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ABSTRACT

In a previous study, subjects that heard a monaurally presented two-clause sentence immediately followed by a probe word (identical word recognition) were faster at recognizing the probe as a sentence word with their left ears than with their right ears. This result suggested that the right ear was particularly efficient at transforming linguistic, auditory stimuli into an abstract representation of meaning. In a replication of this earlier study, 20 college students completed either the task for identical word recognition or a task requiring semantic matching (saying a synonym). As predicted, the structural task produced a left ear advantage similar to the earlier results, while the semantic task produced a right ear advantage. Right/left ear reaction times varied as a function of both task and the position of the target word. Right ear responses exhibited particular difficulty with recognizing words in initial clauses, while the reaction times between the left and right ears for initial clauses did not differ in the synonym task. Left and right ear reaction times were similar for recognizing words in final clauses; but the left ear was significantly slower than the right ear in the semantic matching of target words in final clauses. These ear differences support the view that the human brain is functionally symmetrical for language processing functions. (Author/RL)

Cerebral Asymmetry for Aspects of Language Processing[1]

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Cerebral Asymmetry for Aspects of Language Processing

Clinical and experimental evidence suggests that the human brain is functionally asymmetrical.[2] It appears that the left or dominant hemisphere is particularly involved in speech and language and the right or nondominant hemisphere in nonlinguistic functions.[3] This does not mean, however, that communication behavior is neatly divided up between the two halves of the brain, with verbal behavior controlled exclusively by the left hemisphere and nonverbal behavior by the right hemisphere. In fact, it is well known that the dominant hemisphere is involved in vision, touch, and motor skills; and the minor hemisphere can perform some language processing. William James (1890), who was well aware of the relationship between loss of speech and "left brain" injury, concluded his classic remarks on brain function in this way: "There is no 'centre of Speech' in the brain any more than there is a faculty of Speech in the mind. The entire brain, more or less, is at work in a man who uses language" (p. 56).

But it is still not at all clear exactly which aspects of linguistic analysis can and regularly do occur in the minor hemisphere. Tests of people with a split brain (i.e., where the interhemispheric connection, the corpus callosum, is severed) show some language comprehension in the minor hemisphere, ranging from comprehension of single words to sentences (Branch, Milner, & Rasmussen, 1964; Gazzaniga, 1967; Gazzaniga and Sperry, 1967; Terzian, 1964; Wada and Rasmussen, 1960; Zaidel, 1973; for a recent review of this issue see Nebes, 1978). Researchers have also studied normal males and females on tasks related to hemispheric specialization. In a recent review of this work, Goleman (1978) pointed out that adult females, more than males, appear to have verbal and spatial abilities on both sides of the brain. Some studies suggest that in children, too, there are major sex and age differences in degree of laterality effects for language function (e.g., Bryden, 1967; Levy and Reid, 1976); although, this is not a consistent finding (Witelson, 1976). It is well known that prior to puberty, damage to the dominant hemisphere results in less severe disruption of language behavior than after puberty (Lenneberg, 1967; Kinsbourne, 1975), a finding which has been attributed to plasticity of the hemispheres. Recent studies have attempted to measure the activity of the minor hemisphere during language processing in normal subjects. Using sophisticated techniques for measuring brain activity, Roemer and Teyler (1977) observed the electrocortical responses of subjects while they heard and thought about the meaning of an ambiguous word. They concluded that: "On the basis of this electrophysiological data, the most parsimonious interpretation is that both hemispheres are involved in some manner in the processing of linguistic information. This is not to say that the processing need be altogether similar in the 2 hemispheres" (p. 58). Other studies dealing with visually presented words have noted a striking lack of hemispheric asymmetry (see, for eample, Bell, 1973; Friedman, Simson, Ritter, & Rapin, 1975a; Friedman et. al., 1975b; Shelburne, 1972). It should be pointed out that based on their review of many studies of evoked potential correlates of differential hemispheric processing of auditory stimuli (verbal and nonverbal), Friedman et. al. (1975b) conclude that asymmetry of evoked potential components is not established. Finally, in direct contrast to a verbal/nonverbal division of labor beteen the hemispheres, Bever (1975) has presented evidence to argue for the position that ". . . it is the kind of processing that determines behavioral asymmetry, not the modality in which the processing is categorized (e.g., language, music, vision, etc.)" (p. 254). Taken together, these findings would caution us against any simple, dichotomous view of brain organization of verbal and nonverbal abilities.

