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A Tale of Two Brains

-or-

The Sinistral Quasimodularity of Language

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ABSTRACT

Four experiments show that people differ strongly in the extent to which they depend on linguistic structure during language comprehension. Structure-dependent people are immediately affected by grammatical variables, while structure-independent people less affected by such variables. A surprising population difference between the two types of people suggests a genetic and neurological basis for the behavioral difference. All subjects were right-handed. However, structure independen people report no left-handers in their family, while structure-dependent people do report left-handers in their family. This suggests that the neurological organisation for linguistic ability in right handers with familial left-handedness, is more diffuse than for right handers with no familial left-handedness. Other facts connect this to a current hormonal theory of the ontogenesis of hemispheric asymmetries.

It is a common belief that there is a normal way of understanding sentences, which is essentially the same for everybody. This presupposition underlies the search for a single mechanism for sentence comprehension. It is also a common belief that there is a normal neurological configuration for language, at least among right-handed people. This presupposition underlies the practice of taking cerebral asymmetries in normals and behavioral syndromes in aphasics to reveal the normal function of a universal configuration. The research reported in this paper suggests that these assumptions are false: individuals differ markedly in the was they process language, and the difference is related to a genetic difference in neurological organisation for langauge.

Most linguistic theories distinguish two aspects of language: The structural system, which concerns syntactic, semantic and phonological knowledge; the conceptual system, which includes lexical reference and

conceptual knowledge of the world. Normal variation in language behavior can be defined in terms of variation in the degree to which a person depends on each of these systems during behavior. In this discussion, we focus on comprehension, in particular on differentiating those people who depend on structural features of the language from those who depend on more on non-structural knowledge of language.

It turned out that the extent to which a subject depends on structure is related to his familial handedness. There are obvious reasons to expect that left-handed people have a different neurological organisation for language from right-handers. Accordingly, we have been keeping track of the personal and familial handedness of our subjects in psycholinguistic studies. Over the last decade, we have frequently noticed that 'mixed-background' right-handers, from left-handed families, respond to language stimuli differently from 'pure background' right-handers. In particular, it seemed to us that during comprehension, 'mixed background' right handers are less sensitive to syntactic variables than 'pure background' right handers, but seem to have more facility with tasks involving single words. In the research reported here, we attended directly to handedness background, using it as the basis for isolating a 12-member group of what we thought would be "structure dependent" people from another 12-member group of what we thought would be "structure independent" people. Three experimental studies confirmed the preliminary differentiation that we made between the group of structure-dependent people and the group of structureindependent people, based on handedness background.

The first study used a percept which is affected by clause boundaries, the perceived location of a brief tone presented objectively during a two-clause sentence. In this paradigm, the listener hears the sentence with a tone in it and must be prepared to write the sentence down and report the location of the tone. On critical trials the listener is unexpectedly presented with a written version of the sentence. The listener locates the tone within a 3-4 word long "window" already marked on the sentence as in Figure 1 below. There were 3 kinds of response windows, one with the center on the word before the clause break, one in the clause break and one on the word after the clause break. The correct location for the tone was always in the center of the window. The serial position of the clause break was varied.)

All listeners reported the correct tone location better when it was objectively in the break between the clauses, than in either the word preceding or following (Figure 2). Responses to "catch" trials, in which there was no objective tone at all, showed a smaller guessing bias in favor of the between-clause position. When the response patterns are corrected for this guessing bias, the mixed-background listeners showed no overall superiority for the clause break, while the pure-background listeners did ($p<.05$ by Fisher exact test on subjects, $p<.025$ by Wilcoxon matched pairs signed ranks test on materials). Apparently, since pure-background subjects are structure-dependent, they have relatively more attention available to listen for the tone between clauses: this suggests that they actively assign each clause a separate representation as they hear it, while mixed-background listeners do not.

