CEREBRAL DOMINANCE, SENTENCE STRUCTURE
AND SENTENCE TYPE

A thesis submitted in partial satisfaction of the requirements of the degree of Master of Arts in Psychology

by

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The thesis of Marjorie Chang is approved:

Committee Chair

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July, 1975
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ABSTRACT

CEREBRAL DOMINANCE, SENTENCE STRUCTURE
AND SENTENCE TYPE
by
Marjorie Chang
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Two sets of sentences, predicate nominative and transitive verb each in two different forms, recursive and nonrecursive were used to investigate the functioning of the normal whole brain under conditions of monaural and binaural input conditions. The nonrecursive form used two simple sentences one after the other, the recursive form combined the two, one as a clause modifying the subject of the other sentence. These sentences were input to the left ear, right ear, and both ears. The left hemisphere is described as functioning in a sequential manner, the right hemisphere in a global manner. From this difference it was predicted that the right hemisphere would process the recursive sentence faster,
the left hemisphere the nonrecursive sentence faster, and that the right hemisphere would process the predicate nominative sentence faster, the left hemisphere the transitive verb sentence faster. Subjects saw a picture and then heard a sentence. They answered "same" if the sentence correctly described something in the picture, "different" if it did not. They indicated their answer by pushing one of two switches. The dependent variable was reaction time, the time from the end of the input to the time the subject made his answer. The data was analysed in a 3x2x2 analysis of variance. A main effect of sentence type (predicate nominative vs. transitive verb) was found, which was produced entirely by the both ears condition. These results were discussed in terms of possible brain organization.
Recent work suggests that the two halves of the brain are organized and function in different ways. It is suggested here that language inputs may be processed in both hemispheres, but in a different way in each hemisphere. This was tested using two sentence structures and two sentence types which present different degrees of organization. Overlapping areas of inquiry are involved. One is the question of cerebral dominance. Is one hemisphere really superior to the other for certain types of input? Another question concerns the actual connections between the two hemispheres. Does one hemisphere inhibit the other and if so under what conditions? Is a monaural response a measure of the response under normal conditions? Another question deals with the nature of language itself. What determines the complexity of a sentence?

In the 19th century a theory of cerebral dominance suggested that language is controlled by the cerebral hemisphere opposite the preferred hand. This now appears to have been an oversimplification and it is currently held that the majority of people, right and left handed, are left-brained for speech. The role of the right hemisphere has not been as clearly defined. Bogen (1969)
says that "The informational capacity of the one is just as great as the other, or, put differently, the other... is not only working just as hard, but also just as intricately." (p.137) Recently some specific activities have been ascribed to the right hemisphere. These include music, location in space, vocal non-speech sounds such as coughing, laughing, and crying. The lists of specific materials better processed by one hemisphere or the other have been generalized by Ornstein (1972), Levy-Agresti and Sperry (1968) and Tenhouten and Kaplan (1973) to a theory of brain functioning. The left hemisphere is considered to be more focused in its neural connections and is seen as specialized for verbal, logical, sequential tasks. The right hemisphere is considered to be more diffuse in organization and is seen as specialized for spatial, holistic and integrative tasks.

Recent experiments in psycholinguistics present evidence for a physiological response to grammatical structures which differs with the side of input. Subjects responded as if clicks they heard while listening to sentences were nearer to clause breaks than they actually were (Fodor & Bever, 1965). Subjects listening to sentences produced a larger GSR with shorter latency
when administered shocks before a major clause break than for shocks after a major clause break, and this effect was much larger for sentences heard in the right ear than for those heard in the left ear (Bever, Kirk, & Lackner, 1968). Also the latency to verify sentences increases when they are heard in the right ear as compared to the left ear (Foss, Bever, & Silver, 1968).

Carey, Mehler & Bever, (1970) found what they considered to be support for a theory of cerebral dominance. In a study of ambiguity they found an interaction of sentence type by ear and they concluded

the right ear may therefore be tentatively considered more sensitive to syntactic differences than the left ear. This sensitivity may be a consequence of the more direct connections of the right ear with the language areas of the left cerebral hemisphere, but it is not yet possible to propose a detailed account for these phenomena. (p. 71)

Subjects were presented a picture, then a sentence in one ear or the other. The subject responded verbally "right" if the picture and the sentence matched, "wrong" if not. Two different sentence types were used, transi-
tive verb and predicate nominative. The reaction times obtained were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Recursive Predicate nominative</th>
<th>Nonrecursive Transitive verb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left ear</td>
<td>980</td>
<td>955</td>
</tr>
<tr>
<td>Right ear</td>
<td>1285</td>
<td>787</td>
</tr>
</tbody>
</table>

The left ear input processed the different sentence types almost equally fast, while the right ear input was much faster with the transitive verb than with the predicate nominative. Mehler and Carey (1968) found the average latency for transitive verb sentences was significantly shorter than those for the predicate nominative sentences. This was with normal listening conditions, and Carey, et al. give further support to that result.