Some theorists have proposed that the left hemisphere is particularly well suited for analytical processes and the right hemisphere for holistic, structural tasks (e.g., see Bever, 1975; Bogen, 1969a & b; Galin and Ellis, 1977; Levy-Agresti and Sperry, 1968). However, what is unsatisfactory about this dichotomy is that, while it may be essentially correct in its description, it does not propose an independent means for specifying the nature of any complex task, say, sentence comprehension, as analytical or holistic. Analytical and holistic are intuitive categorizations which, to be useful, must be assessed independently of behavioral data. Otherwise the data and their explanation become circular. Moreover, since sentence comprehension probably consists of domains or "levels of processing," it may well be an oversimplification to speak of sentence processing as a unitary left/analytic vs. right/holistic task.

Psycholinguistic evidence suggests that sentence processing occurs over time, as the raw, incoming signal is transformed into a semantic reading (Craik and Lockhart, 1972; Craik and Tulving, 1975; and many others). According to Craik and Tulving (1975), during language comprehension, a verbal stimulus is processed in various qualitative ways--structural, phonemic, and semantic--and it is encoded to a more or less elaborate degree at each level or domain (Degree of Encoding Elaboration). They maintain that ". . . retention depends critically on the qualitative nature of the encoding operations performed; a minimal semantic analysis is more beneficial than an extensive structural analysis" (p.268). They suggest that the memory trace is a record of the encoding operations carried out during analysis of the stimulus plus the "features checked" during encoding. A greater number of features checked (especially semantic features) entails a more elaborate memory trace.[4] It would seem to follow that the "degree of encoding elaboration" is related to the functional organization of the brain. Indeed, studies of electrophysiological activity of the brain show evidence for qualitative differences in processing as a function of time and brain structure.

In their review of electroencephalographic measures of hemispheric specialization, Donchin, McCarthy, and Kutas (1977) write: "The ERP [event-related potential] is not a uniform entity. The data accumulated over the past decade strongly supports the contention that the series of voltage oscillations, lasting several hundred milliseconds after the eliciting event, represents a composite of largely independent components related to successive levels of processing within the nervous system (McKay, 1969; Donchin and Lindsley, 1969)" (p.214). Within the first 300 or so milliseconds after the onset of an auditory event, the electrocortical response is influenced by a number of variables. At first it is influenced primarily by the physical or acoustic dimensions of the stimulus. Within the first 200 milliseconds, the shape of the cortical waveform depends upon the modality (Goff, Matsumiya, Allison, & Goff, 1969). About 100 milliseconds later, a component of the waveform with a latency of at least 300 milliseconds is not modality-specific (Squires, Donchin, Squires, & Grossberg, 1977) and is not specifically affected by physical stimulus properties (Johnson and Donchin, 1976). This later component, called P300, seems to be affected by information processing activities related to task demands. Speaking of the components of the electrocortical configuration, Donchin, McCarthy, and Kutas (1977) say:

> It is evident that the ERP represents progressive stages of analysis of the stimulus event. The earliest components appear to faithfully index the quality of the stimulus event and are stable over a range of psychological manipulations; hence their usefulness in ERA and neurological diagnosis (Starr and Anchor, 1975). With increasing latency from the event, the ERP components reflect more complex properies of the stimulus in a psychophysical and a psychological sense. Ultimately, the P300 component is independent of stimulus characteristics except in how they affect the psychological aspects of the event (pp. 215-216).

The foregoing neurological and psycholinguistic evidence clearly implies that sentence processing is likely to elicit a range of neural activities and behavioral results. Roemer and Teyler (1977) proposed that: ". . . early and late components may be dissociated, with the early components more sensitive to sensory aspects of linguistic stimuli and late components more responsive to semantic aspects" (p. 58).

Brown, Marsh, and Smith (1973) showed that when the same physical occurrence of an auditorily presented ambiguous word (e.g., the word "fire") took part in different phrases that brought out its various meanings, subjects produced different electrocortical waveforms as a function of the word's meaning. Moreover, these differences were greater for left hemisphere recordings than for right (also, see Chapman, Bragdon, Chapman, & McCrary, 1977; Teyler, Roemer, Harrison, & Thompson, 1973; Marsh and Brown, 1977). Donchin, McCarthy, and Kutas (1977) point out that there is evidence for a systematic relationship between brain structure, linguistic structure, and task demands, as observed in various electrocortical measures, such as P300 components, their amplitudes, and their latency. In this same connection, various psychological studies of choice reaction time (and/or retention) show that the nature of the task (e.g., classifying each letter of a word as a consonant or a vowel, deciding if two items are physically identical, saying a sentence that is semantically related to a stimulus sentence, deciding if a probe rhymes with any word in a sentence, memorizing sentences) and the structure of the linguistic stimulus are intimately related to reaction time and retention of the test materials (Craik and Tulving, 1975; Green, 1975; Mistler-Lachman, 1974; Shulman, 1970, 1974). At the same time, we know relatively little about the relationship between functional brain structure, linguistic structure, and task requirements. The purpose of the present study is to learn more about how the two sides of the intact, adult brain differ in initial sentence processing, i.e., processing that goes on during and immediately after a sentence is heard. More specifically, the right hemisphere is compared to the left with two tasks--one which requires a same/different judgment (presumably a structural match) and the other which requires additional semantic processing (presumably a conceptual match).

