemisphere spatial abilities, particularly depth perception, 2) differentiated structural organization of the right hemisphere and 3) interference models of inter/intrahemispheric interactions.

In memory of my father,

Dr. Albert Abraham Wasserstein,

a kind, gentlemanly physician who
instilled in me the desire to seek
knowledge, and the confidence to
pursue that desire.

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CHAPTER I

INTRODUCTION

Statement of the Problem

Clinical studies have suggested that the right hemisphere (RH) is specialized for nonverbal, particularly visual-spatial, functions (e.g., Weisenberg and McBride, 1943; Patterson and Zangwill, 1944; Bogen and Gazzaniga, 1965; Kimura and Durnford, 1975). Attempts to characterize the nature of this RH advantage have included: 1) postulating an advantage for processing of nonverbal material, irrespective of task or modality (Milner, 1975), 2) postulating an advantage for performing some types of operations on information (Hecaen and Anglergus, 1963; and DeRenzi, Scotti and Spinnler, 1969) and 3) postulating a different 'gestalt-synthetic' form of information processing in the RH than the 'analytic-sequential' form subserved by the left (Bogen, 1969; Nebes, 1971; Levy, Trevarthen and Sperry, 1972). However these conceptions do not account for the importance attributed to both the left and right parietal lobes for spatial skills (Crichley, 1953; Semmes, Weinstein, Ghent and Teuber, 1955; Luria, 1973), and findings of selective RH impairment in some visual-perceptual tasks and not others,

within the same sample of patients (Ettlinger, 1960; DeRenzi and Spinnler, 1966; Warrington and Taylor, 1973). The characterization and nature of the perceptual, spatial or other processes underlying the nonverbal advantage of the RH, hence, remains obscure. This research was intended to extend understanding of RH functions through examining and refining one measure, closure tests, associated with integrity of the RH.

Background

Specialization of the Right Hemisphere

Evidence for Specialization

The clinical observations of Broca, Wernicke, and other 19th century neurologists provided the first indication of lateralization of function in the human brain. The high correlation between aphasic disorders and left-hemisphere (LH) lesions in right-handed patients suggested that the neural substrate of language was primarily located in the left half of the cortex, which came to be referred to as the dominant or major hemisphere. The right half of the cortex, in contrast, was seen as non-dominant (or minor) because of the minimal obvious impairment of higher cortical functions following lesions to the hemisphere (Gazzaniga and LeDoux, 1978).

With the introduction of psychometric testing and statistical techniques in the 20th century, findings in clinical populations with unilateral lesions began to suggest that the major-minor divisions of the hemispheres applied to linguistic domains only. Fairly early on, greater impairment on tests requiring manipulation or appreciation of forms and spatial relationships was reported for RH lesioned populations (Weisenberg and McBride, 1935) and supported by numerous subsequent clinical studies (e.g., Neilson, 1938; Brain, 1941; Paterson and Zangwill, 1944; McFie and Zangwill, 1960). One of the visuo-spatial tasks which was most consistently associated with RH dysfunction is facial discrimination (e.g., Warrington, 1967; DeRenzi, Faglioni and Spinnler, 1968; Yin, 1970; Benton and Van Allen, 1972).

Other clinical studies of auditory tasks involving perception of tonal sequences and melody (Milner, 1962; Shankweiler, 1966), as well as appreciation of affective material (Gardner, King, Flam and Silverman, 1975) and incidence of affective disorders in unilateral lesions (see Flor-Henry, 1978 for review) also found greater impairment in RH lesioned populations. These later studies extended the inferred RH superiority beyond the purely visual-spatial domain.

Further evidence for specialization of the RH came from the eventual demarcation of non-dominant hemisphere syndromes.

Consistent with the RH specialization for some nonverbal functions inferred from the clinical studies, syndromes more frequently seen in RH patients were found to be characterized by mainly nonverbal cognitive deficits. Most typical were disorders of 1) spatial orientation as manifested in constructions, drawings, topographical concepts (Warrington, James and Kinsbourne, 1966; Hecaen and Assal, 1970); 2) hemifield inattention to personal and extrapersonal space (Critchley, 1953; Hecaen, 1968); 3) agnosia (i.e., inability to know) for familiar faces (Hecaen and Angelergues, 1962); and 4) amusia (i.e., inability to understand music (Nielson and Sult, 1939; Spreen, Benton and Fincham, 1965). However, unlike LH syndromes, those associated with the RH were often also associated with either bilateral (Meadows, 1974 for review of some of the above) and even unilateral LH lesion (Weinstein, 1969; Cole and Perez-Cruet, 1964). Despite a lack of consensus as to the extent to which these deficits occurred exclusively as a result of RH lesions, findings supported developing notions of RH specialization for some tasks.

The emergence of the Bogen and Vogel series of split-brain patients added new dimensions to the study of hemispheric functions. Sectioning the cerebral connecting fibers isolated the information received by each hemisphere, leaving each side capable of detecting and responding with only the contralateral sensory and motor pathways. Under special

experimental constraints, each hemisphere could be studied independently of the effects of the other. Consequently, hemispheric function could be assessed directly rather than by inferring function from the capacities lost following unilateral damage.

One of the earliest findings was that the hand controlled by the RH (left hand) was superior in the construction of block designs, and also copying or drawing figures like a Necker cube, swastika or Greek cross (Bogen and Gazzaniga, 1965; Bogen, 1969). One of the more intriguing observations (Bogen and Gazzaniga, 1965) was that when free use of both hands was available, the hand controlled by the LH (right hand) always tried to help, but only succeeded in undoing the correct response originally made by the RH (left hand). Such observations supported the inference that the two hemispheres operated differently. Later studies with the same patients examined appreciation of spatial relationships in the tactile modality (Nebes, 1971a and 1972; Zaidel, 1973), and the acquisition of concepts involving spatial qualities like height, size and shape (Kumar, 1971). Findings of superior RH performance on such tasks extended the inference of RH superiority beyond purely visual perception and motor praxis, and strengthened belief in the existence of RH specialization.

Such dramatic findings from split-brain patients and the more subtle findings from patients with unilateral lesion

stimulated research in lateral differences in normals. Using a variety of techniques, primarily tachistoscopic and dichotic listening tasks, superiority of the left hemisphere for verbal-linguistic material was consistently supported (e.g., Geffin, Bradshaw and Wallace, 1971; Rizzolatti, Umiltà and Berlucchi, 1971). Findings of RH superiority in melody discrimination (Kimura, 1964), basic visual perception of line orientation, depth, point localization, rapid enumeration of nonverbal stimuli (Kimura and Durnford, 1975) and face recognition (Rizzolatti et al., 1971; Hilliard, 1973) have been more difficult to replicate (e.g., Geffin et al., 1971; Gaede, Parsons and Bertera, 1978).

As a large number of variables are known to affect normal tachistoscope performance (see White, 1968 for review), the inconsistent findings for ostensibly RH tasks in normals may derive from procedural differences in studies (e.g., exposure duration, degree of lateral displacement and size of visual angle of stimulus, presence or absence of fixation digits). These could introduce artifact and cancel (or reverse) lateral differences which would otherwise appear. Part of the variability may also derive from the choice of stimulus materials. Some forms of complex visual stimuli have been shown to be sensitive to different encoding strategies, such that linguistic stimuli like words can be treated as physical configuration and abstract patterns can be

verbally labelled (Cohen, 1972; Seaman and Gazzaniga, 1973). The study of hemispheric specialization in normals is hence fraught with methodological difficulties. Given these considerations, it may be the case that the more consistent LH findings in normals reflect a more robust nature for LH functions, rather than the corollary inference that only the LH is specialized.

In summary, findings drawn from brain-damaged populations have strongly suggested that the LH is responsible for linguistic, and possibly abstraction abilities. While at first seen as unimportant for higher cognitive functions, clinical evidence has further suggested that the RH is responsible for some musical, affective and visual-spatial functions. These were demonstrated through the use of psychometrics, statistics and special experimental procedures in patients with unilateral disease or commissurotomy, and are consequently less readily apparent than the processes subserved by the left. Findings from normal populations have supported the inferences of the importance of the LH for verbal functions but, like the RH syndromes delineated earlier, have been labile for those processes inferred to be subserved by the RH.

Characterization of Right Hemisphere Specialization

Despite the described inconsistencies, the clinical

findings have led to a general consensus that the RH is specialized in some way. The precise nature of these special functions, however, is still unclear. Attempts to explicate the character of right hemisphere specialization are as equivocal as the findings which suggest the existence of such a specialization. Seemingly depending on the data base from which inferences have been drawn, different characterizations have developed.

Noting the many instances of symmetry in the functional organization of the two hemispheres (e.g., primary sensory projection areas and motor cortex), some investigators have examined patients with complementary unilateral lesions in order to ascertain whether the differences outweigh the resemblances. Through such studies impairment in similar dimensions of cognition (e.g., memory) have been shown for temporal and frontal lobes, differing only in the type of material affected by corresponding left or right lesion. Left temporal lobectomy in the dominant hemisphere was found to impair selectively the learning and retention of verbal material (Meyer and Yates, 1955; Milner, 1958), regardless of whether a recall or recognition procedure is used (Milner and Teuber, 1968). Conversely, removal of the right temporal lobe leaves verbal memory intact but impairs the recognition and recall of visual and auditory patterns that do not lend themselves well to verbal coding (Milner, 1962; 1967; Shankweiler, 1966; Warrington and James, 1967). Unilateral

frontal lobectomy was found to disturb temporal ordering of events (Milner, 1975) and ideational fluency (Jones-Gotman and Milner, 1977), the content of which varies with each hemisphere. Such comparisons have led some authors (Milner, 1968; 1975) to postulate that the functional difference between the hemisphere relates to the material being treated, verbal or nonverbal, irrespective of the modality of presentation or the task required.

The material-specific conceptualization, however, does not clarify the perceptual and/or spatial processes underlying the presumed nonverbal advantage of the right cortex, nor does it clarify the nature of the linguistic processes which underlie the verbal advantage of the LH. Furthermore, it circumvents the importance attributed to both the left and right parietal lobes for spatial skills (Critchley, 1953; Semmes et al., 1955; Luria, 1973). Finally, it does not account for findings (within samples of patients) of selective RH impairment in some visual-perceptual tests and not others (Ettlinger, 1960; DeRenzi and Spinnler, 1966; Warrington and Taylor, 1973).

Other clinical investigators have attempted to articulate the nature of this postulated RH nonverbal specialization by examination of the task demands of the nonverbal findings. This approach focuses on analysis of lateralized tests (or deficits) in order to infer the underlying processes which may be lateralized. Comparison of performance of groups of

left or right brain-damaged patients, without consideration of the locus of lesions within the hemisphere, is most typically used. Through this approach numerous explanations of RH nonverbal specialization have emerged. Several are listed below.

Hecaen and Angelergues (1963), in a study of visual agnosia, advanced the hypothesis that the RH was responsible for the ability to isolate similar objects within a category, while the left was responsible for categorization. A similar dichotomy was postulated by De Renzi et al. (1969) when they attributed a role of discrimination and organization of sensory data to the RH, and the role of naming and associating meaning of the data to the LH. Kimura (1966) postulated that the RH is more proficient at processing stimuli which due to either their novelty or visual complexity cannot be easily given verbal labels. Yin (1970) and Teuber (1975), working with facial recognition tests, speculated that the RH may be specialized for appreciating social information and/or generation of concrete visual schemata. Luria (1973), noting the types of gnostic disturbances most typically seen in RH patients, postulated that the RH may be specialized for the processing of information coming from the individual's own body.

Each of the above provides hypotheses for further research in the processes responsible for the nonverbal findings. However the diverse hypotheses have not been well

integrated, nor developed into a more comprehensive theory of RH specialization.

The most compelling characterization of RH specialization arise primarily out of the study of commissurotomed patients. As noted earlier, in these patients the two hemispheres continued to function apparently independently. The striking differences in the responding of each hemisphere led investigators of split-brain phenomena to postulate that each hemisphere had a distinct mode of information processing. Based on findings of dysgraphia (i.e., impaired ability to write) in the hand controlled by the left hemisphere and dyscopia (i.e., impaired ability to copy geometric designs) in the hand controlled by the right hemisphere, Bogen and Gazzaniga (1965) first suggested that two different types of thought processes are lateralized in the left and right brains, and termed them 'verbal-symbolic' and 'visual-spatial' respectively. As the RH was eventually found to have some rudimentary verbal capacities in these patients, Bogen (1969) in a later paper retranslated the two types of lateralized thought into 'propositional' thinking in the LH and 'appositional' thinking in the RH. Propositional was intended to denote, after Jackson (Taylor, 1958):

. . . not a mere sequence . . . it consists of words referring to one another in a particular sequence (so that each) modifies the meaning of the other. (pg. 130)

Hence propositional referred to thinking which deals with relationships among linguistic entities. Appositional was

a provisional term chosen to permit use of some descriptive label until more information was gathered. For Bogen it implied:

. . . a capacity for apposing or comparing of perceptions, schemas, engrams, etc., but has in addition the virtue that it implies little else.
(pg. 150)

Hence appositional was intentionally ambiguous, and referred to thinking that was the outgrowth of placing psychic elements in juxtaposition or proximity.

Levy and Sperry (1968) extended this line of reasoning based on qualitative as well as quantitative differences in the performance of the hemispheres in split-brain patients. They devised a test requiring a complex understanding of cross-modal spatial transformations. Subjects held blocks in one hand, and were required to select the visual pattern which would represent what the block would look like unfolded into two dimensions. The task required the subject to either mentally fold up the visual pattern or unfold the tactual block. They noted that in addition to two to three times better performance of the RH, qualitatively the RH tended to be rapid, direct and silent. In contrast, when the LH was tested the same subjects often took as much as 45 seconds to respond, were hesitant, and made running verbal comments on their logical approach. They concluded this indicated that the two hemispheres were processing the same information in entirely different ways: the left in 'verbal,

symbolic, analytic-sequential' terms while the right used 'gestalt-synthetic visualizations'. From an analysis of interactions in the data, Levy further inferred the presence of a mutual antagonism of interference between the two modes of mental processing. Other researchers working with split-brain populations have supported these earlier observations of qualitative differences in the responses of the left or right cortex (e.g., Zaidel and Sperry, 1971).

Although the 'gestalt-synthetic/appositional' characterization of the RH accounts for some of the findings the material-specific explanation could not account for (e.g., selective RH impairment on some perceptual tasks and not others could be understood, in this context, as reflecting those visual-perceptual tasks which can only be performed efficiently via a gestalt-synthetic mode), it still circumvents the importance attributed to both parietal lobes for synthetic abilities (Luria, 1973). Additionally, testing the information-processing characterization of RH specialization has been problematic. The 'analytic-sequential' description of the LH has lent itself well to the use of finely differentiated psycholinguistic entities as operationalizations of this construct. For example, speech sounds and grammatical units have been demonstrated to show LH sensitivity in both normals and brain-damaged subjects (Cutting, 1972; Simerntskaya, 1974). However definitions of RH 'gestalt-synthetic/appositional' mode of information

processing are few and imprecise, making operationalization of this conception difficult. Only Nebes (1971a) provides some description of this RH style, beyond merely labelling it. For him it consists of superiority in the ability to generate a percept of the whole from partial information. Other researchers attempting to create their own stimuli according to their understanding of what is meant by 'gestalt-synthetic/appositional' have either yielded inconclusive findings (Geffin et al., 1971; Bradshaw, Gates and Patterson, 1976), or pointed to the need for greater clarity in the terms (Goldberg, Vangham and Gerstman, 1978).

In conclusion, although the RH is generally considered to be specialized for some functions, no satisfactory explanations of the nature of this specialization exist. The various answers to this question either do not account for all the findings, do not coalesce into one theory, or are too ambiguous to provide clear operationalizable specifications. The obscurity is likely a reflection of the inherent difficulty in translating nonverbal processes into verbal form. More importantly, it may also be a reflection of the perceptual tasks used to infer underlying lateralized functions. Typically complex picture stimuli are used in such research. Providing these stimuli fit a common verbal description, different pictures (and resultant tests) are assumed to be indices of the same perceptual process. The construct validity of such tests is seldom examined, and the

possibility that measures of nonverbal functions may not be well defined by only verbal criteria is seldom considered. Consequently there may be unclear understanding of the actual processing demands of complex perceptual tasks, and data gleaned with such measures may be confounded by undefined sources of variance. As closure tests are among the most frequently used complex perceptual tasks in RH research, this general state of affairs can be illustrated and examined with such measures.

Closure Tests and Right Hemisphere Functions

Closure tests require identification of whole figures from incomplete visual information, a task frequently described as 'visual synthesis' by users of these instruments (Talland, 1965; Lansdell, 1970). Several examples of closure tests are shown in Appendix A. Such tests are presumed to measure a unitary process 'closure', originally given psychological currency by the Gestalt psychologists. Various forms of these tests (Street, 1931; Thurstone, 1944; Mooney, 1951 and 1957; Ekstrom, French, Harman, and Dermen, 1976, to cite a few) have been used in studies of neuropsychological functions and RH specialization.

Diverse neuropsychological issues including: effect of extent of ablation (Lansdell, 1961 and 1968), perceptual components of amnesic syndrome (Talland, 1965), visual

agnosia (DeRenzi and Spinnler, 1966), facial recognition and prosopagnosia (DeRenzi, Faglioni and Spinnler, 1968), and differentiation of functions within the RH (Newcombe and Russel, 1969) have been examined using one or another of these tests. Conclusions drawn from these studies concur that performance on these measures is predominantly affected by RH cortical lesions and more sensitive than other complex perceptual tests. In those studies where locus of lesion within the RH and/or relationship to other behavioral measures has been examined, performance has been found to be most sensitive to right temporoparietal lesions (Newcombe and Russel, 1969) and dissociated from performance on some visual-motor (Lansdell, 1970) and spatial imagery (Newcombe and Russel, 1969) tasks.

The reliable findings of greater RH impairment on these measures led some investigators to characterize the RH as being specialized for the operation of the 'closure' process (Lansdell, 1970; Nebes, 1971), irrespective of the measure used. Using the same rationale, other investigators used performance on closure tests as the best index of postulated RH gestalt processing (Bogen, 1972), or to infer access to and/or integrity of the RH in normals (Thompson, 1977; Gur and Reivich, 1980).

In the literature outside of neuropsychology, equally diverse issues have been examined using closure tests with normal populations. Most typically factor analytic methods

have been used. Performance on closure tests has come to be seen as a relatively independent perceptual factor (Thurstone, 1944; Roff, 1952), dissociated from verbal factors (Street, 1931; Botzum, 1951; Ohnmach and Fleming, 1972; Messick and French, 1975) and intelligence (Street, 1931). Especially interesting are findings linking performance on these tests with immediate perception (Mooney, 1960), synthetic-inductive thought (Thurstone, 1949; Pemberton, 1952) and appreciation of formal qualities (Mos, Wardell, and Royce, 1974). These attributes are consistent with some of the earlier described characterizations of the RH as specialized for direct, synthetic, visual-spatial processing (Levy-Agresti and Sperry, 1968 ; Bogen, 1969).

The convergence of findings from neurological and normal subjects support the use of closure tests in research on RH processes. However, the methodological difficulties considered earlier are especially pronounced with these measures. There is considerable conceptual ambiguity surrounding the meaning of the 'closure' concept upon which they are based. Possibly due to the historical accident that none of these tests were created by gestalt psychologists, there is also considerable variability in the ways closure tests were constructed.

Closure Concept

The 'closure' concept was given psychological currency by the Gestalt psychologists who emphasized the dynamics and formal aspects of experience. Considerable ambiguity surrounds the meaning of this concept, which can best be explicated in the context of a consideration of the general Gestalt approach.

Based on compelling observations of spontaneous subjective figure-ground articulation, perceptual constancies and some illusions (e.g., phi-phenomena), the Gestaltists raised the question:

are the parts of a given whole determined by the inner structure of that whole, or are the events such that . . . the total activity is a sum of the part-activities (Wertheimer, 1922, pg. 14)

and chose the position that part-processes are themselves determined by the whole conditions. They argued that any given complex, both in experience and the physical world, is organized according to the "needs and conditions . . . [of the] . . . whole" (Kohler, 1922). Reversing the traditional scientific method of breaking up complexes into components in order to derive laws, they attempted to derive principles active in whole complexes.

Although the Gestaltists stressed the necessity of a systemic approach in all research areas, they focused on understanding mental events in terms of context, intrinsic structures and structural principles. Like other psychological

schools of their period, they directed their approach primarily towards examination of perception. However, in contrast to the then prevailing Structuralists school's contention that complex perceptions consisted of pointillistic sensations tied together by associations, they maintained that perception had immediate and unified organization, and was not different from sensation. The program they set for themselves was to discover why spontaneous patterns emerge, and generalized their conclusions to other areas of psychology.

Their position that perception was directly organized (and that principles could be generalized) was based on a central premise that there is a parallel in the structure and processes of organization in matter and our experience, termed 'isomorphism'. This term literally means identical (iso) in form (morphic) and denoted a direct relationship between the organization of physical structures in the world, the organization of physical processes in the nervous system, and our phenomenology (Kohler, 1920). Consequently the domains of physics, physiology, and other forms of cognition were seen as continuous and operating under the same principles. Findings and constructs from different areas came to be used interchangeably, and without modification.

Considerable obscurity surrounds many of the statements of the Gestalt psychologists, which have been described as

so subjective and qualitative that quantitative operationalization is difficult to achieve (Hochberg and McAlister, 1953). Their tendency to interchange data and constructs from different disciplines may contribute to this ambiguity. Another difficulty is that they did not maintain their various concepts, laws, and principles as absolutely separate entities since their descriptions of different ideas had considerable overlap, and were at times identical with those of others (Hsiao, 1928). The 'closure' concept fell victim to these vicissitudes.

Wertheimer (1923) included 'closure' as one of eight principles accounting for organization of stimulation in perception. The other organizing principles included: proximity, similarity, common fate, objective set, good continuation, good curve, and past experience. 'Closure' here referred to a 'self-enclosed area' the presence of which led to the experience of a unit. Wertheimer also termed 'closure' as one of three 'whole properties' which define a good Gestalt (i.e., a well-organized structure), the others being equilibrium and symmetry, without clarifying the relationship of this use of 'closure' to its description as an organizing principle. Hence in this paper, 'closure' referred both to a definition of figure and one intrinsic structural principle which creates a figure. Others attempting to translate Wertheimer's use of 'closure' into a literal representation could be led to interpret it as

referring primarily to contour information.

Kohler (1920) in a theoretical paper examining the possible cortical processes underlying gestalt phenomena used 'closure' to subsume all stationary states in physics and perception. Based on the premise of isomorphism, Kohler generalized principles from electromagnetic physics to perception. He described 'closure' as the equivalent of when a state reaches entropy, which he understood to postulate a conservation of energy in systems. He maintained that:

in all processes ending in a state independent of time, development is in the direction of minimal energy in the ultimate structure (pg. 52)

and termed this 'closure'. Hence 'closure' in this paper was an energetic concept referring to a tendency for Gestalten to result when the distribution of forces within a system is minimal and stable. This description of 'closure' as a stable system of energy does not indicate how this concept differs from Wertheimer's other "whole property" of equilibrium (i.e., balance within a system). Like Wertheimer, however, Kohler used 'closure' here to define form. Others attempting to translate Kohler's use of 'closure' into a literal representation could be led to interpret it as fleshing out its meaning for visual figures to include the silhouette (as well as the contour of the shape seemingly implied by Wertheimer), since a "minimal and stable" distribution of substance within a closed system suggests homogeneous distribution of substance within boundaries.

Koffka (1928) most clearly illustrates how 'closure' was used by the Gestalt psychologists in overlapping and unclear contexts. He shared Kohler's energetic definition of 'closure' as an 'end in a transitional process', and generalized its application beyond material phenomena and perception to include thought. 'Closure' was seen as occurring in thinking when a problem was solved through an alteration of the perceptual or conceptual field, which he and later Wertheimer (1945) saw as analogous to insight. Most confusing, however, was his assertion that 'closure' was synonymous with 'completeness' which left ambiguous its relationship to another gestalt phenomenon, 'completion'. Completion referred to a tendency for patients with field cuts and normals in their blind spot to "fill in . . . unseen parts" (Fuchs, 1921). It was seen as resulting from a tendency of unstabilized processes moving towards Pragnanz, or good form, of which 'closure' was considered an attribute (Koffka, 1935). As Wertheimer (1922) argued that completion resulted from the operation of many Gestalt laws, this confounding of terms leaves unclear whether 'closure' referred to a single principle or to several of the principles postulated to operate in a whole system.

Hence the meaning of 'closure' in the Gestalt literature is unclear, and connotes more than it denotes. It was applied in literal and figurative contexts, labeled as both an 'organizing principle' of perception and/or a 'whole

property' of figures. The term 'closure' was used irrespective of modality or task, not clarified as to whether it can be achieved in different ways, and poorly differentiated from other related but different Gestalt principles.

History of the Construction of Closure Tests

For purposes of RH assessment, the conceptual ambiguities surrounding the meaning of 'closure' in the Gestalt literature may have been mitigated had they created their own measures. However, except for Koffka's incomplete triangle (1928) and the original subjective (or anomalous contour illusion created by Schuman (1904), they made no closure stimuli. All extant closure tests were constructed by other psychologists attempting to create appropriate operations of an illusive construct, for which there exists only vague specifications for its literal representation.

The original closure test was developed by Street (1931) for use in a psychometric study as a measure of 'visual perception'. He termed perception a 'specific hypothetical component of the intellectual process', initially seemingly seeing visual perception as a 'unitary mental faculty'. He turned to the writings of the Gestalt psychologists¹ for specification of rules governing perception. He then constructed degraded stimuli which he

1. Particularly the writings of the least precise Koffka.

felt were 'picture puzzles' requiring the action of Gestalt principles in order to be perceived as forms.

Street's stimuli were constructed so that by deletion "parts of each figure . . . become ground". His decision regarding what was to be placed in the figure and what was to be allowed to merge with the ground was determined by application of his understanding of three Gestalt laws of perception: 1) figure-ground (i.e., "figure predominates; ground sets off"), 2) Law of Pragnanz (i.e., "a gestalt tends to become as sharply defined as possible"), and 3) 'closure' (i.e., the energetic definition of 'closure'--"the mode of distribution of energy shifts in the direction of a minimum of Gestalt energy"). Despite including the two other principles, he emphasized understanding of 'closure' for construction of items; maintaining that:

as the density of energy is shifted from the figure field to the ground field, the perceiving of the picture becomes more and more difficult.
(pg. 5)

He felt that in order to perceive the picture it was necessary to "complete the structure", causing the figure to emerge from the ground, which he identified as "bringing about a closure". Items thus created were selected for inclusion in his final test based on: 1) ease of scoring (i.e., those with clear-cut right or wrong answers), 2) absence of sex and/or age differences (i.e., avoiding those suggesting the operation of additional factors of

either life experience or development), and 3) discriminability (i.e., elimination of those showing close overlapping degrees of difficulty).

Street's description of the construction of stimuli and of the task demands suggests that he used 'closure' as central to and perhaps identical with, both the definition of a final state of figure and the process of creating figure. It is not clear from these descriptions whether 'closure' was superordinate to the other two principles, and whether it implied the additional Gestalt principle of 'completion' as part of its definition. His choice of naming his test a "Gestalt Completion" rather than 'closure' test does not clarify the above questions, as he used the title to designate a generic name employed in the mental faculties literature for any measure (irrespective of modality) in which the subject had to supply missing information. Further, numerous later authors working with this and similar measures have consistently referred to Street's test as an operationalization of 'closure' (Mooney, 1951; 1954) or an aspect of 'closure' (Thurstone, 1944; 1949; Pemberton, 1952a and b), without consideration of the confusion of this principle with 'completion' or the other principles Street described. Consequently the poor differentiation in the Gestalt literature between 'closure' as an organizing principle, as a definition of whole structure, and as possibly synonymous with 'completion' was incorporated

into Street's test.

How these ambiguities were literally translated into the creation of his stimuli is as a result also unclear. Street's use of Kohler's energetic definition of 'closure' suggests that deletion of both contour and silhouette information may have partially directed creation of items. However, given Wertheimer's designation of 'completion' as subsuming many organizing principles, the possible blurring of 'closure' with 'completion' suggests that other stimulus information (e.g., proximity, similarity, good curve) may also have been considered in the generation of stimuli. Street thus created a test carefully screened for the effects of demographic and statistical parameters, but crystallizing the obscurity inherent in the 'closure' concept.

Despite the unclear specification of how Street decided to operationalize the vague concept upon which his test centered, numerous subsequent investigators devised additional tests modeled on his (e.g., Leeper, 1935; Sheehan, 1938; Thurstone, 1944; Verville and Cameron, 1946; Mooney, 1951; 1958; Pemberton, 1952; Ekstrom et al., 1976). These other tests were termed either closure or completion tests, and shared a common verbal description of incomplete or fragmented figures which require the subject to 'see' the whole form. Unlike Street, these later investigators most typically did not even attempt to relate the construct validity of their measures to the writings of the Gestalt

psychologists, or consider exclusion of items which might be affected by either demographic or statistical considerations. Specification of how stimuli were generated ranged from describing them as incomplete silhouettes (Thurstone, 1944; Verville and Cameron, 1946), high contrast photographic reproductions copying only highlights or shadows of features (Mooney, 1956), to no description at all (Leeper, 1935). Consequently the remaining closure tests consist of a potpourri of arbitrarily designed fragmented figures, which are not even grounded in nebulous theory.

Given the above considerations the extent to which various closure tests comprise homogenous measures of one perceptual process is suspect. Additionally, sex differences may contribute another source of uncontrolled variance in performance on these tests. As discussed previously, Street demonstrated that sex differences (most typically in favor of males) could exist for given items and eliminated these from his instrument. By contrast, other test constructors do not mention similar exclusion of items and apparently did not consider this issue in the construction of their tests. The extent to which performance on these other closure tests is affected by sex is also an open question.

Rationale for the Present Investigation

An empirical relationship has been established between performance on closure tests and lateral specialization of

the RH. However, despite a common verbal description of the task (i.e., visual synthesis of partial information), the understanding of their underlying perceptual demands (and consequently underlying lateralized processes) is imprecise. Further, there are unanswered questions regarding additional neuropsychological processes or neuroanatomical loci being tapped by these measures.

Closure Tests and Items

Users of the various closure tests have assumed that a unitary process, common to each test, underlies performance despite the fact that the actual empirical interrelationships of these measures have yet to be determined. Given the obscure construct and sometimes arbitrary specifications upon which these tests are based, it is likely that resultant tests may reflect interpretive differences and in fact measure different processes. Support for this possibility comes from the incidental observation of one investigator (Pemberton, 1951a) that factor loading on 'speed of closure', Thurstone's term for the factor measured by closure tests (1944), changed somewhat when a new closure test was substituted for the original created by Street. This finding suggests that different closure tests may require different processes. Given the tendency to use measures as interchangeable indices of 'closure', the actual amount of shared

variance needs clarification.

The assumption that items within a given test uniformly measure 'closure' is also questionable. Phenomenologic examination of items shows that in addition to absolute difficulty, they differ along formal and content dimensions. Curved or angular lines, irrelevant noise, actual contour information, and verbalizable features occur in different amounts and combinations. Sizes of stimuli vary widely, subtending markedly different degrees of visual-angle. Subject matter ranges from organic to inorganic, and simple to compound stimuli (e.g., boy, boy on bike). Consequently there is considerable variability in the stimulus array of the different items.

Consistent with these phenomenological observations, there is direct evidence from experiments that items within a given test are related to more than one parameter. Most research with closure tests have used these instruments as unitary measures. However in the few studies where item analysis is reported, heterogeneity has been demonstrated. Street (1931) observed that boys performed better on the first form of his test. He consequently analyzed items and found differential performance as a function of sex for many of them. As described earlier, he subsequently excluded those showing any sex differences. Verville and Cameron (1946) found some items in their closure test to be answered more quickly by either males or females, and/or the younger

or older groups. Most interestingly, Leeper (1935) studied the effects of cueing on Street's test. This author found that verbal abstract categories (e.g., animal or furniture), used as cues, aided perception of some stimuli but not others. These findings indicate that performance on different closure items, and as a result the test they come from, may be impacted by subject variables as well as by different processing strategies.

Support for the possibility that some items may be 'closed' via more than one process is suggested by another incidental observation by Pemberton (1951b). She noted that at times either "an analytic or holistic" approach was used by different subjects. It is interesting that these are the same terms used to describe qualitative differences in styles of perceptual processing attributed to the left and right cortex respectively (Hecaen, 1963; Levy-Agresti and Sperry, 1968; Zaidel and Sperry, 1973). Pemberton's observation may even suggest that some items can be processed via either LH or RH modes.

Given that 'closure' has most typically been related to the RH through effects only evident in large samples with statistical techniques, additional sources of variance stemming from the considerations delineated above may have been masked. As these postulated additional sources of variance may not have significance for lateralized functions, further research is needed with the various closure tests.

Those most frequently used in RH research, like the Street and Educational Testing Service Gestalt Completion Tests (1931 and 1976), would be of particular interest. Analysis of the interrelationship of tests and test items is necessary for both 1) isolating what is common in closure tests, and 2) articulating the right-brain aspect of these measures. Additionally, the effect of sex needs to be reevaluated for any closure instruments used in laterality research.

Neuropsychological Processes and Loci

The consensus of opinion in the neuropsychological literature is that the right temporo-parietal or parietal cortex is most associated with impaired closure test performance. However, the studies which have provided this specificity of loci (Lansdell, 1968; 1970; and Newcombe and Russel, 1969) have typically used 'closure' stimuli constructed from faces, hence confounding 'closure' with facial memory (and/or facial discrimination) which is also known to be sensitive to lesions in these areas (Milner, 1968; DeRenzi et al., 1968; Yin, 1970). These same studies have not specifically addressed the question of specificity of locus via designing the experiment so that all areas were systematically sampled; findings were incidental observations. Further, no clinical study has examined the relative contribution of the more anterior cortex with any closure

measure. Given the weak but consistent correlation of performance on closure tests with perceptual or conceptual "flexibility or fluency" factors (Sheehan, 1938; Thurstone, 1944; Mooney, 1954; Ohnmacht and Fleming, 1972; Messick and French, 1975, to cite a few), functions ascribed to the frontal lobes (see Jones-Gotman and Milner, 1977 for review), performance on closure tests may also be related to these areas.

Other studies have used different items from some closure tests (without specifying the basis of their selection) as measures of "complex visual discrimination" or "appositional processing" in the RH (DeRenzi and Spinnler, 1966; and Bogen et al., 1972, respectively). These have not concerned themselves with either differentiation of sensitivity in different loci or the possibility that "complex visual discrimination" or "appositional processing" may involve several dimensions, only some of which include 'closure'.

Given the consideration delineated above, further research into the neuropsychological processes and neuro-anatomical loci related to closure test performance is necessary. As there are emerging indications of dissociation of visual-perceptual functions within the RH (Warrington and James, 1967; Benton and Van Allen, 1972; Fried, Mateer, Ojemann, Wohms and Bedio, 1980), of differentiation of some complex functions within the RH (Newcome and Russell, 1969), and strong

suggestion that closure tests may not tap a unitary perceptual dimension, the relationship of performance on closure measures to other aspects of RH perceptual functions needs clarification. The RH aspects of performance on closure tests needs to be disconfounded from neuropsychological functions of facial memory, facial discrimination, and from general undifferentiated perceptual dysfunction. Further, the indications that closure test performance may be sensitive to either frontal and/or temporo-parietal regions suggests that the relative anterior to posterior neuroanatomical contributions be fruitfully investigated.