There are some questions about Carey et al.'s interpretation of their results. They mention that the right ear has more direct connections with the language areas of the left cerebral hemisphere. What of the left ear? Has it more direct connections with an area of the right hemisphere capable of some lesser kind of language processing or has it a less direct route to the language areas of the left cerebral hemisphere. This connection presumably would be by way of the corpus callosum, considered to be the fastest neural pathway from one
hemisphere to the other. If the signal input to the
left ear is processed in the right hemisphere in a lesser
area for language then their data should show a greater
reaction time for the left ear input. Their data did not.
The difference between left ear input reaction time and
right ear input reaction time would be an indication of
the dominance of the left cerebral hemisphere for language.
If the signal input to the left ear is processed in the
left hemisphere and has to reach that hemisphere by a
longer route then their data should show a greater
reaction time for inputs to the left ear. The difference
would be small and equal for the two sentence types
and would represent the time necessary for the transfer
of the incoming signal from the right hemisphere to
the left hemisphere. This did not happen. Instead
the two different sentence types were done in very
nearly the same time when input to the left ear, but
took quite different times when input to the right ear.
If one part of the brain is "more sensitive", i.e. more
responsive to the differences that are present in the
different kinds of sentences, there must be some mechanism
available to see to it that a faster, less sensitive
area capable of a response does not make that response.
What kind of brain organization can permit an interaction of type of input and ear or input? Theorists working with dichotic inputs have some suggestions.

Kimura (1964), discussing dichotic listening, suggests that each hemisphere has units which respond to stimulation from the contralateral ear, others which respond to stimulation from the ipsilateral ear, and some which can respond to either ear. When the two ears are stimulated with different material, the contralateral connections dominate over the ipsilateral. She also describes the contralateral pathways as shorter and therefore more efficient. Kinsbourne (1970) suggests an attentional model. In subhuman species the two hemispheres differ only in the area they serve, the right or the left. Reciprocal innervation inhibits the other hemisphere. For monaural data, according to Kimura, a stronger signal arrives at the contralateral hemisphere and a few milliseconds sooner, and according to Kinsbourne, that hemisphere has an attentional set due to the monaural signal. The monaural signal is received sooner, more strongly, or more expected at the contralateral hemisphere where it is processed and the ipsilateral hemisphere is then inhibited to some degree. Thus, under monaural
conditions input to one ear is processed in the contralateral hemisphere.

What differences could there be between the two types of sentences used by Carey et al. that could suggest a reason for the interaction? The sentences are alike in that they consist of the words "They are..." followed by a participle and a noun. They differ, however, in two important ways, sentence type and sentence structure, which are confounded. The transitive verb sentence can be analysed into a noun phrase and a verb phrase:

```
Sentence
  They are installing benches.
```

```
Noun phrase
  They

Verb phrase
  are installing benches

  verb
  are installing

  object
  benches
```

The predicate nominative structure presents a more complex situation.

```
Sentence
  They are incoming signals.
```

```
Noun phrase
  They

Verb phrase
  are incoming signals

  Verb
  are

  Sentence
  signals coming in

  Noun
  signals

  Verb phrase
  come in
```
In this example the grammatical structure of one sentence is embedded in another sentence. It is this complication that Carey et al. use to explain the greater reaction time of the predicate nominative sentence. A grammatical rule that is repeated like this is called a recursive rule and in the present study a sentence with another sentence embedded in it is called a recursive sentence. The predicate nominative sentences used by Carey et al. are recursive, the transitive verb sentences are non-recursive. Chomsky (1972) says of a similar sentence that "the deep structure, in the traditional view, is a system of two propositions, neither of which is asserted, but which interrelate in such a way as to express the meaning of the sentence." (p. 29) Here the two propositions are "Signals come in" and "They are signals come in", neither of which is asserted. It is just this kind of thing, the putting together of non-asserted relationships, that is described as the mode of functioning of the right hemisphere.