At present much of the behavioral evidence showing asymmetry of language function between the ears comes from the dichotic listening task (Kimura, 1963; Ingram, 1975; Knox and Kimura, 1970; Bryden, 1966, 1967; and others). In the dichotic listening task the subject hears different auditory stimuli simultaneously in both ears and is asked to recall as much as possible. Typically, adults do better with verbal stimuli in the right ear and nonverbal stimuli in the left, which has generally been interpreted as evidence for laterality of language function. The findings from the dichotic listening task fall short, however, in at least three ways: (1) they establish evidence for lateralization of language function under highly specific circumstances which may rely upon competition for attention in a limited capacity system (Broadbent, 1962). That is, we may be learning more about attention mechanisms than language processes *per se* (see Kinsbourne, 1970, for his attentional model of asymmetry; also, Allport, Antonis, & Reynolds, 1972); (2) we do not know from the dichotic listening task exactly which levels or domains of language processing (Craik and Lockhart, 1972; Craik and Tulving, 1975) are more efficiently carried out in the dominant hemisphere compared to the minor hemisphere (see Haaland, 1974); and (3) the evidence does not inform us on the question of how much processing can be accomplished by the minor hemisphere. It is worth noting that Braine (1967) has discussed the conflicting sets of data obtained with visual stimuli presented unilaterally (i.e., separately to each visual field) versus bilaterally (i.e., simultaneously to each visual field); various studies found that subjects showed better recognition (of letters) in the right visual field with unilateral presentation (Mishkin and Forgays, 1952) and better recognition in the left field with bilateral presentation (Heron, 1957; Bryden and Rainey, 1963; Harcum, 1964; Kimura, 1959). The suggestion here is that unilateral and bilateral conditions may be mediated by different mechanisms. We need to collect data on brain structure and language processing with monaural (one ear at a time) as well as dichotic procedures, just in case there is an interaction between the conditions of testing and the subject's performance.

When subjects are presented with linguistic stimuli in one ear at a time, we get some idea of the capacity of each ear/hemisphere system for processing language (Frankfurter and Honeck, 1973). With such monaural presentation, some evidence suggests that the dominant ear is particularly sensitive to sentence structure. For instance, Bever (1971) reported an asymmetry of the ears for the immediate processing of sentences but not lists of words. Subjects successfully recalled more sentences heard in the right ear than the left. In addition, he found that when subjects hear various sentence forms (e.g., active, passive, negative, question, negative passive, passive question, negative passive question) in the right ear, they show fewer meaning-changing syntactic errors than for sentences presented to the left ear. Bever concluded that ". . . the dominant ear is more directly involved in the processing of the syntactic and semantic aspects of speech and that its involvement qualitatively affects perceptual judgments and immediate recall" (p. 14). Shedletsky (1979) reasoned that right after a sentence is heard in the right ear it is more fully processed than right after it is heard in the left ear. We should recall that Craik and Lockhart (1972) and Craik and Tulving (1975) suggest that a more fully (or elaborately) processed sentence implies a greater degree of semantic analysis. They add that, "since the organism is normally concerned only with the extraction of meaning from the stimuli, it is advantageous to store the products of such deep analysis, but there is usually no need to store the products of preliminary analyses" (p. 675). Hence, information concerning the exact words of the just-heard sentence may be less available in the dominant hemisphere than the minor hemisphere. That is, if the subject is required to retrieve information about the surface structure of a sentence right after the sentence ends, for example, whether or not a particular "word" (i.e., its auditory representation) occurred in the sentence, then the subject should have more trouble with right ear than left ear presentations.

In line with this idea, it was found that presentation of the sentence to the left or right ear did have a reliable effect on reaction time in a probe recognition task (Shedletsky, 1979). On the average, subjects took significantly longer to recognize a probe-word from a sentence heard in the right ear than a probe-word from a sentence heard in the left ear (regardless of which ear the probe-word was heard in). If the left ear advantage in this simple, word-recognition task was due to the minor hemisphere's ability to process structural aspects of stimuli (i.e., corresponding to the early components of the EEG with a relatively short latency), then a task requiring semantic analysis of the sentence and the probe-word may produce different results between the two ears; namely, a semantic task requirement ought to bring out a right ear advantage. (Nebes, 1978, has discussed recent evidence which bears upon cerebral asymmetry for structural and conceptual matching). This study tests the idea that item-recognition will produce a left ear advantage and semantic matching a right ear advantage.

