Bever, T.G., Carrithers, C., Cowart, W., & Townsend, D.J. (1989). Language processing and familial handedness. In A. Galaburda (Ed.), *From neurons to reading.* Cambridge, MA: MIT Press. pp. 342-360

Chapter 12

Language Processing and Familial Handedness

Thomas G. Bever, Caroline Carrithers, Wayne Cowart, and David J. Townsend

---

The hand that rocks the cradle rules the world.
—W. R. Wallace

A common belief is that all normal people process language in the same way. This presupposition underlies the search for a single set of mechanisms for sentence processing. Another common belief is that there is a normal neurological configuration for language, at least among right-handed people. This notion underlies the belief that cerebral asymmetries in right-handers reveal that language function is predominantly dependent upon particular areas in the left hemisphere. The research reported in this chapter challenges some aspects of these beliefs. We review a number of studies suggesting that right-handers may fall into two groups that differ markedly in their relative dependence on structural and conceptual information during language processing. The differences are linked to a familial trait, left-handedness. Right-handers with no left-handed family members (RHF) depend relatively more on grammatical relations between words; right-handers with left-handed family members (LHF) depend more on the conceptual information of individual words. On our view, familial left-handedness may signal a heritable trait that alters the developmental processes determining the cerebral organization of language. At the end of this paper we shall briefly speculate on how the neurological differences in linguistic organization might arise and how they might result in different language-processing styles.

Classical clinical evidence suggests that language function is more dependent on certain areas in the left hemisphere than the right, even among most left-handed people (Broca 1961; Luria 1947; Russell and Espir 1961). Yet some facts indicate that left-handedness is associated with a different neurological representation for linguistic ability. For example, left-handers with left-hemisphere damage relatively often suffer no aphasia at all and show higher incidence of recovery from aphasia (Luria 1947; Russell and Espir 1961; Hecaen and Albert 1978).

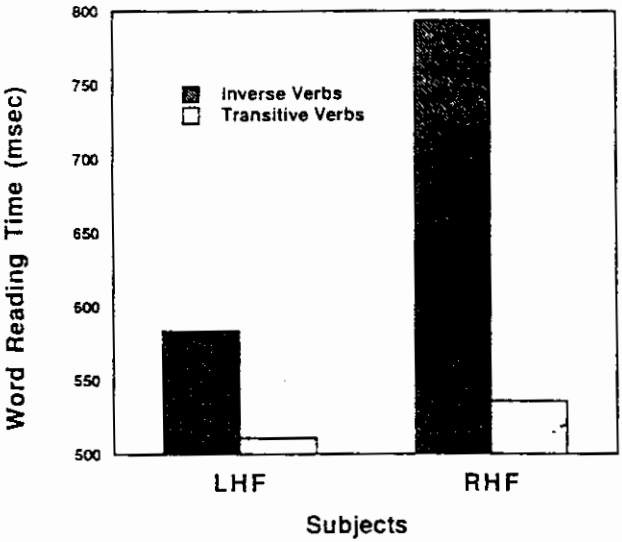

Figure 12.4
Final word reading time for sentences with transitive verbs ("hit") and thematically inverse verbs ("scare"). (See Carrithers 1988.)

surprising result found in the preceding study of self-paced, word-by-word reading: the average reading times per word were 21 percent slower for RHF right-handers than for LHF right-handers.* On our interpretation, forcing an RHF right-hander to read on a word-by-word basis interferes with the usual comprehension process in a way that does not hold for the LHF right-handed reader.[13] This hypothesis predicts that RHF right-handed readers should read faster when a whole clause is presented at a single time, since the minimal unit of syntactic structure is the clause (Bever et al. 1973, 1980). We tested this by having a new group of subjects read sentences in a clause-by-clause self-paced task.[14] As predicted, mean clause reading time for RHF right-handed subjects was faster by 15 percent than for the LHF right-handers.*

Auditory Word Segregation

It was important to test the hypothesis that separate word access is easier for LHF right-handers than for RHF right-handers in the auditory mode. To do this, we specially recorded a set of short essays, so that in some cases all the closed-class function words were presented to one ear while the content words were presented to the other ear. Even when the function and content words were segregated by ear, they were presented in the correct order for grammatical sentences.

The words were presented slowly, about one per second. This slow word-by-word presentation was used to exaggerate any disruption in comprehension when combined with segregating the content from the function words in different ears. Each auditorily presented essay was followed by written content questions.[15] RHF right-handers performed better on the questions when all the words in the essay were presented to the same ear.* Conversely, LHF right-handers performed better when the content and function words were segregated in separate ears (figure 12.5).*

This further supports the idea that LHF right-handers approach language comprehension first in terms of accessing individual words. Segregating the content and function words to different ears actually makes the comprehension task easier for them because it simplifies the acoustic isolation of each word. Conversely, such segregation makes the comprehension task harder for RHF right-handers, because it interferes with their normal mode of processing.