Carey, et al.'s data can be explained by using the ideas that the two different hemispheres work in two different ways and that the monaural signal is processed in the contralateral hemisphere. If language, as opposed
to speech, is present in both hemispheres, then language may be processed in both hemispheres, in one manner in one hemisphere and in a different manner in the other hemisphere. It might be hypothesized that the linear structure of nonrecursive transitive verb sentences would be more quickly processed by the linear procedures of the left hemisphere than by the more diffuse procedures of the right hemisphere; the recursive predicate nominative sentences containing two propositions, might be more quickly processed by the right hemisphere than by the left. When the input is a recursive sentence input to the right ear only, it goes to the left hemisphere for processing. When the input is a nonrecursive sentence input to the right ear only, it also goes to the left hemisphere for processing. If the left hemisphere is better at processing sequential material, the right ear input would process the nonrecursive sentence faster than it does the recursive sentence. The situation reverses with input to the left ear. Both sentence types input to the left ear are processed in the right hemisphere which is hypothesized to be better in more global activities.

The difference between predicate nominative and
transitive verb sentences was not used here in explaining the Carey, et al. data. However these two sentence types may be processed differently in the two separate hemispheres. The verb "to be" functions as an equals sign. There is no action or time, which sounds again like the specialization of the right hemisphere. Gazzaniga (1970) presents research which supports the idea that the predicate nominative sentence might be better processed by the right hemisphere. He says that with commissurized patients

the right hemisphere can in no way respond to verbs, that is, simple printed-out commands. Flash the commands "laugh:, "smile", "tap", "hit", and so on, to the left hemisphere, and there is no problem. Flash these requests to the right hemisphere, and the patient fails to make a response. The best language-rich patients are even unable to point to pictures that best portray the action. (p. 130)

He discusses this data to "support the view that the adult right hemisphere carries out very little language activity in the normal state." However, the right hemisphere may be better able to process the sentences
without action, while the left hemisphere may be more suited to actions and sequence.

This discussion has been limited to the monaural condition. The normal binaural listening condition is also of interest. Following Kimura, the contralateral inputs to the two hemispheres are identical, as are the ipsilateral inputs, so the two hemispheres process the input from the two ears at the same time. Following Kingsbourne, the attentional bias of input from both ears simultaneously is no bias at all, and both hemispheres process the material at the same time. In either case the imbalance caused by the monaural input condition is not present. The hemisphere that processes fastest controls the response without waiting for the slower hemisphere. Thus it was predicted that in the both ears condition, the nonrecursive sentence would be processed in the same time as the nonrecursive sentence was processed by the left hemisphere (right ear input), while the recursive sentence would be processed in the same time as the recursive sentence was processed by the right hemisphere (left ear input).

A 3x2x2 factorial design tested 3 auditory conditions (monaural left and right plus binaural), two sentence
types, (predicate nominative and transitive verb), and two sentence structures, (recursive and nonrecursive).

The following are examples of the latter two variables:

Predicate nominative, recursive:

The animal which is a fish is the victim.

Predicate nominative, nonrecursive:

The animal is a fish. It is the victim.

Transitive verb, recursive:

The man who beats the drum makes the music.

Transitive verb, nonrecursive:

The man beats the drum. He makes the music.

Each sentence is presented in two forms, a nonrecursive form and a recursive form. The nonrecursive form is two simple sentences, one after the other; the recursive form combines the two simple sentences. The nonrecursive form is not one sentence, but two. They could be linked by inserting "and", but since this would add an extra word it was not done. To avoid confusion the word "statement" is used for both forms. The number of words is the same for all statements. In the nonrecursive statement the two separate sentences are joined by being placed together and by refering to the same picture. In the recursive statement the one sentence is embedded in the other and
becomes a restrictive clause modifying the subject of that sentence. The only differences between the two forms are the minimal transformations needed to make the recursive embedding. The pronoun subject of the second sentence of the nonrecursive statement becomes, in the recursive form, a relative pronoun.

The difference in complexity between the two sentence structures, recursive and nonrecursive, would appear in the data either as a main effect, indicating a different complexity to the whole brain, or as an interaction, indicating a difference in complexity to the separate hemispheres. It was predicted that there would be no main effect of sentence structure, but that there would be an interaction of sentence structure and ear of input, with the right ear input being faster for the nonrecursive statement than for the recursive statement than for the nonrecursive statement.

A parallel situation was predicted for the predicate nominative-transitive verb difference: no main effect of sentence type, but an interaction of sentence type and ear of input, with the right ear input faster for the transitive verb statement than for the predicate nominative statement and the left ear input faster for
the predicate nominative statement than for the transitive verb statement.