In summary, the construct validity of closure tests and their items, the effects of sex on closure test performance, the relationship of whatever is common in these closure measures to other RH visual-perceptual functions, and the possibility of specificity of loci within the RH sensitive to these tasks remains unclear.

Objective

This study aimed to clarify the relationship of performance on closure tests with RH perceptual functioning. Two intersecting experiments were used, the first with normal subjects and the second, more important experiment, with brain-damaged subjects.

The first experiment examined the assumption of the

uniformity of these measures, provided preliminary attempts to create new closure measures, and assessed the contribution of selected subject variables on closure test performance. Data from this study were further used for generation of norms. The second experiment examined the differential sensitivity of the various closure measures to RH dysfunction, attempted to define their underlying lateralized perceptual process through the use of concurrent criterion tests, and explored the relationship of performance on closure measures to locus of lesion within the RH. The interrelationship of performance on closure and facial recognition measures was examined in both the normal and brain-damaged samples.

CHAPTER II
ASSESSMENT OF CLOSURE TEST PERFORMANCE
IN NORMAL SUBJECTS

Method

The aims of the first experiment were to 1) examine the assumption of a uniform underlying process measured by different closure tests, 2) create first approximations of more refined closure measures through multivariate techniques, 3) examine the contribution of selected subject variables to performance on these tests and 4) generate normative data for any new measures created. Further, the relationship of performance on these measures with another test of RH visual-perceptual processing, facial recognition (memory), was explored.

Subjects

Subjects (Ss) were 70 undergraduate (39 males and 31 females) student volunteers in experimental or introductory psychology classes, at City and Fordham Universities. The mean age of Ss was 26, with a range of 17-57. The distribution of age was positively skewed (.40). Subjects were asked

to participate only if they had corrected normal or normal vision.

Measures

Subject variables (of sex and age) were assessed by a brief preliminary questionnaire.

Four extant closure tests: Street Gestalt completion Test--13 items (1931), Street Unstandardized figures--9 items (in Thurstone, 1944), a subset from Mooney Closure Test--11 items (1951), and Ekstrom et al. Educational Testing Service Gestalt Completion Test--22 items (1976), with a total of 55 items used. Items from all tests consisted of incomplete objects, animals or people. Several items from the Street and Mooney Tests were modified in order to maximize uniformity of stimulus arrays. Specifically, those pictures with form information in white-on-black ground were transposed into the more typical black-on-white ground format. Figural information which had no relationship to the depicted shape was treated as irrelevant noise, and deleted. Similar modifications have been used by other authors (Leeper, 1935; Thurstone, 1944; Thompson, 1977). The subset of Mooney Closure Test stimuli consisted primarily of items modified thusly, except for two exploratory items retained in their original 'reversed' figure-ground form. Examples of the modified items appear below.

Reversal of figure-ground

Before



After



Removal of noise

Before



After



Facial memory was assessed by Milner's two sets of facial stimuli (1968). Set One consisted of 12 target faces to be remembered. Set Two consisted of a choice array of 24 faces, including those from the first set.

Procedure

Group test administrations, with 10-30 Ss at each session were used. All stimuli were presented by opaque projector onto a white screen. The size of projected images and distances of Ss from these images were held constant across different administrations. The Ss sat 10-20 feet

from the screen. Depending on the item, closure stimuli ranged from approximately 4-9 square feet. Depending on the Set, facial arrays ranged from approximately 9-14 square feet. The sequence of administration was held constant (i.e., subject variable questions, closure items, faces), and all Ss completed testing in a single 1-hour session.

Closure stimuli were projected for 15 seconds each, except for two sample items. The Ss were read the following instructions:

I am going to show you a series of incomplete pictures of people, animals and things. At first these pictures may be a little confusing as lines and shapes have been left out. Your job will be to supply the missing information in your mind, and tell me what the whole thing might be.

Please try to be as specific as possible in your answers, for instance if you see only the head of a man write "head of man" rather than "man". Also, please do not be afraid to guess; sometimes people are correct even when they think they are wrong. So always write down something.

They were given the opportunity to ask questions regarding the task while viewing the samples. In order to assure correct sequencing of answers Ss wrote on the answer sheet, the number of each item was called out before it was shown.

A 45-second viewing time was used for Set One of the Milner Faces, consistent with Milner's procedure (1968). However, Milner found normals to have near perfect performance with a one-minute delay between exposure of Sets One and Two, while immediate recall led to somewhat lower performance. Given the asymptotic behavior described above

and in order to increase the range of performance for subsequent analysis, her procedure was slightly modified. An immediate recall paradigm and one-minute time constraint for selection of target faces from Set Two was used. The Ss were read the following instructions:

Now I am going to show you a set of 12 faces which I would like you to try and remember. You will have 45 seconds to study them. Then I will put up another set of 24 faces in which you will find the 12 you have just been examining. You will have one minute to write the corresponding numbers of these faces on the answer sheet. Please put down 12 numbers, even if you have to guess. You will find the numbers in the bottom corner of each picture.

Questions and Forms of Analyses

The questions were 1) are closure tests a uniform measure of 'closure'; 2) is closure test performance affected by sex and 3) do closure tests and facial recognition measure a common RH visual-perceptual process. All other analyses were post-hoc and principally geared towards 1) creating a more refined closure measure for future research with brain-damaged Ss, and 2) clarifying the relationship of the new closure measure with extant closure tests, with sex and with facial recognition. Additional post-hoc analyses were performed regarding the contribution of age to performance on all closure measures.

The assumption of a uniform underlying process measured in the different closure tests was examined by correlation

of all possible pairs of tests, and correlation of each test with a composite measure of total closure performance (i.e., performance on all tests combined). A Pearson correlation procedure was used. A similar intercorrelation of all pairs of items (i.e., stimuli from the tests) was performed. It was predicted that the amount of shared variance in the different tests and their items should be very high, if a single overriding process underlies performance on the various closure tests. As a statistically significant relationship can exist (with a large enough sample) when the absolute amount of variance accounted for is quite low (Haber and Runyon, 1971), strength of shared variance was evaluated by consideration of the actual amounts of shared variance rather than by the presences of a statistically significant relationship per se. The values of actual amount of shared variance was derived through squaring the correlation coefficients which described the relationship between the comparisons. Considerable unshared variance was defined as less variance shared than unshared by any two tests (i.e., less than 50%).

Several subgroups of closure items were extracted statistically. Initially factor analysis (principal factoring, without iteration) of all 55 closure test items was used in an attempt to create orthogonal dimensions of closure tests. Use of this procedure was made contingent upon findings of considerable unshared variance between the various closure

tests in previous analyses. If the shared variance was 50% or greater, then the tests could be understood as more uniform than not and multivariate techniques would not be used. If the shared variance was less than 50%, then the tests could be understood as measuring several processes and multivariate techniques would be used to isolate dimensions. As two factor analyses of all (or most) of the items yielded poor factor solutions, a categorical analysis was used to create new closure item groupings. Subsets of items which differentially discriminated overall performance were isolated and used to create a new closure measure (Sum Best). Additional factor analysis and multiple regression procedures (described in Appendix B) were used to attempt assessment of the construct and content validity of this new closure measure.

Pearson correlations were used in the remaining analyses to examine 1) the interrelationship of the new closure measure with the extant closure tests and overall closure performance, 2) the contribution of sex and age to both individual closure items and all closure measures, and 3) the relationship of performance on all closure measures with facial recognition.

Results

Organization of Data

Results are presented in three sections. Section 1 presents data which examine the assumption of homogeneity of the various closure tests and overall closure test performance. Here are also presented 1) the various statistical techniques employed to generate new closure groupings and the rationale for their use; 2) the items which constitute a new exploratory closure measure; and 3) findings which examine the relationship of this exploratory closure grouping to the original closure tests and Total. Section 2 presents data which examine the contribution of subject variables to all of the above closure measures. Section 3 presents data which explore the relationship of all of the above closure measures with facial recognition.

Section 1 - Closure Tests, New Closure Measure, Interrelationships

Correlations of Extant Closure Tests

Table 1 shows intercorrelations of performance on all closure tests together with their correlations with a sum taken over the four of them. That sum will henceforth be referred to as Total. Total had a mean of 26.9 (S.D. = 8.3), safely below the possible ceiling of 55 for this measure.

Table 1

Intercorrelation of Performance on
Closure Tests, and Total (N=70)

	<u>STREET</u>	<u>STREETU.</u>	<u>MOONEY</u>	<u>E.T.S.</u>	<u>TOTAL</u>
STREET		.47***	.60***	.58***	.79***
STREETU.	.47***		.35**	.52***	.70***
MOONEY	.60***	.35***		.60***	.78***
E.T.S.	.58***	.52***	.60***		.90***
TOTAL	.79***	.70***	.78***	.90***	

* = .05
** = .01
*** = .001

Performance on all pairs of closure tests correlates significantly (range $r = .35$ to $.60$), and each test correlates significantly with Total (range $r = .70$ to $.90$). Despite the significant intercorrelations of all pairs of closure tests (i.e., $P = .001$ for all), at best only 36% of the actual variance was accounted for by the correlation of any two tests. These findings indicate that the various closure tests, while sharing certain commonalities, cannot be described by a unitary set of characteristics. An item analysis further demonstrated heterogeneity of stimuli (only 6 of the 55 closure items had a $.5$ or better inter-item correlation).

However there are relatively higher correlations between performance on any given test and the composite Total measure (range $r = .70$ to $.90$, range shared variance 49% to 81%). Hence to the extent that the tests have a shared variance, it is most stably measured by Total. This indicates a common, albeit weak, underlying dimension or dimensions. Consequently, several statistical techniques were used in an attempt to articulate the 'closure' factor (or factors) common to these measures, and create a new, more refined closure measure.

Factor Analyses of Closure Items

Initially all 55 items were disembedded from their respective tests and factor analyzed by a principal

factoring, with iteration, method (Harman, 1967). Each item was treated as a single variable. A 19 factor solution, accounting for 75% of the variance, was derived when the minimum eigenvalue criterion was set at 1.0. This criterion ensures that only factors accounting for at least the equivalent of the variance accounted for by a single variable will be treated as significant. Inferences drawn from this analysis are limited by the fact that 1) the number of subjects (70) only slightly exceeded the number of variables (55), and 2) variables had only binary values (i.e., 0 or 1). Both of these above limitations could contribute to an expansion of the number of factors through the artifacts each introduces into the factor analysis procedure (Gerstman, 1979). Despite these considerations, however, the finding of numerous factors supports previous inferences that closure tests measure multidimensional processes, although the absolute number of dimensions is unclear.

In an attempt to reduce the artifact introduced by the binary data base, a subsequent factor analysis employing two modifications by Tukey (1979) was performed. As extremes in either performance level of Ss or mean accuracy levels of variables give disproportional weight to the limited variance generated by these parameters in a factor analysis with binary data, subjects beyond + or -1 standard deviation (S.D.) Total performance, and items with extremely restricted ranges of variability (i.e., less than 13% accuracy or better

than 90% accuracy) were eliminated. The consequent factor analysis of this truncated sample (i.e., 67 Ss and 44 items) yielded a 16 factor solution accounting for 73% of the variance.

The varimax notated loadings revealed an inelegant picture since few items loaded uniquely on single factors. As in the first solution, the results of this second factor analysis indicate that a multiplicity of dimensions are measured by these tests, and that most items are themselves multidimensional.

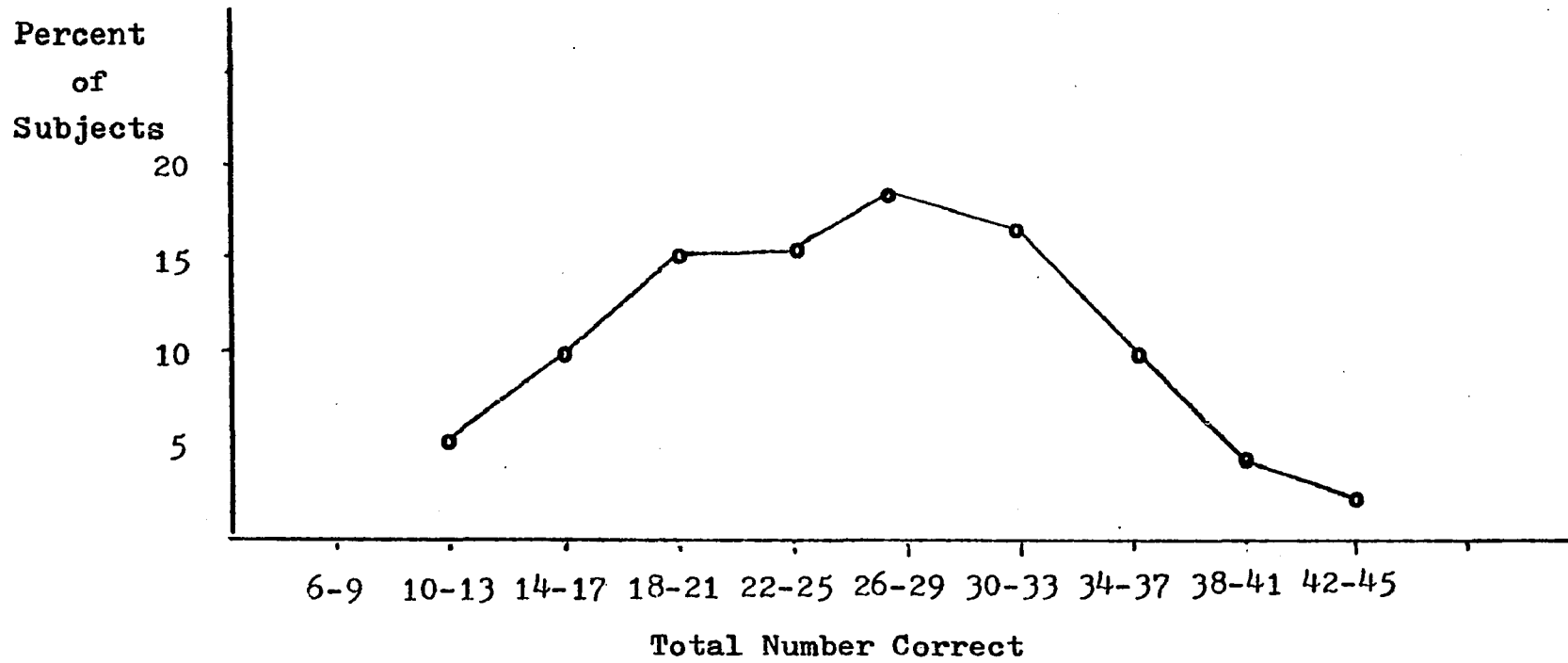
Categorical Analysis of Closure Items

Given the findings of extreme complexity in the dimensions of closure tests from the above factor analyses and the indication that the Total most stably measures the shared variance among tests, an auxiliary statistical method was employed as an alternate procedure to more meaningfully regroup items.

Figure 1 shows the frequency distribution of Ss Total performance. The distribution was very close to normal; the percent of Ss at each level of performance was approximately equally distributed around the mean (26.93), skew was minimal (.01) and 64% of the Ss fell within the area between + or -1 standard deviation (S.D.). The normal distribution of Total permitted making comparisons of Ss at cut-off points above

Figure 1

Frequency Distribution of Total Performance



and below certain values as the proportions of variance are equal. Consequently all 55 items were analyzed based on their ability to discriminate overall performance. This procedure additionally permitted regrouping of all items into mutually exclusive groups of stimuli, not possible with the factor analysis given the aforementioned complexity of items.

Table 2 shows three distinct categories of stimuli yielded by generating Chi Square matrices on each item for high or low overall performers (beyond plus or minus 1 S.D., N's of 12 each). Phi coefficients for each item, and mean Phi value for each group of items are also provided. For the Poor discriminators, no item distinguished the high performers from the low performers. In the Average group, typically three to four times as many high performers passed the item as did low performers, consistent with the average offset of the two groups. Conversely, for the Best discriminators, the pass rate for high performers was at least five times that for the low performers, considerably exceeding average expectations. The Phi statistic which is shown in this table provides an additional measure of strength of association between variables in 2 X 2 Chi Square tables. It was observed that the mean Phi values for each category of discriminators (i.e., .23, .50 and .71 for Poor, Average and Best respectively) corresponds to the levels of discriminability of the three groups of items.

Table 2

Three Ranges of Item Discriminability (N=24)

<u>POOR</u>		<u>AVERAGE</u>		<u>BEST</u>	
Item #	Phi Value	Item #	Phi Value	Item #	Phi Value
S1	0	S4	.77	S8	.77
S2	.21	S6	.50	S9	.58
S3	0	S7	.53	S11	.51
S5	.30	S10	.38	S12	.71
SU21	.30	S13	.38	SU14	.75
M29	.38	SU16	.58	SU15	.60
M33	.45	SU17	.51	SU18	.75
ETS35	0	SU19	.50	M23	.46
ETS37	.17	SU20	.71	M25	.77
ETS38	.45	SU22	.51	ETS40	.68
ETS39	.30	M24	.31	ETS45	.85
ETS42	.21	M26	.60	ETS46	.92
ETS44	.21	M27	.68	ETS48	.68
		M28	.38	ETS52	.92
		M30	.58	ETS53	.64
		M31	.50	ETS54	.77
		M32	.50		
		ETS34	.43		
		ETS36	.71		
		ETS41	.51		
		ETS43	.45		
		ETS47	.59		
		ETS49	.38		
		ETS50	.50		
		ETS51	.43		
		ETS55	.19		
Phi \bar{X} =	.23		.50		.71

In an attempt to relate these discriminability categories to other factors possibly important for measuring 'closure' ability, their level of difficulty and relationship to Total was assessed. Table 3 shows the mean accuracy and correlation to Total for each of these three categories of stimuli and their individual items. Values in this table are based on the whole sample (N = 70). Mean difficulty of items in each group in part accounted for the categories. Poor discriminators consisted primarily of very easy or very difficult items. Average and Best discriminators were primarily in medium to medium-hard ranges. However the three categories had overlapping ranges of item difficulty and varying degrees of uniform correlation to Total performance, suggesting that the distinctions are based upon underlying dimensions as well as difficulty. The subset of items which best discriminated performance are shown in Figure 2. The composite score on these items will henceforth be referred to as Sum Best.

Assessment of the New Closure Measure

Table 4 shows the correlation of the Sum Best closure measure with the four closure tests and Total performance. The uniformly high correlation (range $r = .68$ to $.77$) of Sum Best with each closure test is higher than that achieved by the correlation between any two extant closure tests (Table 1). The Sum Best and Total measures share 81% of their variance

Figure 2

Items Which Best Discriminated Total Performance

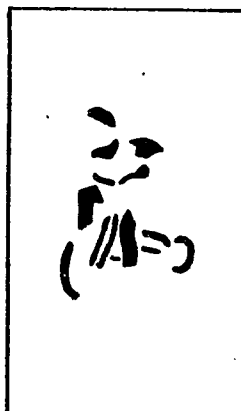
S8



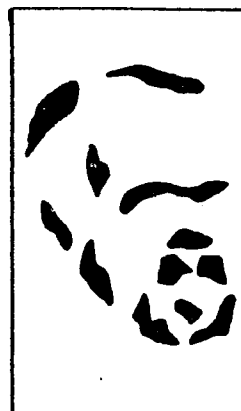
S9



S11



S12



SU14



SU15



SU18



M23



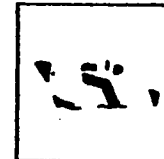
M25



ETS 46



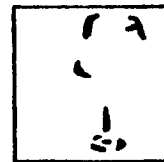
ETS48



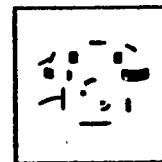
ETS52



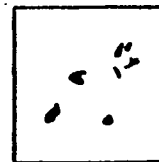
ETS40



ETS45



ETS53



ETS54



Table 3

Mean Accuracy and Correlation to Total of the Three Ranges of Item Discriminability (N=70)

POOR			AVERAGE			BEST		
Item #	Mean Accuracy	Correlation to Total	Item #	Mean Accuracy	Correlation to Total	Item #	Mean Accuracy	Correlation to Total
S1	.96	-.04	S4	.73	.60***	S8	.30	.50***
S2	.99	.19	S6	.46	.32**	S9	.26	.40***
S3	1.00		S7	.84	.41***	S11	.23	.29**
S5	.91	.23*	S10	.07	.32**	S12	.13	.41***
S21	.94	.26*	S13	.07	.36***	SU14	.39	.42***
M29	.94	.41***	SU16	.59	.35***	SU15	.34	.35***
M33	.78	.27**	SU17	.84	.39***	SU18	.56	.36***
ETS35	.00		SU19	.53	.31**	M23	.19	.42**
ETS37	.59	.24*	SU20	.81	.53***	M25	.21	.55***
ETS38	.86	.40***	SU22	.49	.38***	ETS40	.50	.50***
ETS39	.89	.30**	M24	.20	.39**	ETS45	.29	.61***
ETS42	.01	.25*	M26	.66	.35***	ETS46	.33	.64***
ETS44	.04	.21*	M27	.57	.35***	ETS48	.47	.50***
			M28	.23	.31**	ETS52	.33	.64***
			M30	.77	.32**	ETS53	.30	.36***
			M31	.40	.35***	ETS54	.29	.58***
			M32	.51	.29**			
			ETS34	.34	.37***			
			ETS36	.70	.53***			
			ETS41	.61	.39***			
			ETS43	.13	.22*			
			ETS47	.37	.41***			
			ETS49	.13	.24*			
			ETS50	.59	.38***			
			ETS51	.80	.32**			
			ETS55	.29	.18			
\bar{X} =	.71	.25	\bar{X} =	.49	.36	\bar{X} =	.33	.47

* = .05; ** = .01; *** = .001

Table 4

Correlation of Performance on Sum Best
with Performance on Extant Closure
Tests and Total (N=70)

	<u>Street</u>	<u>StreetU</u>	<u>Mooney</u>	<u>E.T.S.</u>	<u>Total</u>
Sum Best	.76***	.69***	.68***	.77***	.90***

* = .05
** = .01
*** = .001

($r = .90$). These findings indicate that the Best discriminators as a group preserve whatever Total represents.

Consequently, Sum Best is a more stable measure of the dimensions shared by the extant closure tests than any other single test.

In an attempt to further assess the construct validity of this new closure measure, additional analyses were performed with the Sum Best items. These are shown in Appendix B, however major findings are reported here. Factor analysis of these 16 items treated as independent variables yielded a 6 factor solution (henceforth called Best Factors), accounting for 70% of the variance. In contrast to the previous factor analyses, most items (i.e., 12/16 items) had a factorial complexity of only 1 (Table A). Essentially all of the Best Factors (i.e., 5/6 factors) correlated significantly with Total (Table B), and one factor (Best Factor #1) was significantly related to all tests. Subsequently, each of the four extant closure tests were used as competitive predictors in multiple regression procedures for each of the Best Factors. The variance in the first four Best Factors was accounted for by predominantly one test. Each of the four tests predicted a different one of these Best Factors (Table B).

Section 2 - All Closure Measures and Subject Variables

Table 5 shows the correlations of selected subject variables with performance on all closure measures (i.e., extant tests, Total, Sum Best). The approximately equal representation of both sexes in this sample (described in Subjects section) permits the planned comparisons with this subject variable. Although it was not initially intended to examine the contribution of age, the sample included a wide distribution (also described in Subjects section). Despite the skew towards younger Ss, post-hoc analysis of this subject variable was also performed for exploratory purposes.

It is observed that either sex or age account for a small portion of the variance in each of the four extant closure tests. In contrast, Total and Sum Best are not significantly related to either subject variable. Specifically, performance on the Street and Mooney tests shows a very slight advantage for males ($r = -.24$, $p = .05$ and $r = -.21$, $p = .05$ respectively). The Street U and E.T.S. tests showed slight negative trends with increasing age ($r = -.33$, $p = .01$ and $r = -.28$, $p = .01$ respectively). An item analysis further demonstrated the differential sensitivity of some items for either sex, age or both.

Further post-hoc analyses with handedness and urban-rural background were performed, and are also reported in

Table 5

Correlation of Subject Variables with Performance on
All Closure Measures and Total (N=70)

	<u>STREET</u>	<u>STREETU.</u>	<u>MOONEY</u>	<u>E.T.S.</u>	<u>TOTAL</u>	<u>SUM BEST</u>
AGE	-.06	-.33**	-.17	-.28**	-.15	-.13
SEX	-.24*	-.11	-.21*	-.17	-.19	-.15
- = male						
+ = female						

* = .05
** = .01
*** = .001

Appendix B (Table D). Sampling limited inferences with these variables.

Section 3 - Relation of All Closure Measures with Facial Memory

In order to explore the relative postulated right hemisphere sensitivity of the various closure tests and the new closure grouping generated in this experiment, these were related to performance on facial recognition. Table 6 shows the correlations of each extant closure test, Total and Sum Best performance with performance on facial recognition. No closure measure showed a significant positive relationship with this other postulated RH sensitive visual-spatial task.

Table 6

Correlations of All Closure Measures
with Facial Recognition (N=70)

	<u>STREET</u>	<u>STREETU</u>	<u>MOONEY</u>	<u>E.T.S.</u>	<u>TOTAL</u>	<u>SUM BEST</u>
FACES	-.03	.07	-.08	-.00	-.01	.00

* = .05
** = .01
*** = .001

Discussion

Summary of Findings

The following is a review of the major findings in this first experiment. The closure tests were not found to be homogeneous: at best 36% of the variance was shared by any two tests. An item analysis further demonstrated heterogeneity of stimuli. To the extent that there was shared variance in all the tests, it was found to be most stably measured in the composite measure of performance on all tests--Total. In order to extract underlying dimensions in these tests, factor analysis and chi square techniques were used with essentially all test items. The first two factor analyses yielded 19 and 16 factor solutions respectively, and items generally did not load discretely on any one factor. The chi square procedure isolated a target set of 16 items which best discriminated Total performance, and hence yielded one exploratory new closure measure (i.e., Sum Best).

The Sum Best variable correlated uniformly highly with each extant closure test, and this correlation was higher than that previously achieved by the correlation between any two tests. Factor analysis of Sum Best items yielded a six factor solution (i.e., Best Factors), with items loading primarily on only one given factor. All Best Factors inter-correlated significantly with Total and Best Factor #1

correlated significantly with all tests. Multiple regression procedures demonstrated that performance on each test was found to primarily predict performance on one respective Best Factor.

Subject variables of age or sex were found to contribute a small portion of the variance on each extant closure test. By contrast, Total and Sum Best closure measures were not significantly affected by these variables. Finally, performance on facial memory and all closure measures (i.e., extant tests, Total and Sum Best) were found to be unrelated.

These results have implications for both an operational specification of the 'closure' concept and research into RH visual-perceptual functioning.

Relation of Closure Tests to the Gestalt 'Closure' Concept

The concerns about the construct validity of closure tests were supported. Findings demonstrate that traditional closure tests, while sharing certain commonalities, do not measure a unitary and exhaustive underlying perceptual (or cognitive) process. The first two factor solutions indicate that many different dimensions are measured by the closure tests in this study. The factorial complexity of most of the test items in these analyses indicates that these conclusions extend to many individual closure stimuli, as well as to the tests.

The most stable relationship between the closure tests

was measured by the composite score Total. The high shared variance between Total and the new closure measure of Sum Best indicates that Sum Best preserves whatever Total represents. If it is assumed that performance on closure tests in fact assesses 'closure', but to different degrees, then both Total and Sum Best appear to be the most sensitive measures of this construct. However, as Total includes all items and factor analyses of these items indicated that many are multidimensional, the Total measure may also tap many extraneous and/or noisy processes.

Although the factor analyses of the 16 Sum Best items also indicated that this is not a homogeneous instrument, Sum Best may be the most refined closure measure created thus far. The low factorial complexity of these items indicates that they tap more unitary dimensions than most other closure items used in this study, eliminating one of the difficulties with Total. Further, as these Sum Best items were selected because of their ability to discriminate Total performance, the factors derived from them may incorporate the more salient dimensions of the shared variance among tests embodied in the original Total measure. For example, the significant loadings of all four closure tests on the first, and other, Best Factor may indicate that it is the unifying thread which runs through the tests. This factor may be considered to constitute a statistically derived consensus of an operational specification of the elusive concept 'closure'.

Conversely, this first Best factor may describe a stimulus dimension which is a consensus among test constructors of an operational specification of 'closure', but which has no relationship to what the Gestaltists might have intended.

A second, less central, consideration raised earlier was that extant closure tests may reflect interpretive or stylistic differences of test constructors. The regression solutions of the different closure tests onto each Best Factor support this concern. Each test predicted a substantial (i.e., roughly one-quarter to one-third) portion of the variance on one of four different factors, suggesting that the 'thematicity' of these factors (noted in the results section) reflects a dimension primarily represented by one particular test. The term 'thematicity' refers to stylistic differences (or themes in the drawings of the test constructors, similar to the stylistic differences found in artists. Hence the 'thematicity' of these factors suggests that different test constructors may have created their own, relatively unique, dimensions. These dimensions may derive from formal (e.g., line qualities, size) content (e.g., organic versus inorganic), or other parameters of the stimuli. Again, these dimensions may, or may not, have any relationship to what the Gestalt psychologists intended to represent as their 'closure' concept.

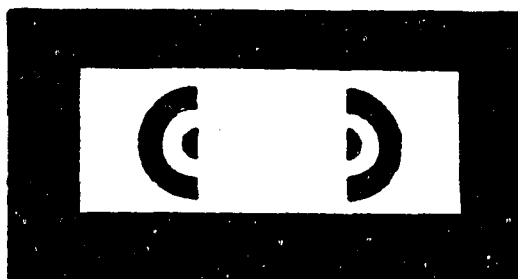
The ambiguity surrounding the 'closure' concept in the Gestalt literature was described in the Introduction. The

findings thus far support the conclusion that this conceptual ambiguity, of necessity, led to ambiguity about the operational specification of 'closure'. As the Gestaltists excelled in pictorial illustration of their concepts, perhaps the best way a closure measure (i.e., test, factor, item) can most safely be defined as assessing 'closure' is through a demonstrated relationship between it and a stimulus (or type of stimulus) generated by them to explicate 'closure'. Subjective contour configurations may provide such an index.

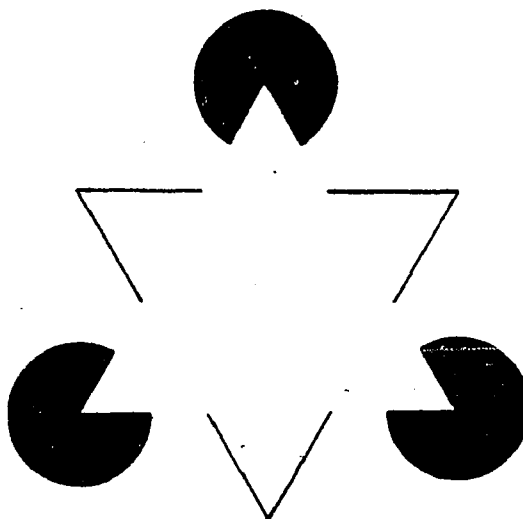
Subjective (or anomalous) contours are visual illusions where, in the absence of real color or brightness gradients, such gradients are perceived (Kaniza, 1976). Such an illusion was first created by the Gestalt psychologist Schumann (1904), and presented in an article discussing the physical parameters which affect the perception of contour. He reported that for a contour to be perceived an abrupt local change in the luminosity of the stimulus field was required. In the course of the investigations he described, however, he noted that under certain conditions contours could be made to appear in areas of the visual field where the physical stimulation was homogeneous. He illustrated this by the pattern shown in Figure 3. Most observers see a center white square, bounded by intermittent black and white on either side, despite the absence of real physical stimulation for the contours of the square. Schumann

Figure 3

Subjective Contour Configurations



Schumann Subjective Contour Stimulus



Kanizsa Subjective Contour Stimulus

concluded that such illusory contours were the result of some organizational process, similar in nature to 'closure'. He created only one such stimulus and the subjective contours in this figure are somewhat unstable. The existing repertoire of these configurations has, however, been expanded in subsequent decades (e.g., Kaniza, 1955; Coren, 1972; Gregory, 1972). Kaniza, in particular, has been able to produce much more stable contours than that of Schumann, as well as demonstrate that curvilinear contour illusions could also be produced. An example of these later stimuli is also shown in Figure 3.

There is no guarantee that the subjective contour illusion exhausts all aspects of the 'closure' concept, nor that such configurations created by other psychologists 1) would have been considered representative of the 'closure' principle by the Gestalt psychologists, and 2) are the result of a single set of perceptual cues. However, the strong phenomenal experience of a luminous bounded surface, superimposed on an underlying figure, is consistent throughout all examples. Consequently, to the extent that such illusions are uniform and conform with the original one created by Schumann, these may be the best index of a relationship to 'closure' with any other measure.

Relation of Closure Tests to Right Hemisphere Functions

The heterogeneity of closure tests demonstrated in this experiment implies that findings with these instruments in laterality research need to be reexamined. The mixed nature of the processing demands of the different tests indicates that, despite a common verbal description of the task (i.e., visual synthesis of partial information), considerable variance in closure test performance is unaccounted for by any one of the tests. Unless one were to use only items which loaded substantially on Best Factor #1, these tests could not be used as interchangeable measures. Further, the mixed nature of the processing demands of many items indicates that they may contribute as much 'noise' as they do 'signal' for any process they are presumed to be measuring. Given the above heterogeneity, the aspect of these tests which is sensitive to the RH remains unclear. It may consist of some or all of the dimensions disclosed in this study, and may not necessarily reflect the Gestalt notion 'closure'.

In addition, facial memory and whatever is assessed by all closure measures appear to be independent and unrelated perceptual processes. Inferences regarding brain-behavior relationships are limited in this study which used normal Ss and no lateralizing techniques. Logically no extensive conclusion can be made given these constraints. However,

a positive correlation between performance on closure measures and facial memory would have been expected if visual-perceptual functions within the RH are uniformly executed, and these tests indeed measure RH functions. Consequently, the absence of any significant positive relationship, between closure measures and facial memory, suggests that visual-perceptual functions may be dissociated within the RH. Such a dissociation would imply that RH visual-perceptual functions are processed in more than a single mode, and may be based on different underlying mechanisms. At a theoretical level, contrary to Levy et al. (1972) and others' (e.g., DeRenzi et al., 1969) assumption of a difficult-to-label but unitary perceptual process subserved by the RH (i.e., "gestalt-synthetic" and "complex-visual discrimination" respectively), there may be more than one such process.

Hence several major questions regarding closure test performance and RH functioning emerge from this study. The first question concerns refinement of the empirical data base relating these tests to the RH. As traditional closure tests have been found to contribute orthogonal dimensions, the extent to which they are interchangeable indexes of RH dysfunction could be examined. Given the multiple sources of variance in these tests, however, a more compelling question would be to clarify the most RH sensitive aspects of these measures. The Sum Best closure measure and its

factors may provide a mode for articulating this issue. If a discrete (or relatively discrete) dimension within these tests is sensitive to RH processing, then one Best Factor (or only a few) should show differentially lower performance as a function of side of lesion in a brain-damaged (BD) sample. If RH processing is sensitive to a composite of the various dimensions required by these tests, then the Sum Best closure measure itself should show a stronger lateral difference than any Best Factor, as it provides the best prediction to performance on all tests.