We studied the form in which listeners immediately represent a clause with a word-recognition technique commonly used in laboratory studies of language

processing (Townsend and Bever, 1978). In this paradigm, a listener hears a word sequence, followed by a single probe word: the listener must respond verbally if the probe word was in the original sequence or not. (Table 3 outlines the paradigm). In our study, the word sequences were main and subordinate clauses (introduced by 'if' or 'though'), all spoken with an intonation pattern suggesting that they would continue with a following clause. Among the probe words were verb-particles and adverbs, which could occur in either a late or an early position in each sentence (Figure 3 presents the six versions of a sample sentence fragment produced from 3 conjunction types x two probe positions). We constructed six experimental sets of 12 critical sequences with one version of each fragment in each set, as well as 12 fragments in which the following probe did not occur.

This task involves isolating a single word from the representation of a whole clause. We predicted that structure independent subjects would perform relatively well on this task, because, by hypothesis, they make more use of the reference of individual words in their processing. This prediction was confirmed for pure-background subjects: they responded positively to word-probes more slowly than did structure-independent listeners ($p<.01$ By a Fisher exact test) (Figure 4). In English, phrase order is one clue to the thematic structure of a clause (e.g., agents precede the verb unless there are special morphemes indicating the reverse). Accordingly, a structure-dependent listener should retain a sequential representation of a clause, if s/he expects that the clause will be integrated with later material. In contrast, a structure-independent listener should retain a clause in an unordered, conceptual form. Consistent with this difference, pure-background listeners were sensitive to the serial position of the probe word in the fragment, and mixed-background listeners were not (the serial position effect was larger for pure-background subjects, $p<.01$ on a Fisher exact). Pure-background listeners responded more slowly to late probes than to early probes. This suggests that they scan their representation of the just-heard sentence fragment from beginning to the end, a self-terminating serial scanning pattern that occurs in many non-linguistic probe tasks. The lack of a serial position effect for concept-dependent listeners suggests that their representation and search of the sentence fragment are unordered.

We ran a complementary study with the same subjects and the same type of sentence material, except that the probe was now a 2-4 word phrase - the listener's task was to say whether the phrase was related in meaning to the sentence. (The order of presentation of the three tasks, tone-location, word-probe and phrase-probe was counterbalanced across the groups). The phrase probe task taps a higher level of representation - meaning - than the word probe task: hence, there were no overall response time differences between the subject groups (Figure 5) All listeners responded more quickly to main-clause probes than to subordinate-clause probes*. This follows from the general view that a main clause can be immediately processed for meaning while a lower-level representation of a subordinate clause must be retained, so that it can be integrated with the ultimate main clause. The distinction between main and subordinate clauses is structural, which explains why the response time difference is larger for pure-background listeners than for mixed-background listeners ($p<.01$ by Fisher exact) (Table 7).

We also carried out a somewhat more naturalistic study of comprehension, which includes reading complete sentences and then answering questions about them. We used a self-paced word-by-word reading paradigm, currently in psycholinguistic fashion. Every time the subject presses a button on a computer keyboard, the next word appears in the same location on a video screen, wiping out the previous word. The final word of each sentence was indicated with a punctuation mark, the period. When finished reading the final word, the subject pressed the button again: this elicited a question about the sentence, which the subject answered.

Twenty-four new male subjects of each type of handedness background participated in this study. The results show that pure-background subjects pressed the button for each word 21% slower (483 milliseconds/word) than mixed-background subjects (399 milliseconds/word) ($p<.001$ by X-square). This finding is consistent with the relative slowness of this kind of person in the word-probe task. On our interpretation, forcing a structure-dependent reader to read on a word-by-word basis interferes with the usual comprehension process, in a way that is not true for the structure-independent reader. (I should note that the structure-dependent readers were slightly better at answering the questions correctly. There was, however, no speed/accuracy trade-off across subjects; $r=.04$. Overall accuracy was about 80%).