Finally, I want to discuss some characteristics of sentence processing which have been well documented and which may interact with ear presentation and task demands. A factor which affects the accessibility of a word in a sentence just heard is its location in the sentence structure (Shedletsky, 1975). Many studies of sentence processing ~~have~~ been interpreted to show that sentences are processed clause-by-clause (Abrams, 1973; Bever, Garrett, & Hurtig, 1973; Bever, Lackner, & Stolz, 1969; Bever, Kirk, & Lackner, 1969; Caplan, 1971, 1972; Fodor and Bever, 1965; Garrett, Bever, & Fodor, 1966; Holmes and Forster, 1972; Jarvella, 1970; Jarvella and Herman, 1972; Wingfield and Klein, 1970). In addition, it has been found that for a two-clause sentence, initial clause words are less accessible than final clause words, independent of serial position within the sentence (Jarvella, 1970; Jarvell and Herman, 1972; Caplan, 1971, 1972). This finding supports the idea that initial clauses are assigned meaning before final clauses are assigned meaning; moreover, that results of preliminary analyses for initial clause words are less accessible than for final clause words. We may expect, then, that in a word-recognition task initial clause words presented to the right ear (which is especially efficient at assigning meaning) will cause greater difficulty than any other clause position/ear orientation. In fact, Shedletsky (1979) found evidence for this clause position by ear interaction. But, we may expect that in a task requiring a semantic match, initial clause words presented to the left ear (which is not efficient at assigning meaning) will cause greater difficulty than any other clause position/ear orientation.

To sum up, it has been proposed that the right ear will differ from the left ear in the depth of analysis (or "degree of encoding elaboration") for immediate sentence processing. As a result, the exact words in right ear sentences will be less readily available than left ear sentences. At the same time, the meaning of right ear sentences will be more readily available than left ear sentences. This difference will show up in faster reaction time to left ear presentation in a same/different structural task and faster reaction time to right ear presentation in a semantically oriented task. These differences by ear and task will be sensitive to sentence structure.

Method

Subjects

The subjects were twenty volunteers at the Stamford Campus of the

University of Connecticut (six males and fourteen females). Subjects were right handed and native speakers of English with normal hearing.

Materials

There were eight two-clause test sentences, heterogeneous as to semantic content. In each test sentence, the clause containing the target word consisted of between nine and eleven monosyllabic words (with the exception of two disyllabic target words); it was either a main or a subordinate clause, in initial or final clause position. The serial position of the target word ranged from one to eight syllables from the beginning of the clause. The following is an example of two initial clause and two final clause test sentences (the target word is underlined):

1. It was nice to <u>often</u> speak to you, though the telephone bill was ridiculously high.
2. While the large couch or the small <u>chair</u> must be moved, the rest of the furniture can remain just where it is.
3. The new girl was a whiz at reading, writing, and arithmetic, while the new boy could not write or <u>speak</u> well.
4. When the boss came into the room, Jack glanced <u>quickly</u> at the work he had done.

Thirty additional sentences were constructed. Six served as practice sentences, three subordinate-main and three main-subordinate sentences. For each clause order (subordinate-main and main-subordinate), one probe was from the beginning of the sentence, one was from the end of the sentence, and one was semantically unrelated to the sentence words. The remaining 24 sentences served as filler sentences to provide semantically unrelated (irrelevant) probes and to vary the serial position of the target word. The filler sentences consisted of 12 subordinate-main and 12 main-subordinate sentences. For each clause order, four probes were from an extremely early position in the sentence, four were from an extremely late position, and four were unrelated to the sentence words.

Design

The design was a 2 X 2 X 2 analysis of variance having 2 between-subject and 1 within-subject variables. The between-subject variables were Ear (sentences presented to the right ear or the left ear) and Task (identical word-recognition vs. say-a-synonym). The within-subject variable was Clause Position (initial vs. final).

The presentation tape was constructed in the following way. Within each half of the list (tape) there was an equal number of subordinate-main and main-subordinate order test sentences, with one target word from an initial subordinate clause, one from an initial main clause, one from a final subordinate clause, and one from a final main clause. Within these limits, test sentences were randomly ordered. An equal number of subordinate-main and main-subordinate filler sentences occurred in each half of the list, with an equal number of relatively early, late, and unrelated targets. The order of the test sentences and fillers was constant for all conditions. Subjects were randomly assigned to conditions (left ear/synonym, left ear/word-recognition, right ear/synonym, right ear/word-recognition).