There are, however, several methodological caveats with the use of Sum Best and the Best Factors which make them of necessity primarily exploratory. The Sum Best variable is composed of mainly difficult items. The inherently restricted range of variability in this measure could create the possibility of a floor effect which would weaken, or even mask, any lateral differences. Further, there might be other closure test items which due to their higher mean accuracy level did not fall into the Best Discriminator category, but which may still be optimally sensitive to RH processing. The Best Factors have their limitation also. Level of performance on each factor is defined by summing weights of relevant items. As these factors were generated from the restricted range of Best Discriminator items, only a very few (i.e., 2-4) loaded primarily on any given factor. Hence for each factor extreme weight is put on single items.

Furthermore, given the heterogeneity of tests and items, there is no a priori reason to assume that the factors generated in a normal sample have relevance for issues of laterality. It could be the case that within a BD population new clusterings might appear which are more relevant than those generated in normals. Consequently until underlying perceptual demands which predominate in these measures are articulated, findings with the both Sum Best and its factors may only serve to point to areas for further study. Given these considerations, an ancillary method of isolating closure groupings would be to merge items according to their consensual similarity with some other hemispheric of theoretically relevant task (e.g., subjective contours or facial processing), and examine differential performance in BD groups.

The second question concerns the relationship of the RH sensitive aspects of closure tests to the Gestalt 'closure' principle, as it would help clarify a term used in building theory of RH processing. The index of 'closure' previously discussed, subjective contour illusions, could be interrelated to all closure measures (i.e., four extant tests, Total, Sum Best and Six Best Factors). If those closure measures which show a differential sensitivity to RH processing also show a high relationship with the ability to appreciate these illusions, then 'closure' could be more more safely ascribed to the RH. This is a likely finding as

Hamsher (1979a) has recently provided an empirical link for subjective contour perception and RH dysfunction. In a study of stereopsis and perception of these illusions in which he used RH lesioned patients and normal controls, he found 35% of his BD sample to be impaired in their ability to see these figures. Although he used no left BD Ss, his findings support the inference that this illusion may be a basis for the lateralized effect of closure tests.

The third question requiring clarification concerns the absence of any significant positive correlations for all closure measures with facial memory. Ascribing the inferred dissociation to RH functioning would require a sample of RH lesioned patients to yield a significant negative correlation, on tasks which show an overall sensitivity to RH impairment. However, as facial memory subsumes both memory and visual discrimination demands, the aspect of this task which is responsible for the inferred dissociation may need to be differentiated. An additional facial discrimination task which demands no memory would be needed to articulate the responsible dimension. If the finding of no relationship between the closure measures and facial memory was based more on the discrimination aspect of the facial memory task, use of an instrument which stresses this function might strengthen the dissociation. Finally, as the closure measures are multidimensional, it is possible that only specific groupings of closure test stimuli will show the necessary inverse

relationship, with either facial memory or facial discrimination.

Relation of Closure Tests to Subject Variables

It has been repeatedly noted that the ability to 'see' the required figures in these tests is a distinctive capacity possessed by individuals in markedly different degrees (e.g., Street, 1931; Leeper, 1935; Thurstone, 1944; Mooney and Ferguson, 1951). Certain subjects are described as experiencing great difficulty in effecting any 'closure' at all, while others perceive most of the intended whole configurations with speed and ease. These differences are unrelated to intelligence (Street, 1931).

Several investigators working with these tests have made post-hoc inferences regarding the nature of the subject variables which account for these individual differences. Street (1931) speculated originally that persons with certain artistic and/or certain unspecified personality traits may perform best. Sheehan (1938) speculated that persons with "more flexible habits of interpretation of primary sensory data" performed best. Other investigators have used more direct behavioral measures or questionnaires to explore these individual differences. Thurstone (1949) related high performance on closure tests to people with high mechanical aptitude, as assessed by various aptitude tests. More

recently, Wasserstein (1974), in a similar vein, related high performance on the Street Test to ability to draw representationally. Pemberton (1952b) related high performance on her closure test to individuals who described themselves (on various interest, value, temperament and personality inventories) as sociable, quick to react, self-confident, systematic and precise, having artistic interests and expressing dislike for logical or theoretical problems. These findings using more experimental techniques support the inferences originally made by Street and Sheehan regarding relevant subject variables.

Findings with less subtle subject variables like sex and age are equivocal. Street (1931) found no significant differences in performance attributable to either age or sex in his original sample of children, once he had removed items specifically sensitive to sex. This finding led Thurstone to remark that it was "an indication that the test involves some factors which mature at an early age, and may be taken as indicative of some fundamental and primitive function" (p. 9). A later study by Verville and Cameron (1946) of age and sex differences in closure test performance of adults, using a new set of stimuli constructed by these authors, revealed differences in reaction times of the groups. Older subjects ranging in age from 35-56 ($\bar{X}=45$) performed worse than the younger subjects ranging in age from 16-23 ($\bar{X}=20$). Younger men showed a slight advantage over females in their

age range. Accuracy comparisons were not reported. In another closure test Mooney (1951) noted no sex differences in performance. Subsequently, Mooney (1957) criticized previous research examining the effect of age and sex on these tests for using test items which were not of a single class, and hence not universally familiar. By constructing yet another closure test consisting only of faces, which were defined as "unidimensional and universally familiar", Mooney then reexamined the issues of age and sex in school children (ages 7-13) and a smaller sample of soldiers (ages unspecified). He found no sex differences but did find performance to be positively associated with age. Age did not, however, account for all individual differences since ranges of subject differences and item difficulties remained as marked in all age groups. By contrast, Lansdell (1968) in a study using Mooney's Closure Faces stimuli, investigated the effect of extent of temporal ablation on lateralized tasks and noted different patterns of performance between the sexes with left brain-damaged females doing better. Most recently, Thompson (1977), in an investigation of cultural differences of predisposition for 'appositional or propositional' thought, using the Street Test, found an advantage for individuals from rural backgrounds as a main effect and a sex by background interaction which favored females.

The effects of sex and age on closure test performance

were also examined in this study, the latter being on a post-hoc basis. Findings demonstrated a weak, but differential sensitivity to either sex or age for all extant closure tests. By contrast, neither Total nor Sum Best was significantly affected by these subject variables. This suggests that the contradictory conclusions in previous research may be largely the outgrowth of their use of different tests. It further supports the inference that either Total or Sum Best is the most stable measure of 'closure', despite their described limitations.

Age deserves special attention. Unlike sex, this was not systematically sampled. Age-related data were analyzed for exploratory purposes. Increasing age was found to be fairly consistently associated with lower performance, this trend only sometimes attaining statistical significance. However, few Ss from older age ranges were likely to have been represented in the described skewed distribution. The absolute impact of age may consequently have been underestimated from this data base. As older subjects with BD may perform poorly because of their age and/or their lesion, this subject variable must be carefully considered when closure measures are used. Either normal age-matched controls or an age-matched sample of BD subjects would be required in order to age correctly, or rule out age effects if necessary.

CHAPTER III

ASSESSMENT OF CLOSURE TEST PERFORMANCE IN BRAIN-DAMAGED SUBJECTS

Method

The second experiment of this study aimed to relate findings from the first experiment to neuropsychological issues of RH assessment, processes and structural organization. The three questions raised in Experiment 1 were addressed. Specifically: 1) the differential sensitivity of all closure measures to side-of-lesion was compared in a brain-damaged sample in order to begin refinement of the empirical data base relating such tests to the RH, 2) the relationship of the ability to perceive subjective contour illusions to any closure test dimension sensitive to RH dysfunction was evaluated, in order to determine if such illusions characterized the underlying lateralized perceptual process, and 3) the relationship of facial memory and facial discrimination with performance on closure measures was examined in order to test the existence of dissociated RH perceptual processes. Additionally, the Mooney Closure Faces Test (1957a), which has historically been one of the closure tests used to ascribe 'closure' to

the RH (Newcombe and Russell, 1969; Landsell, 1968 and 1970), was examined to determine 1) its relation with other closure measures, and 2) its relationship to facial discrimination with which it may be confounded. Finally, the relative sensitivity for closure performance of different loci within the RH was explored.

Subjects

Essentially all patients with unilateral cortical lesions, and no gross organic mental syndrome, admitted to the neurosurgery service of Mt. Sinai Hospital College of Medicine between 9/79 and 6/80 were tested. A total of 31 patients was evaluated, primarily preoperatively (19 preoperative, 4 postoperative). These were equally distributed between the left- and right-side lesioned samples. Patients who were left-handed for writing, or had had recent cerebral infarct (i.e., less than three months) were excluded from further analysis, as either cerebral organization may have been atypical in the case of the first group and unresolved concurrent ischemic changes might have obscured specificity of localization of lesion in the second group. Patients with arteriovascular malformation (AVM) were also excluded if they showed no neurological or neuropsychological deficits corresponding to the location of their lesion, as an AVM can exist without impacting cognitive functions (Mattis, 1979).

The majority of patients had neoplastic growths of various types.

A final sample of 23 patients (12 right BD, 11 left BD) constituted the experimental groups. Locus of lesion was determined by computerized axial tomography (CAT scan) in 20 of them. For the remaining 3 patients, it was determined by angiogram and surgical reports. Clinical and pathological characteristics of individuals in this neurological sample are shown in Table 7, and include age, sex, lesion type, locus and extent. The Ss are listed from youngest to oldest in each group. Drawings of lesions for each S are shown in Appendix C.

For both the left-side (LBDs) and right-side (RBDs) lesioned groups, distributions of age, sex, as well as lesion type, locus and extent are shown in Appendix D (Tables E through I respectively). Statistically there were no significant differences between the groups on any of the above variables (Fisher's Exact P Test used), although the RBDs had slightly more females (45.5 versus 66.7% for LBDs and RBDs respectively, Table F), the LBDs had slightly more Ss with signs of hidden ambidexterity (36.4 versus 16.7% for LBDs and RBDs respectively, Table G), and no Ss in the LBDs had lesions of lateral temporal areas (0 versus 16.7% for LBDs and RBDs respectively, Table I). Mean age was 41.5, ranging from 18-69 for the LBDs, and 40.4, ranging from 20-69 for the RBDs. Both groups included lesions from essentially

Table 7

**Clinical and Pathological Characteristics
of Neurological Sample, Individual Cases (N=23)**

Left Lesion								Right Lesion							
S#	Age	Sex	Type	Locus	Extent	Tested	Ambidex- terity	S#	Age	Sex	Type	Locus	Extent	Tested	Ambidex- terity
2	18	M	G	F	2	PRE	-	3	20	M	G	MT	2	PRE	-
10	26	M	G	P-O	1	PRE	3	8	21	F	Abs.	F (R)	4	POST	1
9	27	M	AVM	P-O	2	PRE	-	1	24	M	AVM	P-O	3	PRE	1
1	30	F	G	F	4	PRE	-	6	30	M	G	F	3	PRE	3
8	31	F	M	MT	3	PRE	1	5	34	F	G	R	2	PRE	1
6	36	M	G	R	1	POST	1	9	36	F	G	MT	1	PRE	1
4	45	M	G	P-O	3	PRE	3	1	39	F	M	MT	2	PRE	-
5	52	F	M	F	2	POST	3	12	46	F	M	MT (F)	3	PRE	3
11	55	F	M	MT	3	PRE	3	2	51	M	AVM	P*	2	PRE	-
7	67	M	G	R	4	PRE	1	11	53	F	AVM	LT	4	PRE	1
3	69	F	M	R	3	PRE	1	4	62	F	M	F*	3	POST	1
								7	69	F	G	P-O*	1	PRE	1

Lesion Type: M = meningioma; G = glioma, glioblastoma, astrocytoma; AVM = arterio-vascular malformation; Abs. = abscess

Lesion Locus: F = frontal; R = rolandic; P = parietal; P-O = parieto-occipital; MT = medial temporal; LT = lateral temporal; () = extends into area within parenthesis; * = not determined by CAT scan

Lesion Extent: 1 = small; 2 = medium; 3 = large; 4 = very large; - = no information obtained on these measures

Ambidexterity: 1 = all right-handed on Annet; 2 = some left on Annet; 3 = positive family history

Tested: PRE = preoperative; POST = postoperative

all areas of the cortex, with wide ranges of involvement (i.e., extent).

The neurological groups were thus well matched for all clinical and pathological characteristics, including age. However, as this sample was considerably older than the normals used in the first experiment (i.e., \bar{x} age = 26, range 17-57), comparisons with normal performance were more limited.

Measures

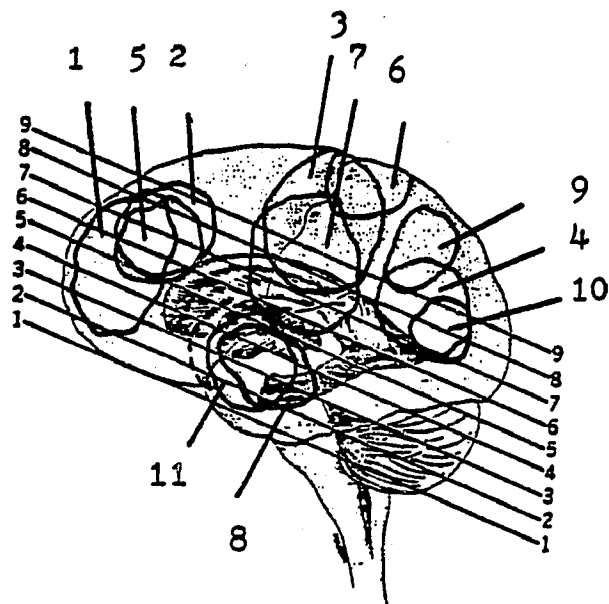
The CAT scans were done with and without enhancement, maximizing discrimination of areas of involvement. For all of the final subgroup of 23 patients, scale drawings of areas of involvement were made by an attending neurosurgeon (Dr. R. Zappulla, Instructor of Neurosurgery at Mt. Sinai Hospital) on an atlas of brain for use in computer-assisted tomography (Schoultz, Morrison and Calhoun, 1976). Additional sections were drawn in for areas in superior regions of the brain which were not available in the atlas. Location and size of lesion was determined from these drawings by the combined consensus of the neurosurgeon and the author.

Figure 4 shows two separate composite drawings of lesions of the left- and right-sided patients respectively. Where edema was substantial enough to encroach into areas

Figure 4

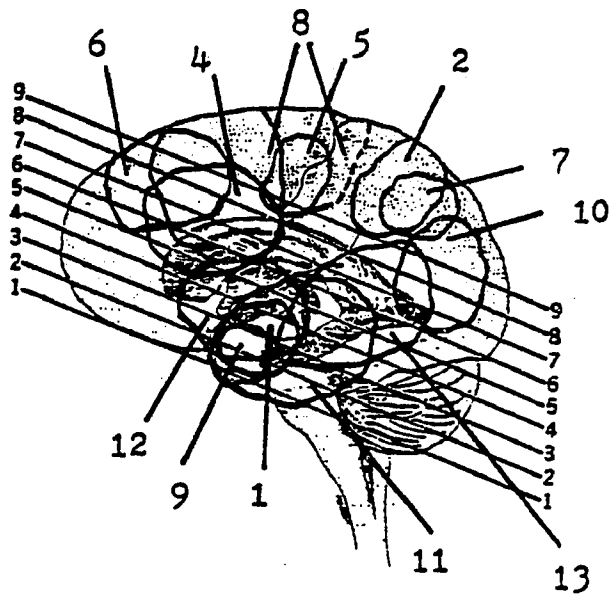
**Composite Drawings of
Left- and Right-side Lesions**

Left-Side Cases



ATLAS OF BRAIN FOR USE IN COMPUTER-ASSISTED TOMOGRAPHY

Right-Side Cases



ATLAS OF BRAIN FOR USE IN COMPUTER-ASSISTED TOMOGRAPHY

considerably beyond the actual lesion, it was drawn in with dashes. Given the small number of subjects within each group (11 left- and 12 right-side lesioned patients), locus of lesion was initially divided into gross categories for purposes of group comparisons of areas of involvement in the two samples. The gross categories consisted of anterior (including prefrontal, frontal and pari-rolandic loci), posterior (including parietal and parieto-occipital loci) and lateral (including medial and lateral temporal loci, and temporo-occipital loci) areas. As it was planned to examine the relationship of some aspects of closure test and other perceptual tests performance to locus of lesion within the RH, lesions were also classified into more refined anatomical categories. These more refined categories consisted of frontal, medial-temporal (including some slight fronto-orbital involvement in one right-side lesioned S), lateral temporal, rolandic, and parieto-occipital (including only parietal, or both). Figure 5 shows the regions in the atlas which correspond to both location systems.

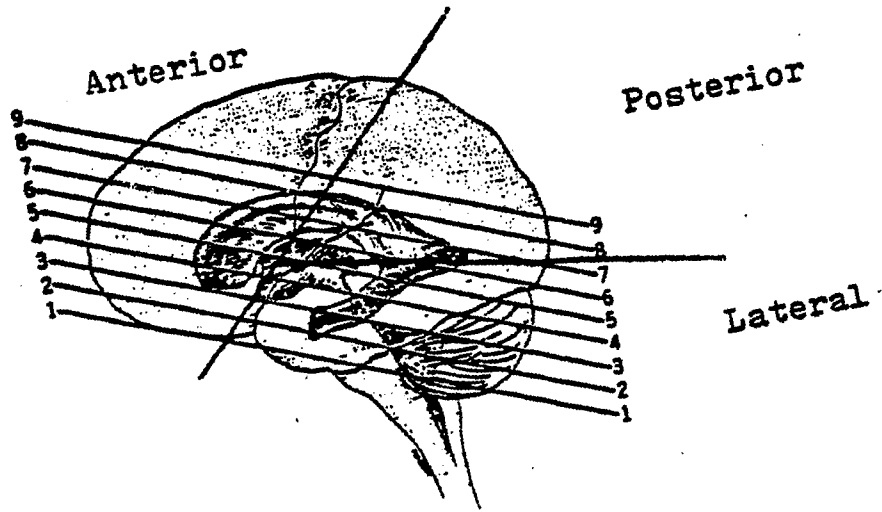
Extent of lesion was determined by classifying them into four ordinally scaled categories: 1 = small, 2 = medium, 3 = large, and 4 = very large.

Closure stimuli consisted of the same 55 items taken from the four closure tests examined in the first experiment. Level of performance on the four extant closure tests as well as on Total and Sum Best was determined by the absolute

Figure 5

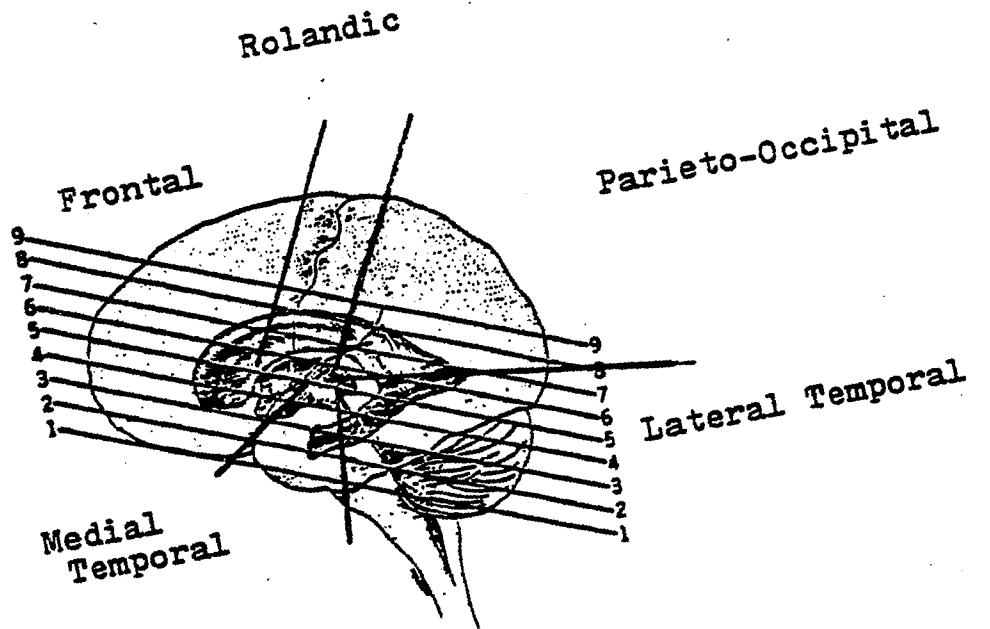
**Regions of the Cortex Subsumed Under
Two Different Location Systems**

Gross Location



AREA OF HEAD FOR USE IN COMPUTER-ASSISTED TOMOGRAPHY

Refined Location



AREA OF HEAD FOR USE IN COMPUTER-ASSISTED TOMOGRAPHY

number of items correctly identified from each measure. Performance on the six Best Factors was determined via computing the factor scores for each factor. This was done by multiplying the absolute score on a given item (0 or 1) by the respective factor weight of that item, and summing the final product. The weights for items were derived from factor-score coefficients provided by the original factor analysis of the Sum Best items. For each factor only those items with a factor weight of at least .1 were included in the computation, as items with lower values than this would not substantially contribute to that factor (Gerstman, 1979). Although percentiles were generated for all closure measures in the first experiment, these were not used for most comparisons in this experiment because of the possible age effect discussed previously.

The Mooney Closure Faces Test consists of incomplete renditions of human faces. A subset of 20 items (out of a total of 40) was selected based on a systematic inclusion of items from all levels of difficulty in the original full set. This selection procedure was designed to preserve ability to discriminate while reducing time required. Examples of these closure stimuli are shown below. Scoring followed criteria provided by Lansdell (1980).

The facial memory task consisted of the same Milner Faces stimuli, Sets One and Two, used in Experiment 1. The facial discrimination task consisted of the Benton and Van

Grown Man or Old ManWomanBoy or Girl

Allen Test of Facial Recognition, Short Form (Levin, Hamsher and Benton, 1975). This examines the ability to recognize faces without involving memory. The Ss match identical front views, front with side views, and front views taken under different lighting conditions. The Short Form calls for 27 separate matches. Scores can be transformed into finely differentiated percentiles, with adjustments for age and education.

The subjective contour task consisted of 15 of such stimuli collected by Hamsher (1979b). These consist of incomplete and/or overlapping figures in which contours of other figures are seen despite the absence of inhomogeneity in the luminosity of these phenomenologically experienced boundaries. Items consist of letters, words and shapes. Scores can be transformed into percentiles collected in a small sample of hospitalized controls. However, as normals typically see all or most of these illusions, these percentiles are very crudely differentiated (i.e., 15/15 = 100th%ile, 14/15 = 48th%ile, 13/15 = 14th%ile, 12/15 = 2nd%ile, 0-11/15 = 0th%ile. An example of such stimuli was shown previously in Figure 3.

Procedure

All Ss were given a simple perceptual screening test consisting of matching stimuli (varying in orientation and/or internal details) from a selection array. Handedness was assessed by the best predictor items from the Annet Scale (1970). They were then given the remaining measures in the following order: Benton Facial Recognition, Closure items from the first experiment, Milner Facial Memory, Mooney Closure Faces Test and Subjective Contour stimuli. All testing was individually administered, and completed in one or two sessions. Total time ranged from 1 to 1-1/2 hours.

The facial recognition task required the Ss to point or call out their choices of target faces from a selection array. For the first 6 faces he/she was told:

See this face, find another just like it down here.

For the remaining 7 target faces he/she was told:

See this face, find three of this person from down here.

Except for the individual administration and recording of the answer by the experimenter, procedure and instructions for the closure tests was the same as in Experiment 1. The facial memory task was also similar to Experiment 1. In order to make the procedure more consistent with that used by Milner, a 90-second delay (rather than the immediate recall

paradigm used previously) was imposed between viewing of Set One and Set Two of the Milner Faces. Instructions were the same as in the first experiment, except for informing the Ss of this delay and asking them not to speak during it.

The Closure Faces Test had no time limit for any given items, but rather a 15-minute limit for total time. This corresponds to half of the time allotted by previous investigators for the whole set (Lansdell, 1968). The Ss were required to sort the pictures into categories by age and sex. They were read the following instructions:

I am going to give you pictures of peoples' faces in which parts have been left out. I would like you to look at these incomplete faces and imagine what the whole face would look like. Your job will be to sort these pictures into one of the six categories I have labeled on the table. The categories are: boy, girl, grown woman, grown man, old woman, old man.

Here is an example of what I would like you to do. This is an incomplete face. If you look at it you may be able to see that it is the face of a young man. You would put it in the pile labeled young man over here. Do you see it as the face of a young man? (If not, then S is shown original picture it comes from.)

OK, now I would like you to sort the rest of these pictures. Start with the ones you find easiest and then come back to the ones you find hard. Sometimes there are two correct answers because the age or sex of the person cannot be accurately judged. So do not be afraid to guess.

You will have 15 minutes. Do the best you can. Any questions?

The subjective contour stimuli had no time limit. The Ss were simply told to outline or name all the shapes they saw in the picture.

Results

Organization of Data

Results are presented in three sections. Section 1 presents data which 1) examine the differential sensitivity of the closure measures from Experiment 1 to the presence of known cortical dysfunction and/or side-of-lesion, 2) the relationship of these measures with concurrent visual-perceptual tasks and several subject variables, and 3) the generation of a final optimally RH-sensitive set of closure items. Section 2 presents data which examine the relationship of the Closure Faces Test with all other closure measures, concurrent measures and subject variables, as well as the differential sensitivity of this test to side-of-lesion. Section 3 presents data which examine evidence for dissociation of visual-perceptual processes within the RH.

Section 1 - In Search of Closure

Table 8 presents descriptive data on the various closure measures for both BD groups, as well as for the normal Ss of Experiment 1. Despite the limitations stemming from age differences between the normal and neurological samples, normal data are provided for exploratory purposes. Two measures of central tendency are given because of the small sample sizes and marked skewness in the BD distributions. For these same reasons, Table 9 presents group contrasts

Table 8

Descriptive Statistics for Performance of Normal, Left
and Right Brain-Damaged Groups on All Closure Measures

		NORMALS (N=70)			LEFT BD (N=11)			RIGHT BD (N = 12)		
		\bar{x}	Median	S.D.	\bar{x}	Median	S.D.	\bar{x}	Median	S.D.
Extant Tests	Street Test	7.13	7.03	1.97	6.27	5.25	2.80	6.41	6.17	2.15
	Street U Test	5.49	5.70	2.13	3.00	2.36	2.10	3.33	3.00	1.50
	Mooney Test	5.48	5.32	2.15	4.09	3.75	2.63	3.50	3.17	2.20
	E.T.S. Test	8.84	8.50	3.99	6.46	8.00	4.78	5.75	4.50	3.57
	Total	25.93	26.17	8.32	18.82	22.00	10.43	18.00	17.50	8.30
New Groupings	Sum Best	5.29	4.50	3.87	4.55	4.25	3.75	3.42	2.83	3.15
	Best Factor 1	.31	.16	.46	.19	.00	.45	.19	.00	.44
	Best Factor 2	.34	.26	.47	.18	.00	.29	.05	.00	.23
	Best Factor 3	.28	.16	.45	.50	.47	.38	.24	.24	.32
	Best Factor 4	.14	.0	.42	.22	.11	.34	.01	.00	.27
	Best Factor 5	.31	.26	.46	.23	.02	.36	.35	.34	.37
	Best Factor 6	.11	.07	.49	.01	.00	.44	.18	.18	.35

Table 9
Group Comparisons (Mann-Whitney U Test)
on All Closure Measures

		Normals vs. Lefts		Normals vs. Rights		Lefts vs. Rights	
		U	P	U	P	U	P
Extant Tests	Street Test	309.5	NS	332.0	NS	60.0	NS
	Street U Test	157.5	.002	169.5	.001	54.5	NS
	Mooney Test	260.5	.08	187.5	.002	58.0	NS
	E.T.S. Test	276.0	NS	234.0	.01	59.0	NS
	Total	240.0	.05	190.0	.003	60.5	NS
New Groupings	Sum Best	349.5	NS	293.5	.10	52.5	NS
	Best Factor 1	317.0	NS	333.5	NS	64.0	NS
	Best Factor 2	295.0	NS	261.5	.04	53.5	NS
	Best Factor 3	262.5	.09	417.0	NS	36.5	.06
	Best Factor 4	306.5	NS	335.0	NS	39.5	.10
	Best Factor 5	344.0	NS	398.0	NS	50.0	NS
	Best Factor 6	336.5	NS	372.0	NS	49.0	NS

nonparametrically. It was anticipated that RBDs should do worse than any other group, if a given closure measure was in fact an RH task. This a priori prediction permits one-tailed probabilities for all RBD comparisons.

The above tables indicate that normals perform better than both BD groups on two of the four extant closure tests, as well as on Total. Conversely, the two BD groups are not distinguishable on these measures. In contrast, for Sum Best and its factors, normals never perform significantly better than LBDs, and in fact show a trend towards poorer performance on Best Factor 3. Normals do perform better than RBDs on Best Factor 2, and show a trend on Sum Best. That trend is actually significant with a one-tailed criterion (i.e., $P = .05$), which is permitted for all RBD comparisons as previously described. Most importantly, the LBDs exceed the RBDs on Best Factors 3 and 4, both effects likewise significant with one-tailed probabilities (i.e., $P = .03$ and $.05$ respectively). They also do better on Sum Best as indicated by the medians in Table 9, but the floor effects on this measure discussed earlier may have prevented attainment of significance.

Table 10 presents descriptive data on the concurrent visual-perceptual measures for the LBD and RBD samples, and corresponding group comparisons. Only eight out of eleven LBD Ss, and ten out of twelve RBD Ss were administered the subjective contour stimuli owing to their receipt late in

Table 10

Descriptive Statistics and Group Comparisons of Performance
on Concurrent Visual-perceptual Measures in
Left- and Right-side Lesioned Subjects

	LEFT BD				RIGHT BD				U	P
	N	X	Median	S.D.	N	X	Median	S.D.		
Subjective Contour %	8	65.5	93	29.9	10	79.8	93	18.4	30.0	NS
Benton Faces %	11	59.7	85	38.0	12	44.2	24	40.8	50.0	NS
Milner Faces %	10	73.9	79	12.0	12	74.8	79	14.5	55.0	NS

the study. However, essentially all of the neurological sample was administered the Benton Facial Discrimination Test (Benton Faces) and Milner facial memory task (Milner Faces). Although no group comparisons were significant, median performance on Benton Faces showed the predicted pattern of lower performance for the RBD sample (i.e., 24th versus 85th%ile for RBD and LBD Ss respectively). Further, the distribution of performance on this measure within the RBD group showed a striking bimodal split (i.e., 6 Ss fell into the 15th%ile or lower range, and 5 Ss fell into the 77th%ile or higher range). Both of the remaining concurrent measures showed no difference in their respective median performances for either group, but had different absolute accuracy levels. For the subjective contour measure the median fell in extremely high accuracy levels (i.e., 93% correct for both BD groups), hence creating a ceiling effect for this measure. The Milner Faces measure, in contrast, yielded low median performance for both groups (i.e., 79% correct).

For both BD groups, Table 11 shows the intercorrelations of all twelve closure measures (i.e., four extant tests, Total, Sum Best and six Best Factors) with the three concurrent measures, and the correlation of all of these visual-perceptual measures with subject variables. A nonparametric correlation is used, given the previously described small N and skewed distributions. The findings will be examined in the order just cited.

Table 11

Spearman Intercorrelation Matrices of Age, Sex, Extent of Lesion, Concurrent Visual-perceptual Measures, and All Closure Measures for Left and Right Brain-damaged Subjects

	RIGHT BD						LEFT BD						
	Subject Variables			Concurrent Measures			Subject Variables			Concurrent Measures			
	Age	Sex	Extent	Subjective Contours %	Benton Faces %	Milner Faces %	Age	Sex	Extent	Subjective Contours %	Benton Faces %	Milner Faces %	
Age	-	-	-	-.50	.09	.23	Age	-	-	-.92***	-.22	.12	
Sex	-	-	-	-.27	0	.11	Sex	-	-	-.27	-.47	-.04	
Extent	-	-	-	-.33	-.35	-.41	Extent	-	-	-.60	-.28	.18	
Street	-.53*	.03	.11	.47	.01	.21	Street	-.58*	-.61*	-.60*	.68*	.10	-.06
Street U	-.51*	.05	.56*	.11	-.59*	-.21	Street U	-.66**	-.80**	-.61*	.64*	.29	.26
Mooney	-.40	-.13	.21	.33	-.52*	-.06	Mooney	-.57*	-.58*	-.59*	.57	.17	.14
E.T.S.	-.56*	-.03	.12	.69*	.901	.25	E.T.S.	-.71**	-.24	-.14	.72*	.29	.01
Total	-.54*	-.05	.28	.51	-.14	.19	Total	-.69**	-.58*	-.48	.72*	.24	.17
Sum Best	-.56*	-.18	.45	.13	-.60*	-.06	Sum Best	-.72**	-.50	-.36	.80**	.31	-.07
Best Factor 1	-.20	-.10	-.06	.21	-.06	-.10	Best Factor 1	-.61*	-.35	-.44	.21	-.29	-.18
Best Factor 2	-.24	.39	.13	.31	-.36	.05	Best Factor 2	-.17	0	-.02	.04	.13	.46
Best Factor 3	-.29	-.46	.21	-.28	-.07	.15	Best Factor 3	-.46	-.26	-.16	.77**	.39	.32
Best Factor 4	-.10	.21	-.01	.42	-.02	.08	Best Factor 4	-.69**	-.47	-.26	.65**	.55*	0
Best Factor 5	-.16	-.36	.44	-.40	-.21	-.24	Best Factor 5	.01	-.33	-.11	.02	.09	-.34
Best Factor 6	-.08	.21	.46	-.38	-.86***	-.37	Best Factor 6	.45	.06	-.06	.55	.10	.47

Performance on the subjective contour stimuli showed a significant positive correlation with seven of the twelve closure measures for the LBDs (range $r = .64$ to $.80$). For the RBDs, in contrast, performance on subjective contours correlated significantly with only one closure measure ($r = .69$). Performance on Benton Faces showed a significant positive correlation with only one of the twelve closure measures for the LBDs ($r = .55$). For the RBD group, in contrast, four of the twelve closure measures showed a significant negative correlation with Benton Faces (range $r = -.52$ to $-.86$), and there was a consistent negative relationship between most of the remaining closure measures and this task. Performance on Milner Faces did not significantly relate to any closure measure, in either group.

Subject variables correlated significantly with only the closure measures and subjective contour task. Of the three subject variables (age, sex and extent of lesion), age correlated significantly with more measures than any other subject variable. In the LBD group, age showed a significant negative relationship with eight of the twelve closure measures (range $r = -.57$ to $-.72$). It is observed that two of the three closure measures which showed either clear or implicit lateral differences in Tables 8 and 9 are included among these (i.e., Sum Best and Best Factor 4). Age also showed an even more powerful negative relationship with subjective contour performance in this group ($r = -.92$),

accounting for almost all of the variance (i.e., 85%). In the RBD group fewer closure measures showed the negative correlation with age (i.e., five out of twelve), and the inverse relationship was generally less powerful (range $r = -.54$ to $-.56$). This group also showed a negative correlation with age for subjective contour performance, although it was not significant.

