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ABSTRACT

Three objectives of research reported here were to describe the neural organization underlying language usage and language loss, to study activities occurring in both cerebral hemispheres, and to study neural changes related to changes in syntactic complexity of stimuli. A dichoptic procedure was chosen. A subject faced a viewing screen on which were flashed a fixation stimulus and two different short sentences, one on either side. The subjects were required to select a response picture appropriate to the sentences. Three subject groups were tested: (1) controls with no history of neurological damage; (2) a group of aphasic patients with unilateral left hemisphere brain damage; (3) a group with unilateral right hemisphere brain damage. The general conclusion was that the right hemisphere appears capable of processing some syntactically simple language stimuli; however, as stimuli become more complex, the left hemisphere may be necessary for comprehension. Testing involving cortical visually evoked responses recorded over both hemispheres simultaneously was conducted to see if visual AER's can be used to detect cortical language processing. It appears to be a useful means to study intra- and inter-hemispheric neural language systems. Charts and graphs illustrating research methods and findings are included. (CHK)

LANGUAGE DOMINANCE AND LANGUAGE PATHOLOGY

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We had several objectives in mind which led to the research I am presenting today. First of all, we wanted to find evidence for language dominance during a normal language processing task. Traditionally, studies have correlated the loss of language functions with damage (15) or disruption (12, 14) of some area of the brain, usually in the left hemisphere. It would be more useful to clinicians if we could describe the neural organization underlying language usage, as well as language loss.

A second objective was to study activities occurring in both cerebral hemispheres. This suggested that either a dichotic listening (2, 10) or dichoptic visual (3, 7) procedure would be most appropriate.

A third objective was to study neural changes which may be related to changes in syntactic complexity of the stimuli. This objective ruled out the dichotic procedure because of obvious difficulties of presenting contrasting sentence stimuli to both ears simultaneously. An auditory task would require so much time to present the stimuli that it would be extremely difficult to assume the two cerebral hemisphere were being independently stimulated.

A dichoptic procedure, therefore, was chosen for this study. The instrumentation for the study is shown on the first slide (Slide 1).

Each subject sat facing the viewing screen, focusing on the fixation point. When the subject was looking at the fixation point, he started the trial by pushing the start button. A stimulus slide (Slide 2) was then flashed for 200 msec. (Aphasic subjects required a 450 msec. presentation). Three stimuli were presented. A fixation stimulus (diamond, heart, club, or spade) which appeared directly on the fixation point was one stimulus, and the other two were grammatically contrasting, four word sentences presented vertically to each side of the fixation stimulus. Subjects were not aware that the two sentences were different.

After the stimulus slide was flashed, a response slide appeared showing six pictures. One picture was appropriate for one of the stimulus sentences and another picture was appropriate for the other sentence. The other four pictures were foils. Subjects had to first identify the correct fixation stimulus, then locate the one picture which illustrated the sentence he comprehended.

This procedure implies that those stimuli presented to the right of the fixation point stimulate predominantly the left (or contralateral) hemisphere and those stimuli to the left of the fixation point, stimulate the right hemisphere. Since it was a linguistic task, the stimuli were contrasting, and the stimulus presentation time was very short; it was assumed any dynamic language dominance of either hemisphere would make language stimuli presented in the contralateral visual field easier for the subject to comprehend.

Before discussing results let us consider the remainder of the testing procedure and the syntactic nature of the stimuli (Return to Slide 1).

After seeing the stimulus slide, the subjects first reported the correct fixation stimulus by pushing the appropriate Row 1 button. Then they picked the appropriate picture for the sentence they comprehended and pushed the Row 2 button under that picture. All responses were recorded on the printout counter data sheet. After a Row 2 response, the instrumentation automatically reset for the next stimulus--response interval.

If the fixation stimulus was not identified correctly, the Row 2 response was scored zero, whether correctly indicated or not.

Now let us look at the type of stimulus sentences presented (Slide 3). One-third of the sentences were of this type, simple declarative sentences. A measure of syntactic complexity was computed by adding the number of deep structure constituents to the number of transformations applied. In this case the total is 9.

The next type of sentence (Slide 4) contained an indirect object and received a complexity score of 13. The most complex type of sentence (Slide 5) contained an embedded sentence in the next verb phrase, and was scored 18. Sixteen presentations of each sentence type were given to each subject.

Three subject groups were tested. 1) Controls with no history of neurological damage; 2) an experimental group of aphasic patients with unilateral brain damage in the left hemisphere; 3) another experimental group with unilateral damage in the right hemisphere. There were 10 subjects in each group.

The results suggest some interesting notions (Slide 6). Look first at the control subjects' responses to the simplest level of syntactic complexity. Out of the 16 trials, they made an average of about 10 correct responses (add LHS's and RHA's). Of these 10 correct, six were for sentences presented in the right visual half field, thus a higher left hemisphere score or a left hemisphere lead.

The right brain damaged group responded very much like the normals except they tended to make fewer overall correct responses.

The surprise to all of us was a complete reversal of apparent cerebral "language dominance" by the left brain damaged group. In addition, notice that as the syntactic complexity increased, the apparent right hemisphere lead of the aphasic subjects decreased. With the most complex stimuli, there was no apparent or statistically significant difference.

The same data shown graphically looks like this (Slide 7). In all cases for all subject groups, as the syntactic complexity increased, the proportion of left hemisphere scores tended to increase, even for the aphasic subjects who demonstrated an overall right hemisphere lead.

Some general conclusions supported by this data are:

1. The right hemisphere appears capable of processing some syntactically simple language stimuli. That the right hemisphere in some way supports language has already been suggested (16). Perhaps this basic ability is present during normal language processing, and does not alter appreciably following left hemisphere damage. Reduced left hemisphere efficiency, however, creates an apparent right brain dominance.