Although they read each word more slowly, pure-background readers are relatively sensitive to structural information within single words as well as word order. We used two types of verbs to explore this. One type of verb was a simple transitive verb such as 'hit, see, love'. These verbs maintain the conventional overlap between grammatical object and thematic object. The other type of verb inverts that relation, such as 'frighten, upset, please': intuitively, the grammatical object of these verbs is the thematic agent of an intransitive form of the verb. The word 'Sam', in "John scared Sam", is the thematic subject of 'scare', in a way that he is not in the sentence "John hit Bill." This fact is reflected differently in different linguistic theories. But, however it is correctly represented, it is a <u>thematic</u> fact about the verb 'scare', not a conceptual fact about the activity of scaring or being scared. We expected thematically-inverse verbs to be comprehended more slowly than simple transitives, just because they violate the conventional relation between syntactis and thematic relations. In fact, final words of sentences with thematically-inverse verbs were read more slowly - as predicted, this effect was much larger for pure-background readers than mixed-background readers ($p<.01$ by X-squared) (Figure 6). (This study also varied other aspects of structure - see Carrithers, 1986).

These results justified our preliminary differentiation of structure-dependent and structure-independent comprehenders. In each of four experiments, the pure-background people depended on aspects of the sentence structure more strongly than the mixed-background people. Consider again the population difference between these two kinds of listeners. Figure 7 lists some population variables that one might think could underly such differences in language processing style. In fact, the subject groups were tightly balanced on each of those variables. (We matched groups closely for SAT scores, using a SAT-yoked design for the first three studies - in the fourth study, the mean verbal SAT scores of the two groups were within 20 points. Right-

handedness was determined by a score of at least 98% on a variant of the Oldfield handedness inventory.)

There was one consistent population difference between the subjects: The structure-dependent subjects had been chosen as reporting only right-handers in their family envelope, while the structure-independent subjects reported at least one left-hander in their family envelope. The envelope included siblings, parents, uncles or aunts and grandparents. At least one left hander in that envelope predicted that a person was structure independent. (With this envelop as a criterion, about 40% of college undergraduates have left-handers in their family. We counted only full biological relatives; any relative who was reported as "having been left-handed, but forced to become right-handed" was counted as left-handed, as were "ambidextrous" relatives.)

Consider some some morals from this result. First, it suggests that there really is more than one way to initiate understanding of a sentence. Some people rely more on structural representations, some on lexical and conceptual knowledge. The implications of this for interpreting existing psycholinguistic research is troubling: it might seem that experimental results would qualitatively change as a function of subjects' handedness background. Fortunately, we have not found that one type of subject reverses the effects shown by the other type. Rather, the groups are mutually relatively insensitive to the conceptual and structural variables. In general this may have added satistical noise to previous studies that did not control for handedness background, but it will not have caused qualitative eccentricity in all cases.

Our finding also emphasizes the importance of understanding how a person goes about processing language before he becomes aphasic. The individual variability among normals highlights the possibility of a "reduced-efficiency" theory of aphasia. On this theory, damage to a portion of the language neurology results in a reduction of the efficiency of all linguistic behavior. If all systems of linguistic behavior become less efficient in aphasia, then those that were prominent when the patient was normal will still be above behavioral threshold: the patient will appear to have those systems, and appear to have actually lost the other systems. Different configurations of aphasic symptoms will result, simply as a function of normal differences. In this regard, it is interesting to note that concept-dependent listeners have the same relative response pattern as agrammatic aphasics with respect to their relative sensitivity to conceptual information and phrase order.

Finally, we can consider specific hypotheses about why familial left-handedness leads to more reliance on extra-linguistic conceptual knowledge and less reliance on language structure. Luria (1954) pointed out that people with left-handers in their family have a larger chance than normal of having aphasia from a gunshot wound but also have a better chance than normal of recovering from it. This suggests that people with familial sinistrality have a relatively widespread neurological module for language - it is temporarily more vulnerable to a randomly located wound, but has more widespread reserves for recovery. People who have only righthanders in their background may have a tighter, more localized neurological module for language. This difference would offer an interpretation of why people with familial left-handedness are

relatively sensitive to conceptual information. If such information is neurologically instantiated throughout the brain, then a larger area for language would allow for more points of contact between language and other kinds of knowledge. Conversely, a small, localized language area would have to depend more on purely linguistic processes. Familial sinistrality may be a phenotypic marker that an individual has a genetic predisposition for a less tighly localized neurological instantiation of language.