Sex and extent of lesion correlated significantly with only the extant closure tests and Total. Most typically only the LBD performance was related to these variables. Three out of four extant closure tests and Total showed an advantage for males in the LBD group (negative $r =$ Male on table). Extent of lesion showed a significant negative correlation with three out of four extant tests in this same group (range $r = -.59$ to $-.61$), and these Ss showed a consistent inverse relationship with extent of lesion for the remaining closure measures. In contrast, for the RBD group only one closure measure showed a significant correlation with extent of lesion, and this was a positive relationship ($r = .56$). Further, there was no general direction for the relationship between this variable and the remaining closure measures in this group. The RBDs also showed no significant correlations with sex and any closure measure.

Findings with the various closure measures (Tables 8 and 9) indicate that the statistically generated new closure groupings are less obscured by the undefined 'noise' in

extant tests and Total. Medians for the Sum Best measure suggested that, despite being composed of multiple orthogonal dimensions, it appeared more sensitive to RH dysfunction than any extant test or even the Total closure measure from which it was derived. More importantly, the differing patterns from the Best Factors, particularly 3 and 4, indicate that something fairly discrete within both extant closure tests and Sum Best is maximally sensitive to RH processing, and/or performed better by LBDs than normals. However given the methodological caveats inherent in these measures discussed previously, it is not clear whether findings discerned with them reflect effects of a particular factor, or effects of some of the items within a factor. Characterization of the underlying perceptual demand (or demands) which predominate in these factors is thus necessary.

Findings with the interrelationship of the various visual-perceptual tasks and subject variables (Table 11) suggest that the underlying perceptual demand may primarily consist of the ability to appreciate subjective contour illusions. Of the concurrent measures, only the subjective contour task had a consistently positive (and pervasive) relationship with closure measures. This was however primarily restricted to the LBD group, suggesting that the ability to appreciate cues for such illusions plays an important role in their closure test performance. The

findings also indicate that for this group, age is a powerful determinant of performance on only the subjective contour and closure measures, providing a further suggestion that there is a commonality between subjective contour illusions and perception of some closure stimuli. In contrast, for the RBDs, subjective contour performance was seldom significantly related to the closure measures, and side of their lesion seemed more important than any other subjective variable in performance on either type of measure. This suggests that the RBDs use other mechanisms in their closure test performance. The general absence of a relationship between the two types of visual-perceptual tasks in the RBD group may reflect an inability of these Ss to perceive such illusions when present in closure stimuli. In this regard it is noteworthy that for the LBD group, all closure measures which previously demonstrated lateral differences (i.e., Best Factors 3 and 4, and possibly Sum Best) shared substantial amounts of their variance with subjective contour performance (range shared variance = 42-46%).

The evidence that appreciation of subjective contours is the underlying perceptual demand responsible for lateral differences found with closure tests is, admittedly, indirect. Additionally, the absence of a demonstrated lateral difference for the subjective contour task itself (Table 10) weakens the inference. However the described ceiling effect with

subjective contour stimuli may have, in part, masked any lateral differences which would have surfaced with a larger sample. In order to further test the hypothesis, the ancillary statistical technique discussed in Experiment 1 was used. For each BD group, all 55 closure items were intercorrelated with overall subjective contour performance. A final subset of eight closure items was isolated, which consisted of only those items sharing better than half of their variance with performance on this measure in the LBD group, and which did not show a significant contradictory relationship in the RBD group. In this manner a group of more homogeneous closure items was created, which had a substantial amount of its variance defined by the criterion index of subjective contours. This group was termed Subjective-Contour Closure Items (SC Items).

Table 12 shows the correlation of each of these SC Items with subjective contour performance, for each BD group. For the LBDs, although the minimum criteria for selection was 50% shared variance, most of these SC Items shared better than 75% with the concurrent measure. For the RBDs, two of these items were never correctly identified and no coefficient could be calculated. Most of the remaining items showed a positive relationship with the subjective contour index, and one was even significant. Figure 6 shows the SC Items; these include three Best discriminator items.

A final consideration prior to reexamining the

Table 12

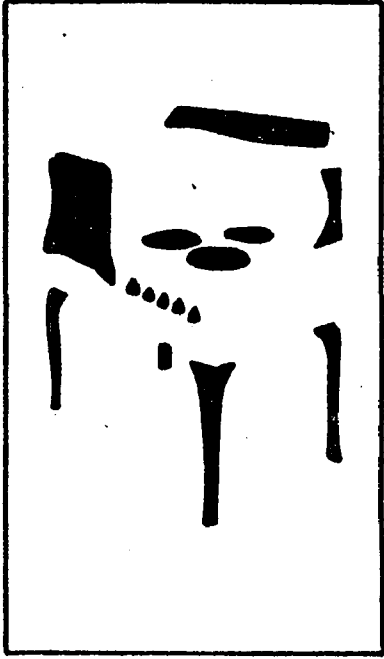
Spearman Correlation Coefficients of Subjective
 Contour Closure Items with Subjective Contour %
 Correct, for Left and Right Brain-damaged
 Subjects (N=11 and 12 respectively)

	S4	S8	S18	ETS37	ETS39	ETS41	ETS51	ETS53
Left BD	.88**	.88*	.88**	.88**	.88**	.76**	.74**	.88*
Right BD	.32	-	-.11	.50	.75**	.18	.54	-

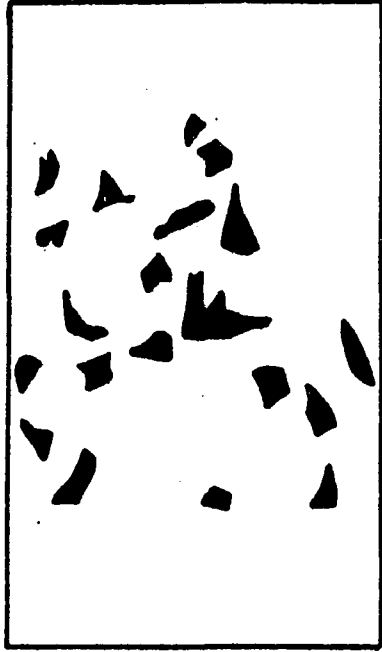
Figure 6

**Items Relating Highly with
Subjective Contour Illusions**

S4



S8



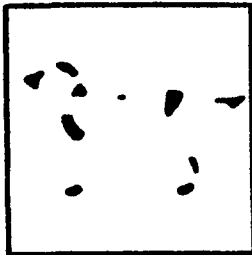
S18



ETS37



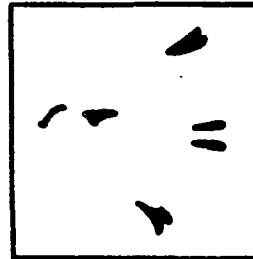
ETS39



ETS41



ETS51



ETS53



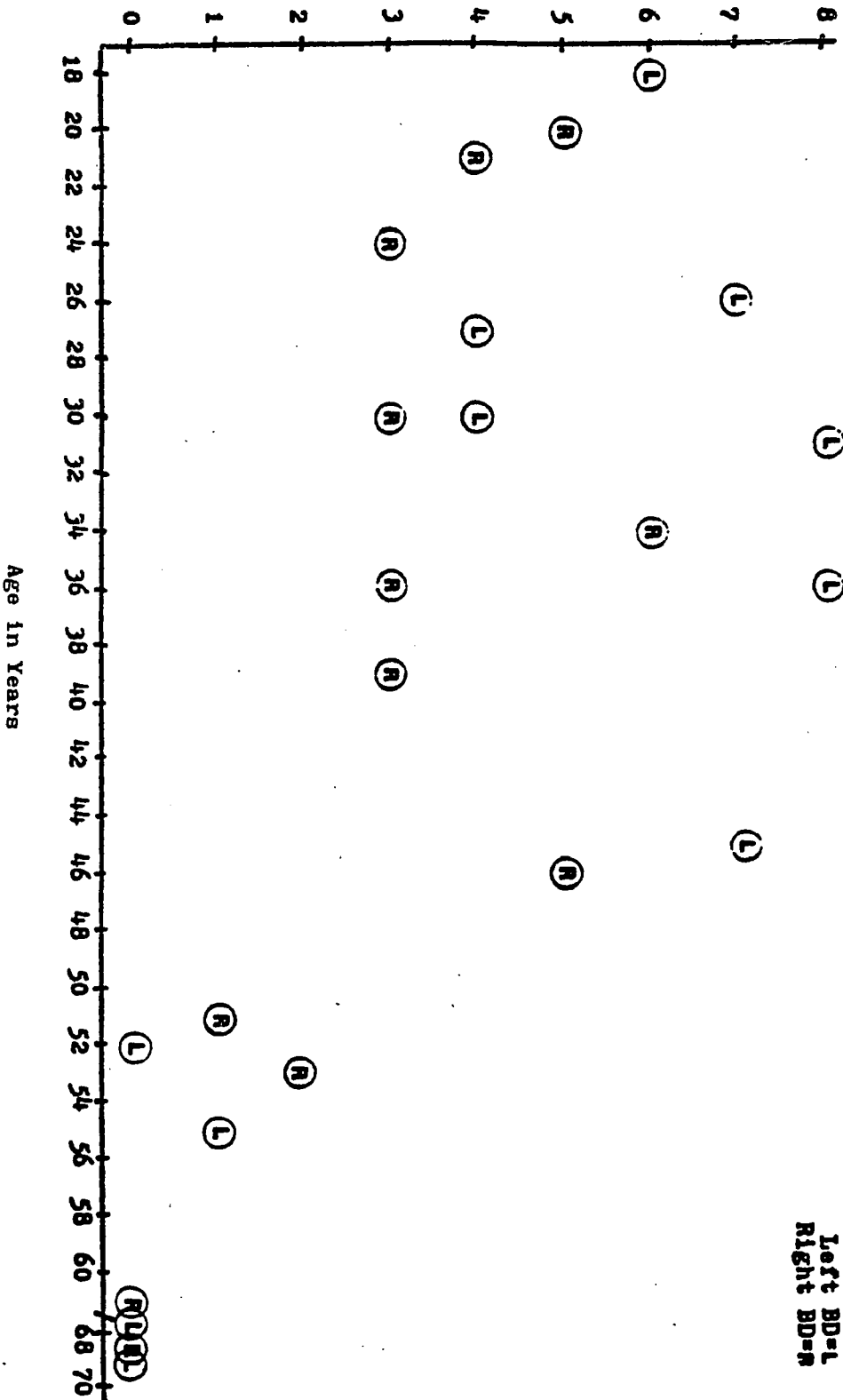
importance of subjective contours for the lateral effect of closure tests was the impact of age. Age was shown to account for the bulk of the variance on this criterion measure in the LBDs, and showed a similar but weaker effect for the RBDs. It was therefore possible that too little residual variance would remain the SC Items for a lateral difference to emerge. If subjective contours were in fact a major underlying perceptual demand in these measures, then it was necessary to circumvent the limitations imposed by age-related variance in this small sample. A scatterplot was used to assess if there were significant deviations from linearity beyond any age point.

Figure 7 shows this scattergram of performance on the Sum SC Items as a function of age, for both BD groups. In both BD groups performance dropped sharply for all Ss over 50 years, although this is stronger for the LBDs. It is also observed that the LBDs younger than 50 generally do better than the corresponding RBDs. Essentially the same proportion (and exactly the same number) of Ss fell into the older-than-50 range for both BD groups. These findings indicated that a critical age range could be isolated for this measure, beyond which performance appears relatively unrelated to side-of-lesion. The Ss in either group who fell into this age range could hence be excluded from further comparisons, as their performance would reflect this subject variable more than whether they are RBD or LBD. The equal

Figure 7

**Scattergram of Performance on Subjective Contour
Closure Items as a Function of Age, for Left and
Right Brain-damaged Subjects**

Number of Correct Subjective Contour Closure Items



distributions of RBDs and LBDs over 50, would help preserve the relative sizes of the two groups.

Table 13 presents descriptive data on the Sum SC Item closure measure, in Ss younger than 50, for both BD groups and the normal Ss of Experiment 1. Table 14 presents group contrasts, again nonparametrically. These tables indicate that the LBD group performs better than both the RBDs and the normals. The normals show a trend towards better performance than the RBDs, which is significant with the permitted one-tailed criterion.

Given the above findings, several additional analyses regarding age-related variance in closure performance were performed, for both the BD and the normal sample.

Table 15 shows nonparametric contrasts of the two BD groups on all closure measures, for only Ss younger than 50. In all cases where differences are significant, the RBDs showed the predicted lower performance. Only the three measures which were most sensitive to RH dysfunction on Tables 8 and 9 (i.e., Sum Best, Best Factors 3 and 4) attained significance, in the case of Sum Best this only being evident with the permitted one-tailed criterion (i.e., $P = .04$). For all three, the P values were lower than those yielded with previous comparisons of the total BD sample. This suggests more powerful effects despite the smaller N , once age variance was removed. It is also noteworthy that both E.T.S. and Total approached a trend (i.e., $P = .12$ and

Table 13

Descriptive Statistics of Performance of Normals
 Left- and Right-side Lesioned Subjects,
 Under 50 Years, on Sum SC Items

	Normals (N=63)			LBD (N=7)			RBD (N=8)		
	\bar{x}	Median	S.D.	\bar{x}	Median	S.D.	\bar{x}	Median	S.D.
Sum SC Items	4.85	4.97	1.56	6.29	6.75	1.70	4.0	3.50	1.20

Table 14

Group Comparisons (Mann-Whitney U Test)
on Sum SC Items, for all Subjects
Younger than 50 Years

Normals vs. LBD		Normals vs. RBD		LBD vs. RBD	
U	P	U	P	U	P
129.0	.04	175.5	.09	7.5	.02

Table 15

Group Contrasts (Mann-Whitney U Test) on All
 Closure Measure for Brain-damaged Subjects
 Younger than 50 (N=15)

MEASURE	U	P
Street	24.5	NS
Street U	25.5	NS
Mooney	18.5	NS
E.T.S.	14.0	NS
Total	15.5	NS
Sum Best	12.5	.07
Best Factor 1	27.5	NS
Best Factor 2	24.0	NS
Best Factor 3	5.0	.008
Best Factor 4	10.5	.04
Best Factor 5	24.0	NS
Best Factor 6	23.0	NS

.15 respectively). For the LBDs, these latter measures as well as Sum Best and Best Factors 3 and 4 all shared the highest correlations with the subjective contour task in Table 11 (range $r = .65$ to $.80$).

Additional analyses of the normal data were performed which attempted to correct for the skewed age distribution in that sample. These are described in Appendix B (Figures A and B, Table C), but the major finding is reported here. A similar critical age range was isolated for performance on several closure measures, although the absolutely low number of older Ss made it impossible to specify that range more precisely than between 36 and 57. This supports the existence of a critical age range as derived from the BD samples, and suggests that the negative impact of age in normal closure performance reflects the subjective contour demands of these measures.

Section 2 - Closure Faces Test

For both BD groups, Table 16 shows the intercorrelation of the Closure Faces Test with all closure measures and the three concurrent visual-perceptual measures, as well as with the subject variables. Findings will be described in the order just cited.

The Closure Faces Test (Closure Faces) shared variance with many closure measures for both BD groups, although this

Table 16

Spearman Correlation Matrices of Subject Variables,
 Concurrent Visual-perceptual Measures and All
 Closure Measures with the Closure Faces Test,
 for Both Neurological Groups

LBD (N=11)				RBD (N = 12)			
	Closure Faces %		Closure Faces %		Closure Faces %		Closure Faces %
Age	-.85***	Street	.53*	Age	-.23	Street	.55
Sex	-.52*	Street U	.67**	Sex	-.08	Street U	.63**
Extent	-.17	Mooney	.62*	Extent	.25	Mooney	.43
Subjective Contour %	.64*	E.T.S.	.83***	Subjective Contour %	.15	E.T.S.	.27
Benton Faces %ile	.58*	Total	.77**	Benton Faces %ile	-.40	Total	.51*
Milner Faces %ile	.08	Sum Best	.80***	Milner Faces %ile	.25	Sum Best	.60**
		Best Factor 1	.41			Best Factor 1	-.13
		Best Factor 2	.35			Best Factor 2	.19
		Best Factor 3	.62*			Best Factor 3	.46
		Best Factor 4	.82***			Best Factor 4	.29
		Best Factor 5	-.02			Best Factor 5	.06
		Best Factor 6	-.35			Best Factor 6	.46
		Sum SC Items	.63*			Sum SC Items	.38

was more consistent for the LBDs. In the LBD group it correlated significantly with nine of the thirteen closure measures (range $r = .53$ to $.83$). In the RBD group there was the same general positive relationship. However, only four of the thirteen closure measures showed a significant relationship and correlation coefficients were typically lower (range $r = .51$ to $.63$). It is noteworthy that for both BD groups, those measures which best tapped the shared aspects of the various other closure tests (i.e., Total and Sum Best) showed a significant relationship with Closure Faces. For the LBDs, however, the shared variance was higher than for the RBDs (59-64% versus 26-36% respectively). In contrast, the Sum SC Item measure did relate significantly with Closure Faces for the LBDs but not for the RBDs.

Concurrent measures showed patterns of relationship with Closure Faces which were often consistent with their relationship to many other closure measures described previously (Table 11). The similarity was best for the subjective contour and Milner Faces measures. The subjective contour task related significantly for the LBDs ($r = .64$), but did not for the RBDs. Milner Faces did not relate with Closure Faces for either group. In contrast, Benton Faces showed slightly different patterns of relationship with this closure measure than it did previously. For the LBDs, while it had shown essentially no relationship with other closure measures, it was significantly related with Closure Faces

($r = .51$). In contrast for the RBDs it showed a negative, although insignificant, correlation which was consistent with previous findings for the other closure measures.

Subject variables also showed patterns consistent with previous analyses. For the LBD group, age showed a powerful inverse relationship with Closure Faces ($r = -.85$) and an advantage for males. Extent of lesion showed a tendency towards an inverse relationship, similar to the pattern shown for this variable earlier, although it was not significant. For the RBDs, no subject variable correlated significantly with Closure Faces.

Table 17 presents descriptive data and group contrasts for Closure Faces. It is observed that although median performance of the LBDs is slightly higher than the RBDs, there is no significant difference between the two BD groups. It is noteworthy that when the BD contrasts were again restricted to only Ss younger than 50, the LBDs' performance was in fact significantly better (i.e., $P = .04$, not tabled).

Section 3 - Evidence for Dissociation of Visual-Perceptual Processes Within the Right Hemisphere

Table 11 had shown that the inverse relationship between some closure measures and some aspects of facial tasks, hypothesized in Experiment 1, did exist. It occurred between Benton Faces, rather than Milner Faces, and Sum Best as well as Best Factor 6. Further analysis (not tabled) also indicated

Table 17

Descriptive Statistics and Group Comparisons of
Closure Faces Test, in Neurological Samples

LBD (N=11)			RBD (N=12)			Mann-Whitney	
<u>\bar{X}</u>	<u>Median</u>	<u>SD</u>	<u>\bar{X}</u>	<u>Median</u>	<u>SD</u>	<u>U</u>	<u>P</u>
70.9	78.8	23.8	70.0	70.0	16.1	57.0	NS

that a similar inverse relationship existed between the Sum SC Item closure measure and Benton Faces. Table 18 presents performance on Sum Best, Sum SC Item and the inversely related Benton Faces, for each RBD patient under 50 years. Clinical characteristics are also provided. For purposes of comparison, performance on all measures is presented in the form of percentiles. Percentiles for the closure measures were generated from the normal data base. The first four cases correspond to Ss who fell in the low ranges of the bimodal split previously described for Benton Faces. The second four cases correspond to Ss who fell in the high ranges of this split. Spearman correlation coefficients for Benton Faces with each closure measure are given underneath the table.

Despite the small number of Ss, the correlations are still significant. The inverse relationship is stronger with Sum Best than with Sum SC Item (i.e., $r = -.76$ and $-.63$ respectively). Level of performance on both closure measures corresponds fairly well in most cases, although the Sum SC Item measure is lower for most RBDs. This is consistent with the greater sensitivity to right BD of this measure. Six of the eight Ss showed average or better performance on one type of measure and borderline or defective performance on the other, suggesting a double dissociation. The remaining two Ss showed a tendency towards low performance on both types of measures, although Benton Faces was

Table 18

Description of Performance on Inversely Related Perceptual
Tasks, and Clinical Characteristics of Individual
Right-side Lesioned Subjects (Under 50 Years)

S#	Age	Sex	Lesion Locus	Lesion Extent	Benton Faces %ile	Sum Best %ile	Sum SC Items %ile
6	30	M	Frontal	3	8	33	13
8	21	F	Frontal (+ Rolandic)	4	8	44	27
5	34	F	Rolandic	2	2	93	77
3	20	M	Lateral Temporal	4	15	60	51
10	24	M	Parieto- Occipital	3	97	23	13
1	39	F	Medial Temporal	2	97	23	13
9	36	F	Medial Temporal	1	90	14	13
12	46	F	Medial Temporal	3	85	44 ¹	51 ¹

SPEARMAN CORRELATION COEFFICIENTS (N=8): Benton Faces with Sum Best -.76**
Benton Faces with Sum SC Items -.63*

¹S had a family history of left-handedness.

relatively lower.

Performance patterns appear unrelated to any clinical characteristic except for locus of lesion. The two Ss with frontal lesions (Ss #6 and #8) appear depressed on all perceptual measures (i.e., 8th%ile for Benton Faces, 33rd and 44th%ile for Sum Best, 13th and 27th%ile for Sum SC Item respectively). All three Ss with medial-temporal lesions show superior performance on Benton Faces (i.e., 97th, 90th and 85th%ile respectively), while their performance on the two closure measures is considerably lower. Two of the three Ss show borderline or defective range closure performance (i.e., 23rd and 14th%ile for Sum Best, 13th%ile on Sum SC Item for Ss #1 and #9 respectively). The other medial-temporal patient (S #12) shows a similar split in performance, but is still well within normal limits on both closure measures (i.e., 44th and 51st%ile for Sum Best and Sum SC Item respectively). The remaining Ss all show the dissociation between measures, but no patterns for loci are evident. It is, however, interesting to observe that the other patient with a temporal lobe lesion (S #3), in the lateral rather than the medial aspect, was not impaired on closure measures (i.e., 60th and 51st%ile for Sum Best and Sum SC Item respectively) and was borderline defective on Benton Faces (i.e., 15th%ile).

Discussion

The first experiment had demonstrated the multiple sources of variance in closure test performance which stemmed from both test items and subject variables. It further suggested that two visual-perceptual tasks ostensibly carried out by a theoretically uniform RH process may be unrelated. Consequently several questions were raised which required turning to a BD data base for clarification. These concerned the need to 1) reexamine the differential sensitivity of the various closure tests to RH dysfunction and isolate an optimally RH sensitive subset (or subsets) of closure stimuli, 2) evaluate the relationship of the RH sensitive dimensions of these measures with the Gestalt 'closure' concept, and 3) test for the existence of a dissociation between RH visual-perceptual processes.

The second experiment addressed these questions through the use of several closure measures and concurrent RH sensitive visual-perceptual tasks in a BD sample. The twelve closure measures from Experiment 1 (i.e., four extant tests, Total, Sum Best and six Best Factors), as well as one other closure test (i.e., Closure Faces) frequently related to RH dysfunction, were used. Additionally, another closure measure was generated (i.e., Sum SC Items) because of its theoretical relevance for ascribing the 'closure' concept to the RH. The concurrent measures were chosen to either

provide a criterion for 'closure' as described by the Gestalt psychologists (i.e., subjective contour configurations), or to separate out the facial discrimination aspect of facial memory tasks.

Despite differences in mean age and in administration procedures, group contrasts included normal Ss for any closure instrument on which data existed from the first experiment. The two BD groups were not significantly different in the representation of subject variables, nor in their distributions of extent, type and loci of lesions. Hence all group contrasts were based on fairly well matched neurological samples. However, subject variables of sex and age, and the lesion parameter of extent introduce sources of variance unrelated to side-of-lesion, but which may also affect performance. In order to tease out specifically the effects of RH pathology on closure measures, effects of these other sources of variance were separately examined within each group. Initially they were measured, and in the case of age, its effects were subsequently eliminated by systematically dropping Ss in some comparisons.

Reexamination of Empirical Data Base
Relating Closure Tests to
the Right Hemisphere

The differential sensitivity of all closure instruments to lateralized cerebral pathology was compared. For purposes

of this discussion, traditional closure tests will refer to the four extant tests, Total and Closure Faces. Like most other closure tests in existence, these share the fact that they were created to fit the common description of 'incomplete pictures requiring visual synthesis', but without statistical or other definition of their construct validity. New closure tests will refer to the closure measures created in Experiments 1 and 2, namely, Sum Best and Sum SC Items. These share the same verbal description as the traditional closure tests, but additionally share the fact that they were created out of attempts to either assess or define the construct validity of closure measures. In the case of Sum Best, many sources of variance in traditional closure tests were eliminated statistically, yielding a somewhat less heterogeneous closure measure. In the case of Sum SC Items, a criterion measure was used to define the closure construct. Because of several methodological considerations discussed previously, Best Factors were not treated as new closure tests. Instead these were included as exploratory closure measures which might serve to point to the existence of certain patterns not readily evident with the other tests.

The absence of significant differences between the LBD and RBD groups on any of the four extant closure tests and Total, indicates that the lateral effects of these traditional measures are weak. Further, the inconsistent patterns for relative performance levels of the three groups supports the

conclusion, from Experiment 1, that these tests are not interchangeable. Findings of superior performance of normals in comparison to both BD groups for Total and two extant tests suggest that factors unrelated to specifically RH processing may be reflected in these less refined measures. In this regard, these traditional closure tests were the more affected by variables of lesion extent and set.

The Closure Faces Test, unlike the other traditional closure tests, showed a significant lateral difference once age-related variance was removed. The relatively greater sensitivity of this measure to RH pathology, however, may stem from its requiring two different RH processes. For the LBDs, this test showed significant positive correlations with almost all other closure measures, suggesting similarity in processing demands. Despite this shared variance, this was the only closure measure (except for Best Factor #4) which also showed a significant positive correlation with Benton Faces in the LBD group. This overlap with other closure tests combined with the unique relationship with Benton Faces, suggests that it is likely that LBDs process Closure Faces as both a facial discrimination and closure task.

The RBDs showed a less consistent relationship between Closure Faces and other closure measures, and a nonsignificant negative relationship between it and Benton Faces. It should be noted that the negative direction of

the relationship with Benton Faces is consistent with the RBD pattern from other closure measures. These findings suggest that the RBDs process Closure Faces in a manner more consistent with only closure tasks. Consequently it is difficult to ascertain the source of lateral differences yielded by this particular closure measure. They may derive from the underlying RH aspect of closure measures in general, or the facial discrimination aspect of this closure test in particular, or both in combination.

In contrast, the new closure tests yield clearer pictures. Both showed the predicted lower performance by the RBDs, and neither was performed significantly better by the normal Ss than the LBDs. This indicates that these measures were more sensitive to specifically RH disease, and less sensitive to sources of variance associated with LH impairment or general organicity.

It is not surprising that the traditional closure tests yielded so few significant lateral differences in this study with small BD samples. Given all of the multiple sources of variance in these traditional measures, their sensitivity to uniquely RH disease becomes weaker. It would most likely require expanded numbers of Ss to replicate previous findings. This is in fact what has been done in other studies (e.g., 62 RBDs and 69 LBDs by De Renzi et al., 1966; and 33 RBDs and 19 LBDs by Lansdell, 1968). By contrast, this study does demonstrate that when irrelevant sources of variance are

attenuated (as in Sum Best) or when the specifically RH-sensitive aspect of these tests was isolated (as in Sum SC Items), then significant differences can emerge despite small samples.

Underlying Perceptual Process and
Its Relationship to Gestalt
'Closure' Concept

It was hypothesized that in order for the RH effect of closure tests to be ascribed to the Gestalt 'closure' concept, there would have to be a demonstrated relationship between any RH sensitive dimension within these tests and subjective contour illusions. It was not possible to make a direct connection between the closure dimensions which showed lateral differences (i.e., Sum Best and Best Factors 3 and 4) and the concurrent subjective contour task because of 1) inconsistent patterns of interrelationship of the closure measures with subjective contours for the two BD groups, and 2) the absence of significant lateral differences for the subjective contour task itself. The inconsistent pattern of relationship with subjective contours for the two BD groups was inferred to reflect an inability of the RBD group to use such illusions when present in closure stimuli. The absence of a lateral difference for the subjective contour task itself was understood to reflect both an overall ceiling effect for this measure in the

neurological sample, and an overpowering deleterious impact of increasing age (particularly for the LBDs) which presumably accounted for any residual variance. This ceiling effect is not inconsistent with the finding that normal Ss also see such illusions very easily (Coren, 1972). It is, however, inconsistent with Hamsher's (1979) finding of a 35% incidence of impairment among his RBD Ss. As mean age in both his and this study was essentially the same, this discrepancy may be understood as the outgrowth of his use of more stimuli (22 versus 15, respectively), a larger sample (23 RBDs versus 10 RBDs, respectively), and different scoring criteria. He seemingly scored more stringently; counting answers as incorrect which included indications that the S may not have seen the subjective contours in their most compelling form. Specifically, he considered an accurate identification of the shape which would have been created by the subjective contours incorrect if the response identified the real forms in the stimulus array as incomplete (e.g., "incomplete circles" led to 0 score). As there had been no a priori reason to believe that this division was a valid reflection of different phenomenal experience (i.e., hypercritical Ss, or overly concrete Ss may have used similar descriptions even if they saw clear subjective contours), this study scored as correct any indication that the shape defined by such illusion was seen (e.g., the same "incomplete circles" if accompanied by either

verbal name or an outline of the correct subjective shape was counted as correct). However, the described ceiling effect corroborates Hamsher's use of the somewhat arbitrary but more stringent criteria. Given the baseline ease of these figures, it also argues that typical subjective contour configurations need to have some manipulation performed with them in order to more sensitively assess individual differences.

Such a manipulation was achieved through creation of the Sum SC Items closure measure. In order to more directly assess whether the ability to perceive such illusions accounted for the underlying lateralized perceptual process in closure measures, the limitations from the data necessitated a manipulation. The algorithm which had been proposed as an ancillary method of analysis in Experiment 1 was used, and a subset of closure test (SC Items) which interfaced highly with this measure was extracted. Performance on each item shared roughly 75% or more of its variance with performance on this concurrent measure in LBDs, and did not show a significant contradictory relationship for the RBDs. This cluster of stimuli is also the most uniform closure measure thus far, as it has been defined through a relationship with a presumably more uniform criterion measure. Once the critical age for a sharp drop-off in performance was determined, and all Ss beyond this age were eliminated, clear and powerful lateral differences surfaced. These findings

indicate that to the extent that such illusions in fact define the Gestalt 'closure' concept, such a process does indeed account for the RH-sensitivity of closure tests. However, there are indications that alternative explanations for the process behind perception of subjective contour illusions exist.

Although 'closure' and 'completion' (used interchangeably) are still the most common explanations offered for subjective contour illusions (e.g., Rubin, 1921; Kanizsa, 1955 and 1976), Coren (1972) has offered an explanation which does not invoke this concept, which is itself elusive. He noted that the phenomenal reports of observers almost always see the subjective contours as bounding an opaque figure which is in front of other pattern elements. Based on this generation of surfaces stratified in depth, he advanced the hypothesis that the perceptual mechanism giving rise to subjective contours and shapes is the same as the mechanism giving rise to three-dimensional depth perception. He went on to support this position by demonstrating that the monocular depth cues of shading, interposition and texture gradients can all be used to generate such illusions, as well as binocular retinal disparity in the special instance of Julesz (1964) stereograms. He concluded that subjective contour illusions were the result of the central nervous system's creation of three-dimensional planes out of two-dimensional stimulus arrays of elements, in situations where

such a transformation leads to a more compactly and meaningfully coded overall organization. Hence, according to Coren, the observer creates the surface indicated by the depth cues and edges it with subjectively supplied contours to bound it. A logical derivative of this explanation would be that the RH effect of closure tests arises out of mechanisms responsible for the perception of space, rather than purely imaginative processes.

Dissociation of Perceptual Processes
and Possible Structural
Differentiation Within
the Right Hemisphere

It had been observed in Experiment 1 that none of the closure measures used in that study showed a significant positive correlation with the facial memory task. This had led to the hypothesis that more than one type of visual-perceptual process might be mediated by the RH. The absence of lateralizing techniques, and complexity of both the closure measures and the facial memory task had, however, limited conclusions. In order to ascertain whether the absence of relationships reflected the existence of two different RH perceptual processes, rather than the alternative possibility that the closure measures were not requiring RH processing, it was first necessary to isolate the specifically RH sensitive dimension within these tests. As facial memory stimuli incorporate a facial discrimination aspect as well,

it was further proposed that if the inferred dissociation was based on this latter perceptual requirement, disentangling and stressing the facial discrimination factor might heighten the effect. Both of these predictions were supported.

For only the RBDs, a significant inverse correlation occurred between several closure measures and Benton Faces. Best Factor #6 pointed to the existence of such a negative relationship, but did not meet the required overall sensitivity to RH dysfunction. However, the two most refined closure measures created in this study, namely Sum Best and Sum SC Items, also showed the significant inverse relationship with Benton Faces, and both did meet the requirement of sensitivity to RH pathology. In addition, most remaining closure measures showed a consistent, even if nonsignificant, negative relationship with Benton Faces. Conversely, Milner Faces showed no significant or consistent patterns with closure measures, indicating that facial discrimination rather than memory for nonverbal material, is the relevant dimension within the original facial memory task.

The inverse correlation suggests there might be different groups within the RH, those who are impaired on facial discrimination but not on closure, and those who are impaired on closure but not on facial discrimination. To the extent that a site-by-task relationship can be demonstrated for these postulated groups, this would constitute a "double dissociation of symptoms", which Teuber (1955) has argued is

the strongest evidence that mechanisms underlying performance on two tasks are actually different. Evidence that such site-by-task specificity may exist will be given later in this section. However, even without clear "double dissociation" inferences are possible. The above findings indicate that a processing demand shared by all closure measures, but required most by Sum Best and Sum SC Items, is apparently separate from that required for facial discrimination. Yet both are apparently mediated by the RH.

It should be acknowledged that Benton Faces itself did not show an overall significant lateral difference, although it was in the predicted direction. A possible explanation follows. Facial discrimination stimuli consist of naturally occurring visual constellations. Consequently, their construct validity is less suspect than that of closure measures, which are constructed and based on an ambiguous notion. The existence of some bihemispheric processing demands in facial stimuli, involving linguistic as well as visuoperceptive components, has been demonstrated (Hamsher, Levin, Benton, 1979). But the preponderance of literature, previously cited in the Introduction, has concurred that this requires primarily intact RH abilities. As was the case for the traditional closure measures, it could be argued that an expanded number of Ss might lead to replication of previous findings. This would probably be borne out. Yet such stimuli are less confounded by the irrelevant 'noise' in

closure stimuli, weakening the argument that the measure itself contributes irrelevant sources of variability which an expanded sample would circumvent. An alternative and more powerful explanation derives from the 1) bimodal split in facial discrimination abilities described in the results section, 2) the possible existence of more than one group within the RH as just discussed and 3) the neuroanatomical correlates of the Ss with the inversely related perceptual functions shown in Table 18.