2. As stimuli increase in complexity, there may be unique neural systems predominantly in the left hemisphere necessary for comprehension. The right hemisphere, however, simply cannot compensate for their functions.

These results and interpretations are interesting, but must be considered as highly speculative. The dichoptic procedure involves a complex visual sensory transmission system and relatively independent stimulation of each cerebral hemisphere is more easily hoped for than controlled for.

We have continued studying these questions concerning language dominance and language pathology, but we have changed our experimental approach. We are now averaging cortical visually evoked responses, recorded over both cerebral hemispheres simultaneously.

(Slide 8) Subjects view the stimuli, which are flashed on an oscilloscope screen for 40 msec., at the rate of one stimulus per second. The computer controls both stimulus presentation and response recording and averaging.

Two types of stimuli were presented during a single testing session (Slide 9). One type was three letter, concrete nouns, each letter of which was computer printed from a dot matrix of four columns of six dots each. The second stimulus type was constructed by altering the letters in each of the nouns so they formed patterns like the one shown on this slide. Patterns had the same number of dots as the words, but were not perceived in a linguistic manner.

A total of 512 stimuli (256 words and 256 patterns randomly mixed) were presented to each subject. Evoked responses were recorded in two standard electrode locations over each cerebral hemisphere (O_1, O_2, P_3, P_4).

The objective of this research, at this point, is simply to see if visual AER's can be used to detect cortical language processing. Previous studies suggest this may be possible. (1, 4, 5, 6, 8, 11, 13)

Preliminary patterns are somewhat encouraging. The following slide (Slide 10) shows a visual AER recorded over the left occipital lobe of a normal subject. The four peaks indicated appear to be the ones most related to the responses to this experimental task. Generally, the responses of interest occur between 100 and 300 msec. There are amplitude and latency differences between the WORD trace and the DOTS trace. Whether or not these differences are significant across a group of subjects has not yet been determined.

The next slide (Slide 11) shows the average response recorded over the right occipital lobe at the same time the previous trace was recorded. Between hemispheres there are noticeable amplitude and latency differences, but tests of statistical significance have not yet been performed.

Within a single hemisphere, changes in the recorded patterns were the most obvious. (Slide 12) Looking at the AER recorded over the left parietal lobe, there is a noticeable increase in the amplitude of P_2, (the second positive peak), occurring at about 225 msec. as compared to P_2 amplitude recorded over the occipital lobe in the same hemisphere, at the same time. This suggests that the parietal electrode over P_3 may be closer to the cortical region in which the maximum cortical potential changes are occurring for the stimuli presented.

The next slide (Slide 13) shows averaged responses to words and patterns (dots) recorded over the left occipital lobe of an aphasic subject. In general, the traces look much flatter than any of the normal subjects. Looking at the directly recorded EEG patterns, however, suggests that in the aphasic subjects there is much increased cortical activity. This may just represent unsuppressed neural activity.

In other words, there may be more cortical activity, but less of it is actually related to meaningful cortical processing, so when the evoked responses are averaged together, the random positive and negative fluctuations tend to cancel each other and the entire trace flattens out.

These studies are not intended to provide any final answers. We are simply probing and examining in the hope that we are heading in a meaningful direction. We do, however, feel inclined to make these two concluding statements:

1. There appear to be specific language skills possessed by the non-dominant hemisphere, yet to be thoroughly described.

2. The visual AER testing procedure appears to be a very useful means to study both intra- and inter-hemispheric neural language systems.