For both factors, sentence type and sentence structure, the both ears input condition added information. If the reaction time for input to both ears equaled the faster monaural input reaction time, it would suggest support for the hypotheses of inhibition and of differential processing of different kinds of input. If the reaction time for input to both ears was less than either of the monaural reaction times, it would suggest that the two hemispheres working together are more efficient than either alone.
Method

Experimental Design

The experiment was a 3x2x2 fixed effects analysis of variance with repeated measures. Each subject received every condition. There were three levels of input: the right ear, the left ear, and both ears; two types of sentences: predicate nominative and transitive verb; and two sentence structures; recursive and nonrecursive. The dependent variable was reaction time, that is the time from the end of the input to the time when the subject pushed a switch to indicate the answer. They were to answer "same" if the sentence correctly described something in the picture, "different" if it did not. To control for sequence effects, the various conditions were independently randomized for each subject.

Subjects

The subjects were 30 CSUN students enrolled in psychology classes. They were required to take part in a number of experiments as part of their course work.
They were right handed (self-report and experimenter observation) with no known hearing problems and were native English speakers.

The data used was taken from 30 subjects out of a total of 62 subjects tested in all. The data from two subjects were discarded because their speech was heavily accented, from two more because of equipment failure, from one more because of experimenter error during the experiment. Data from another 27 subjects were discarded because they made errors and correct answers were necessary for data analysis. The data used was taken from the 30 tapes with correct answers.

Apparatus

Audio tapes of statements were played on a Wollensak Model #5250 tape recorder running at 7 1/2 ips. The subjects heard them through a Mura SP-202 L Stereophonic 8 ohm headphone with an independent adjusting knob on each earphone. A small brown table easel held the pictures which the experimenter turned by hand. The timing was controlled by a Beckman Offner type RS two channel paper tape dynograph with two event markers. Each sentence was recorded as it was heard as a wave form on a paper tape. Two switches activated the event markers.
which recorded the answer, same or different, and the
time of the answer on the same tape.

Procedure

The subjects were told that they were taking part
in an experiment in psycholinguistics to study the way
in which language is processed. They then heard a
brief passage while they adjusted the headset so it
was comfortable for them and equally loud in both ears.
They were told that they would see a picture and after
a pause would hear a statement through the headset and
that the statement would consist of one or two simple
sentences. They were asked to respond as fast as they
could while still being accurate. They responded by
pushing one of the two switches centered in front of
them, one behind the other. The switches were labeled
"same" and "different", and the labels were rotated so
that for half the subjects the "same" switch was closer,
for half the "different" switch was closer. The switches
controlled the event markers which recorded the answer.
The time for the answer was measured on the paper tape
from the end of the statement to the closing of the
switch as indicated by the event marker.

The sentences were designed so that both of the
propositions and the final word are necessary for a decision. The decision process starts when the final word is known. Speech, however, does not cut off suddenly and the time to reach any predetermined level varies with the final sound of the word. In addition, the assumption that processing starts only with the end of the sound is unwarranted. The redundancy of language makes it likely that the final word is known before its end is heard. The assumption is made here that the word is known at the beginning of the final syllable of the final word. All final syllables for sentences in this study began with a consonant belong to the class known as stops. These are characterised by the air being completely stopped and then released explosively. This provides a precise point for measurement. These two separate points, stop and plosion, can easily be seen on the paper tape record. During the stop no sound is made and the recording pen draws a straight line. The plosion is characterised by an easily observed resumption of amplitude movement by the recording pen. The timing of the reaction time runs, therefore, not from the end of the sound, but from the beginning of the final syllable as indicated by the plosion of the consonant
beginning that syllable. (There is one exception. The word "music" showed, over several efforts to get a final plosion, a reliable separation between "mu" and "sic".) A series of master tapes were made and this point was marked on the tape.

A verbal response was not used because verbalizations are considered to originate in the left hemisphere, and this could bias the results. The signal from right brain activity would have to cross to the left hemisphere to provide the verbal report. This time difference, for a simple visual pattern discrimination, has been estimated at 35-40 msec. (Filbey and Gazzaniga, 1969). Other studies quoted by Geffen, Bradshaw, and Wallace (1971) have also found differences in reaction times when the response involves sideways movement. Some studies have found a difference in reaction time with "same" and "different" answers, so only "same" answers were used for data in this study.

The problem of delivering equal volume to each ear is both difficult and important. The tapes were made by patching from one original tape, so that the original for left ear, right ear, and both ears is identical. The volume for the two channels was set for optimal
recording volume using the two separate visual displays built into the recorder. When the tape was played to the subjects the two different channel volumes were set equal on the tape recorder using the same two visual displays. Thus the volumes for the separate channels were set independently. The subjects were asked to adjust the headset so the sound was equal in both ears. It is not likely that the volume was equal to both ears for all subjects, nor equal to all subjects, but any error should not be a systematic one and could counteract any systematic error which might have occurred in the tapes or hearing differences in the subjects.