Recall that the two frontal patients seemingly showed impaired performance levels on both types of perceptual tasks. All other patients in the case-by-case analysis demonstrated inverse relationships between types of measures, and neuroanatomical loci of patients showing opposite patterns of performance were non-overlapping. The depression of the frontal patients' performance on both types of measures are difficult to attribute to perception per se. Impaired performance on perceptual tasks in patients with such lesions has been related to their premature and impulsive answers, reflecting the disintegration of systematic analysis and synthesis (Luria, Karpov and Yarbuss, 1966). It is consequently difficult to comment on the absence of dissociation for these Ss. In the remaining patients there are indications of site-by-task specificity, especially for the closure measures. No clear relationship was discernible for locus of lesion in those patients showing impaired facial

discrimination. However, none of these Ss had lesions in medial temporal areas. In contrast, two of the three patients who showed impaired closure performance did have lesions in this region. The other medial temporal lobe patient showed a performance difference between the two types of measures, which was consistent with the pattern of better than average facial discrimination and lowered closure ability, seen in the other medial-temporal patients. This pattern was not as strong on the closure measures for this particular patient, but the attenuated difference may reflect her family history of left-handedness. It has recently been shown that such a family history leads to higher spatial capacities in women (Healy, 1980). Interestingly, one of the measures which was used to assess spatial abilities in that study included the Street Test. It is noteworthy that no LBD patient under 50 years with a medial-temporal lobe lesion showed this pattern, and the one other RBD with temporal lobe involvement, but of the lateral rather than the medial region, was intact on closure and impaired on Benton Faces. This provides additional evidence that closure instruments are most sensitive to specifically medial-temporal regions of the RH, and that this same region is most likely not involved in facial discrimination. Additionally, visual field defects occurred for some Ss on each side of the dissociation, although slightly more frequently for the side in which the medial-temporal patients fell (i.e., 1 out of the 4 with impaired Benton Faces, and

2 out of the 4 with impaired or lower Sum Best and Sum Sc Items). However, as other research has demonstrated that such field defects do not account for closure test deficits (DeRenzi et al., 1966; Newcombe and Russell, 1969), and the role of field defects in facial discrimination is equivocal (DeRenzi et al., 1968; Benton and Van Allen, 1968), this slight difference most likely does not account for the dissociations.

Given the small sample, inferences to a larger population of RH patients are tentative. However, the evidence in this study strongly suggests the existence of structural as well as functional differentiation within the RH. To the extent that circumscribed regions within the RH have been demonstrated to be uninvolved in facial discrimination tasks (i.e., medial-temporal), locus-of-lesion is a powerful source of variance, in addition to side-of-lesion. The small sample size in this study could not circumvent this parameter, and hence was unable to replicate significant lateral differences with Benton Faces.

More importantly, there are theoretical implications which derive from the suggestions of structural specificity within the RH. Findings in this study are consistent with those of Newcombe and Russell (1969) and Fried et al. (1980), who also found differential organization for complex visuo-spatial functions. They are, however, inconsistent with a major theoretical position articulated by Semmes (1968). She

maintained that the RH is characterized by diffuse representations of functions, and saw this as the underlying mechanism which facilitated the multi-modal integration necessary for its superior spatial capacities. Semmes based this conclusion on findings with several tasks in patients with different unilateral lesions. On cutaneous discrimination measures she found deficits resulting from lesions in the left sensorimotor region for the right hand, but from diffuse regions in the RH for the left hand. When testing ipsilateral controls as well, these patterns were repeated, again implying a diffuse representation of somatosensory mechanisms in the RH which is independent of the hand tested. On a more complex spatial orientation task, she again found deficits localized for the LH (i.e., posterior parietal damage). In contrast, the RH again showed no such specific localization, and impaired orientation only occurred with concomitant sensory deficits. This led her to suggest that the type of extensive lesion necessary to produce one deficit in a diffusely organized hemisphere would necessarily disturb sensory functions as well.

Semmes' evidence is persuasive. She may, however, have overgeneralized from her data base. Although she did examine separate regions in both hemispheres, these were crudely differentiated into four categories which were themselves not always mutually exclusive (i.e., nonsensory-motor lesions and sensory-motor lesions; these latter were subdivided into:

precentral gyrus, postcentral gyrus, and/or posterior parietal areas. A patient involving both sensory-motor and nonsensory-motor would be included in the sensory-motor group; patients with overlapping lesions in the sensory-motor group were included in more than one category). This confuses possible specificity. Additionally, the preponderance of her measures involved relatively elementary sensory-motor functions like: sense of passive movement, touch-pressure threshold, two-point discrimination, and point localization. Even among these, the absence of localization with the RH was not equally as strong for all tasks. Finally, she only used one complex task, which she labeled spatial orientation. Given what has been demonstrated in this study, this may not necessarily be what she measured.

As this study has suggested the existence of site-by-task specificity within the RH for complex visual-perceptual functions, and the possible neuroanatomical correlates represent a division between deep and more surface regions of the hemisphere, the studies are not comparable. It may further be the case that both are correct. Diffuse representation of elementary capabilities may in fact define the necessary underlying mechanism responsible for superior RH spatial abilities, but even within such a diffuse context, differentiation can exist for functions which require integration of different elementary sensory-motor information.

Evidence for Inter- and Intrahemispheric Interactions

Recall that the LBDs performed significantly better than both the RBDs and the normals, on the RH mediated Sum SC Items. This finding is consistent with an interpretation of release from inhibition of RH functions, when the normal interference of the LH is disrupted by disease. Levy (1969) has proposed that because of competition between the hemispheres for control of the motor mechanisms for the production of speech, the major hemisphere (usually the LH) has evolved a capacity to inhibit or interfere with the capabilities of the other hemisphere (usually the RH). Levy indirectly supported this theory by demonstrating that sinistrals with presumably bilateral representation of language did less well on performance scales of the Wechsler Adult Intelligence Scale (WAIS) than did dextrals, who presumably had more differentiated hemispheres. The WAIS was used as a measure because it had been shown that the verbal scale reflects major hemisphere abilities and the performance scale reflects what are usually minor hemisphere abilities (Arrigoni and DeRenzi, 1964). Her original evidence can be criticized for blurring the distinctions between inter- and intra-hemispheric processes. However, subsequent investigations with split brain patients (e.g., Levy et al., 1972; Teng and Sperry, 1973) and normals (McKeever and Huling, 1971; McKeever, 1971; Cohen, 1980) have provided

additional evidence for this interference model of hemispheric interactions. There are also several case reports of the return of some language following removal of a diseased LH (Smith, 1966; Zangwell, 1967), suggesting the release of linguistic abilities of the remaining RH which were originally suppressed.

Findings supporting this theory from patients with focal disease have typically dealt with interhemispheric processes as they affect linguistic material. It may be the case that the visual analog has not been previously demonstrable due to the 'noise' in the instruments used to assess RH integrity, as was the case with the traditional closure tests. It may also be the case that either sampling, or more likely that differences in administration procedures, account for the finding. This last caveat refers to the disparities in visual angles resulting from the differences between the group administration of closure tests to normals on a large screen, and the individual tests of BD Ss viewing stimuli in the near visual field. Coren (1972) has incidentally observed that such illusions are more compelling when small visual angles are used, but provides no empirical data. These particular group differences may thus reflect visual angle disparities, rather than differences in levels of processing between the groups. However, since no quantitative evaluation of the strength of this parameter exists, it is possible that the difference between the

normal and the LBD groups represents a real difference rather than a procedural artifact. Replication and control for the effects of visual angle are necessary for more definitive statements.

In addition to this evidence for interhemispheric interactions, this study also suggests the existence of intrahemispheric interactions within the RH. It is recalled that six Ss in Table 18 had inversely related performances on Benton Faces and the two new closure tests, and loci of lesions for the two performance patterns were nonoverlapping.* Among five of these six cases, Ss were impaired on one task while being above average or superior on the other. If these two types of tasks measured independent RH processes, then one would expect essentially average performance on the measure of the intact RH capacity. The almost uniformly high performance levels in the measure of the intact capacity (either facial discrimination or closure, depending on the S) in these cases suggests that the two processes measured by these tasks may be reciprocally related. That is, if one's facial discrimination is impaired, closure ability will be augmented, and vice versa. As discussed for the evidence of interhemispheric disinhibition, this finding may also be a sampling artifact. Replication is necessary for further discussion.

*The remaining two Ss were depressed on both types of perceptual tasks, and shared frontal lobe involvement. These will not be further considered because of the reasons discussed in the previous section.

Summary

It was shown in Experiment 1 that closure tests typically used in RH research may in reality measure much more than they are inferred to be measuring. This occurs despite the fact that all stimuli conform to the same verbal description. It was shown in Experiment 2 that closure tests can be differentiated through the use of statistical procedures, and hence made powerfully sensitive to the presence of RH disease. Further, appreciation of subjective contour illusions was found to be the perceptual process underlying lateral differences found with closure tests. It was seen in both Experiments 1 and 2 that certain subject variables, like age and family history of left-handedness, can have a potent impact on assessment of RH dysfunction. Without careful consideration of these parameters, lateral differences or nuances of RH functioning might have been lost.

Several serendipitous findings emerged through the use of the new closure tests. Experiment 1 suggested that contrary to theory, two different visual-perceptual processes may be mediated by the RH. Experiment 2 confirmed this hypothesis and further suggested, again contrary to theory, that there might be site-by-task specificity within the RH similar to that found for the LH. Finally, a model of interhemispheric interactions was supported, and RH intrahemispheric interaction was suggested.

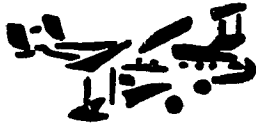
Appendix A

Closure Tests

STREET GESTALT COMPLETION TEST



A



B



S1



S2



S3



S4



S5



S6



S7



S8



S9



S10



S11



S12



S13

STREET FIGURES - UNSTANDARDIZED



SU14



SU15



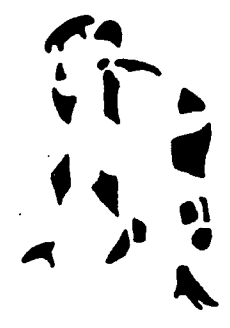
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SU17



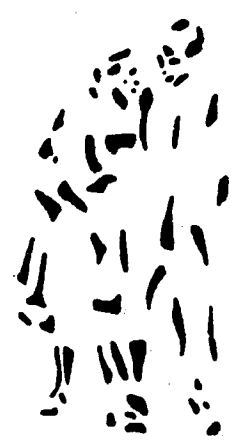
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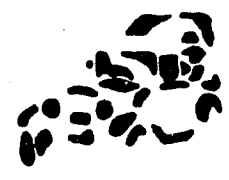
SU19



SU20



SU21



SU22

MOONEY CLOSURE TEST



M23



M24



M25



M26



M27



M28



M29



M30



M31



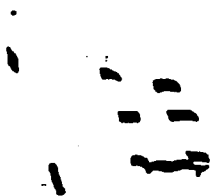
M32



M33

EDUCATIONAL TESTING SERVICE

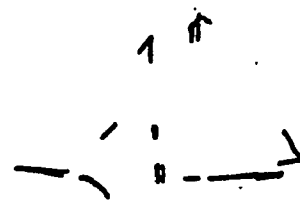
GESTALT COMPLETION TEST



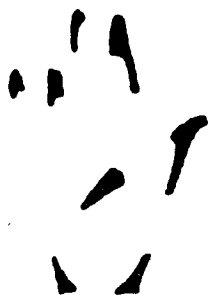
ETS34



ETS35



ETS36



ETS37



ETS38



ETS39



ETS40



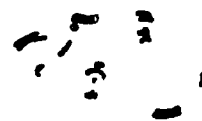
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ETS42

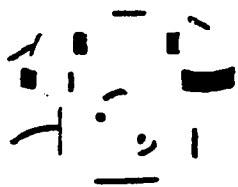


ETS43

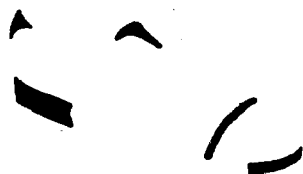


ETS44

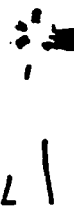
EDUCATIONAL TESTING SERVICE
GESTALT COMPLETION TEST (CONT.)



ETS45



ETS46



ETS47



ETS48



ETS49



ETS50



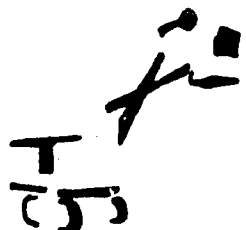
ETS51



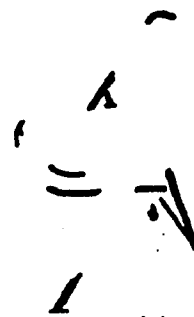
ETS52



ETS53



ETS54



ETS55

KEY TO ITEMS

A	Bust of Man	M29	Airplane
B	Airplane	M30	Child
S1	Dog, Puppy	M31	Dog's Face
S2	Sailboat, Boat	M32	Engine Car, Train
S3	Cat, Pussy	M33	Horse and Rider
S4	Stove	ETS34	Flag
S5	Baby, Child, Boy	ETS35	Hammer Head
S6	Table	ETS36	Boat
S7	Soldier, Man With Pole, Man With Tool	ETS37	Hand or Glove
S8	Horse and Rider, Horse	ETS38	Hen, Chicken
S9	Rabbit	ETS39	Dog
S10	Engine Car, Train	ETS40	Lamp
S11	Child on Tricycle	ETS41	House
S12	Face of Man	ETS42	Cart
S13	Camera Man, Person Kneeling	ETS43	Faucet
SU14	Baseball Player	ETS44	Bicycle
SU15	Dog	ETS45	Telephone
SU16	Tennis Player	ETS46	Shoe
SU17	Couple Dancing	ETS47	Windmill, Weather Vane
SU18	Eagle	ETS48	Boat
SU19	Runner, Sprinter	ETS49	Kite
SU20	Horse and Buggy	ETS50	Archer
SU21	Couple, Two People	ETS51	Bird
SU22	Car	ETS52	Skate
M23	Horse Head, Horse	ETS53	Cat
M24	Man's Profile	ETS54	Steam Shovel, Crane, Tractor
M25	Telephone	ETS55	Folding Chair
M26	Head of Person		
M27	Ship		
M28	Horse and Rider		

Appendix B

Additional Analyses from Experiment 1

Further Analysis of Best Discriminator Items

The Chi square procedure provided a group of items which most stably discriminated overall performance (Best Discriminators), as described in the composite measure of Total. This set consequently also provided items which may have incorporated the most relevant common dimensions from Total, and hence the most relevant common dimensions in the shared variance among all closure tests. Further, there were only 16 variables in relationship to the 70Ss; removing one of the possible sources of artifact in a factor analysis of binary data described previously (i.e., subject to variable ratio being too low). The fairly homogeneous variance of the items in this group minimized the other source of artifact (i.e., extreme values having too much power). An additional factor analysis of these 16 target items was performed. Using a traditional minimum eigenvalue criterion of 1, a six-factor Principal Components solution was derived accounting for 70% of the variance.

Table A shows the varimax loadings for items on each of these Best Discriminator factors (Best Factors). For each item, mean accuracy and standard deviations are also provided. Like the previous factor analysis of all or most items (i.e., factor analyses of closure items), some items had a factorial complexity of greater than 1. However most (i.e., 12/16 items) loaded on predominantly one factor.

Table A
 Varimax Loadings of 16 Best
 Discriminator Items on the
 Best Factors (N=70)

Item #	Best Factor 1	Best Factor 2	Best Factor 3	Best Factor 4	Best Factor 5	Best Factor 6
S 8	.21	-.01	.42	.69	.14	.03
S 9	.63	-.26	.18	.26	.33	.22
S 11	.09	.11	-.11	.84	.00	.12
S 12	.13	.18	.03	.16	.79	-.04
S 14	.14	.70	-.11	-.02	.46	.02
S 15	.07	.05	.40	-.26	.53	.26
S 18	.25	.29	-.09	.21	.10	.73
M 23	.72	.25	.13	-.17	-.34	.07
M 25	.77	.19	.05	.16	.13	.01
ETS 40	.45	.33	-.02	.05	.06	-.57
ETS 45	.76	.21	-.08	.18	.25	-.07
ETS 46	.46	.37	.35	.27	-.07	.34
ETS 48	.02	.25	.69	.01	.16	.20
ETS 52	.24	.75	.34	.00	.13	.17
ETS 53	.05	.02	.78	.10	-.05	-.27
ETS 54	.24	.62	.31	.39	-.13	-.05

The relationship of these factors with other closure measures was examined. Table B shows the correlations of the six Best Factors with the four extant closure tests and Total. All Best Factors except Best Factor 6 correlate significantly with Total, suggesting that these measure a significant portion of the variance in this composite measure, despite the limited number of items they derive from. Except for Best Factor 1 which correlates significantly with all closure tests, all other factors correlate significantly with some tests and not others. As the factors are orthogonal, dimensions must be considered unique for each factor. Hence the Best Factors may be differentially sensitive to unique dimensions present in only (or primarily) some tests. These findings suggest a 'thematicity' which may be shared by some tests and not others, which contribute differentially to overall performance demands.

In order to ascertain the relative independent contributions of the different closure tests to each Best Factor, each of them was subjected to a multiple regression with the four closure tests as competitive predictors, and under the constraint that only statistically significant improvements would be permitted. In the case of Best Factors 1, 3 and 5, the regressions ran but a single step, the entering variables being underlined in Table B. For the remaining Best Factors, the regressions ran two steps, the primary enterer being shown in Table B by a solid underline,

Table B

Correlation of Best Factors 1-6
with Extant Closure Tests and
Total Performance (N=70)

	Street	Street U	Mooney	E.T.S.	Total
Best Factor 1	.51***	.29**	.60***	.38***	.53***
Best Factor 2	.11	<u>.52***</u>	.29***	<u>-.49***</u>	.47***
Best Factor 3	.26**	.15	.26*	<u>.54***</u>	.43***
Best Factor 4	<u>.48***</u>	.04	.13	.20*	.25*
Best Factor 5	.36***	<u>.41***</u>	.07	.13	.27*
Best Factor 6	.08	<u>.27**</u>	.03	<u>-.18</u>	.01

* = .05
** = .01
*** = .001

and the secondary enterer by a dashed line. The bulk of the variance accounted for in the regression solutions of the first four factors came from the first variable in each, with cumulative proportions of variance ranging from 23% to 35%.

Best Factor 1 was substantially predicted by performance on the Mooney Test (35% out of 35% accounted for), Best Factor 2 was primarily predicted by the Street U Test (28% out of 33% accounted for), Best Factor 3 was only predicted by the E.T.S. Test (29% out of a total of 29% accounted for) and Best Factor 4 was primarily predicted by the Street Test (23% out of 28% accounted for). Best Factors 5 and 6 were less well predicted by performance in the tests. Best Factor 5 seemingly tapped a residual dimension of the Street U Test since its 16% contribution here is less than its 28% contribution to Best Factor 2. Best Factor 6 tapped a dichotomy between the Street U and E.T.S. Tests as both entered significantly in the solution (7% and 14% of the variance accounted for respectively), yet their contributions were of opposite sign, i.e., positive for Street U and negative for E.T.S. Hence this last factor may describe a dimension which implies the presence of one trait and the absence of another, reflected in these respective tests. These findings from the regression procedure strengthen the previous inference of a 'thematicity' in the individual tests, and indicate that this 'thematicity' may correspond

to orthogonal dimensions which are less shared by the other tests. They further indicate that the Sum Best closure measure incorporates the diverse 'themes' present in the tests.

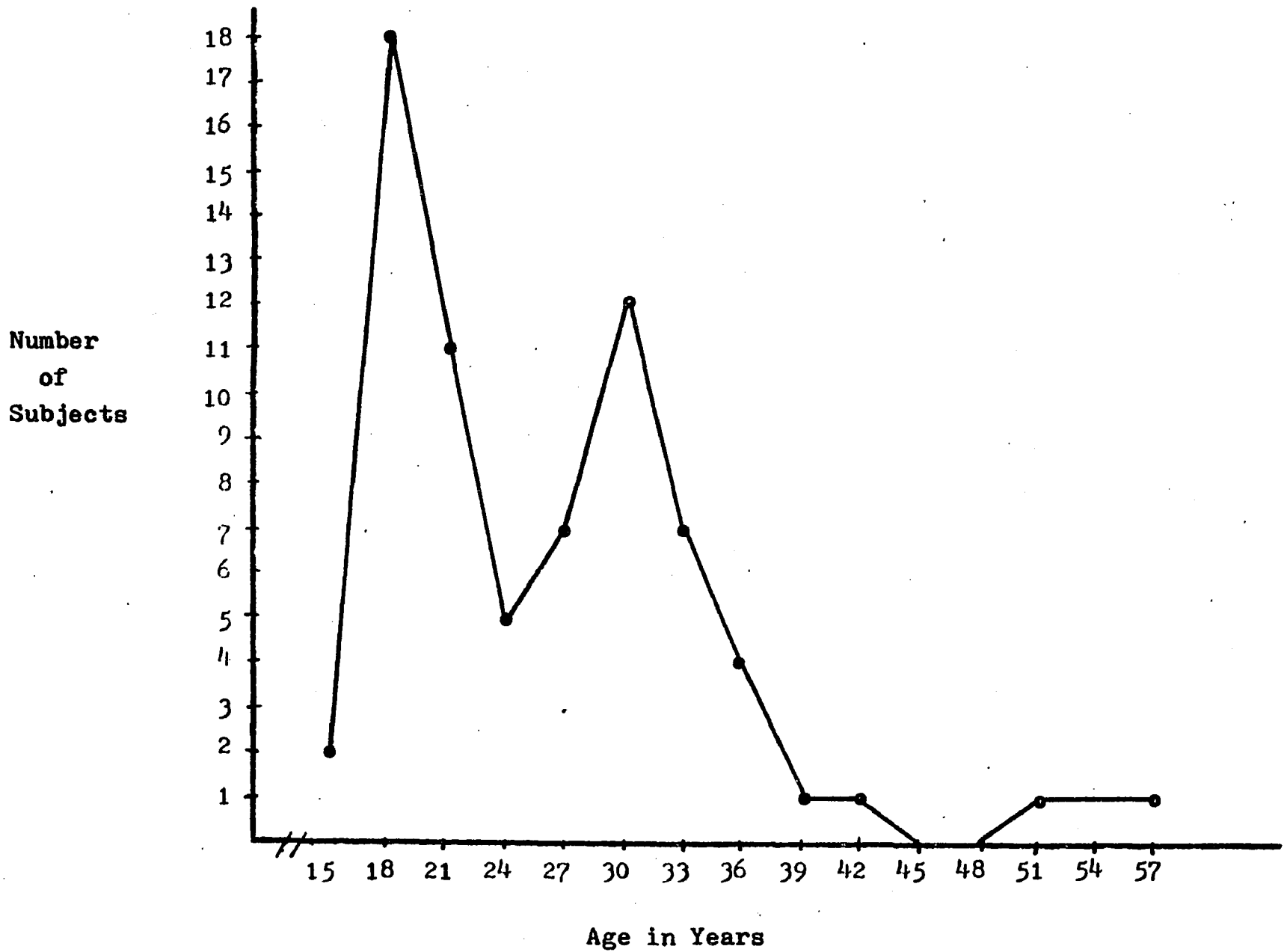
Further Analyses of Subject Variables

As Age was positively skewed in this sample and its effect on closure performance was possibly underestimated, effects of this variable were reanalyzed in order to 1) reassess the trend of a deleterious effect of age for each test, and if possible 2) articulate the age at which it begins happening.

Figure A shows the frequency distribution of age in the sample of normal Ss. As described previously, the distribution was positively skewed (.40) and bimodal (i.e., 17-19 and 29-31 years). However, a wide range of ages was represented (i.e., 15 to 57 years). Consequently, a transformation of this variable was performed which preserved the range and attempted to attenuate the effects of the positive skew. Age was recoded into five units (i.e., age in years 15 through 19 = 1, 20 through 24 = 2, 25 through 29 = 3, 30 through 35 = 4, 36 through 57 = 5). These age units were chosen to maximize discriminative ability and, although statistically were treated as ordinal, interval scaling was preserved in the first four units corresponding to the

Figure A

Frequency Distribution of Age in Normal Sample



younger ranges. Numbers of Ss in each were unequal (i.e., 28.6, 21.5, 17.2, 22.8, and 9.9% for Age units 1, 2, 3, 4, and 5, respectively). Given the constraints imposed by scaling of and unequal N in these Age units, appropriate nonparametric statistics were used in all subsequent analyses of this variable.

Table C shows the Spearman Correlation values of Age with performance on extant closure tests, Total and Sum Best closure measures. When compared to Table 3 in Chapter II, which is based on the skewed data, correlation coefficients of Street and Mooney tests remain essentially unchanged ($r = -.06$ versus $-.03$, and $r = -.17$ versus $-.18$ respectively). In contrast, Street U and E.T.S. tests show slightly lower but still significant values ($r = -.24$ versus $r = -.28$, $p = .01$ respectively). Most importantly, both Total and Sum Best show a significant fall-off with increasing age which was originally not evident ($r = -.25$, $p = .05$ versus $r = -.15$, not significant and $r = -.25$, $p = .05$ versus $r = -.13$, not significant for Total and Sum Best respectively).

Figure B shows Histograms of mean performance of each Age unit for those closure tests which showed a significant age effect in the previous analysis. Mann-Whitney U t-test comparisons between the youngest group (i.e., 1) and all other groups (i.e., 2 to 5) were used to determine whether there were critical age ranges which most typically showed the decrease in closure performance. Although the general

Table C

Spearman Correlation of Categorized Age
Units with Performance on Closure
Tests, Total and Sum Best (N=70)

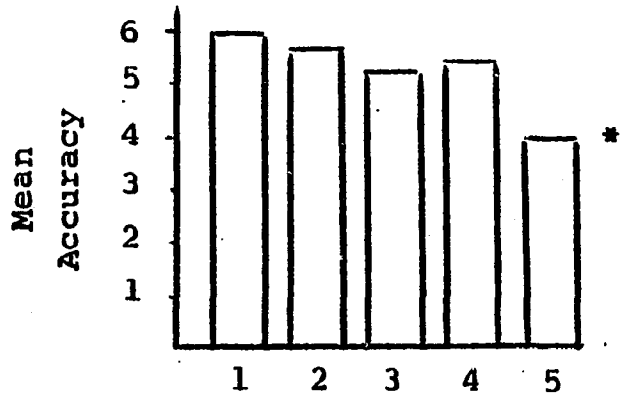
	Street	Street U	Mooney	E.T.S.	Total	Sum Best
Age	-.03	-.24*	-.18	-.24*	-.25*	-.25*

* = .05

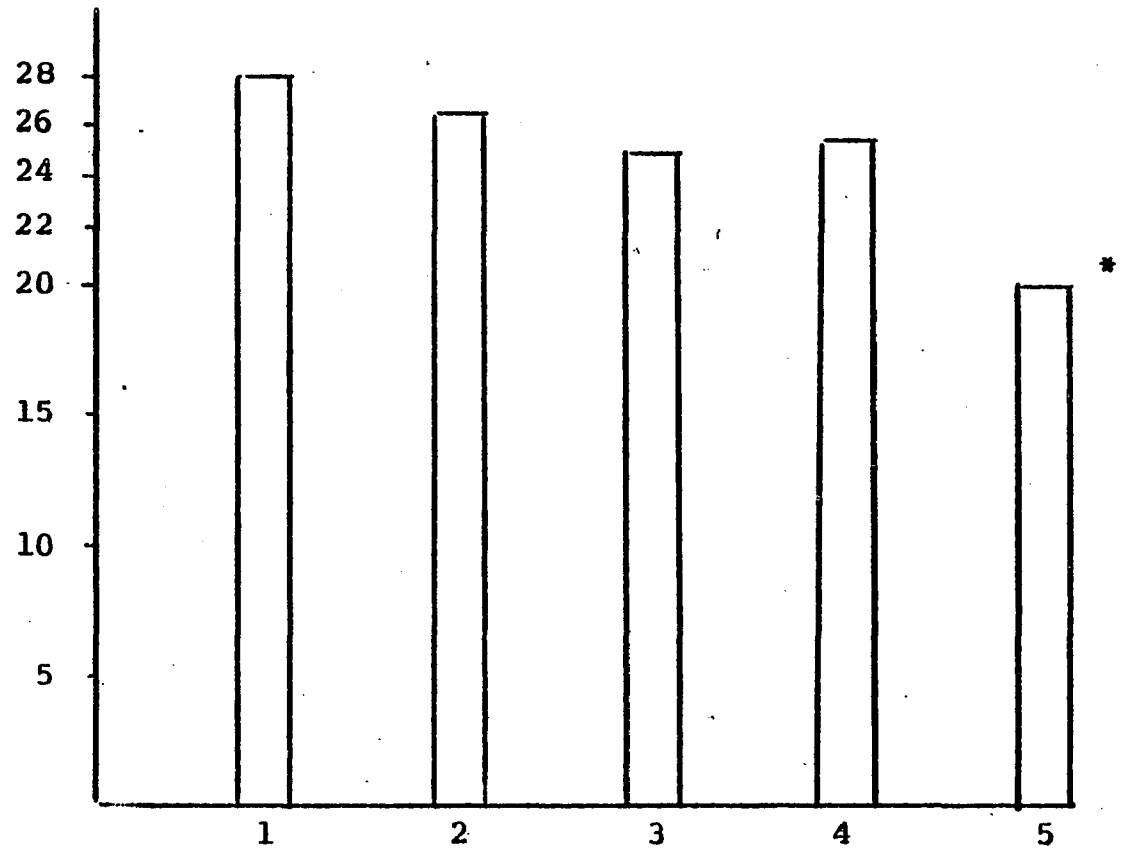
Figure B

**Histograms of Mean Performance on Each Closure Test
Showing a Significant Relationship with Age
as a Function of Age in Units (N=70)**

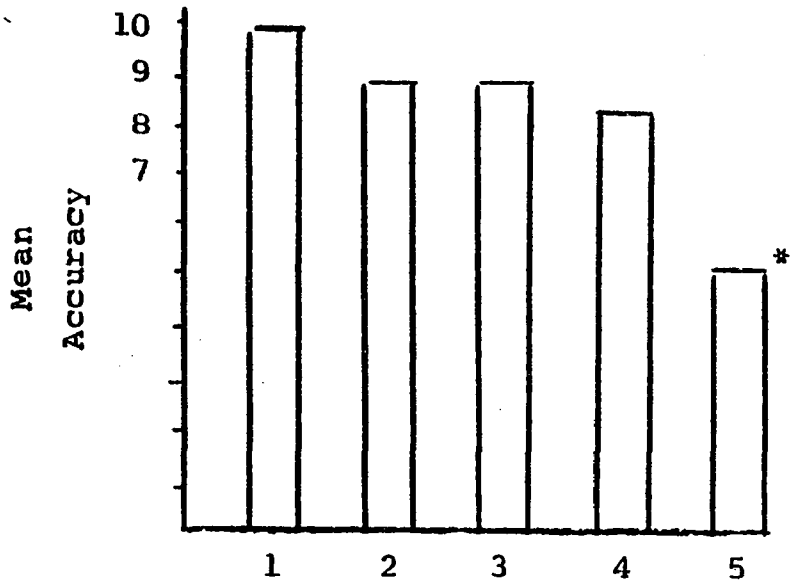
Street U by Age



Total by Age



E.T.S. by Age



Age in Units

direction for all tests examined was increasingly lower performance as a function of age, this reached statistical significance in all three tests (i.e., Street U, E.T.S. and Total) only for Age unit 5 (i.e., Ss 36 through 57). As the absolute frequency of Ss in this oldest group was extremely low (7), it was impossible to determine critical ages more specifically than above 36 years.

Data had been collected on the handedness and urban or rural background of all Ss, as both are postulated to have importance for brain-organization (Nebes, 1971b and Thompson, 1977, respectively). Analyses with these variables were post hoc and intended to explore the importance of other subject variables to performance on different closure measures. In order to ascertain the limitations of inferences regarding the contribution of these subject variables from this sample, descriptive statistics were initially examined. Both handedness and background had extremely unequal numbers of Ss in their respective cell (i.e., 61 right-handed, 8 left-handed and 1 ambidextrous; and 53 urban versus 17 rural Ss respectively). Table D shows the correlations of these subject variables with the extant tests, Total and Sum Best measures. In this sample handedness did not significantly affect any closure instrument. By contrast, a significant relationship favoring urban background is evident for four of the six closure measures, and the remaining tests showed consistent but nonsignificant

Table D

Correlation of Handedness and Urban-Rural
Background with Extant Closure Tests,
Total and Sum Best (N=70)

	Street	Street U	Mooney	E.T.S.	Total	Sum Best
Handedness	-.06	.10	-.04	.07	.10	.01
- = right						
+ = left						
Background	-.19	-.35***	-.05	-.21**	-.25*	-.27**
- = urban						
+ = rural						

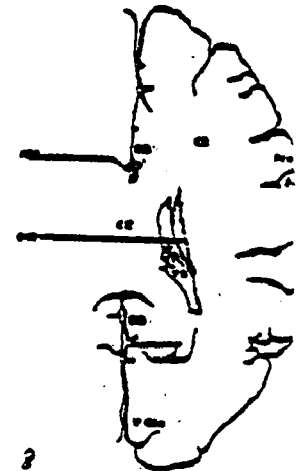
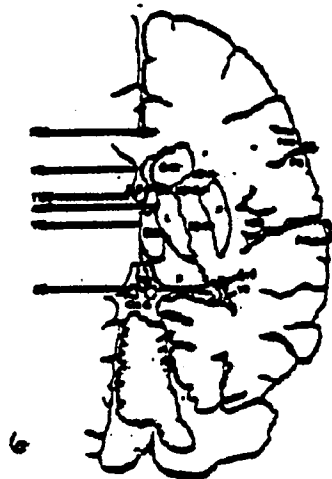
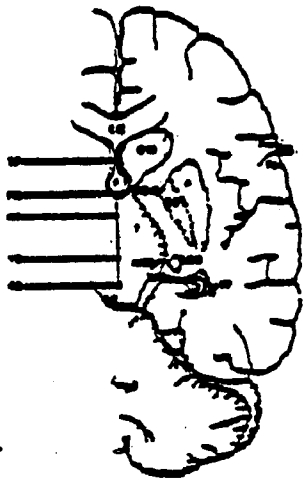
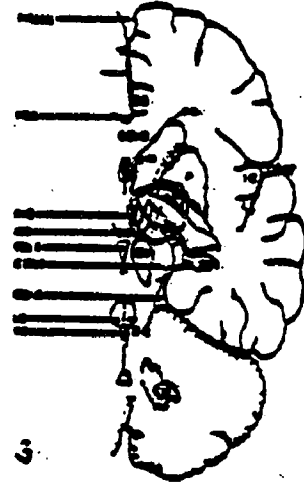
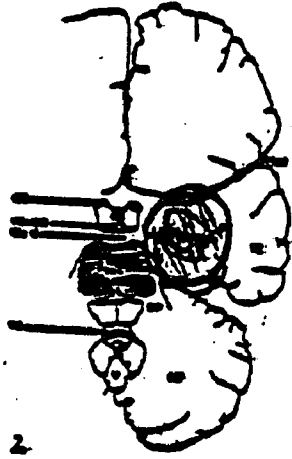
* = .05
** = .01
*** = .001

findings. Specifically, the Street U, E.T.S., Total and Sum Best measures showed the significant relationships (i.e., $r = -.35$, $p = .001$, $r = -.25$, $p = .01$, $r = .25$, $p = .05$ and $r = -.27$, $p = .01$, respectively).

Given the described distributions of these two subject variables, it is exceedingly unlikely that their normal distributions of variance were represented. Consequently, findings may represent sampling artifact. Findings do, however, suggest that other subject variables, in addition to sex and age, can contribute to performance on some closure measures.