Apparatus

The list of sentences was tape recorded by a male Standard American speaker. Filler and test sentences were recorded on one channel in a monotone (an oscillator aided in keeping pitch constant) with an attempt to reduce clause boundary juncture. Sentences were recorded in this way to encourage subjects to segment the sentences according to syntactic knowledge rather than intonational cues. Probes were recorded on a second channel. The interval between the end of the last word of the test sentence and onset of the probe was approximately one-third of a second.

Sentences and probes were presented auditorily to subjects with a tape recorder and stereophonic headphones. Onset of the probe activated a voice operated relay which started a millisecond timer. The subject's spoken response stopped the timer via a microphone and a second voice operated relay.

Procedure

Subjects were tested individually in an item-recognition task which will be called "identical word-recognition," or a modification of that task, which will be called "say-a-synonym." In both tasks the subject was presented with the same tape recording, so that on each trial the subject heard a sentence immediately followed by a probe word. In the identical word-recognition condition, the subject was instructed to say "Yes" if the probe was present in the sentence (i.e., the identical word) and "No" if it was not. In the say-a-synonym condition, the subject was instructed to ". . . say a word that means approximately the same thing as the word that comes after the sentence, when it [the probe] was a word that actually occurred in the sentence." If the probe word didn't occur in the sentence, then the subject was instructed to say "No." Speed and accuracy of response were encouraged.

Half of the subjects in each task heard the sentences and probes in the left ear and half in the right ear. Reaction time was measured from the onset of the probe to the subject's response. The experimenter also recorded the word(s) spoken by the subject in his/her attempt to produce a synonym.

Results

Each subject contributed 8 data points. Out of the overall total of 160 data points, some were missing due to equipment failure (5 instances), no response after a ceiling of 2.5 seconds (5 instances), responses 2 or more standard deviations from a subject's mean recognition latency for test sentences (1 instance), and/or errors (8 instances). If 3 or more of a subject's 8 data points were missing, that subject was replaced. Three subjects were replaced and their data excluded from further analysis. Recognition latency data for error trials (5%) were not included in the subsequent analyses. Missing data were not replaced[5]; instead, the condition with the largest number of missing data was used to establish the number of scores per condition, which was 13 scores for each combination of ear, task, and clause position. Hence, some scores were randomly excluded from each of the other conditions. It is worth noting that all 8 of the errors and 4 out of 5 "no responses" (i.e., 2.5 seconds elapsed) came from initial clause targets.

The "synonym" responses were scored on a lax basis. Only 1 response, which was actually an antonym, was scored as an error; all others were accepted, even though they often bore a family resemblance to the probe rather than a synonym relationship (see Table 1).

Insert Table 1 about here

The mean reaction time was computed for each combination of ear (right vs. left), clause position (initial vs. final), and task (identical word-recognition vs. say-a-synonym), as shown in Table 2. The task and the

Insert Table 2 about here

clause position of the target word had sizeable effects on reaction time. Overall, subjects took 671 milliseconds longer to "say-a-synonym" than to indicate whether or not the probe occurred in the sentence just heard. For sentences heard in the left ear, subjects took 842 milliseconds longer to "say-a-synonym" than to say that the probe word occurred in the sentence; for right ear presentation, subjects took 500 milliseconds longer to "say-a-synonym" than to indicate presence of the probe in the sentence. Table 2 shows that the right ear took 176 milliseconds longer than the left for identical word-recognition and 166 milliseconds less than the left to "say-a-synonym." Initial clauses produced longer reaction time than final clauses for all comparisons; but clause position was confounded with serial position from the end of the sentence. In the identical word-recognition task, reaction time for initial clauses in the right ear was 240 milliseconds greater than for the left ear, as shown in Fig. 1. However, in the synonym task, right ear presentation resulted in a 71 millisecond shorter reaction time than for left ear presentation (of initial clauses).

An analysis of variance was performed to assess the significance of these observations and to test for interactions. Two reliable main effects were found: Reaction time for the identical word-recognition task was significantly faster than reaction time for the "say-a-synonym" task [$F(1,84) = 124.3$, $p < .01$]. Additionally, initial clauses produced longer reaction time than final clauses [$F(1,84) = 9.2$, $p < .01$].

A significant interaction was found for Ear (left vs. right) and Task (identical word-recognition vs. say-a-synonym) [$F(1,84) = 6.7$, $p < .05$].

When subjects had to indicate whether a probe word occurred in a sentence just heard, they produced longer reaction time to right ear than left ear presentation. The reverse occurred when subjects said a synonym for the probe word; here, right ear presentation produced shorter reaction time than left.