It is interesting to integrate this speculation with a recent theory that left-handedness is the expression of particular hormonal events in utero (Geschwind and Galaburda, 1987). They note that left-handers have a much higher incidence of auto-immune disorders than right handers, which indicates special hormonal events in utero. We recently conducted a survey of University of Rochester undergraduates and found that right-handers with left handed families report allergies much more frequently than pure right handers. It appears possible that familial sinistrality is a marker for people who become neurologically predisposed to acquire left-handedness in utero, but who have not expressed it haptically.

In conclusion, we propose an interpretation that familial right-handers have a beautiful, well-formed small languge module, whereas people with left-handers in their family have a correspondingly ugly, mishapen, large module: that is, their language function is neurologically instantiated in a "quasimodule".

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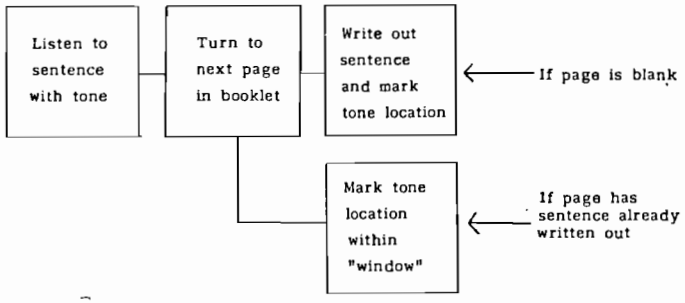
FIGURE 1

LOCATION OF BRIEF TONES IN 2-CLAUSE SENTENCES



Center window position relative to clause break

BEFORE	When Harry hit / the door he / saw Bill
IN	When Harry hit the door he saw Bill
AFTER	When Harry hit the / door he saw / Bill

FIGURE 2

LOCATION OF TONES IN 2-CLAUSE SENTENCES

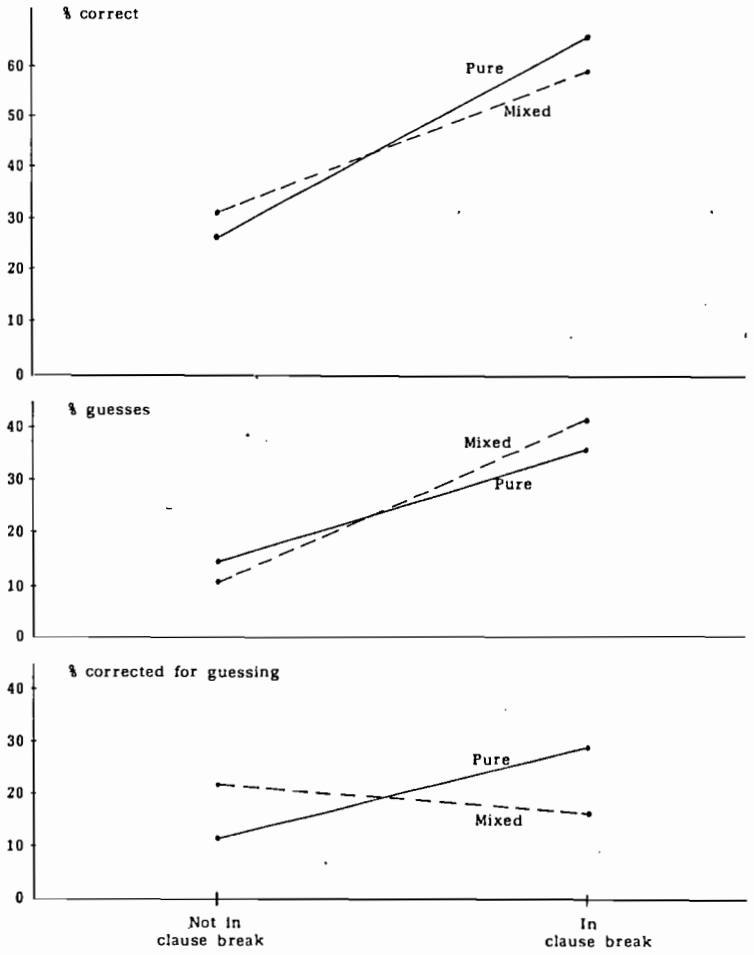
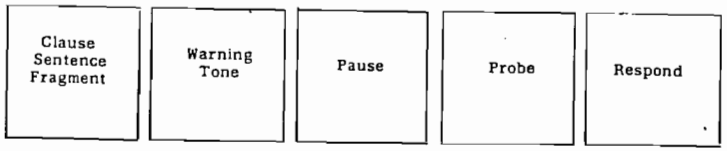


FIGURE 3

AUDITORY WORD PROBE STUDY (24 SUBJECTS)



If John was careful to call everybody in the class up yesterday....