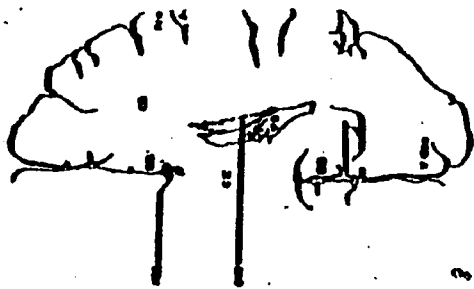
Appendix C

**Drawings of Lesions for Each
Brain-damaged Subject**





4



3



6



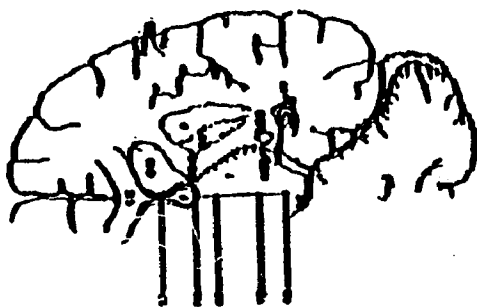
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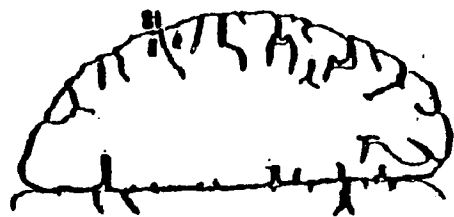
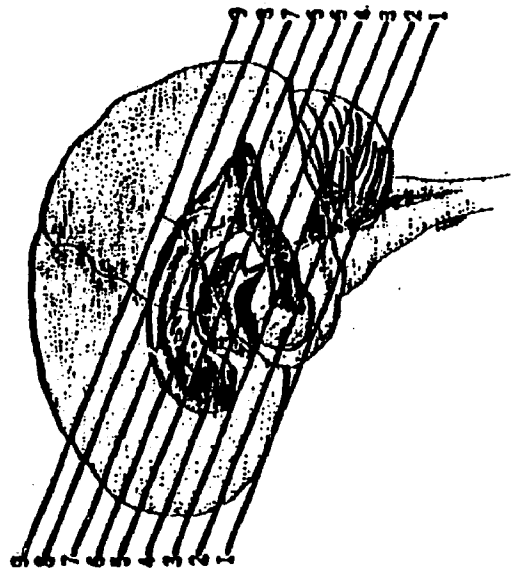
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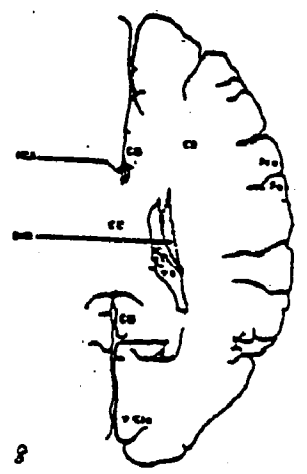
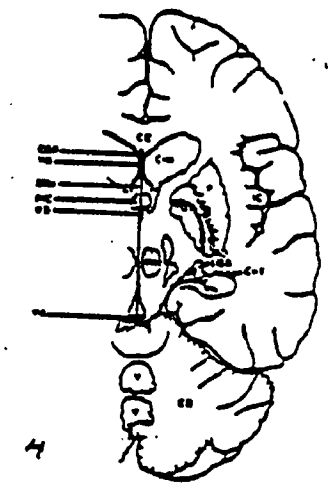
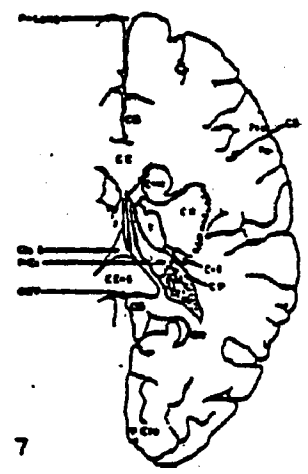
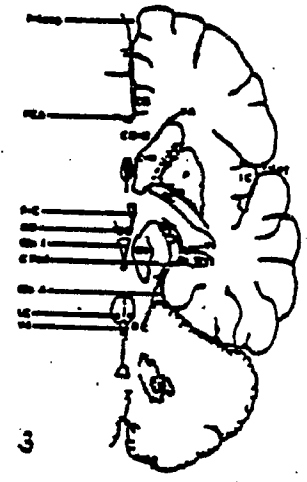
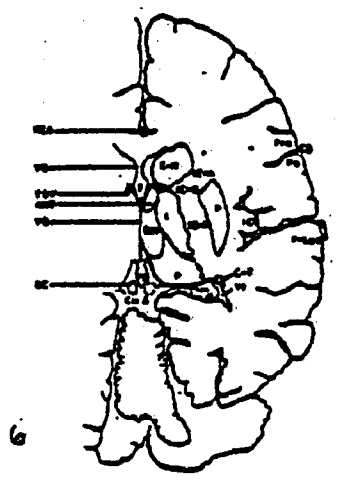
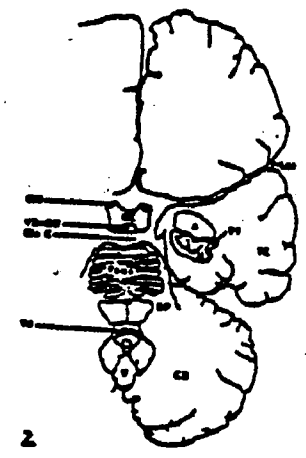
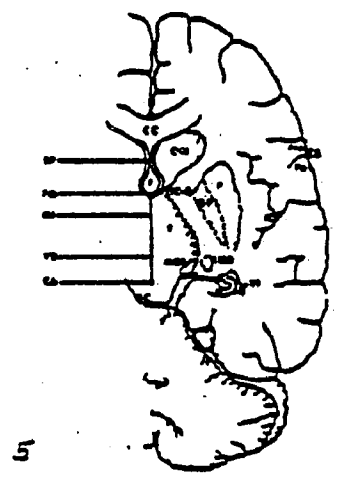


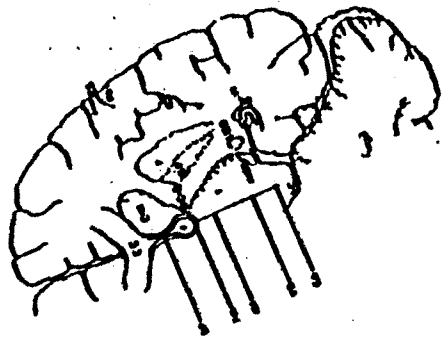
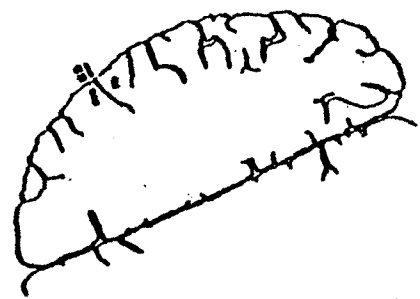
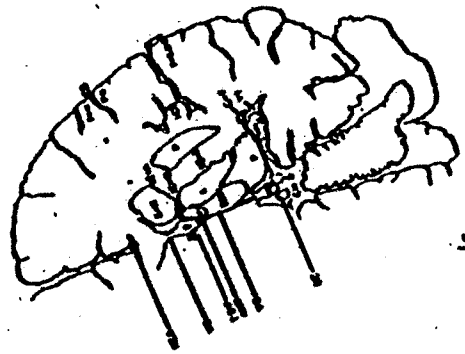
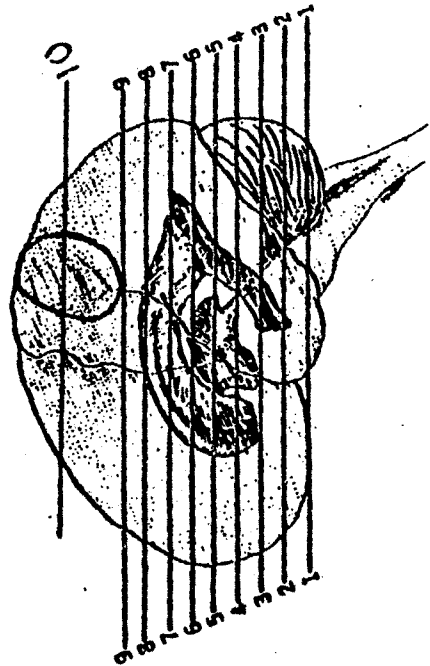
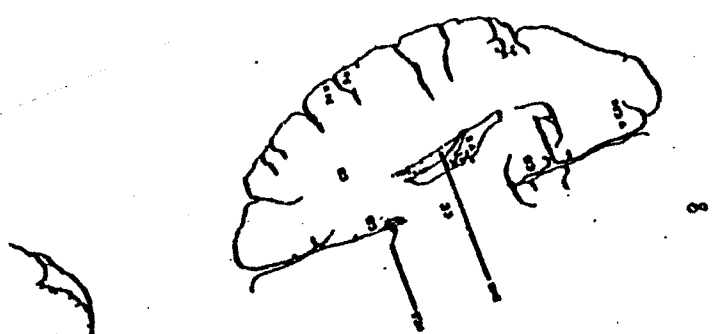
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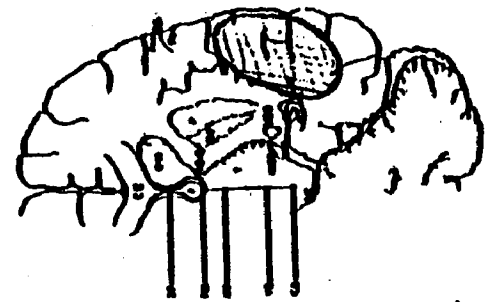
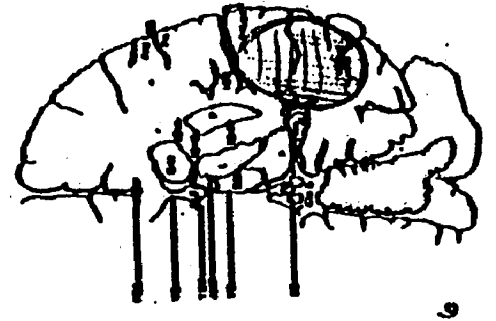
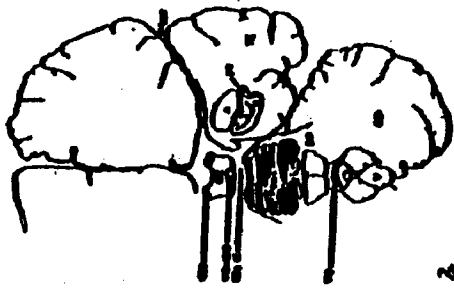
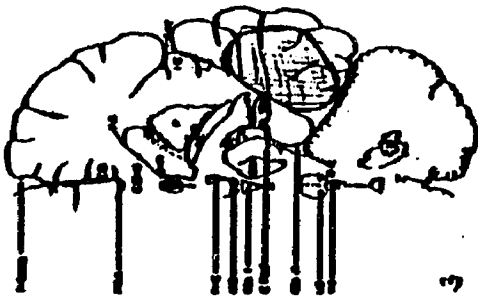
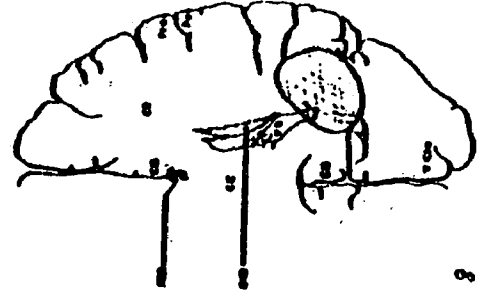
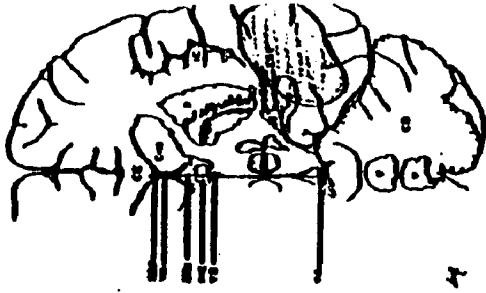
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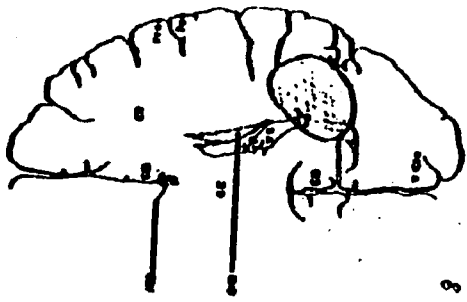




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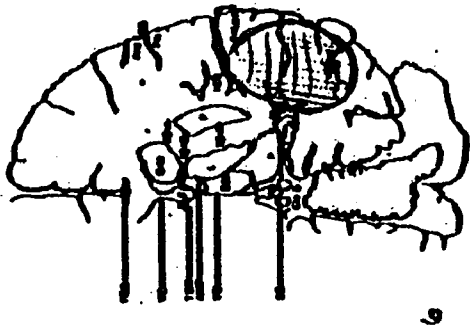




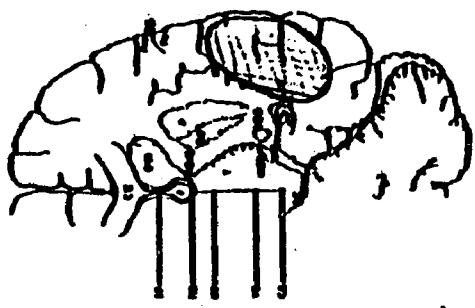
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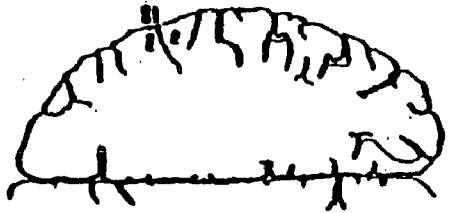
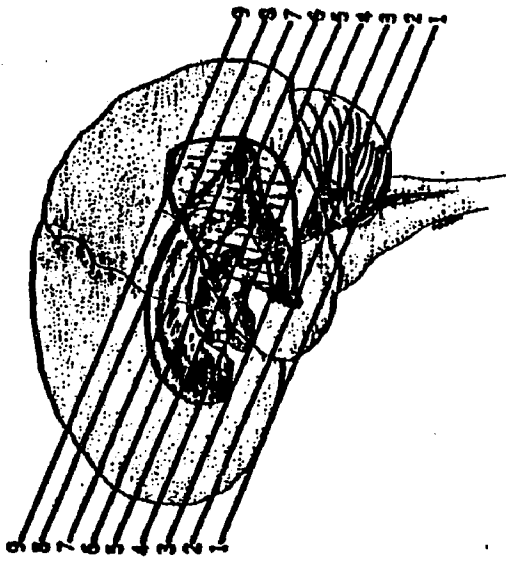
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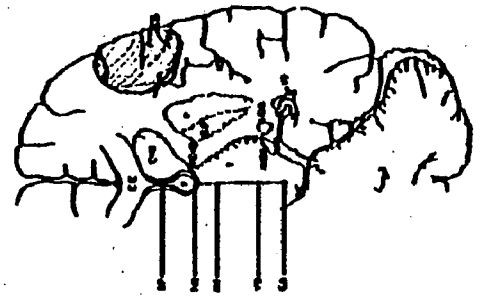
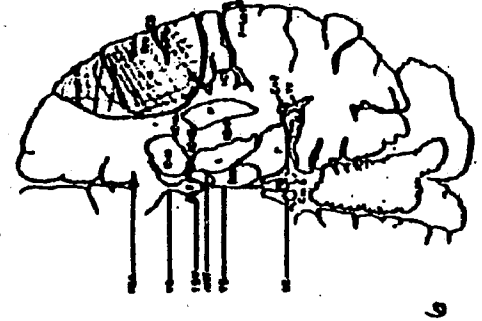
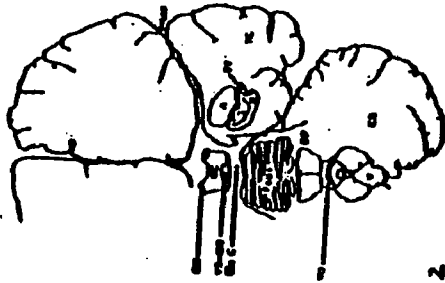
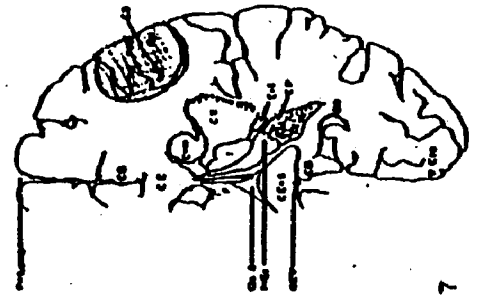
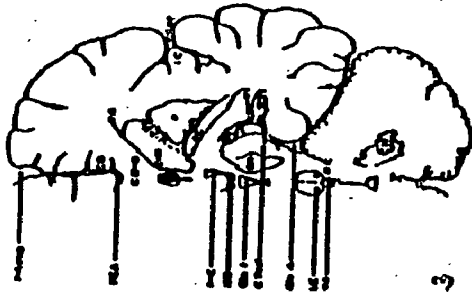
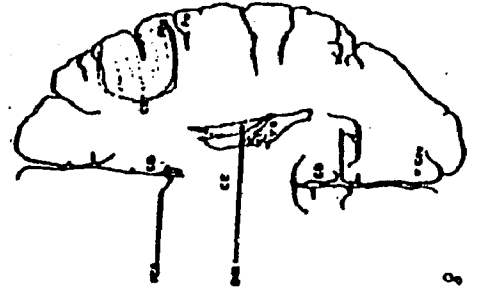
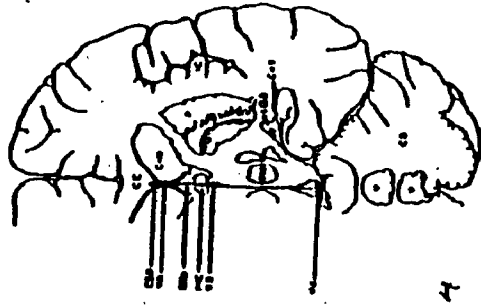
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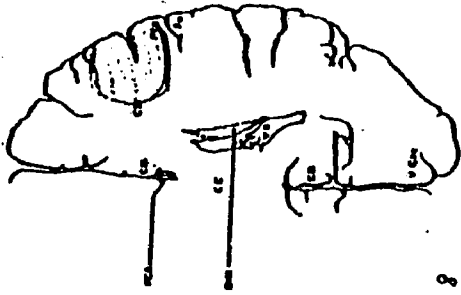


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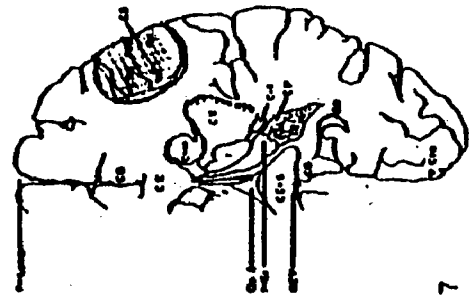


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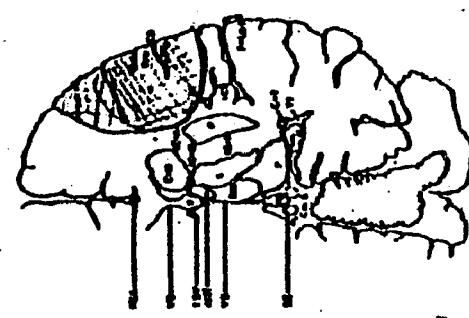




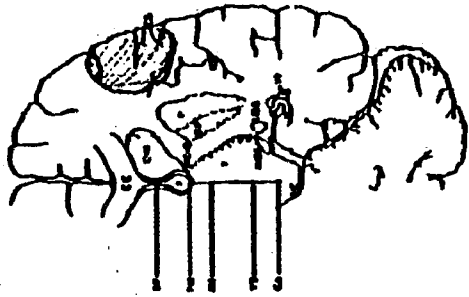
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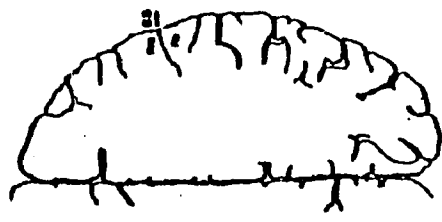
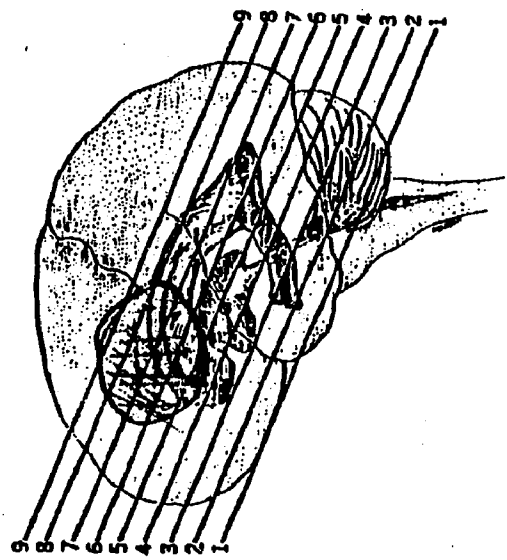
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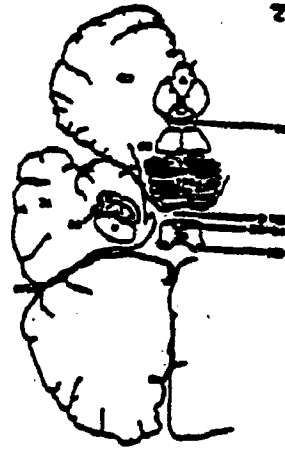
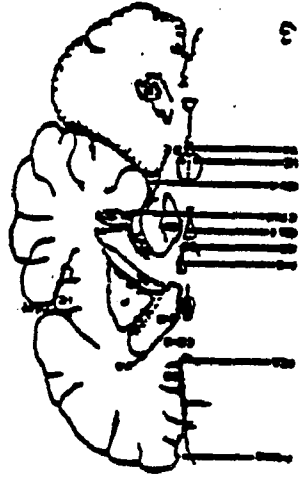
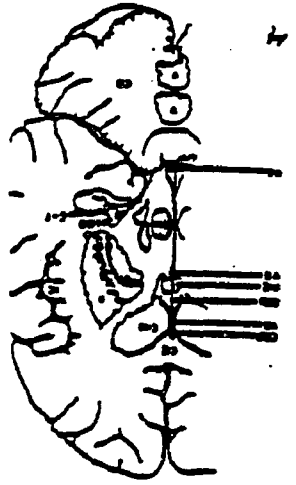
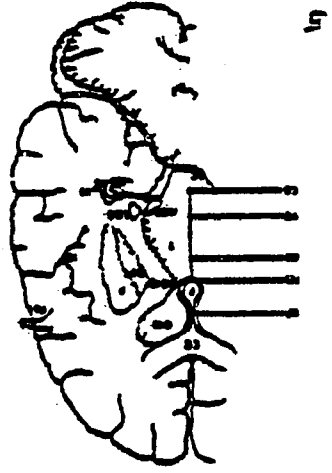
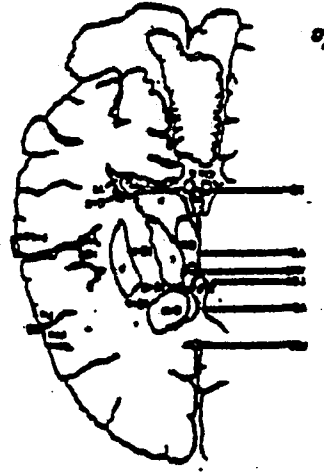
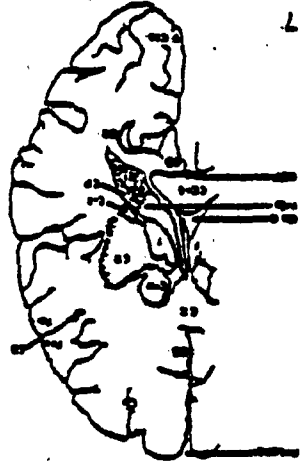
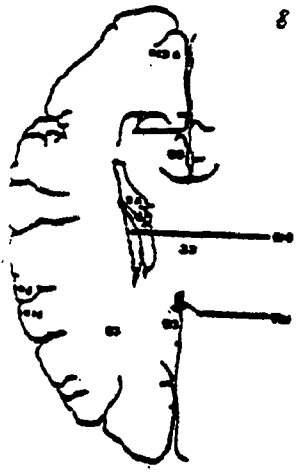
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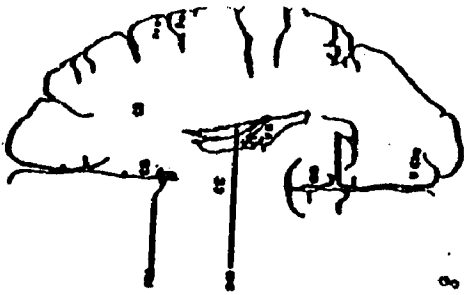
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RBD S#5



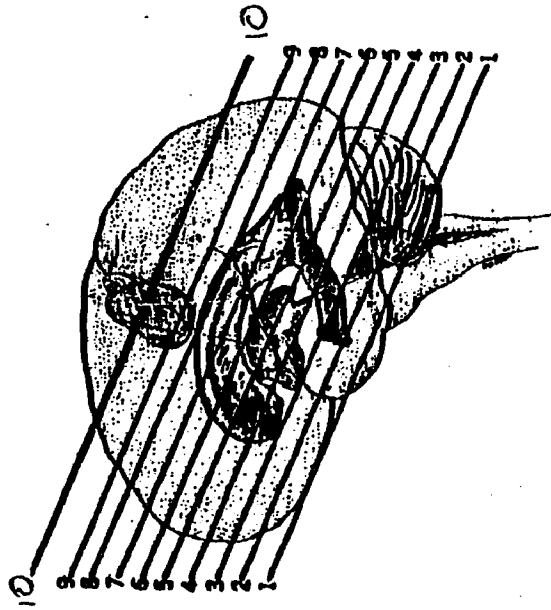
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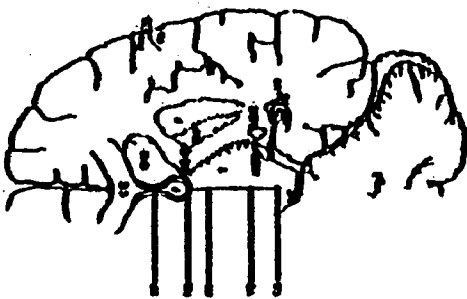
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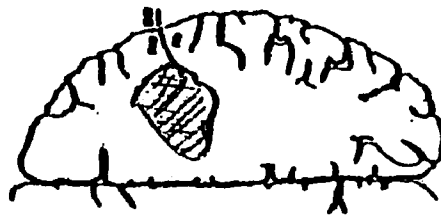
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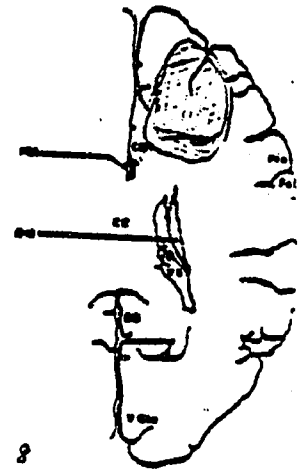
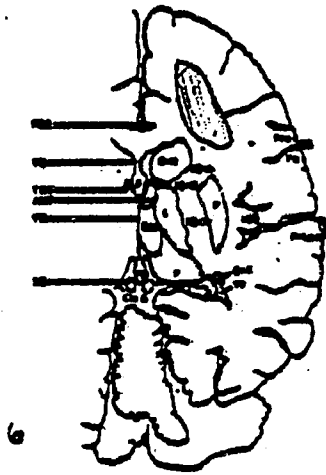
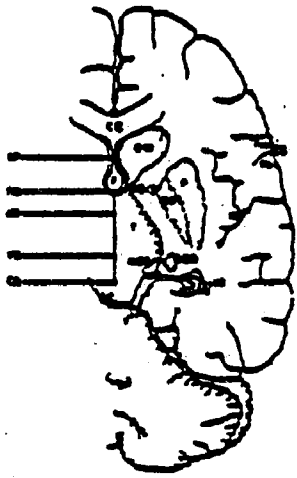
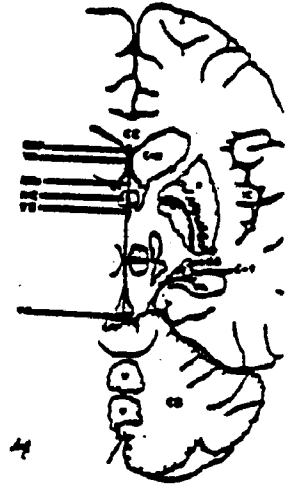
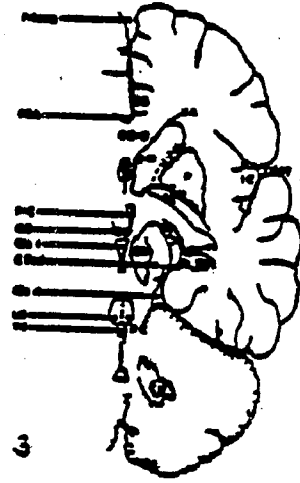
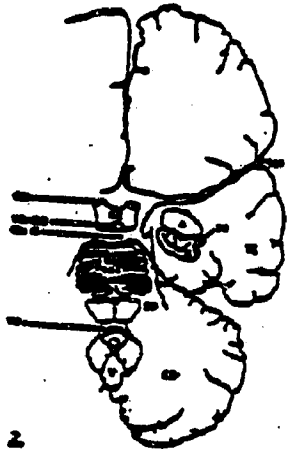
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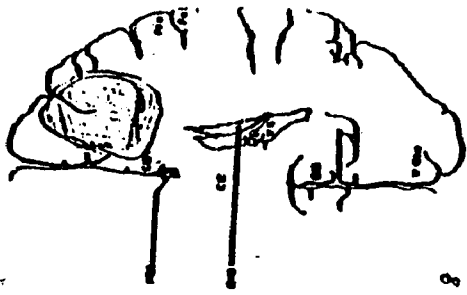


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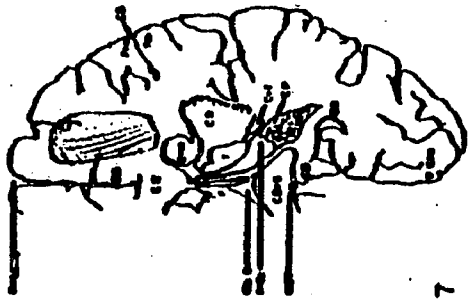
HEAD OF MAN FOR USE IN COMPUTATIONAL TESTS

F. W. SCHMIDT, J. S. WOODWARD AND J. S. COLLIER





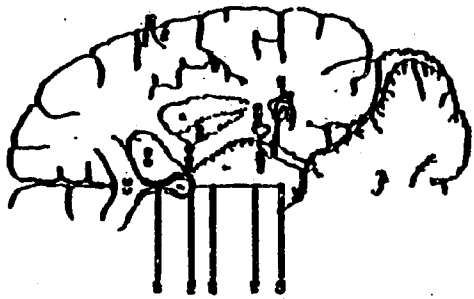
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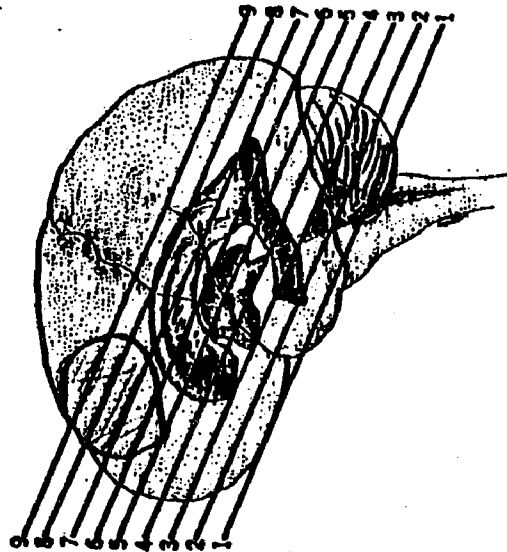
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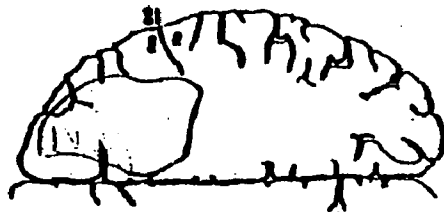
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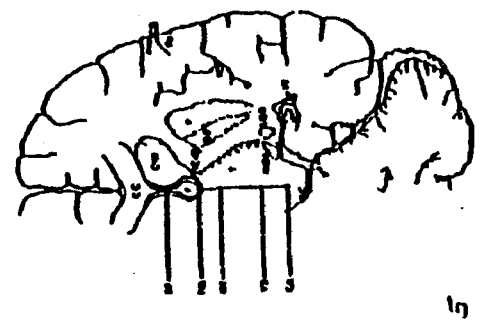
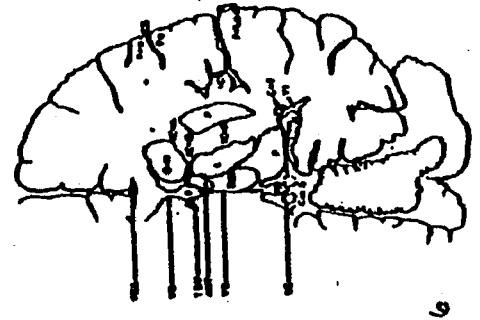
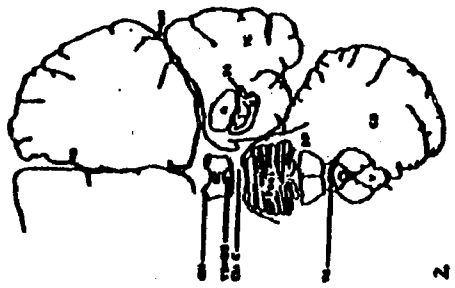
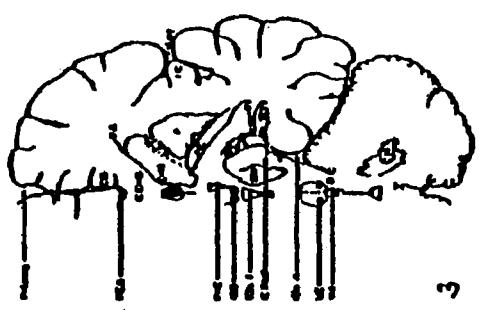
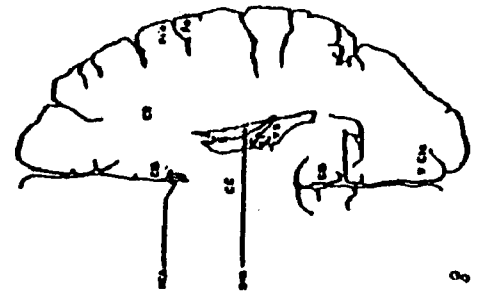
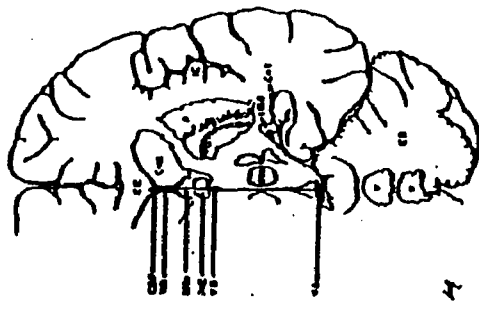