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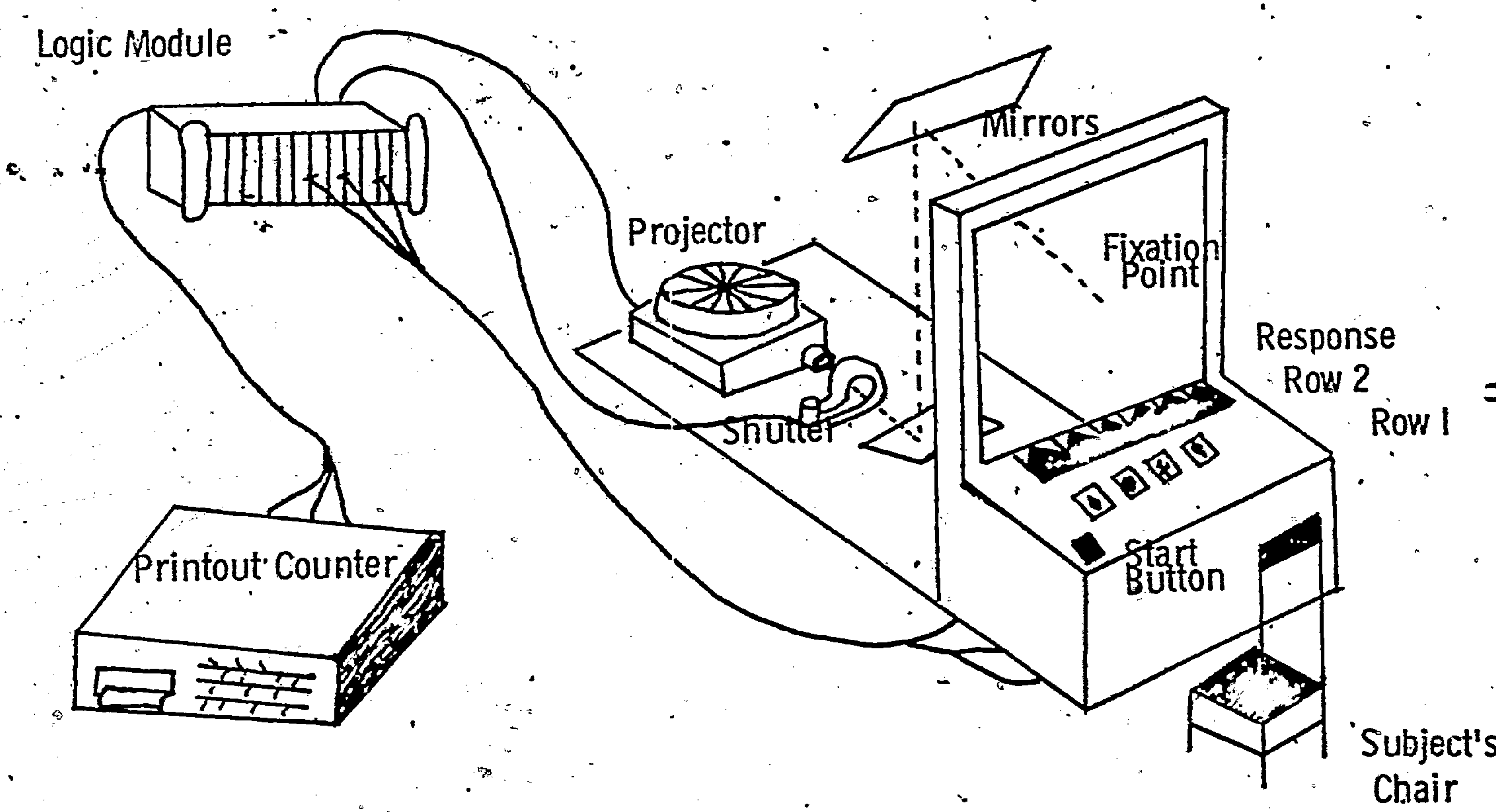
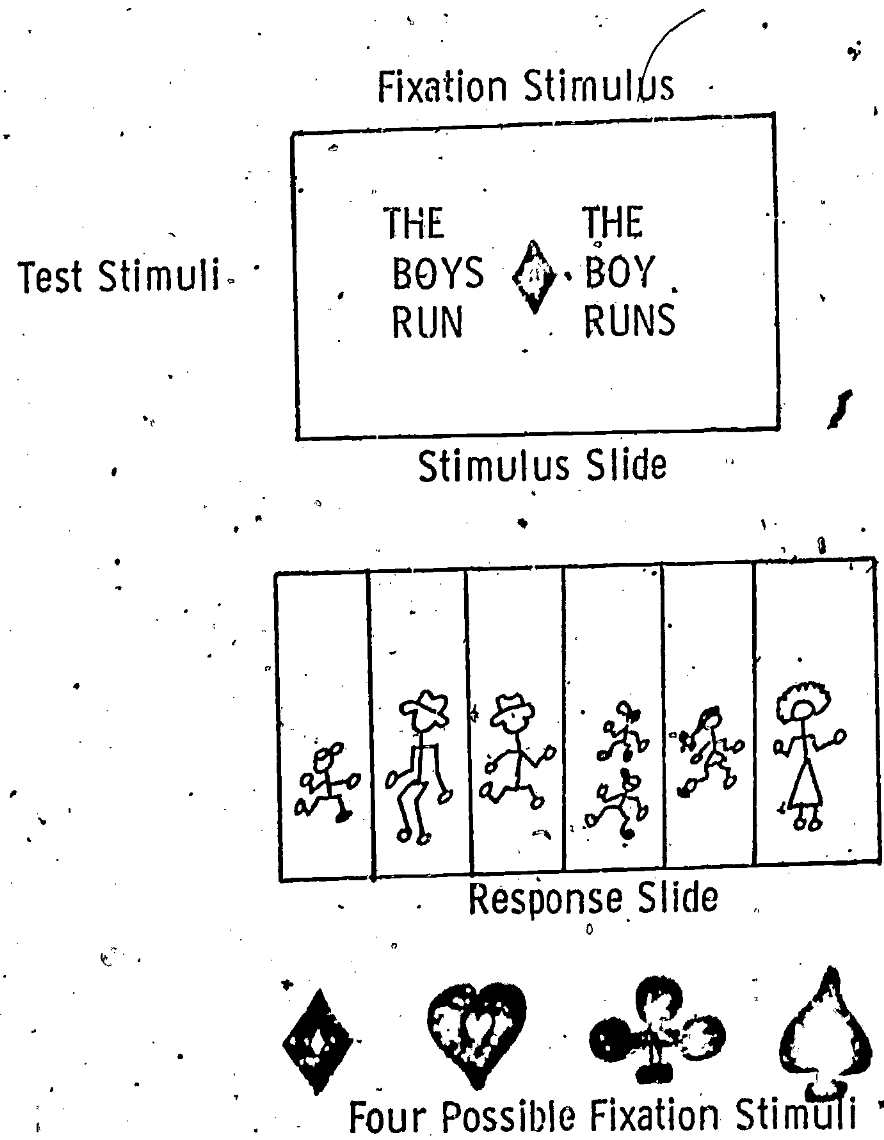