Probe Word: UP

FIGURE 4

WORD PROBE RECOGNITION TIME

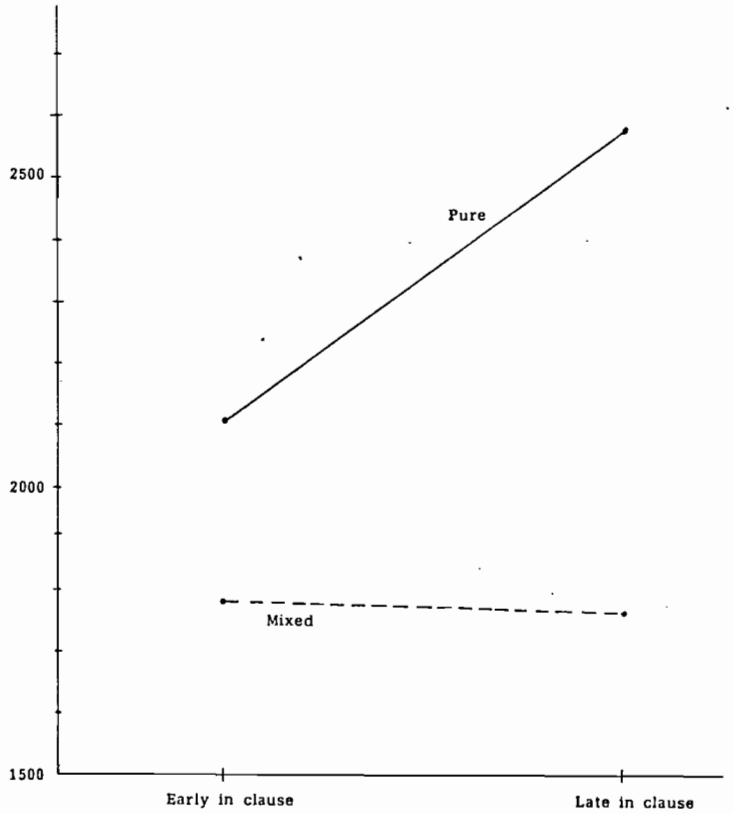


FIGURE 5

AUDITORY PHRASE PROBE STUDY (N = 24)

Subordinate { if / though } John was careful to call yesterday....