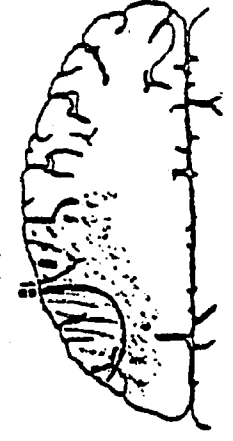
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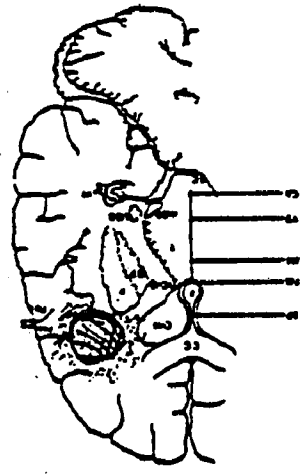
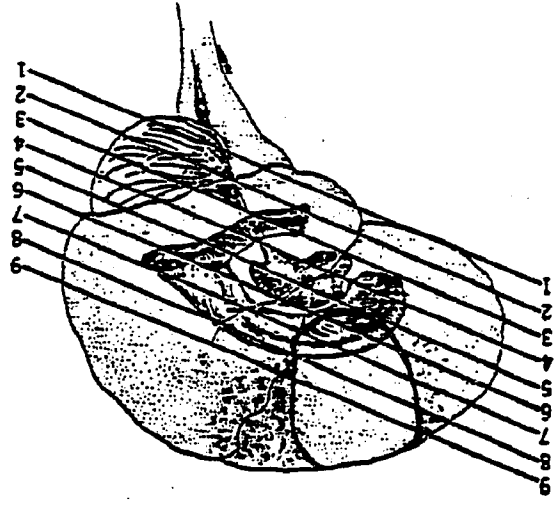
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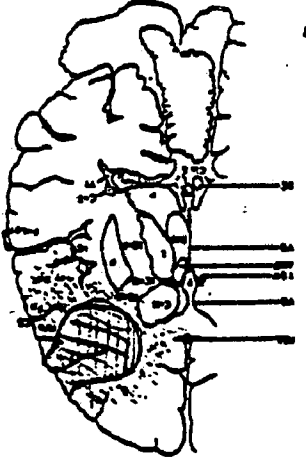




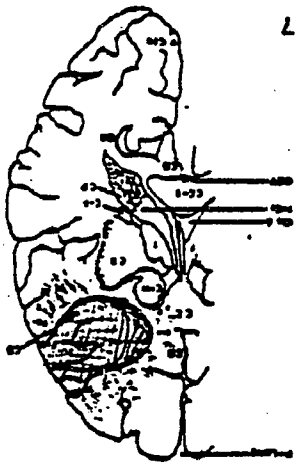
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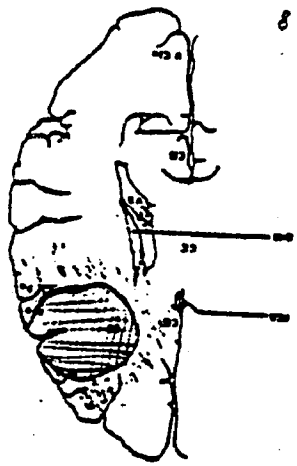
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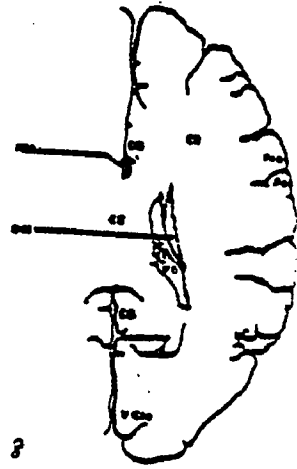
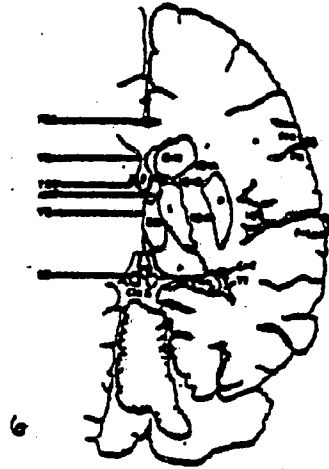
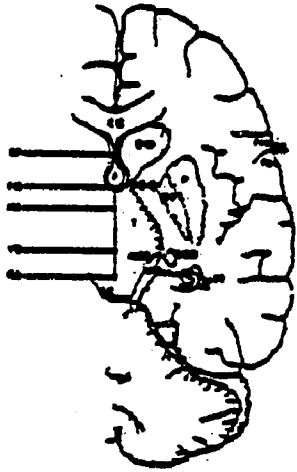
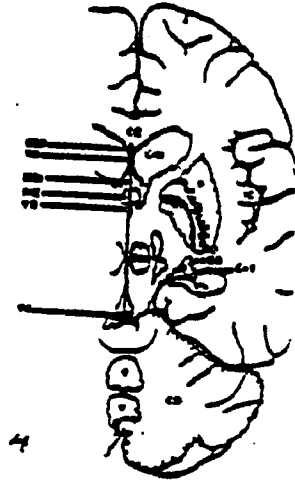
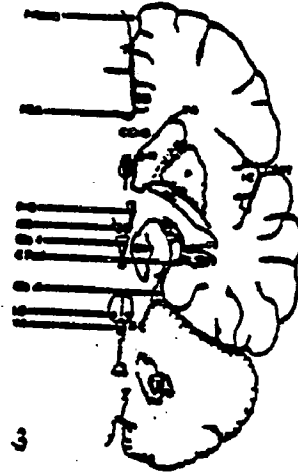
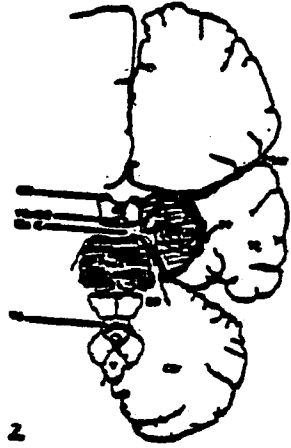
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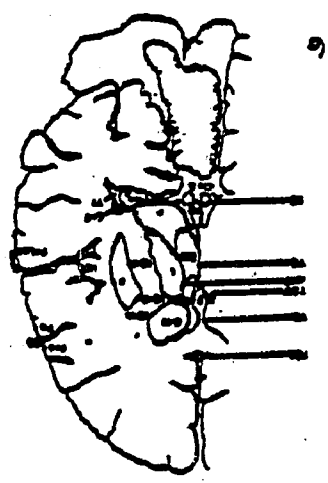
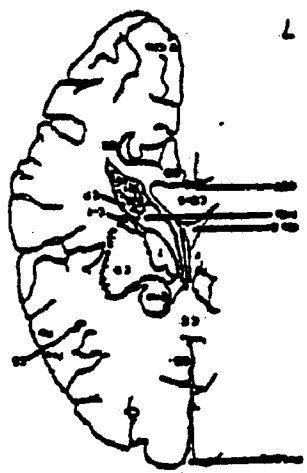
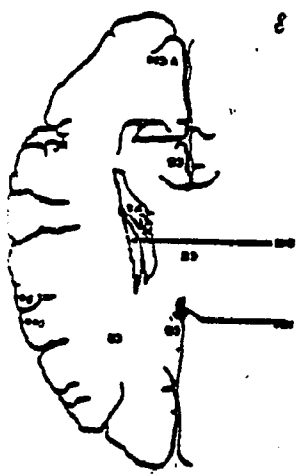
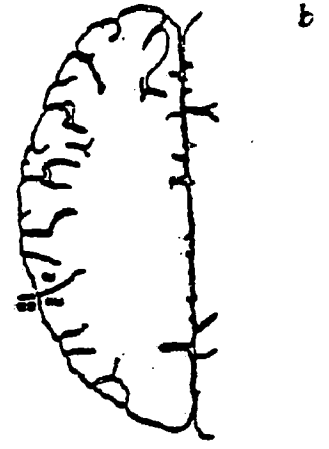
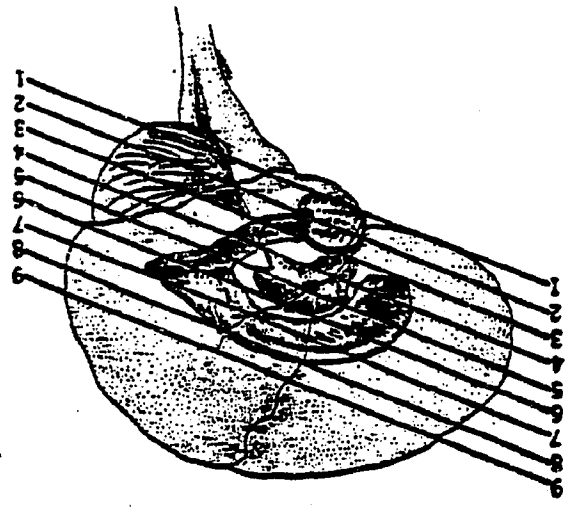


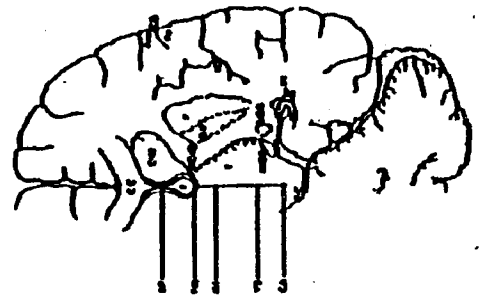
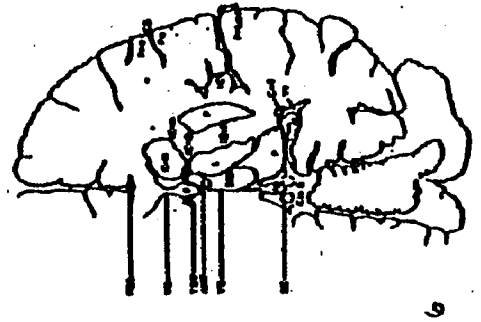
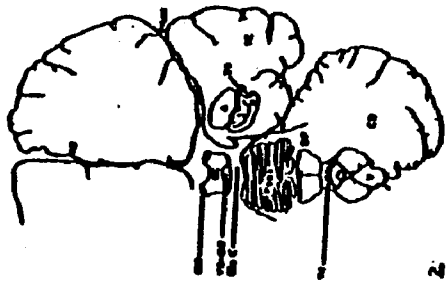
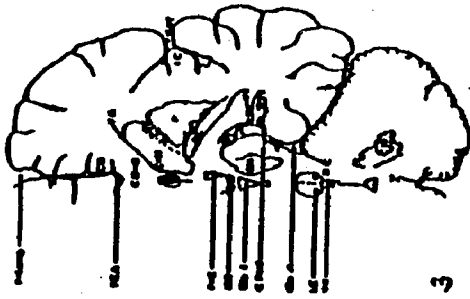
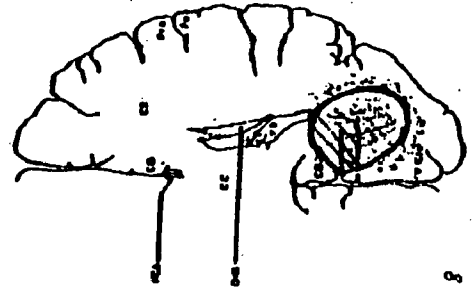
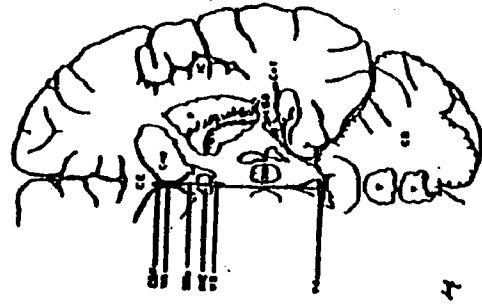
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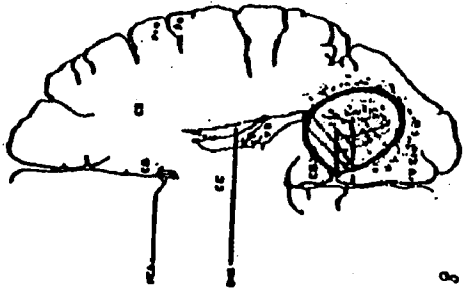


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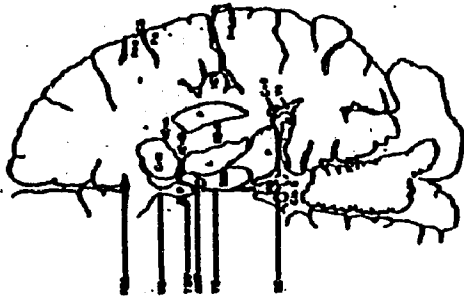




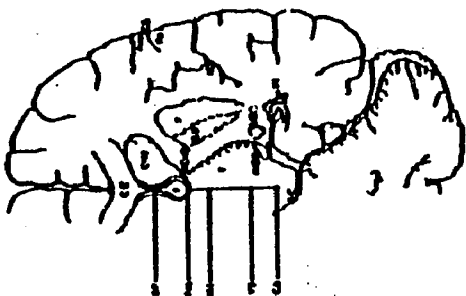
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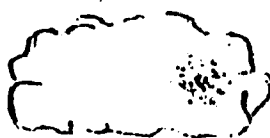
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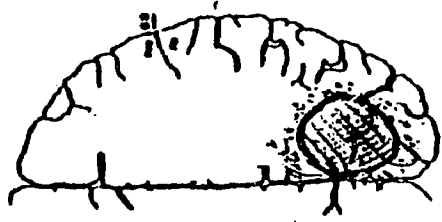
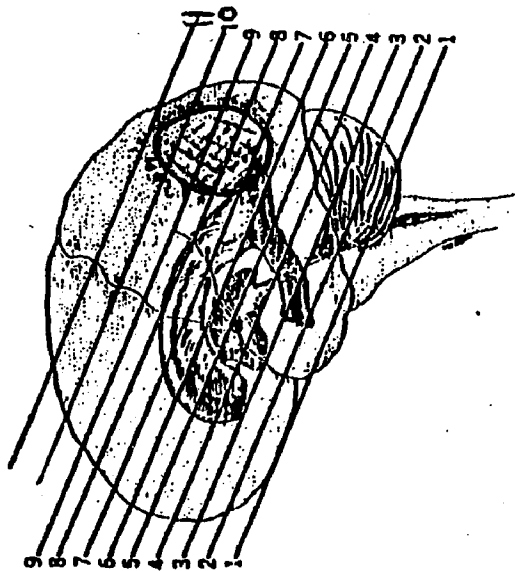
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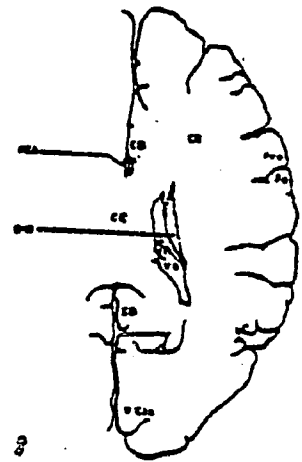
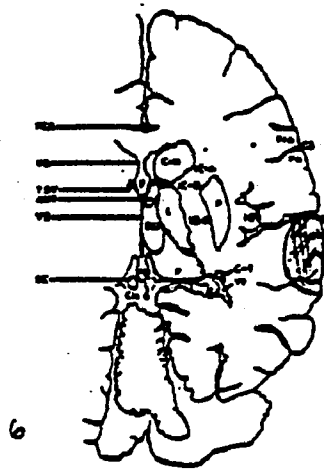
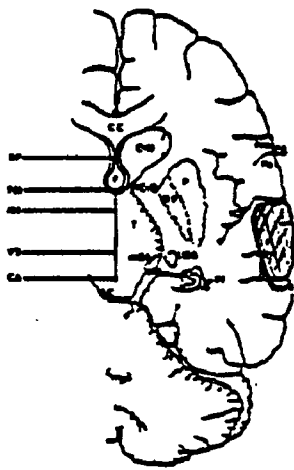
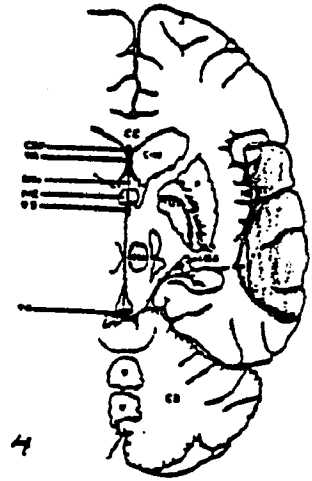
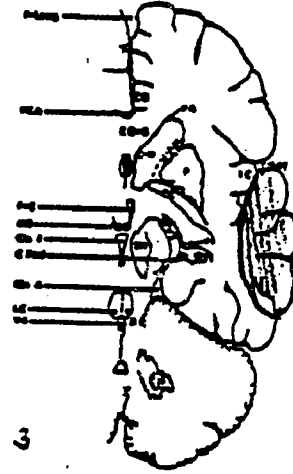
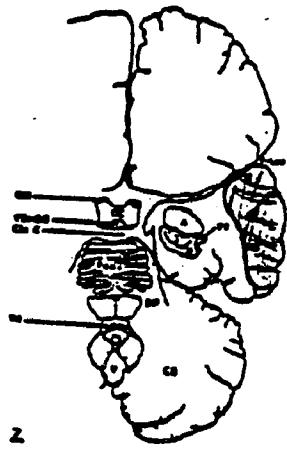


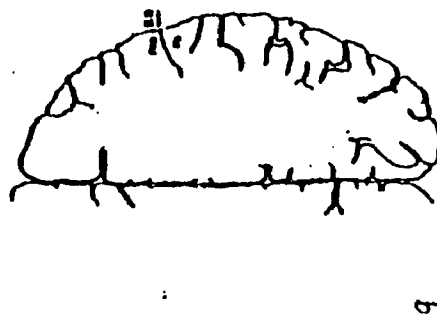
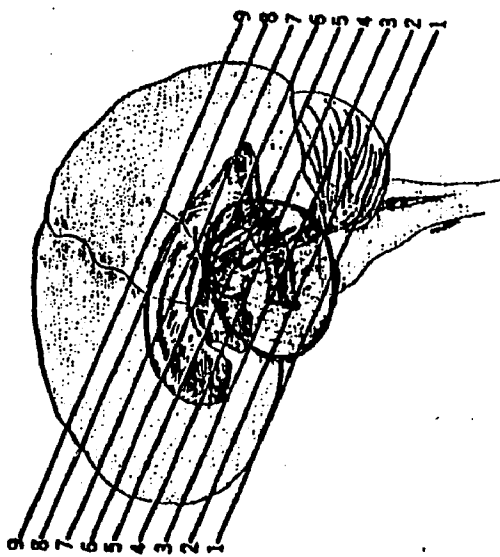
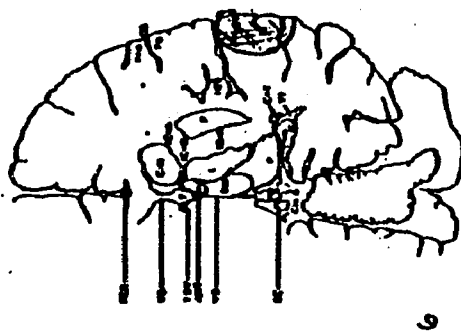
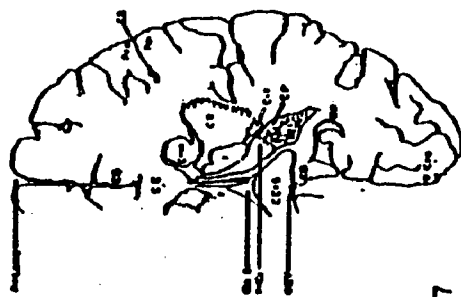
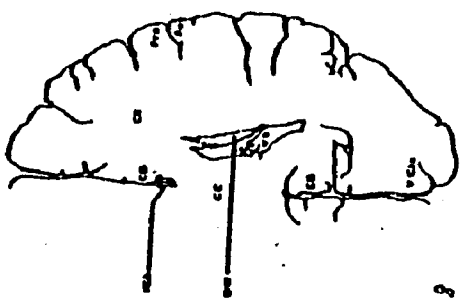
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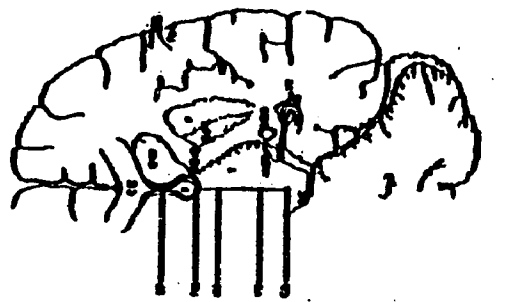
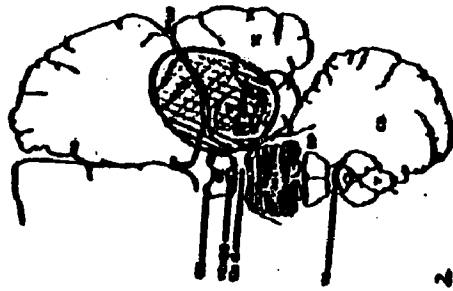
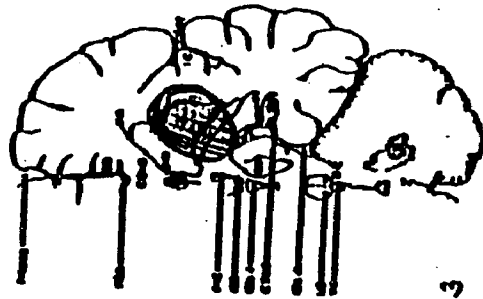
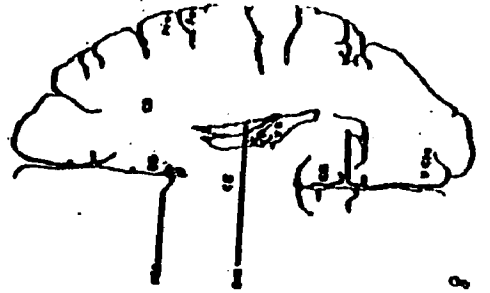
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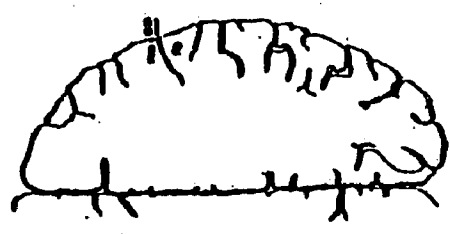
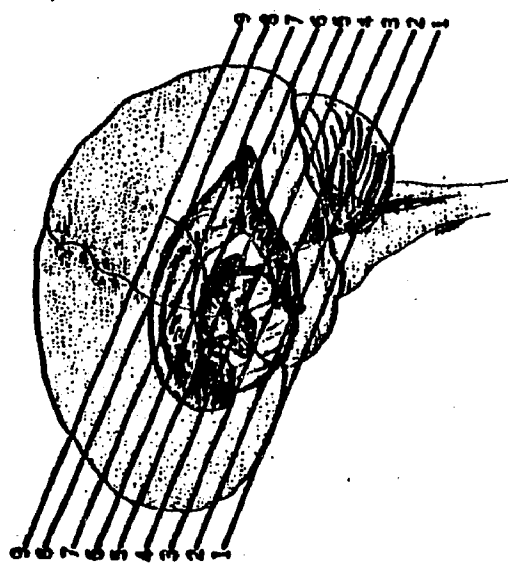
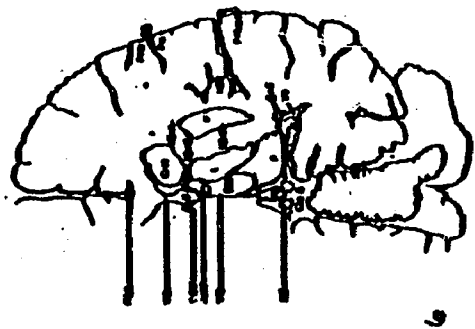
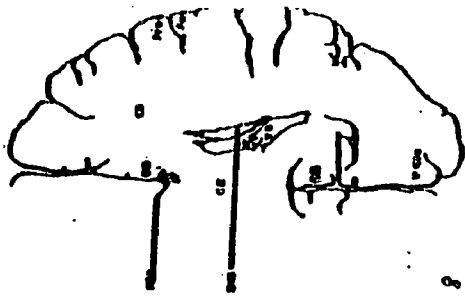




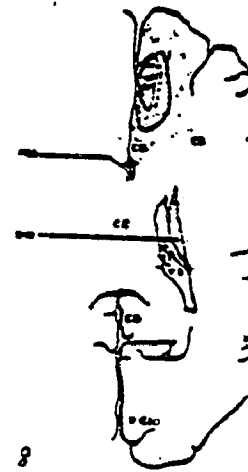
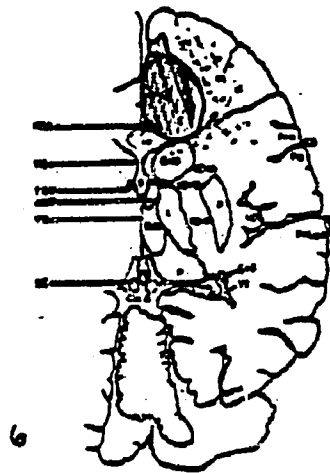
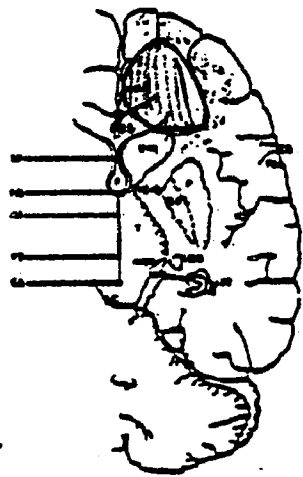
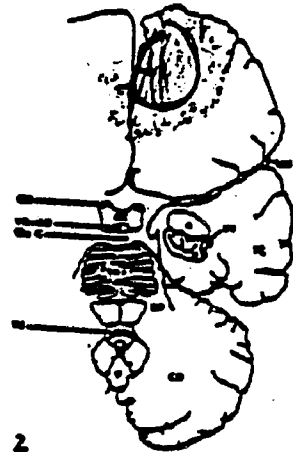
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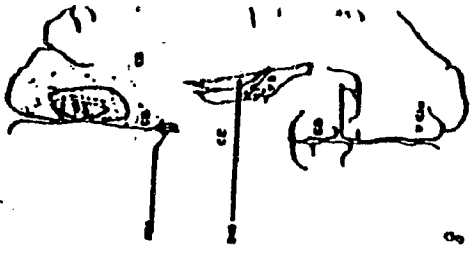
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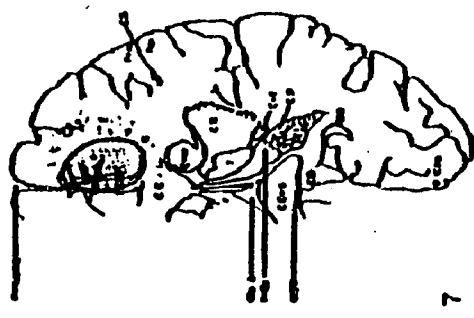


CLASS OF BRASS FOR USE IN COMPUTATIONAL MECHANICS

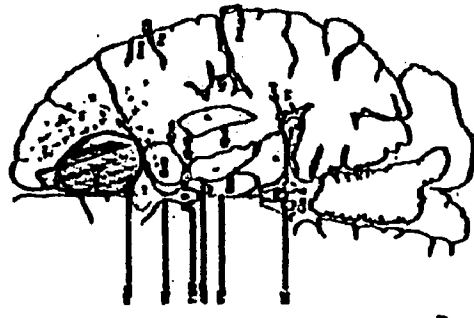




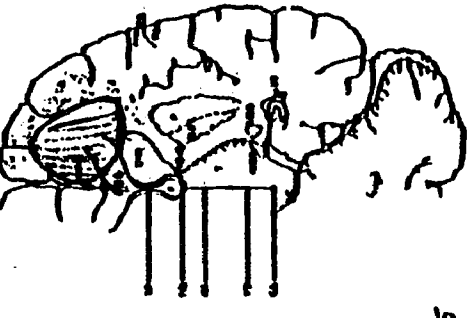
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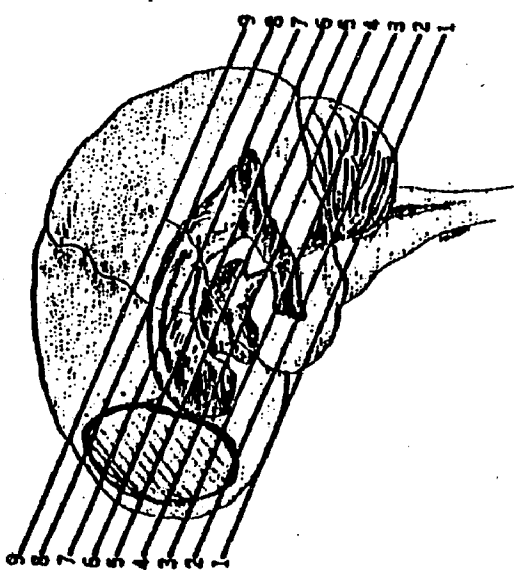
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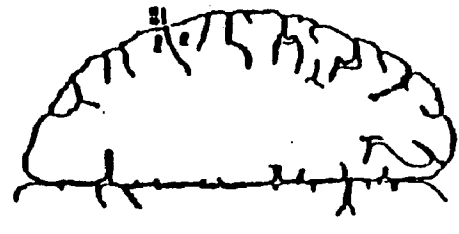
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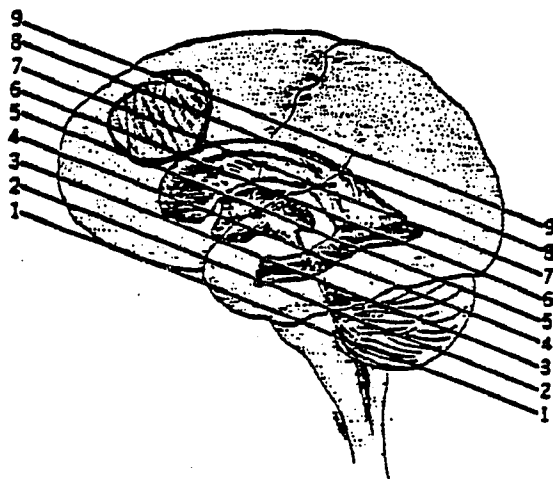
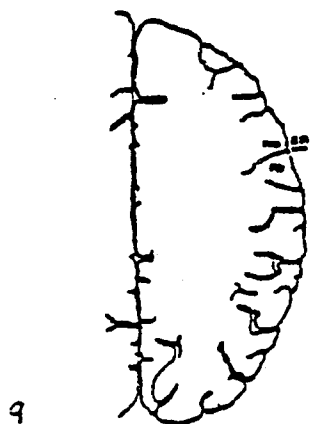
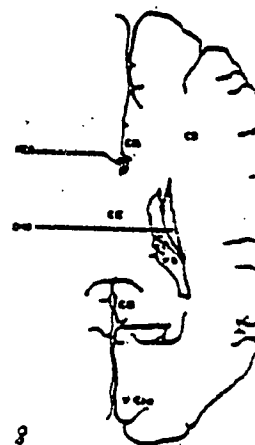
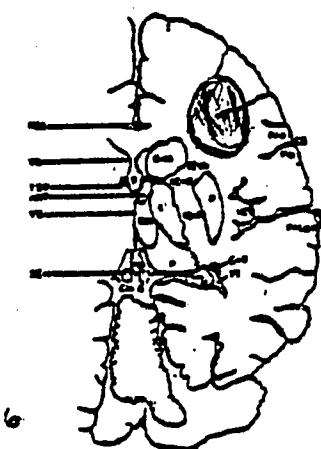
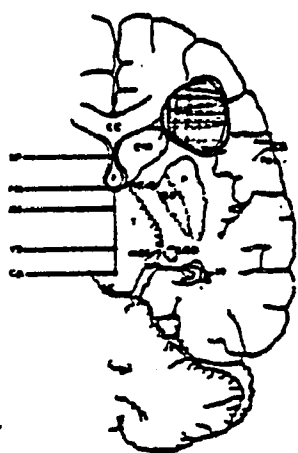
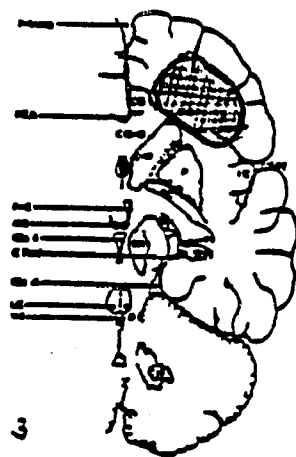
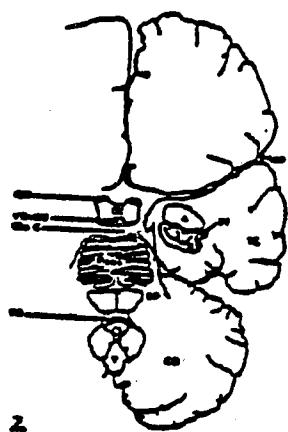
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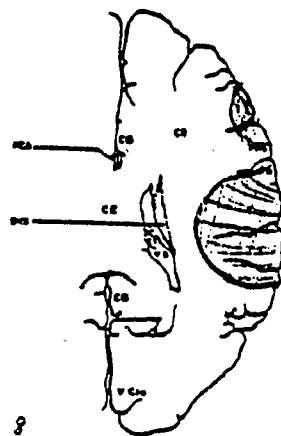
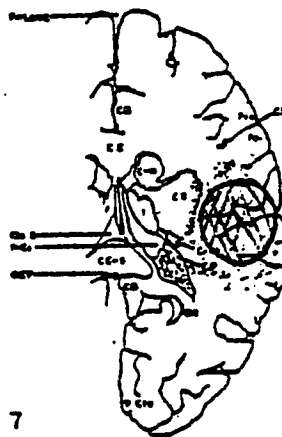
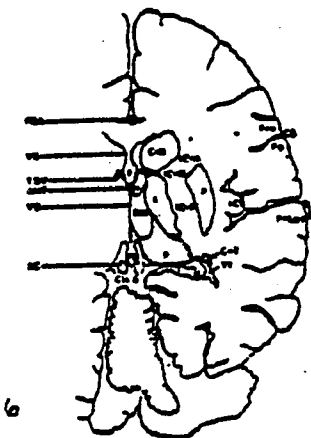
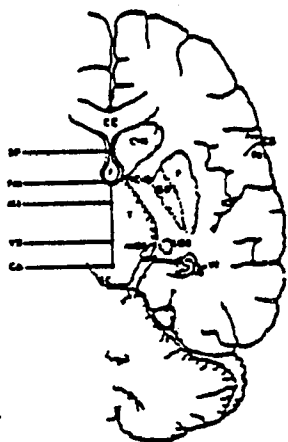
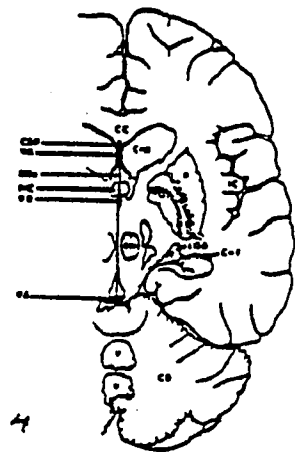
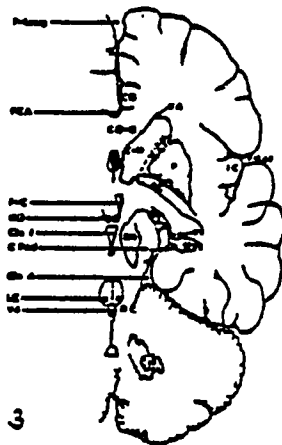
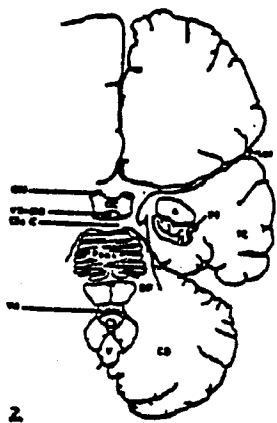