The effects of Ear, Task, and Clause Position are shown in Fig. 1. It is clear that the increase in reaction time for initial right ear targets compared to left ear targets is greater for the word recognition task than for the synonym task. This observation was tested with the Wilcoxon matched-pairs signed-ranks test, using individual subjects' reaction times as single scores to determine if the mean reaction times appearing in Fig. 1 were significant. The difference between right and left ear initial clause targets in the word-recognition task was significant ($T = 28$, $N = 16$, $p < .05$, two-tailed). The difference between right and left ear initial clause targets in the synonym task, however, was not significant ($T = 42$, $N = 12$, $p > .05$, two-tailed). Conversely, for the synonym task final clauses in the left ear compared to the right ear show a significant difference in reaction time ($T = 32$, $N = 17$, $p < .02$, two-tailed); but in the word-recognition task, final left and right clauses do not differ significantly ($T = 46$, $N = 18$, $p > .05$, two-tailed).

In sum, the results support two main conclusions of interest. First, the left ear is faster than the right at finding out whether or not a probe word occurred in a sentence just heard; conversely, the right ear is faster than the left at saying a synonym for a sentence word. Second, the right ear has particular difficulty with initial clause words in the word-recognition task; in the synonym task, on the other hand, the reaction time did not differ between the left and the right ear for initial clauses. For final clauses, however, the left ear does not differ from the right ear in speed of word-recognition. But the left ear is significantly slower than the right in saying-a-synonym for final clause words.

Discussion

The main reason for carrying out this experiment was to explore the idea that the minor hemisphere can perform as well as the dominant hemisphere on some tasks involving linguistic stimuli and that the two hemispheres would differ according to the task demands. It was thought that the minor hemisphere would do well on structural analyses and the dominant hemisphere would do well on conceptual analyses. This idea grew out of an earlier study, Shedletsky (1979), in which it was demonstrated that, in an identical word-recognition task, when subjects hear a complex sentence immediately followed by a probe word, (1) recognition latency is shorter for left ear than right ear presentations; and (2) there's a statistically significant interaction for clause position by ear: initial clauses heard in the right ear produce a longer reaction time than for any other ear/clause position combination. Initially, these findings seemed surprising, since, ordinarilly, with many conditions, speech presented to the right ear is reported faster and with greater accuracy than speech presented to the left ear. But the longer reaction time for the right ear was accounted for by assuming that its efficiency at transforming linguistic stimuli into a semantic representation was a deficit in a task which required matching for identical physical dimensions. It was proposed that by the time the probe word was heard in the right ear, the sentence items were recoded and preliminary analyses discarded. On the other hand, it was supposed that the left ear benefitted from its deficiency at semantic processing. Since the left ear was not efficienct at semantic recoding, the internal representation of the sentence closely resembled the stimulus sentence when the probe word was heard. To test this idea, the present study attempted to replicate the earlier study and to find out if the main effect for ear of presentation is neutralized or reversed with a task that requires semantic processing. Hence, the identical word-recognition task in the present study is a replication of the earlier study. The say-a-synonym task was designed to test each ear/hemisphere's ability to search for a word(s) that would be equivalent in meaning to the target word.

The results from the identical word-recognition task are in perfect agreement with the earlier findings. Left ear reaction time is faster than right ear reaction time; and the initial clause heard in the right ear produced longer reaction time than any other ear/clause position combination.

Although it is unusual to find a left ear advantage in a task involving linguistic processing, it now appears that the word-recognition task used here can be performed more quickly by the minor hemisphere than the dominant hemisphere. This finding is consistent with the position that right and left hemispheres ought not to be regarded as nonverbal and verbal, respectively, but rather as differing in the specific cognitive operations each does best.

The say-a-synonym task is a further test of this proposal. When subjects had to decide whether the probe word occurred in the sentence, and, in addition, had to say a synonym for it, the left ear advantage disappeared. In contrast to the word-recognition task, in the synonym task the right ear was significantly faster than the left, suggesting that the right ear is especially efficient at performing the conceptual aspects of the task. Moreover, in agreement wuth this interpretation, initial clauses heard in the left ear took longer than initial clauses heard in the right ear for the synonym task; this was opposite to the findings for word-recognition.

Since the left ear does relatively poorly at assigning meaning to linguistic stimuli and since initial clause items are harder to retrieve than final clause items, the left ear system has special difficulty finding synonyms for initial clause words. The right ear system, on the other hand, functions well at transforming linguistic stimuli to a semantic reading, and therefore does particularly well at a semantic match.