Main { ∅ }

Phrase probe: talk on phone

FIGURE 6

PHRASE PROBE RECOGNITION TIME

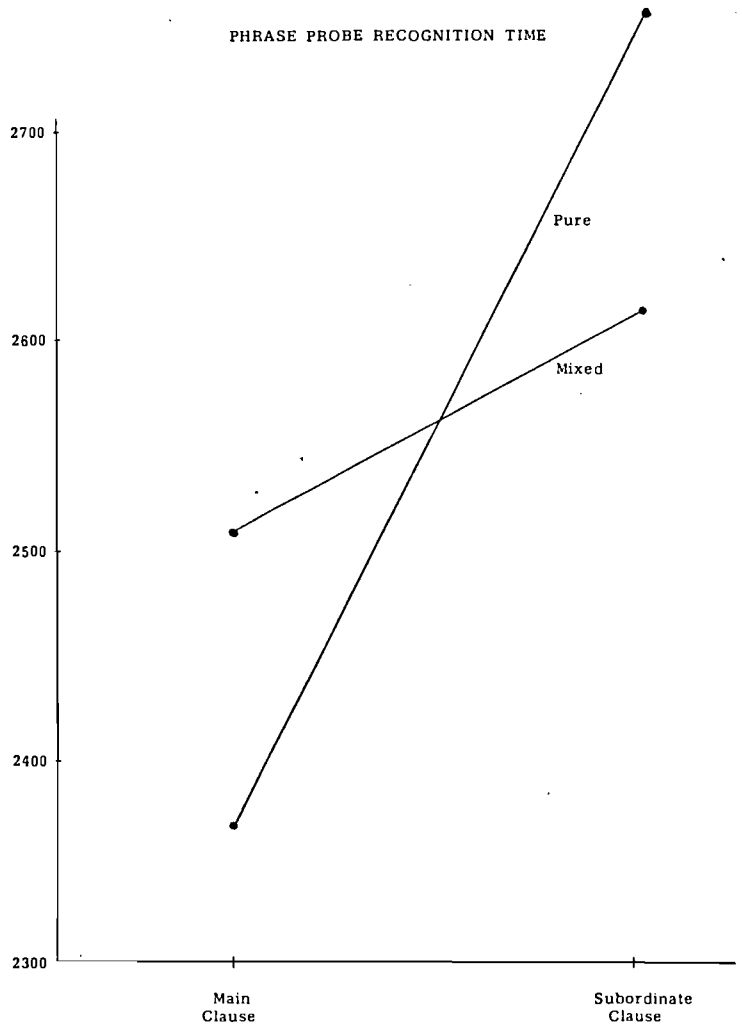


FIGURE 7

FINAL WORD DWELL TIME

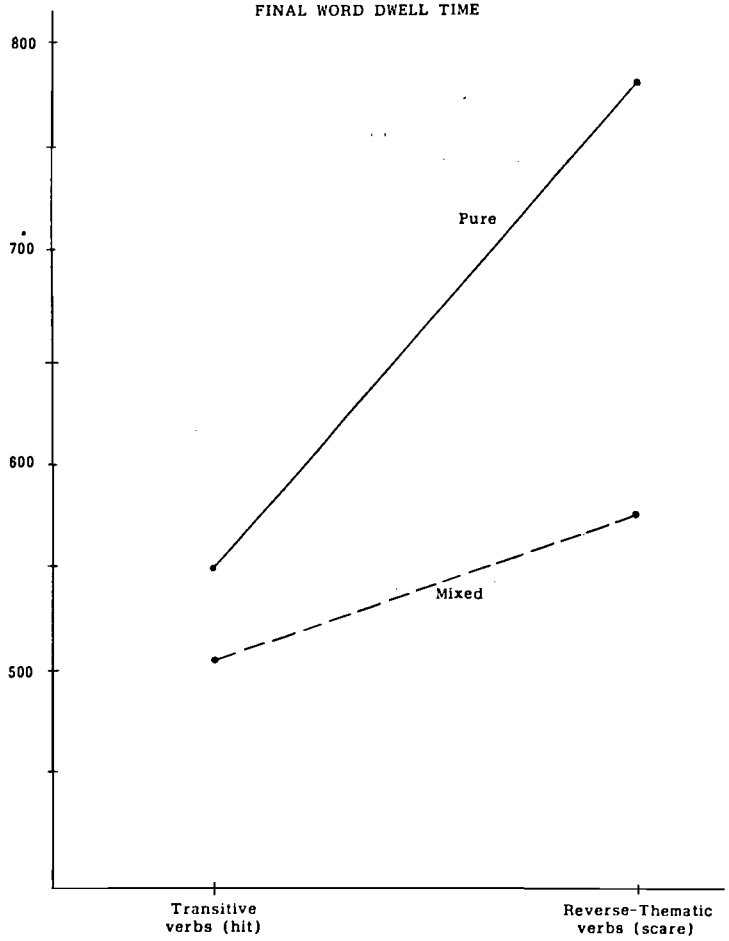


FIGURE 8

COMPARISON OF
STRUCTURE-DEPENDENT AND CONCEPT-DEPENDENT GROUPS

Age	College	College
Sex - Studies 1-3	6 male, 6 female	6 male, 6 female
Study 4	24 male	24 male
First Language	English	English
VSAT - Studies 1-3	450-700	450-700
	Yoked Design (see text)	
Study 4	Mean=620	Mean=640
Handedness	Right-handed	Right-handed
Familial Handedness	Right-handed family	At least one left-hander in family