Materials

The pictures were all color photographs taken from magazines, almost all illustrations from The National Geographic. A brief description of all pictures is found in the Appendix. They were selected to be as similar in style and color quality as possible. They were mounted on white cardboard approximately 7 inches by 11 inches, the pictures themselves ranging from about half that to almost that size. There were twelve pictures: six associated with predicate nominative statements and six with transitive verb statements.
The sentences used are listed in the Appendix with the descriptions of the pictures. The sentences to be used for data were all to be answered "same". To provide a choice, 12 similar filler sentences were used to be answered "different". In addition there were 8 sample sentences, 4 to be answered "same", 4 to be answered "different".

Thirty tapes were produced on which the order of the experimental statements were separately randomized for each subject. Each tape was a complete unit containing instructions and sample sentences. A framework was developed by picking answer conditions from a hat, twelve "different" answers and twelve "same" answers. The twelve filler sentences similar to the experimental sentences were used in the "different" answer condition. The twelve experimental sentences were assigned by the following method. The six predicate nominative pictures were labeled A thru F, the six transitive verb pictures labeled G thru L. These were placed in the twelve "same" slots of the framework by shuffling pennies labeled appropriately. The order of the sentences, the sentence type, and the answer conditions were randomized in this way. Each picture was then arbitrarily assigned a
recursive or nonrecursive condition and an ear of input. These were rotated for subsequent tapes. During the experiment the pictures were re-ordered on each trial to match the order on the tape.
Results

Mean reaction time to sentences of different types (predicate nominative or transitive verb) and different structures (recursive or nonrecursive) under different input conditions, left ear, right ear, or both ears, are given in Table 1. These data, on inspection of the

Table 1

Mean Reaction Time (seconds) to Sentences of Different Type and Structure under Three Input Conditions.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Left Ear</th>
<th>Right Ear</th>
<th>Both Ears</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicate Nominative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recursive</td>
<td>.979</td>
<td>1.025</td>
<td>1.282</td>
<td>1.095</td>
</tr>
<tr>
<td>Nonrecursive</td>
<td>1.107</td>
<td>1.004</td>
<td>1.118</td>
<td>1.076</td>
</tr>
<tr>
<td>Marginal mean</td>
<td>1.043</td>
<td>1.015</td>
<td>1.200</td>
<td>1.086</td>
</tr>
<tr>
<td>Transitive Verb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recursive</td>
<td>1.117</td>
<td>.989</td>
<td>.970</td>
<td>1.025</td>
</tr>
<tr>
<td>Nonrecursive</td>
<td>.998</td>
<td>1.015</td>
<td>.939</td>
<td>.984</td>
</tr>
<tr>
<td>Marginal mean</td>
<td>1.058</td>
<td>1.002</td>
<td>.955</td>
<td>1.005</td>
</tr>
<tr>
<td>Marginal means</td>
<td>1.050</td>
<td>1.008</td>
<td>1.077</td>
<td>1.045</td>
</tr>
<tr>
<td>Grand Mean</td>
<td></td>
<td></td>
<td></td>
<td>1.045</td>
</tr>
</tbody>
</table>
scatter diagram, appeared skewed and perhaps lacking in homogeneity of variance. The ratio of largest range of scores to smallest range of scores indicated that some improvement in homogeneity of variance could be had with a square root transformation. Means and standard devia-

Table 2

Means and Standard Deviations of Transformed Data (Square Root of Reaction Time, mm.)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Left Ear</th>
<th>Right Ear</th>
<th>Both Ears</th>
<th>Row Means</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predicate Nominative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.632</td>
<td>2.007</td>
<td>3.258</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.850</td>
<td>3.435</td>
<td>2.151</td>
</tr>
<tr>
<td>Marginal means</td>
<td>M</td>
<td>11.081</td>
<td>11.073</td>
<td>11.924</td>
</tr>
</tbody>
</table>

| **Transitive Verb**   |          |           |           |           |
| Recursive            | M        | 11.421    | 10.777    | 10.749    | 10.982    |
|                      | SD       | 3.871     | 2.601     | 2.438     |           |
| Nonrecursive         | M        | 10.926    | 11.027    | 10.414    | 10.789    |
|                      | SD       | 2.984     | 2.789     | 3.047     |           |
| Marginal means       | M        | 11.174    | 10.902    | 10.582    | 10.886    |
| Marginal means       | M        | 11.128    | 10.988    | 11.253    | 11.123    |
Results

Mean reaction time to sentences of different types (predicate nominative or transitive verb) and different structures (recursive or nonrecursive) under different input conditions, left ear, right ear, or both ears, are given in Table 1. These data, on inspection of the

Table 1

Mean Reaction Time (seconds) to Sentences of Different Type and Structure under Three Input Conditions.