The idea that the right ear shows an advantage over the left for semantic transformation of linguistic stimuli gains support from a memory study (Frankfurter and Honeck, 1973) which varied semantic well-formedness (meaningful vs. anomalous), syntactic structure (right-branching vs. self-embedded), and monaural presentation (right ear vs. left ear). Subjects heard sentences followed by a number counting delay task, and then they had to recall the sentences. The right ear produced better recall for content words (in sentence order) than the left; however, when order of recall was ignored, the difference between ears did not reach significance. Most importantly, when protocols were scored for meaning preservation (proposition recall), the right ear was superior to the left. Since no interaction was found for ear by semantic well-formedness (regular vs. anomalous sentences), the evidence does not support a strictly dichotomous view of hemispheric specialization.

In short, it appears that the right ear performs better than the left at manipulating the meaning of linguistic stimuli, while the left ear performs better than the right in a simple choice reaction time--a same/different judgment for words. These ear differences are plainly in line with the clinical and experimental evidence on brain asymmetry reviewed earlier in this paper. Moreover, these results suggest that behavioral data closely conform to some findings obtained with electro-cortical measures, and they underscore the need to test the ears monaurally (i.e., separately) as well as dichotically (i.e., simultaneously). These results lend credence to the suggestion that others have made, namely, that the whole brain takes part in language behavior (e.g., Bever, 1975; James, 1890; Roemer and Teyler, 1977). Witelson (1976) has even gone so far as to suggest that the minor hemisphere's involvement in structural, spatial functions may be especially important in reading. In order to learn more about the simultaneous functioning of the two hemispheres and their integration of information, we need to study various tasks which separarately and jointly place specific task demands upon the two hemispheres.

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Footnotes

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[2]Normally, one hemisphere in the adult brain is dominant in the processing of speech stimuli (Bever, 1970; Buchsbaum and Fedio, 1970; Gazzaniga and Hillyard, 1971; Geschwind, 1965; Hecaen and Ajuriaguerra, 1964; Kimura, 1967; McAdam and Whitaker, 1971; Milner, 1962; Morrell and Salamy, 1971; Mountcastle, 1962; Neville, 1974; Teuber, Battersby, and Bender, 1960; Wood, Goff, and Day, 1971; Zangwill, 1960).

[3]It has been estimated that the left hemisphere is dominant for speech in approximately ninety percent of right handed adults and sixty percent of left handed adults (Branch, Milner, and Rasmussen, 1964; Bryden, 1965; Kimura, 1967; Satz, Achenbach, Pattishall, and Fennell, 1965). All the studies discussed in this paper used right handed adults; therefore to simplify matters, we shall speak as if the left hemisphere is dominant for speech. Since each hemisphere has a functionally primary neurological connection with the contralateral ear (right ear to left hemisphere, left ear to right hemisphere; see Kimura, 1967), the right ear has generally been referred to as dominant and the left ear as non-dominant.

[4]Craik and Tulving's Degree of Encoding Elaboration bears some similarity to William James' distinction between <u>knowledge of acquaintance</u> and <u>knowledge about</u>; James discussed a relative distinction in the degree of operations performed upon incoming (nervous) signals resulting in more and less connections (relations) between it and other sensations and ideas

(see James, chapters VIII and XVII, 1890).

[5]An additional analysis of variance was performed in which missing data were replaced. Missing data were estimated from row and column scores (see Winer, 1962, pp. 487-490). The results obtained in this way were nearly identical to the results obtained by not replacing missing data. A main effect was found for Task $[F(1, 134) = 204, p < .01]$; and a main effect was found for Clause Position $[F(1, 134) = 11.76, p < .01]$. The interaction for Ear by Task was also significant $[F(1,134) = 9.76, p < .01]$.

Table 1

Responses in the Say-a-Synonym Task as a Function of Presentation Ear, Probe Word, and Clause Position of the Target Word

	Initial Clause Target				Final Clause Target			
Subject	clowns	often	chair	speak	beer	quickly	sliced	soon
				Left Ear				
1	mimes	X	seat	talk	liquor	fast	cut	now
2	funny-men	frequent-ly	X	talk	brew	X	cut	now
3	character	quickly	seat	talk	alcohol	fast	M	X
4	funny-men	frequent-ly	seat	talk	X	speedily	cut	X
5	jokers	X	couch	talk	alcohol	fast	cut	X
				Right Ear				
6	funny	seldmm[a]	seat	talk	alcohol	fast	cut	immediate
7	people	lot	sofa	talk	alcohol	fast	chopped	recently
8	funny-people	frequent-ly	seat	talk	alcohol	hurried-ly	cut	quickly
9	fools	X	seat	talk	alcohol	fast	cut	quickly
10	funny-men	frequent-ly	seat	talk	Miller	fast	chopped	X

Note. X = an error (i.e., a "No" response, or no response); M = equipment failure.