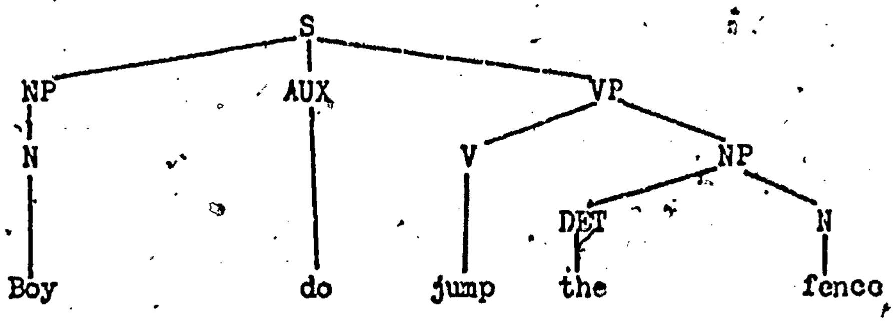
INSTRUMENTATION

SLIDE I

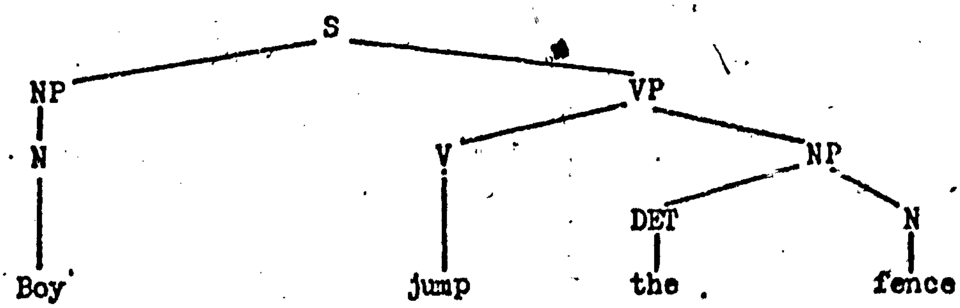

Fixation Stimulus
Test Stimuli
THE BOYS RUN
THE BOY RUNS
Stimulus Slide
Response Slide
Four Possible Fixation Stimuli

Slide 2

Deep Structure



Surface Structure



<u>Transformations Required to Derive Surface Structure</u>

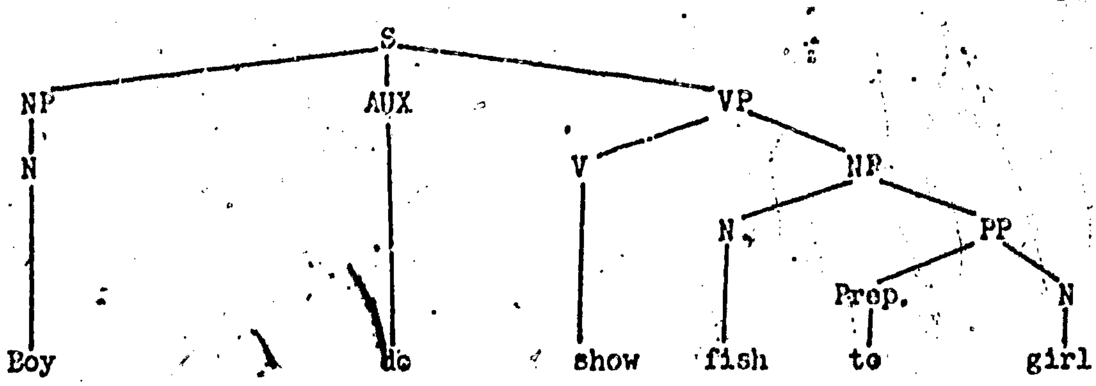
1. Aux. Deletion
   (do ⟶ ϕ)

  8 Deep Structure Constituents
<u>+ 1</u> Transformation
  9 = Measure of Sentence Complexity

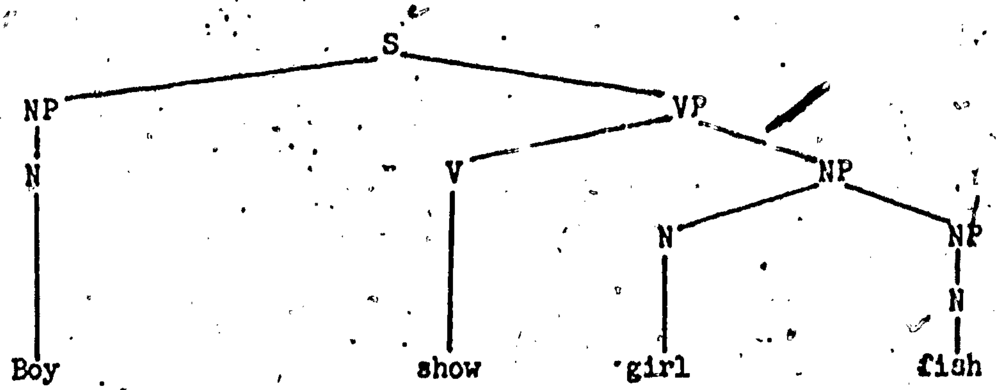
Figure 1. Syntactic Complexity I

SLIDE 3

Deep Structure



Surface Structure



<u>Transformations Required to Derive Surface Structure</u>

1. Aux. Deletion
   (do $\longrightarrow \phi$)

2. Indirect Object Permutation
   (N + PP $\longrightarrow$ PP + N)

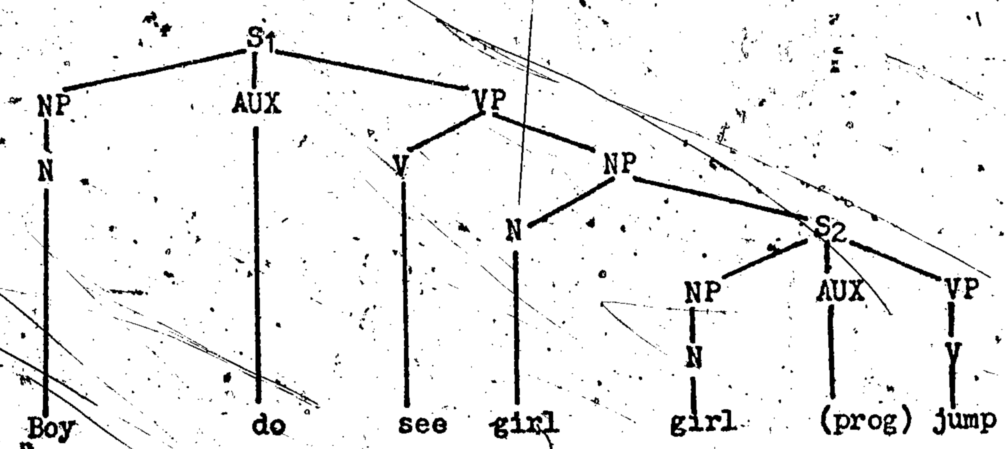
3. Preposition Deletion
   (to $\longrightarrow \phi$)