<table>
<thead>
<tr>
<th>Ear of Input Conditions</th>
<th>Ear of Input</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left Ear</td>
<td>Right Ear</td>
</tr>
<tr>
<td><strong>Predicate Nominative</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recursive</td>
<td>0.979</td>
<td>1.025</td>
</tr>
<tr>
<td>Nonrecursive</td>
<td>1.107</td>
<td>1.004</td>
</tr>
<tr>
<td>Marginal mean</td>
<td>1.043</td>
<td>1.015</td>
</tr>
<tr>
<td><strong>Transitive Verb</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recursive</td>
<td>1.117</td>
<td>0.989</td>
</tr>
<tr>
<td>Nonrecursive</td>
<td>0.998</td>
<td>1.015</td>
</tr>
<tr>
<td>Marginal mean</td>
<td>1.058</td>
<td>1.002</td>
</tr>
<tr>
<td>Marginal means</td>
<td>1.050</td>
<td>1.008</td>
</tr>
<tr>
<td><strong>Grand Mean</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3

Summary of Analysis of Variance of Transformed Data

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear of Input (A)</td>
<td>2</td>
<td>1.985</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Error (A x S)</td>
<td>58</td>
<td>7.066</td>
<td></td>
</tr>
<tr>
<td>Sentence Type (B)</td>
<td>1</td>
<td>25.576</td>
<td>4.317*</td>
</tr>
<tr>
<td>Error (B x S)</td>
<td>29</td>
<td>5.923</td>
<td></td>
</tr>
<tr>
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**Note**

*p < .05*
tested only for input to both ears since, as is evident in Fig. 1, it is only at that level of input that differences occur as a function of sentence type. In order to test the assumptions of homogeneity of variance and of covariance at the both ears level the Box test was used. If the covariances are homogeneous the correlations between all pairs of different treatments remain constant. The Box test evaluates this assumption by testing the symmetry of the variance-covariance matrix. When the matrix has the required symmetry both the variances and covariances are considered to be sufficiently homogeneous.

Fig. 1. Mean reaction times, in seconds, as a function of ear used and sentence type.
Here the 4x4 variance-covariance matrix at the both ears input level (formed by treating the four kinds of sentences as levels of a single variable) has the required symmetry, chi square (8) = .766, p > .05. The 2x2 predicate nominative transitive verb matrices at the recursive and non-recursive levels were not significantly different, chi square (3) = 6.783, p > .05, and were, therefore, used to form the pooled predicate nominative-transitive verb matrix. This pooled 2x2 matrix also had the required symmetry, chi square (3) = .000, p > .05. This then permitted a test of simple main effect of sentence type at the both ears levels which was statistically significant, F (1,29) = 9.114, p < .01.
Discussion

These results give no support to the theory of Cerebral Dominance advanced here, which requires the following interaction: the right ear input recursive sentence should have a longer reaction time than the right ear input nonrecursive sentence, and the left ear input recursive sentence should have a shorter reaction time than the left ear input nonrecursive sentence. This did not occur. From that interaction some notion of inhibition could have been inferred for without it the faster hemisphere would respond. The lack of interaction does not rule out inhibition however. The two hemisphere may have the same response times even while behaving independently and in very different ways. The present results give no indication either way.

The theory of left hemisphere superiority for verbal input requires that the right ear input reaction times be smaller either (1) by the time it takes for a left ear input to cross the corpus callosum from the right hemisphere to the left hemisphere or (2) by the difference in processing time between the two hemispheres if inhibi-
tion occurs. The magnitude of this difference is not known. The results here are nonsupportive, showing no reliable difference between ears.

In the both ears input condition, the prediction was that the two hemispheres would work simultaneously and the reaction time would be equal to the faster hemisphere with the same kind of input. This did not occur. Nor was the reaction time for both ears lower than for either alone, which would have indicated some increase in efficiency when the two hemispheres worked together.

The variance in all 12 conditions were heterogeneous, as were those at the left ear and right ear input levels. The variance was homogeneous at the both ears level. Whether this is due to chance or to the functioning of the brain is undetermined.