[a]"seldom" was the only response offered as a synonym which was scored as an error.

Table 2

Mean Reaction Time (in Milliseconds) as a Function of Presentation Ear, Task, and Clause Position of the Target Word

	Left Ear		Right Ear	
Clause Position	Identical	Synonym	Identical	Synonym
Initial	482	1309	722	1238
Final	363	1221	475	960
Task Mean (Within-Ears)	423	1265	599	1099

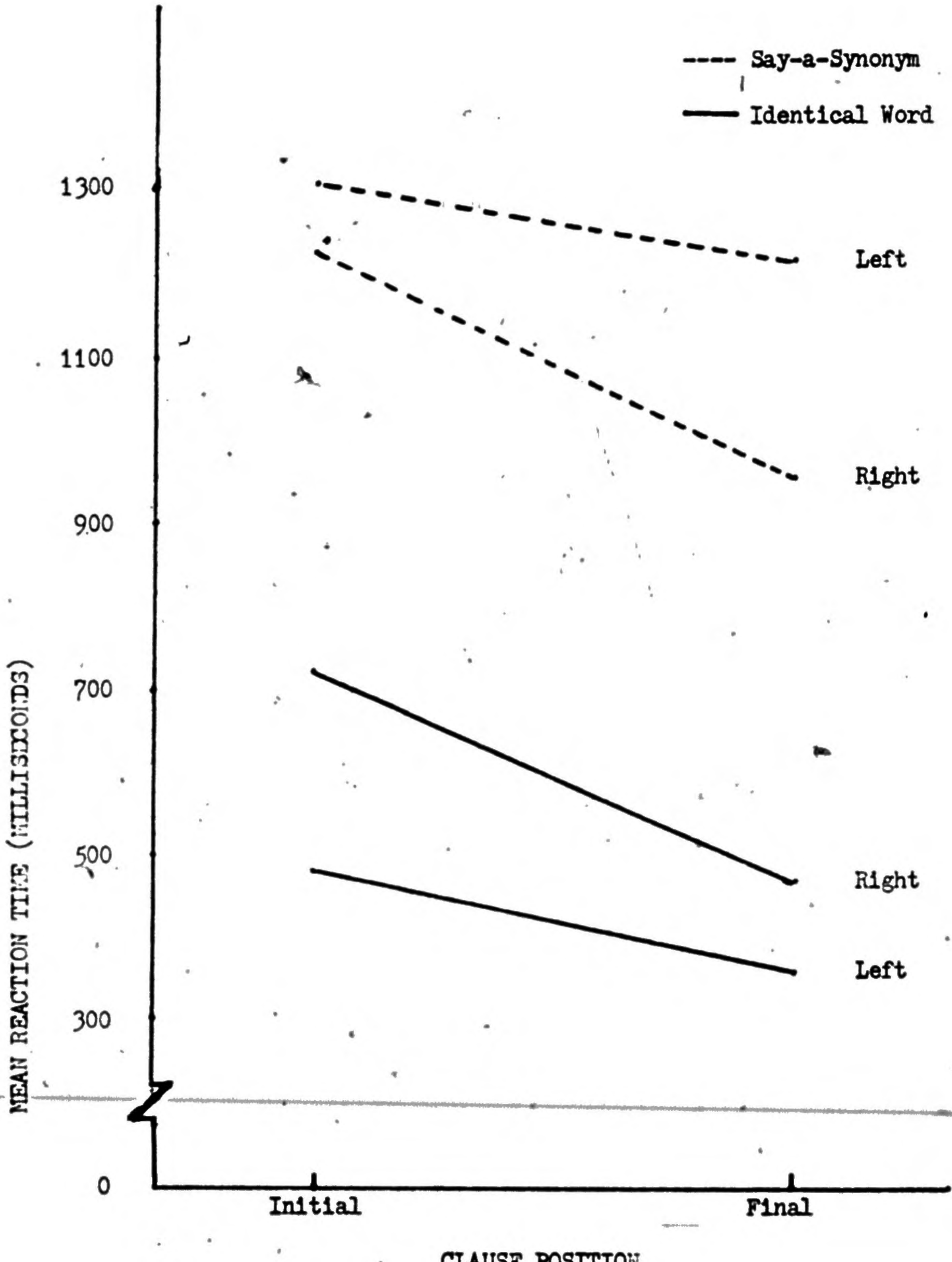

Fig. 1. Reaction time as a function of the ear hearing the sentence and the probe word, the clause position of the target word, and the task.