  10 Deep Structure Constituents
<u>+ 3</u> Transformations
  13 = Measure of Sentence Complexity

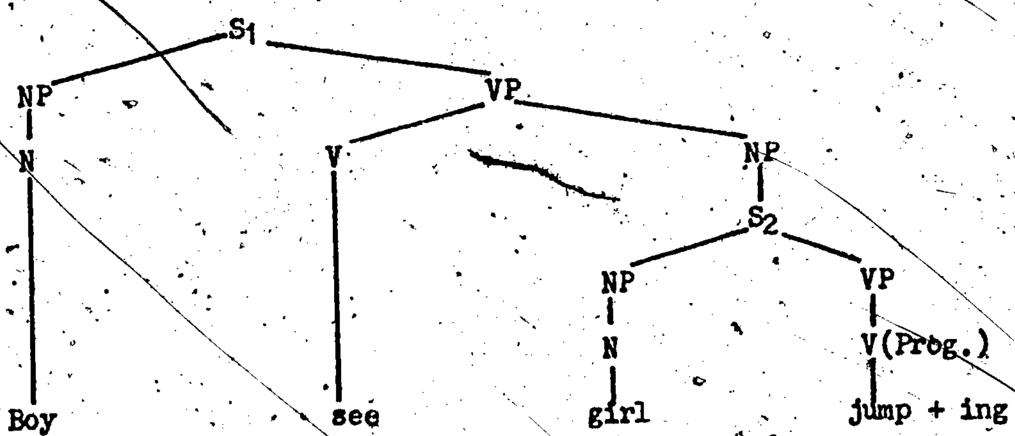
Figure 2. Syntactic Complexity II

SLIDE 4

Deep Structure



Surface Structure



Transformations Required to Derive Surface Structure

1. Aux. Deletion
(do $\longrightarrow \emptyset$)

2. -ing Permutation

3. Equivalent NP Deletion
(NP_x + $NP_x \longrightarrow NP_x$)

4. Embedded Progressive "is" Deletion
(S_1 + NP + is + V + (Prog.) $\longrightarrow$
S_1 + NP + V + (Prog.))

14 Deep Structure Constituents
+ 4 Transformations
18 = Measure of Sentence Complexity

Figure 3. Syntactic Complexity III

SLIDE 5

TABLE II

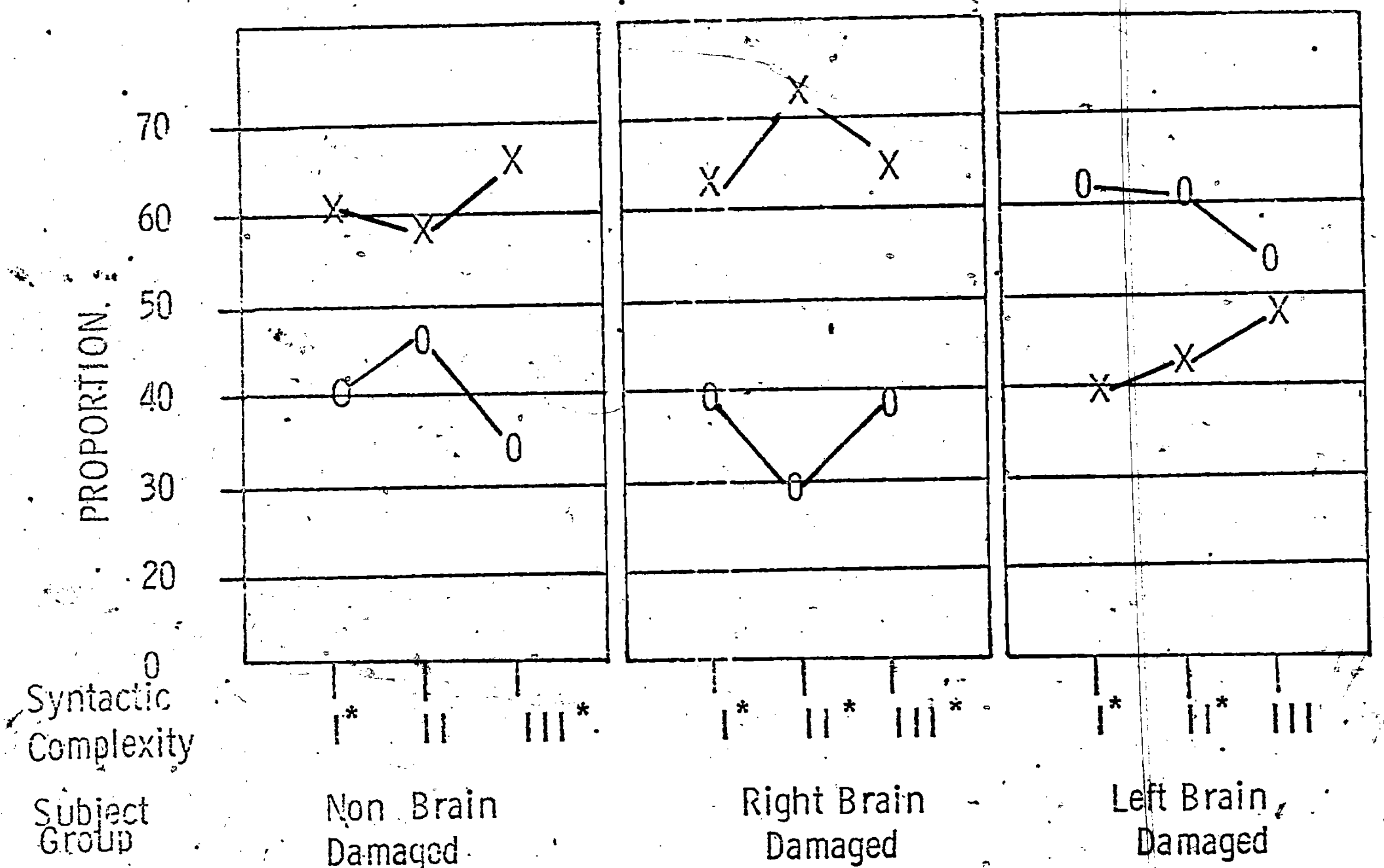
MEAN CORRECT SCORES ACCORDING TO SUBJECT, SYNTACTIC COMPLEXITY, AND CEREBRAL HEMISPHERE SCORE