The significant simple main effect of sentence type only at the both ears level is a curious result. It suggests that the functioning of the brain under normal binaural input conditions may be different from that under monaural inputs. For these simple sentences verification that the words fit the picture may be all that is necessary to give a correct answer and the two separate hemispheres may do that much. In the both ears
input condition the two hemispheres may in addition act
to integrate the information in some way. For the transi-
tive verb statement little more is involved than what
was done in verifying the name of the action taking
place. The redundancies which occur when the subject,
verb, and object are combined may make it easier to
process the words in a sentence than separately. In
making decisions about the predicate nominative sentences,
however, there is the need not only to verify the words,
but also to check the validity of the statements. The
verb "to be" functions as an equal sign and the validity
of that equality must be checked, e.g., Is a tortoise a
reptile?, Is a ruin still a building:, etc.. These
kinds of verifications may be what is done in inte-
grating these predicate nominative sentences.

Gazzaniga (1970) presents a study with different
results for one hemisphere or both. Using both normals
and split brain patients, he flashed letters to either
visual field or to both visual fields and the subjects
were required to point to the letter seen on a list of
letters. The response measure was not reaction time, but
accuracy, the number of letters correctly identified.
He says:
Under conditions of double field stimulation, their average rose only a little, with the net result that the ratio of double field score to the single field score was never higher than 1.09. This suggests that in the normal, intact brain, separate, direct stimulation of one hemisphere allows performance at a level that cannot be transacted when parallel and similar stimulation is performed on the other hemisphere. (p. 114)

This was said in the context of the split brain patients for whom the ratios are as high as 2.00. However a ratio of 1.09 is not a trivial difference from a ratio of 1.00. In the present case all subjects who did not give all correct answers were discarded. It maybe that the complexities of the predicate nominative sentence require longer to process for an equal accuracy.

These results suggest caution in using different sentence types. The method of equating sentences on surface structure and drawing conclusions based on deep structure differences confounds sentence type and sentence structure. The results found may be due to the difference in sentence type as well as to the difference in structure.
Although the statements were short and simple, and combined with simple uncluttered pictures, an amazing variety of interpretations occurred. One way to control for this would be to use subjects all currently involved in the same activity, e.g. all members of a baseball team, and to use pictures and words closely related to that activity. This would increase the chance that they were interpreting the pictures and words in the same way.

The difference between the nonrecursive and the recursive conditions was due only to the transformation of the two sequential sentences into a single statement with one sentence embedded in the other. The two are very close. Recursion is found also in the self-embedding sentence. This type of embedding is much more difficult. An example is the sentence "The dog which the boy kicked bit the girl." in which the object of the embedded sentence is the subject of the embedding sentence. This more difficult situation may show a difference which was not found here.

The present results were obtained using different sets of pictures with the two different sentence types. To give further support to these results further testing should be done with only one set of pictures to remove
the possibility that the difference found was due to the difference in the pictures rather than due to the difference in the sentence types.

The present result suggests that the two hemispheres acting together process stimuli differently than does either hemisphere separately. It suggests that experiments dealing with the two separate hemispheres separately also include the two hemispheres together with the same stimuli and under the same conditions. The present results could be extended using other kinds of sentences offering different kinds of organization. Earlier authors suggested that the longer reaction time for the predicate nominative sentences might be due to the more complex deep structure. Here the deep structure was held constant and yet the predicate nominative sentence took longer to process with input to both ears. The predicate nominative sentences used here were constructed to be parallel to the transitive verb sentences. The transitive verb sentences had a subject, object, and verb. The complement of the predicate nominative sentences had to be a noun to match the object of the transitive verb sentences. This requirement created a complexity of its own. The predicate nominative
sentences became statements involving overlapping categories, e.g., building, castle, ruin. A next step could be to compare predicate nominatives with the complement an adjective with those with the complement a noun, e.g., "The ruin is old." with "The ruin is a castle."
The redundancy of "ruin" and "old" would parallel the redundancies in the present transitive verb sentences, while the "castle" would call on some knowledge of castles. A difference found only with input to both ears would give further support to the suggestion made here that the two hemispheres integrate the material in some way not done by the separate hemispheres.
References


Appendix

A list of the sentences used with a brief description of the accompanying pictures.

Experimental sentences and pictures

A. Two men working, one using a shovel to lift gravel into a wagon, one using a rake to spread the gravel in the wagon.

R The man who uses the rake moves the gravel.

nR The man uses the rake. He moves the gravel.

B. Four men, two rowing in a boat on top of a wave, two standing in the surf waiting to help.

R The men who row the boat ride the breaker.

nR The men row the boat. They ride the breaker.

C. Two men and several other figures around a relief map. One man, wearing a uniform, points to the map with a long pointer. The other man looks intently at the map.

R The man who uses the pointer gives the lecture.

nR The man uses the pointer. He gives the lecture.
D. Three boys, two on a farm wagon, one on a bicycle.