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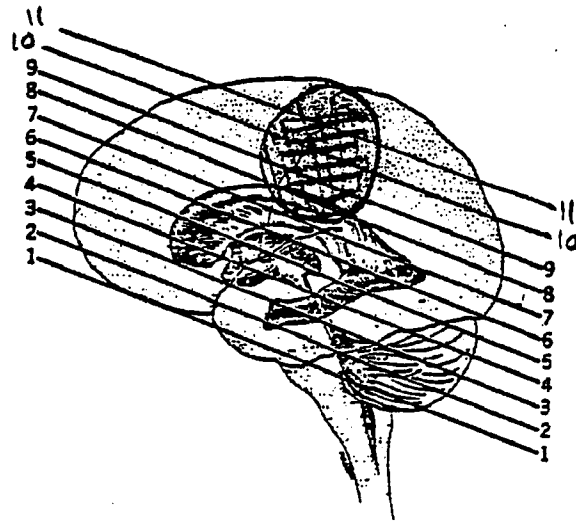


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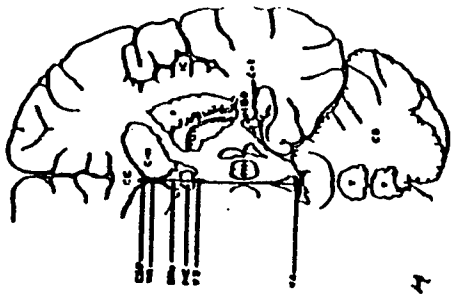
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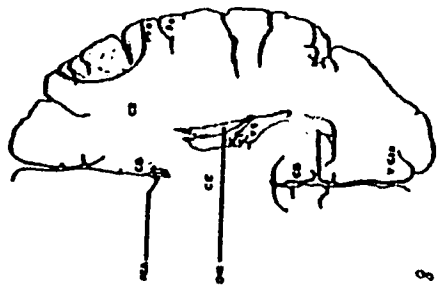
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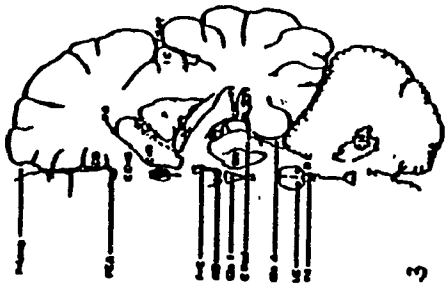
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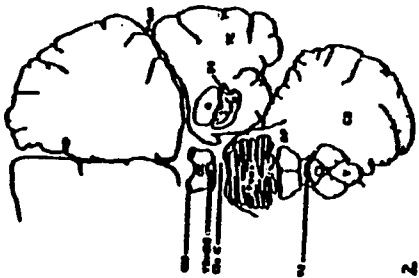
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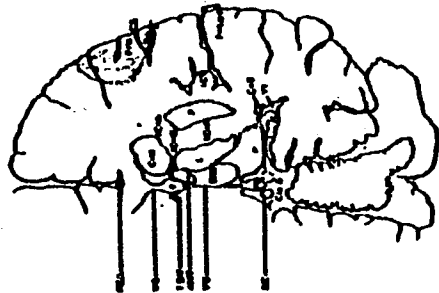
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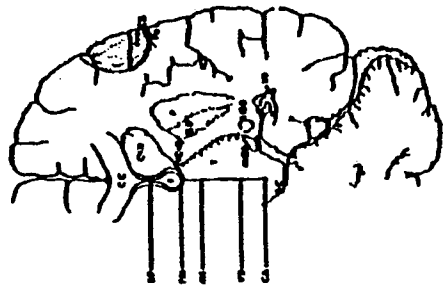
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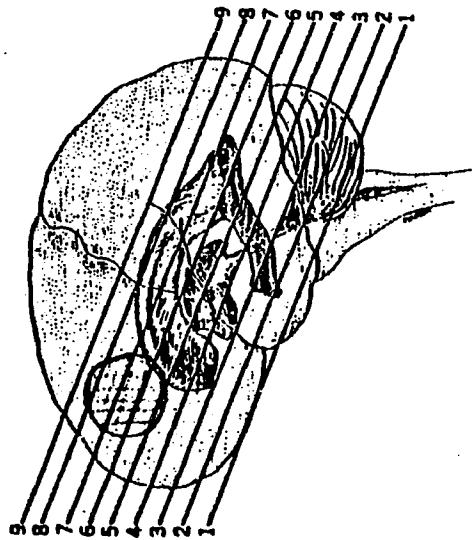
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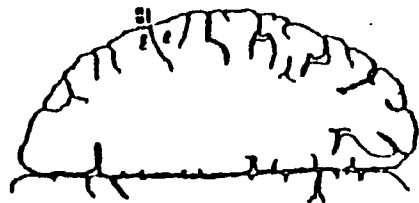
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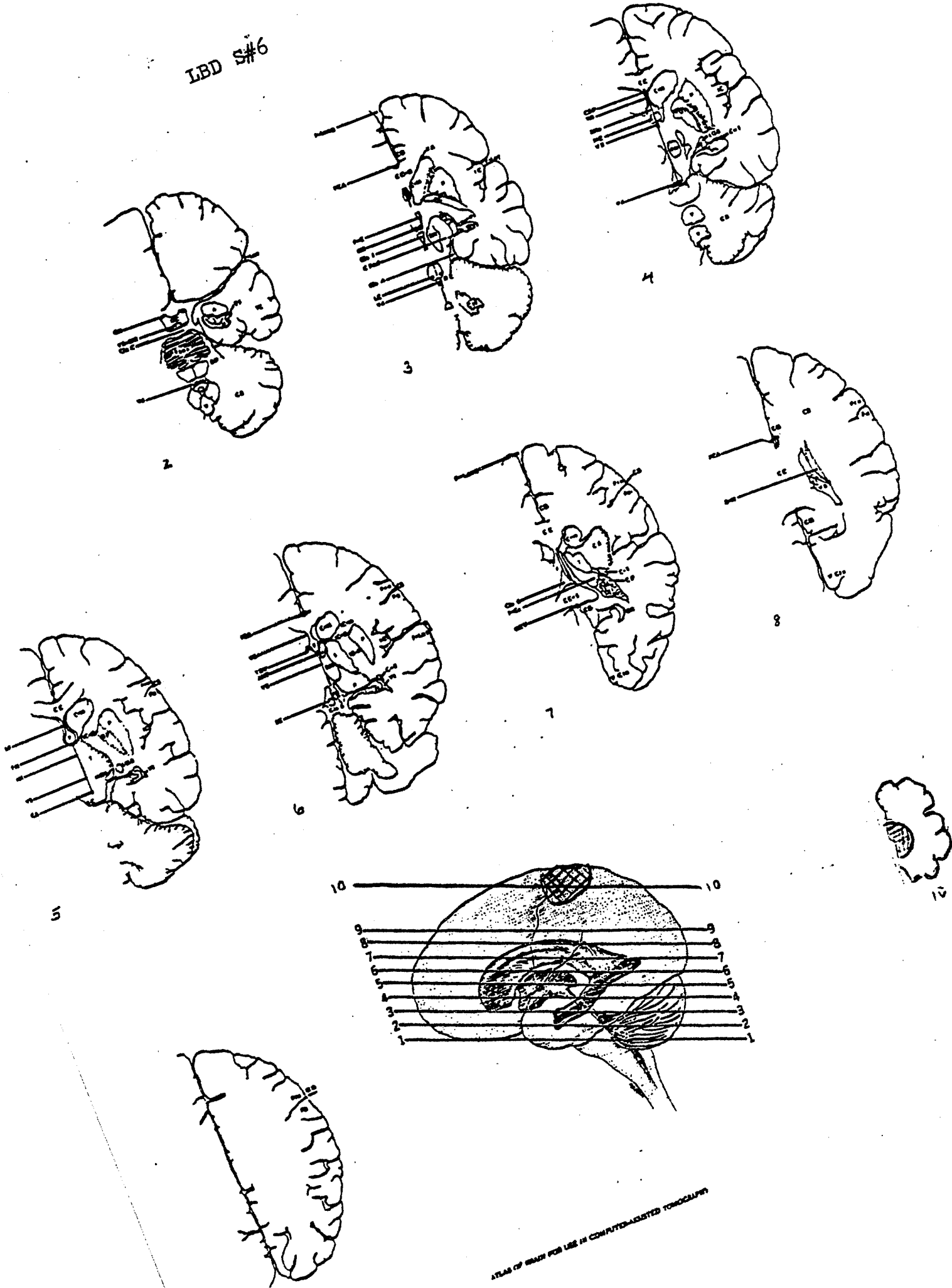


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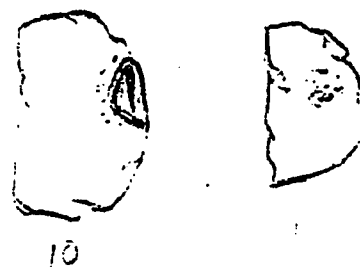
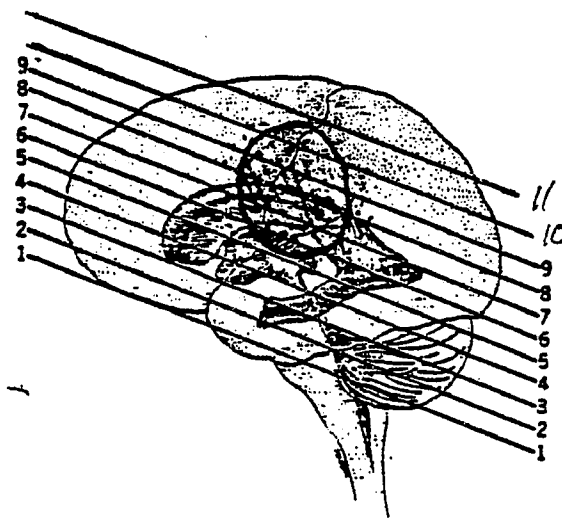
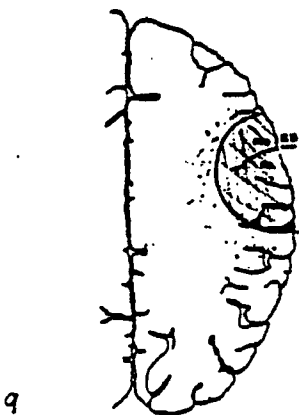
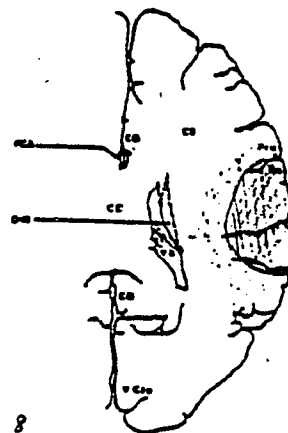
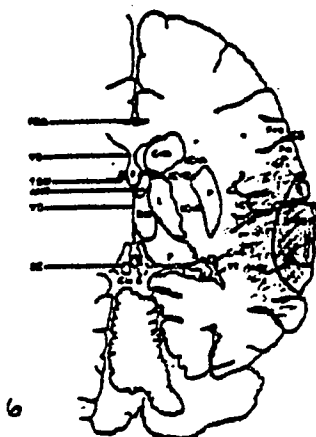
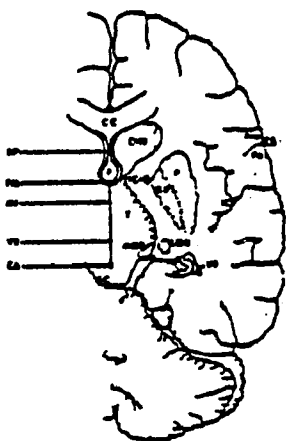
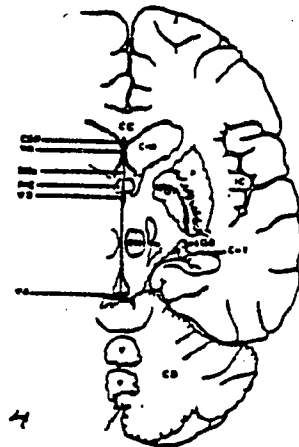
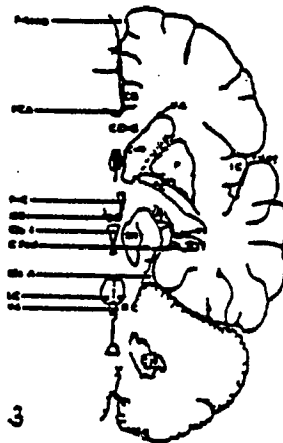
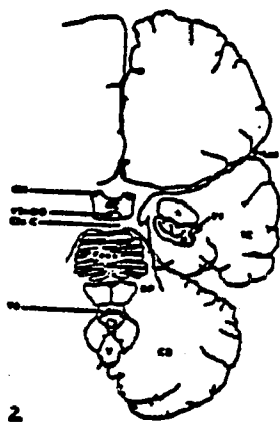
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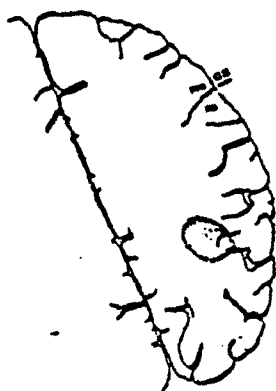
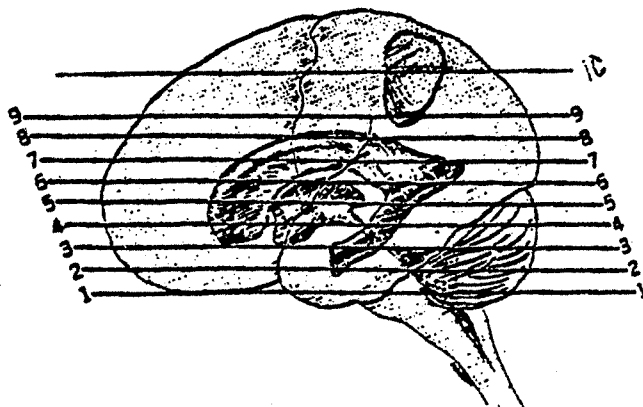
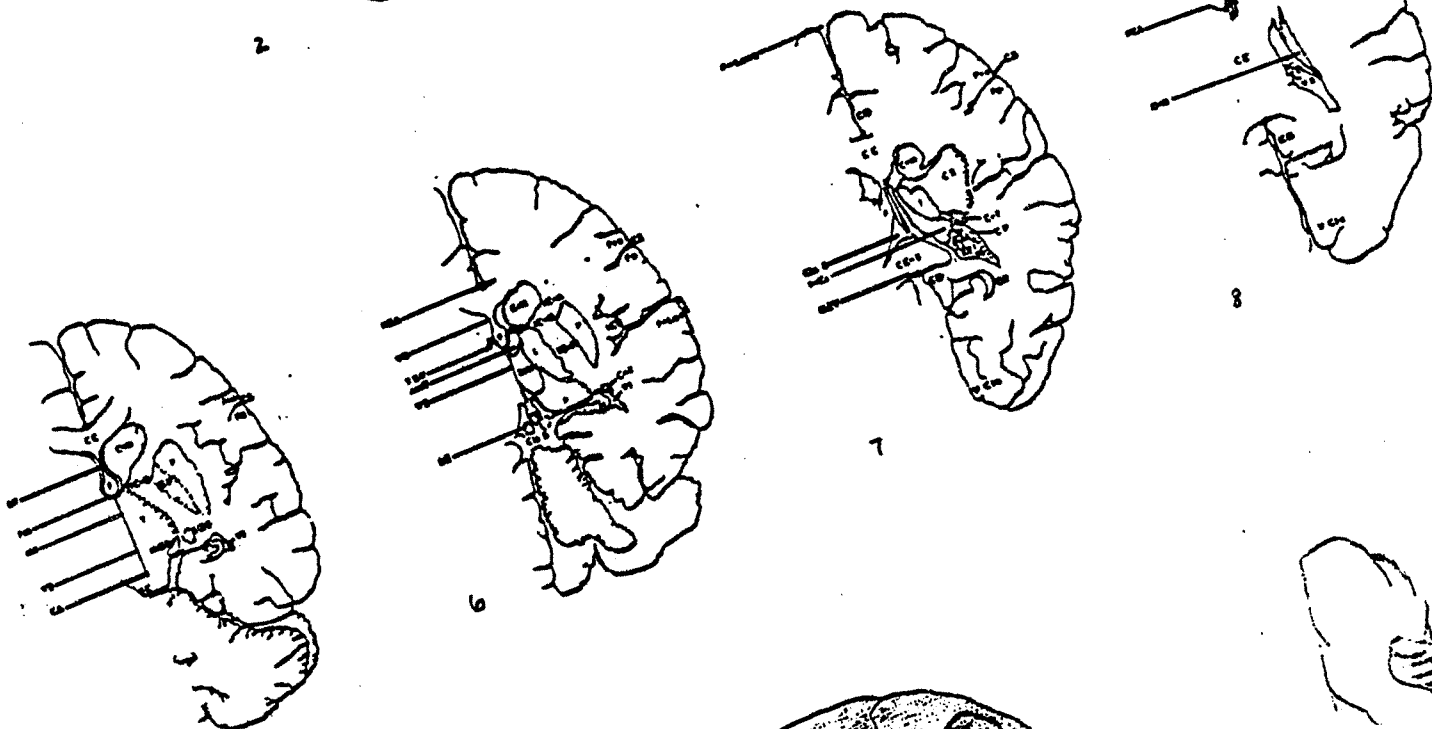
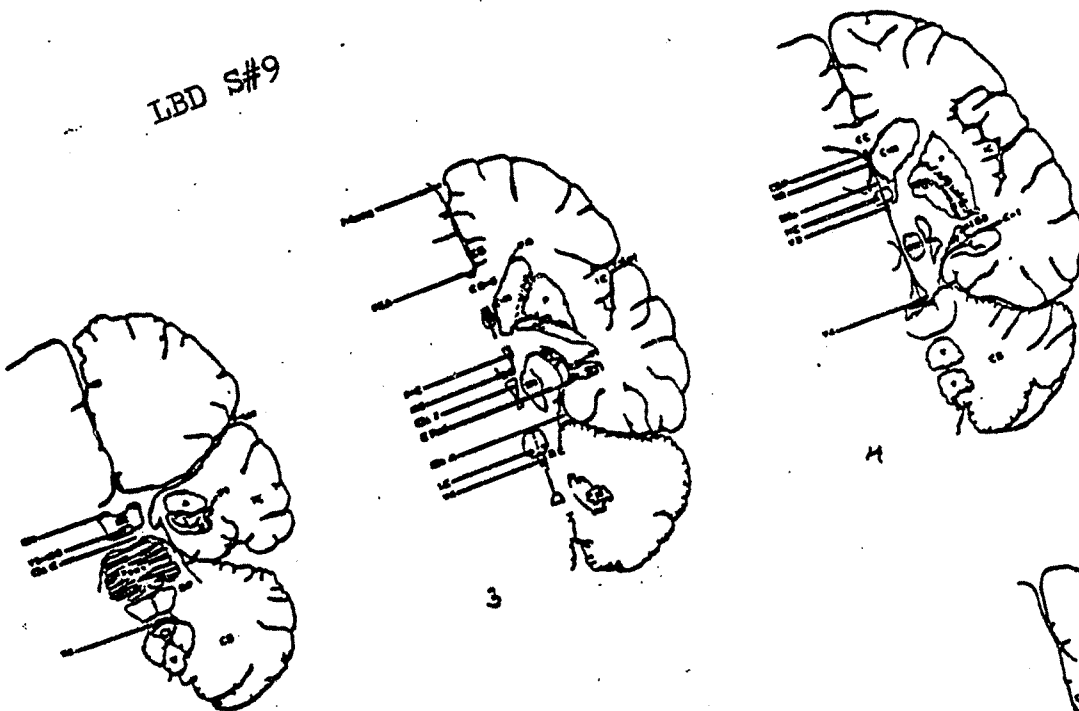


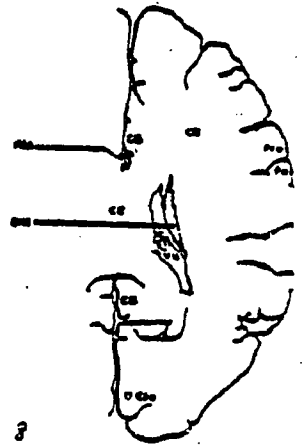
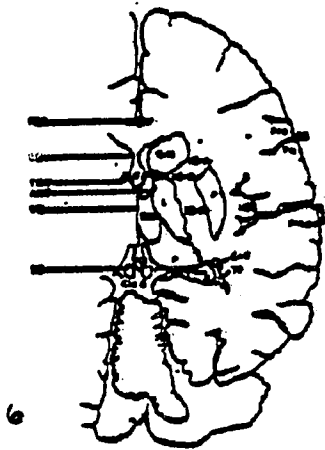
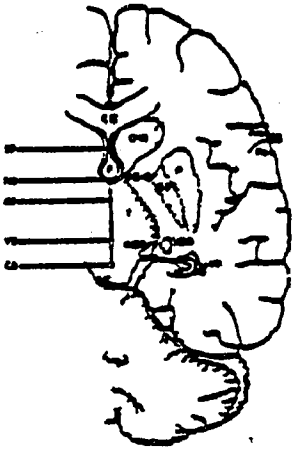
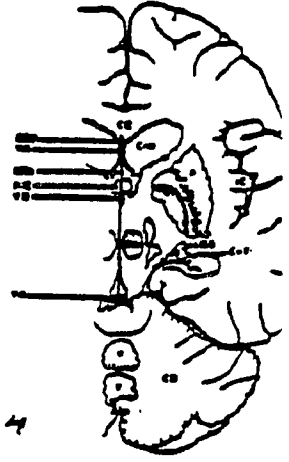
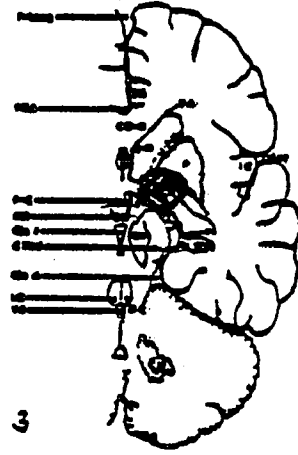
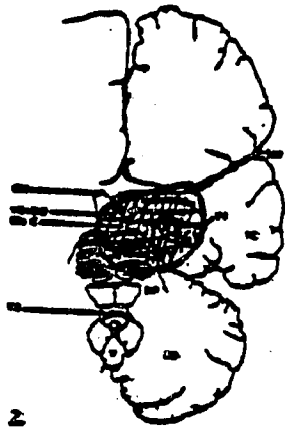
ATLAS OF HEAD FOR USE IN COMPUTER-ASSISTED TOMOGRAPHY

T. W. SCHULTZ, R. MORRISON AND J. G. CALDWELL



LBD S#9



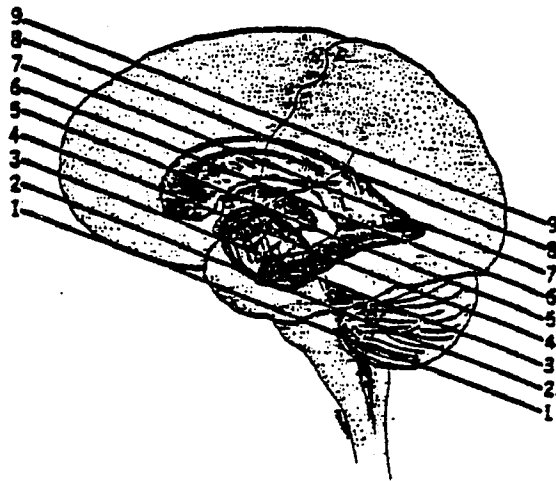
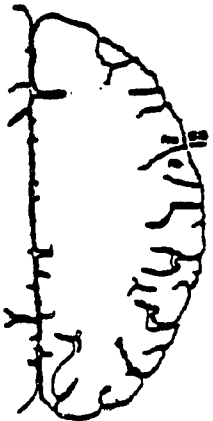


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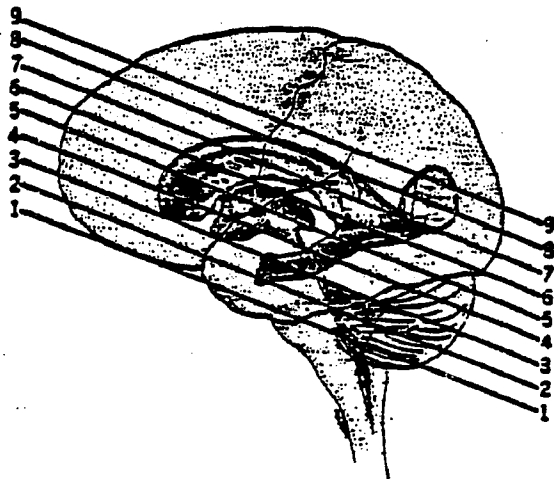
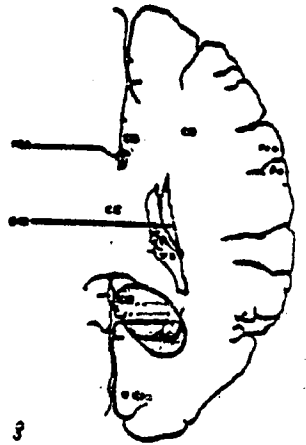
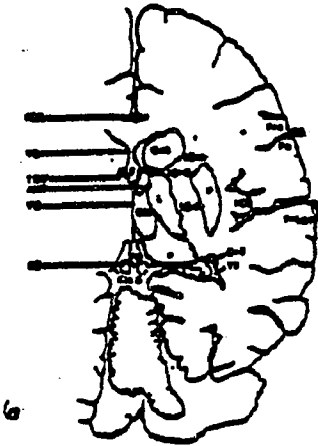
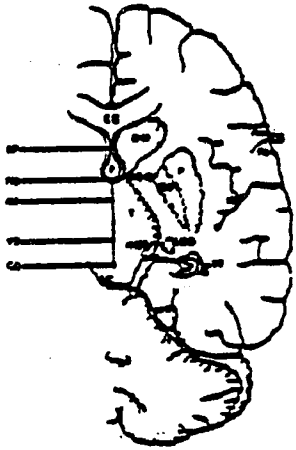
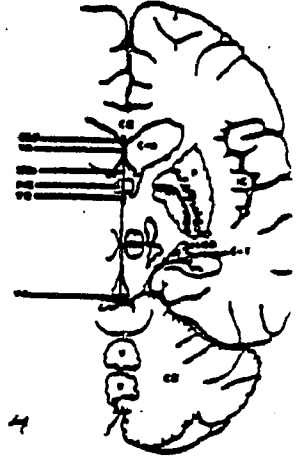
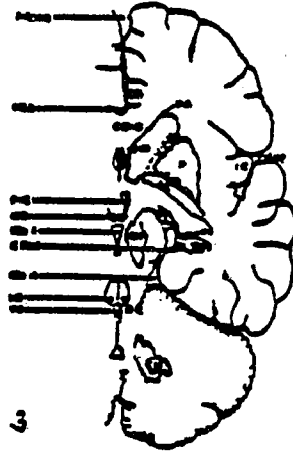
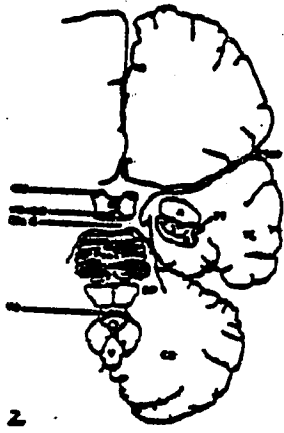
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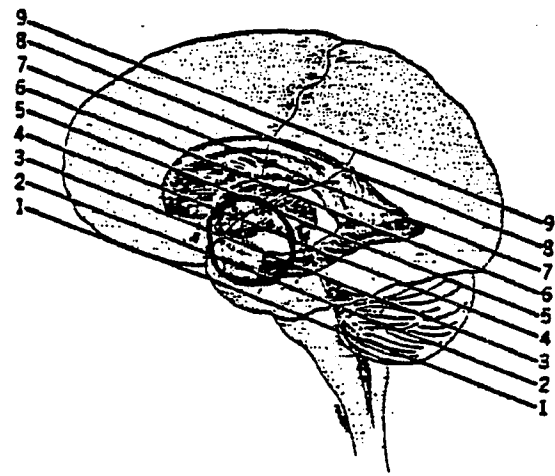
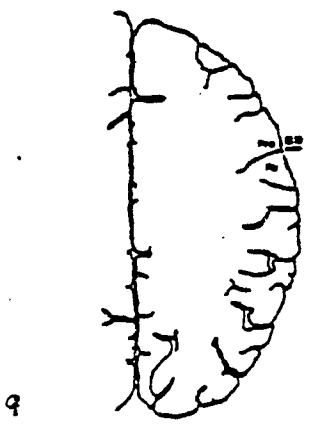
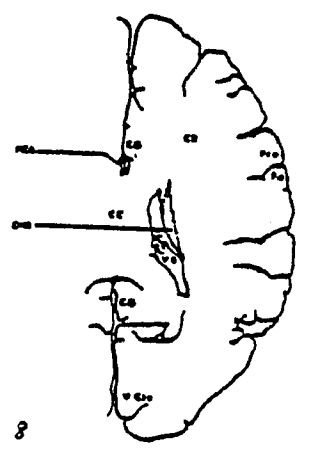
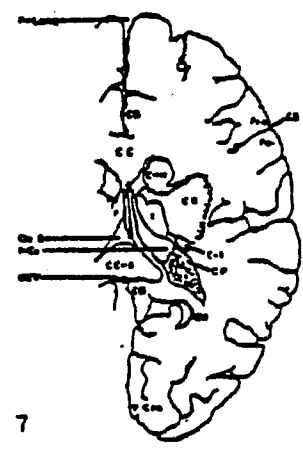
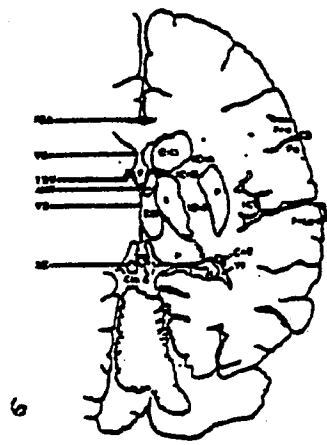
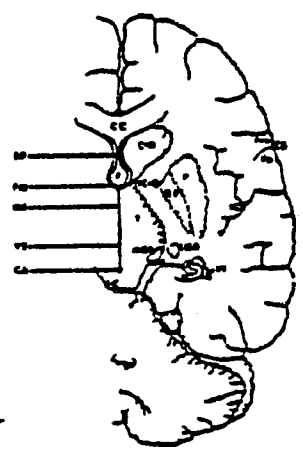
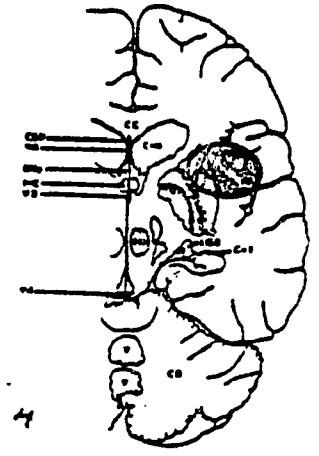
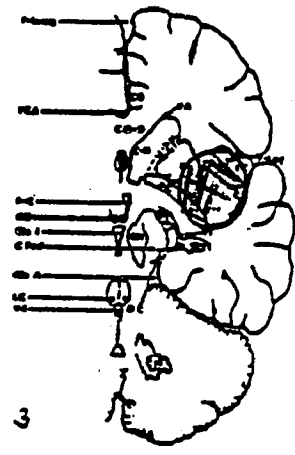
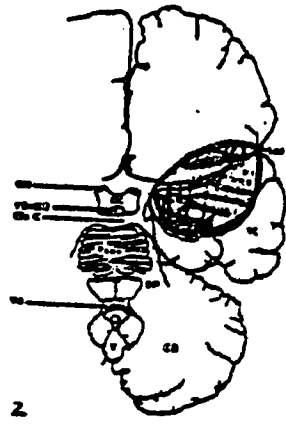
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LBD S#11



Appendix D

**Tables of Frequencies of Subject Variables
and Clinical Characteristics of
Brain-damaged Samples**

Table E
Distribution of Ages in Left- and
Right-side Lesioned Patients

Age	Left BD		Right BD	
	#Ss	%	#Ss	%
17-30	4	36.4	4	33.3
31-40	2	18.2	3	25.0
41-50	1	9.1	1	8.3
51-60	2	18.2	2	16.7
61-69	2	18.2	2	16.7

Table F
Distribution of Sex in Left- and
Right-side Lesioned Patients

Sex	Left BD		Right BD	
	#Ss	%	#Ss	%
Male	6	54.5	4	33.3
Female	5	45.5	8	66.7

Table G

Distribution of Indexes of Possible Ambidexterity
in Left- and Right-side Lesioned Patients

	Left BD		Right BD	
	#Ss	%	#Ss	%
Pure Right- handed	3	27.3	7	58.3
Mixed-handed	-	0	-	0
Family Hx. Left-handed	4	36.4	2	16.7
Missing Data	4	36.4	3	25.0

Table H

Distribution of Type of Lesion in Left-
and Right-side Lesioned Patients

	Left BD		Right BD	
	#Ss	%	#Ss	%
Meningioma	4	36.4	4	33.3
Glioblastoma	6	54.5	4	33.3
Vascular +	1	9.1	3	25.0
Other	-	0	1	8.3

Table I

Distribution of Locus of Lesion, Using
Gross Categories, in Left- and
Right-side Lesioned Patients

	Left BD		Right BD	
	#Ss	%	#Ss	%
Anterior	6	54.5	4	33.3
Posterior	3	27.3	3	25.0
Lateral	2	18.2	5	41.7

Table J

Distribution of Locus of Lesion, Using
More Refined Categories, in Left-
and Right-side Lesioned Patients

	Left BD		Right BD	
	#Ss	%	#Ss	%
Frontal	3	27.3	3	25.0
Rolandic	3	27.3	1	8.3
Parieto-Occipital	3	27.3	3	25.0
Lateral Temporal	-	0	2	16.7
Medial Temporal	2	18.2	3	25.0

Table K

Distribution of Extent of Lesion in Left-
and Right-side Lesioned Patients

	Left BD		Right BD	
	#Ss	%	#Ss	%
Small	2	18.2	2	16.7
Medium	3	27.3	3	25.0
Large	4	36.4	4	33.3
Very Large	2	18.2	3	25.0

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