	Syntactic Complexity						Group Combined Averages	
	I		II		III			
Subjects	LHS	RHS	LHS	RHS	LHS	RHS	LHS	RHS
Normals	6.18*	4.09*	5.27	4.18	5.55*	2.73*	17.00*	11.00*
Right Brain Damaged	5.00*	3.11*	5.11*	2.00*	5.00*	2.89*	15.11*	8.00*
Left Brain Damaged	3.80*	6.00*	3.40*	5.18*	4.00	4.52	11.20*	15.70*

*Related LHS's and RHS's proportions are significantly different ($\leq .05$) according to Binomial Test (Siegel, 1956).

SLIDE 6

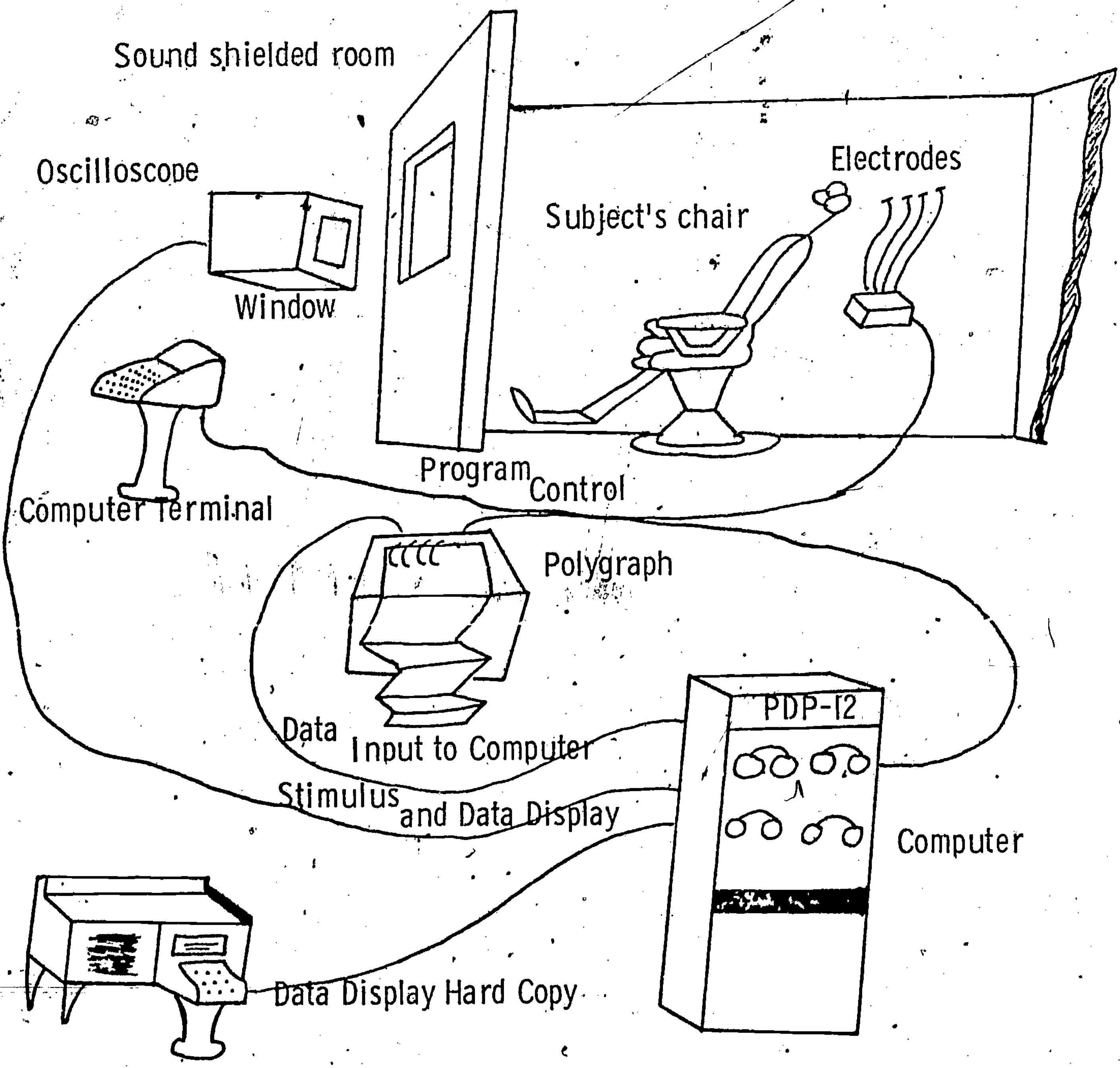
PROPORTIONS OF LHS'S AND RHS'S FOR EACH SUBJECT GROUP FOR EACH LEVEL OF SYNTACTIC COMPLEXITY



X——X = LHS's. 0——0 = RHS's.