On the wagon one boy is barely visible, one is standing, holding the reins, driving the wagon. The boy on the bicycle is hitching a ride by holding the edge of the cart.

R The person who holds the reins drives the wagon.

nR The person holds the reins. He drives the wagon.

E. A boy, smiling, muddy, sits on a motorcycle and holds a large trophy. His arm is held by a girl with long blond hair, two boys his age and an older man watch, and a younger boy reaches out to touch the trophy.

R The boy who straddles the bike wins the trophy.

nR The boy straddles the bike. He wins the trophy.

F. Two men, one beating a drum, one doing a handkerchief dance.

R The man who beats the drum makes the music.

nR The man beats the drum. He makes the music.

G. A moss covered roofless castle in the foreground, behind several buildings, smaller, painted, assorted farm buildings.

R The building which is a ruin is the castle.

nR The building is a ruin. It is the castle.
H. A girl riding a very large tortoise. A goat has its front feet up on the tortoise shell. Assorted people in the background, some watching, some not.

R The animal which is a tortoise is a reptile.

nR The animal is a tortoise. It is a reptile.

I. A bowl of cereal, a glass of orange juice, a cup of coffee, and a pitcher of milk.

R The liquid which is a stimulant is the coffee.

nR The liquid is a stimulant. It is the coffee.

J. An underwater spider holding a small fish with one leg.

R The animal which is a fish is the victim.

nR The animal is a fish. It is the victim.

K. Two figures looking off to one side. A girl wearing an airline bag over one shoulder, a young woman wearing a uniform.

R The individual who is a stewardess is the adult.

nR The individual is a stewardess. She is the adult.

L. A young woman on a motor scooter. On the back is a very young child in a covered kind of wicker seat.

R A person who is a passenger is the baby.

nR A person is a passenger. It is the baby.
Sample sentences and pictures

1. A mixture of salad vegetables.
   A vegetable which is white is the lettuce.

2. Two figures, woman and child. The child holds a large mixing spoon over a bowl while the woman pours in water from a measuring cup.
   The woman pours the water. She stirs the batter.

3. Snow scene, two children, one wearing a hat and taking a picture of the other, smaller, on skis, being enticed to slide to a female figure.
   The child wears a hat. He holds the camera.

4. Wild flowers, poppies and lupins, in the foreground, a large cactus behind.
   The flower is a poppy. It is a cactus.

5. Two men, one on either side of a girl, behind whom is a statue of Napoleon. One man pours brandy into a glass held by the other.
   The man who holds the glass pours the brandy.

6. Outside a stockade, five mounties in dress uniform, two small boys, a man in a sport shirt, a young woman holding the arm of one of the mounties.
   The person who is a woman is the mountie.

7. Cooked salmon on a barbecue grill surrounded by alter-
nating lemon and parsley.

A garnish is green. It is the parsley.

8. Two women, one spinning wool, one knitting.

The woman who knits the yarn uses the needles.

**Filler sentences and pictures**

1. An elderly couple on an airplane, the woman holds her knitting on her lap, the man holds a camera.

   The woman has her knitting. She holds the camera.

2. A woman pushes a stroller with two babies, in front walks a young girl carrying a ball.

   The woman pushes the stroller. She carries the ball.

3. Two figures, one pointing, talks to a man on a bicycle.

   The man rides the bicycle. He points the way.

4. Mixed green peas and small white onions. The picture is slightly magnified.

   The vegetables which are green are the onions.

5. Three boys in the street, other figures behind them on the sidewalk. The boys wear mitts on their right hands and stand in an equilateral triangle. One appears to have thrown something to the other.

   The boys play in the street. They play football.

6. A campground scene, two figures, a man and a woman, watch while a man takes pancakes off a griddle.
The camper who is a woman is serving the breakfast.

7. A bed with a gold cord spread, children playing with a separate orange spread, a toy airplane on the floor. The spread used as a toy is gold colored.

8. Three figures, two men and a woman. One man carries a child on his shoulders, the other has a small dog on a lead.

The man who carries the baby walks the dog.

9. Three figures, a woman in the background, two men, one seated, with his fingers on the buttons of a calculator, one standing holding a rolled paper. The man holds the paper. He pushes the buttons.

10. A vineyard, in the background people picking grapes, in the foreground two figures carrying large baskets on their shoulders. One has a drum in his left hand.

The man who carries the drum hauls the apples.

11. A fish with two black lamprey eels fastened to it. The fish is eating the two black lamprey eels.

12. Marionetts suspended from above. Three figures, a girl above, a girl below and a man.

The marionetts are puppets which do not need strings.