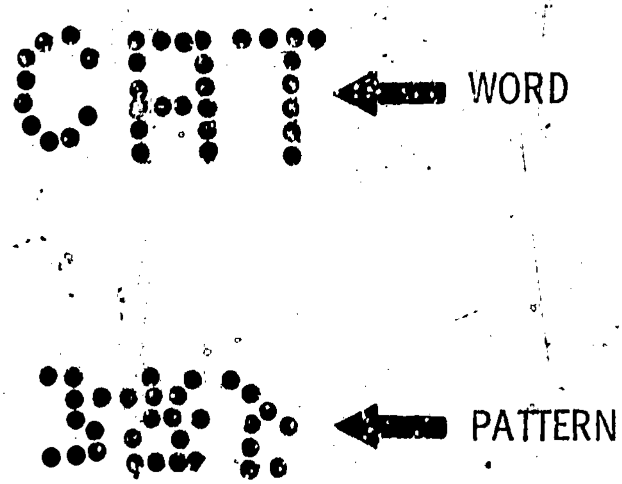
(*) = Proportions significantly (< .05) different

SLIDE 7



INSTRUMENTATION

SLIDE 8

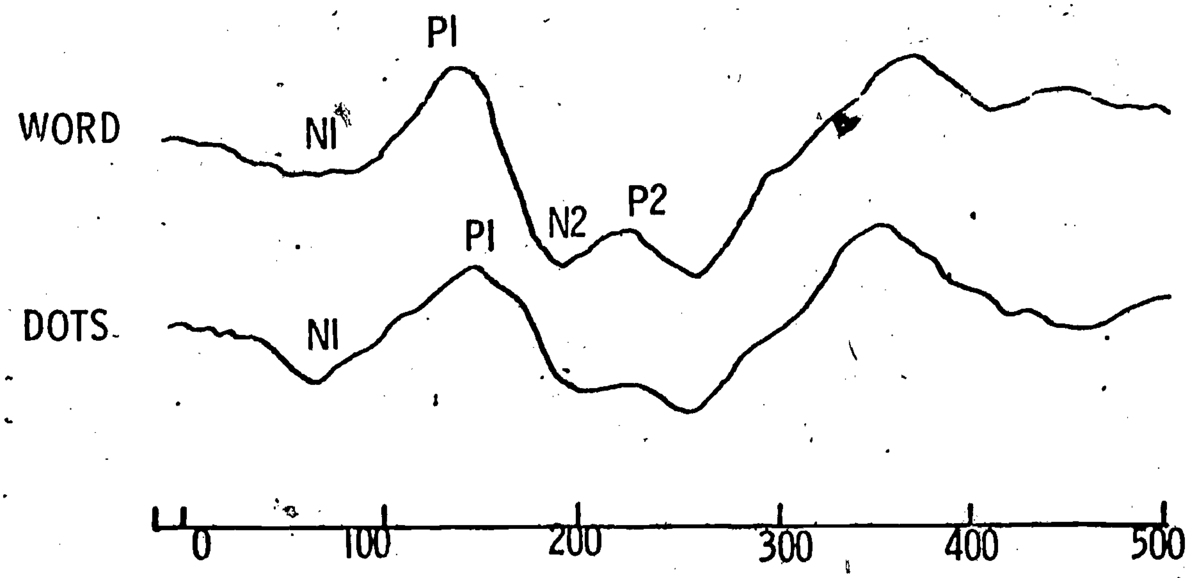


SLIDE 9

C. M.

ELECTRODE 01

BLOCK NUMBER 69
MULTIPLIED BY 3

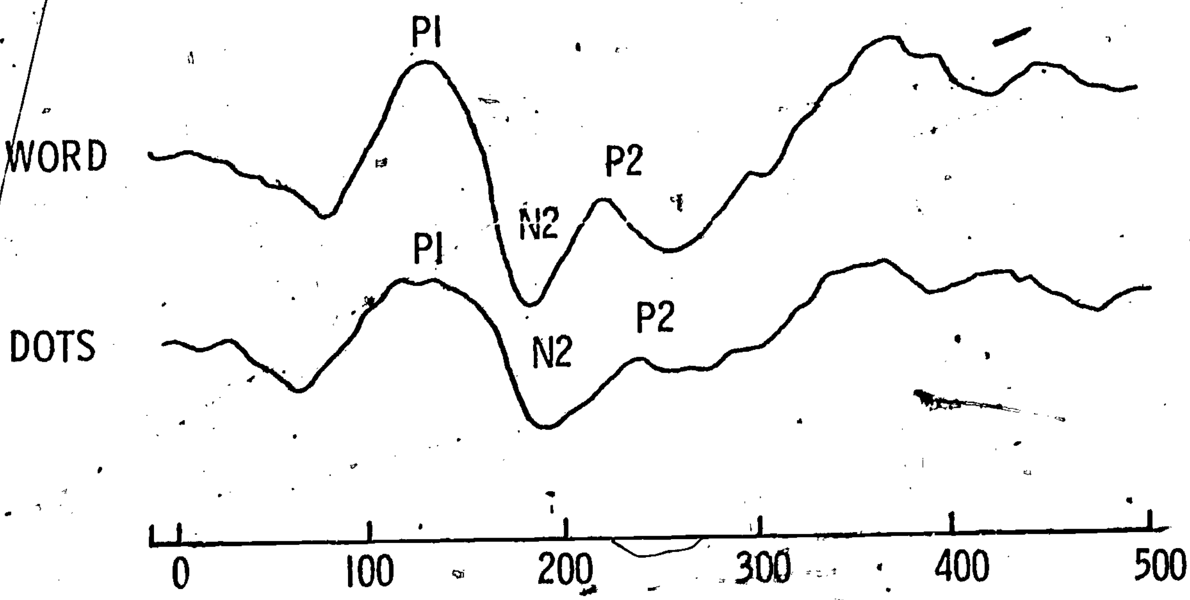


SLIDE 10

C. M.

ELECTRODE 02

BLOCK NUMBER 68
MULTIPLIED BY 3

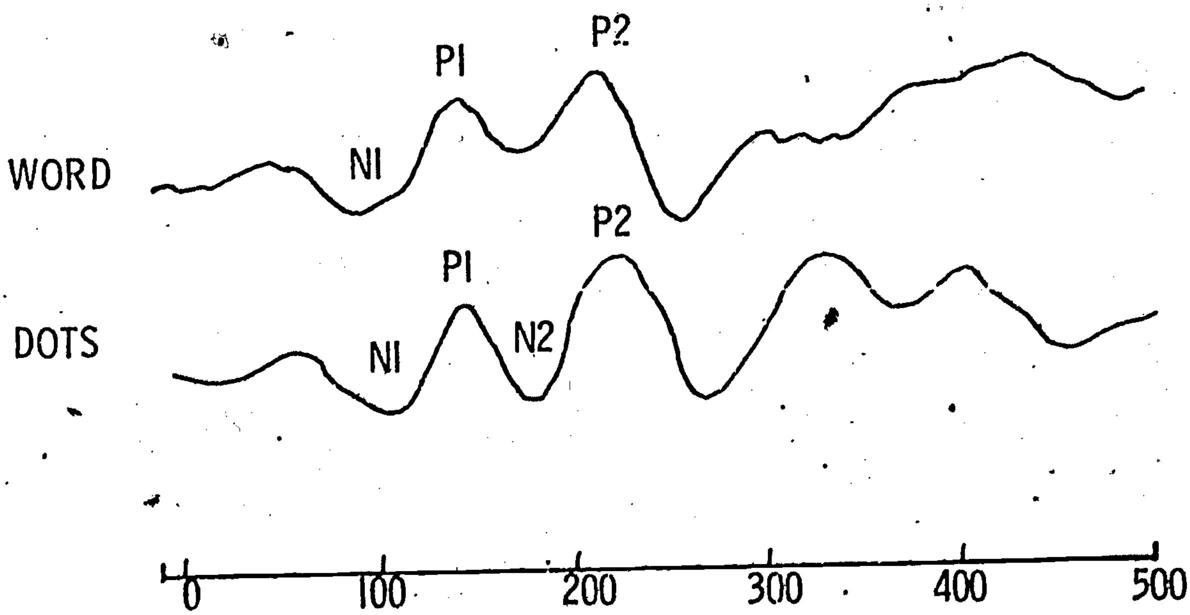


SLIDE.II

C. M.

ELECTRODE P3

BLOCK NUMBER 101
MULTIPLIED BY 3

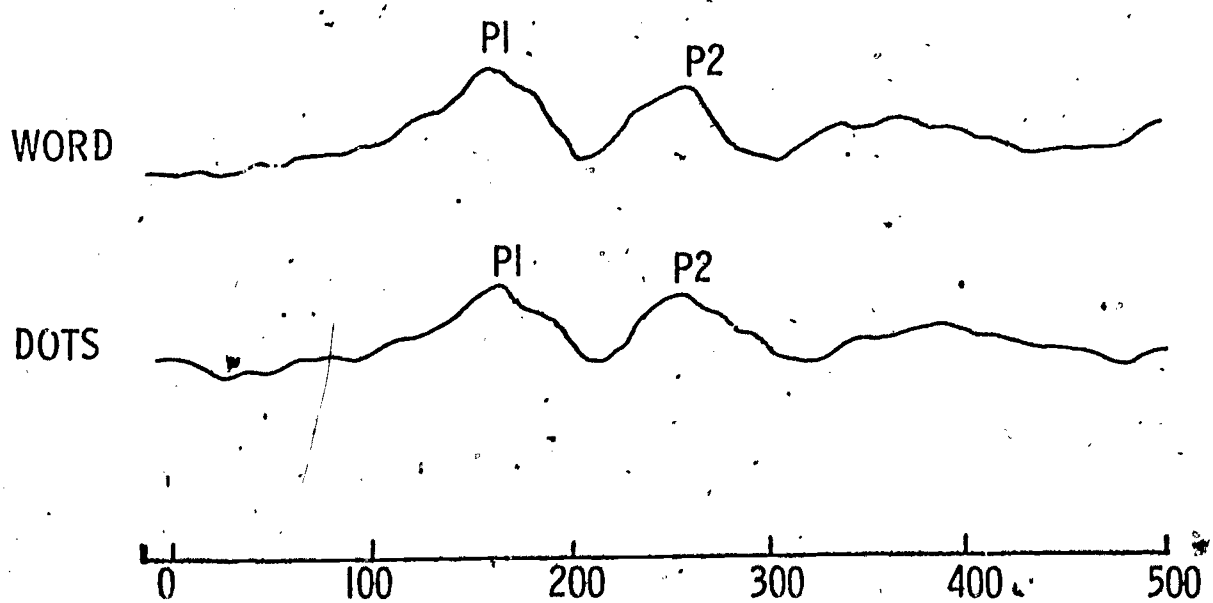


SLIDE 12

R. K.

ELECTRODE 01

BLOCK NUMBER 260
MULTIPLIED BY 3



SLIDE 13