The Effects of Associative and Semantic Priming on Lexical Decision

The preceding two studies are consistent with the view that LHF right-handers benefit from individual word presentation during comprehension more than RHF right-handers, but the studies do not bear

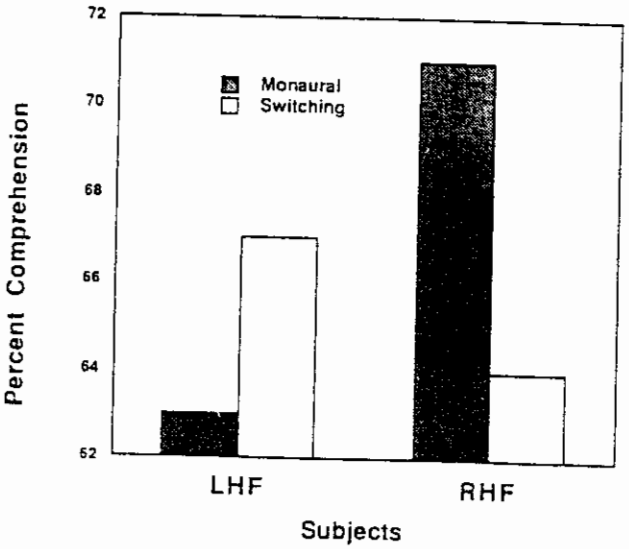

Figure 12.5
Postauditory written essay-comprehension score as a function of whether the essay was presented monaurally or with the function words heard in one ear and the content words heard in the other ear (Iverson and Bever 1989).

on the kind of lexical information that LHF right-handers access. We noted above that RHF right-handers are more sensitive to the structural information borne by certain verbs. So LHF right-handers must be accessing nonstructural, lexically borne information.

It is difficult to test for access of lexically based conceptual information during ongoing sentence comprehension, as the buildup of a representation of the conceptual information conveyed by the entire sentence may obscure the effects of individual words. Hence, we started our investigation of the hypothesis that LHF right-handers initially access nonlinguistic information in individual words, with a standard single-word experimental task: deciding that a sequence of letters is a word. This process can be affected by preceding words, and the amount of time it takes to make the lexical decision is often used to probe for the extent to which a word is primed by different kinds of contexts. For example, a critical word (e.g., lily) can be preceded by a word in the same semantic category (e.g., rose) or by a word that is highly associated with it (e.g., frog). A semantic prime is linguistically related to the critical word because they are defined as in the same semantic category. Associatively related words are related conceptually. Hence, we can use the amount of each kind of priming to tap the extent to which a subject arrives at the two kinds of lexical representation: associative priming taps a conceptual representation of the relation between the words in the world, whereas category priming taps a linguistic representation of their relation.

Various studies have found that both kinds of primes can have small facilitating effects on lexical-decision time (Lupker 1984), though there are some differences in the literature on this point (Fischler 1977a, 1977b). We designed a study with sets of semantic and associative prime words, along with unrelated control prime words. On each trial, a subject first fixates on a central target ('+'), then a prime word appears for 0.75 second, followed by the probe letter sequence. In the cases of interest, the letter sequence is a word. The amount of priming occasioned by the prime word is indicated by how much faster the probe word is recognized following a related prime than following an unrelated control (table 12.1).[16]

Table 12.1
Lexical decision materials

	Prime	Probe
Category prime	ROSE	LILY
Unrelated control	DOG	LILY
Associate prime	POND	LILY
Unrelated control	DOG	LILY

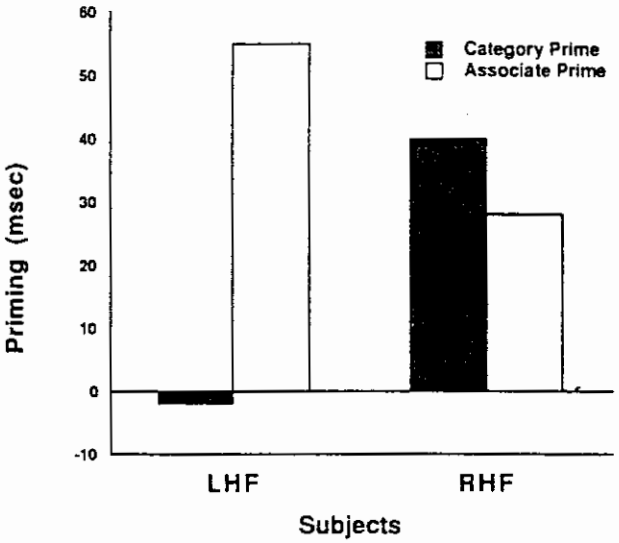

Figure 12.6
Amount of lexical-decision (LD) priming for semantic category and associative primers. Priming score is (LD preceded by unrelated word) − (LD preceded by a priming word). (Burgess and Beves 1989)

We contrasted LHF with RHF right-handers, using both kinds of priming. The results show a strong interaction between familial handedness and the kind of priming relation* (figure 12.6). LHF right-handers show less category priming than associative priming.* These results suggest further that LHF right-handers access conceptual information in individual words more directly than grammatical information, whereas RHF right-handers access grammatically encoded information more readily than conceptual information.

Utterance Length and Grammaticality in Young Children

These experiments all point in the same direction: right-handed people from right-handed families are more sensitive to syntactic structure than are right-handed people from families with left-handers. It also appears that they deal with single-word tasks less well. These generalizations invite speculation about individual differences in language development. In particular, we might expect that RHF right-handed children would typically show earlier syntactic development than LHF right-handed children. We subjected this hypothesis to a preliminary test by examining the speech of 43 two-year-old children who participated in another study (Gerken 1987).[17] The mean age of the two groups was the same (26 months) and the pro-

portion of females was within 4 percent. The RHF right-handed children actually showed a lower mean length of utterance than LHF right-handed children.* The mean length of utterance includes both grammatical ("I do that") and ungrammatical ("Me do that") utterances. To assess children's sensitivity to grammatical structures, we calculated the percentage of each child's multiword utterance types that were well-formed sentences an adult could use in isolation. Overall, RHF right-handed children produce a higher proportion of such utterances than LHF right-handed children.* The higher grammaticality rating of RHF right-handers was not due to the fact that LHF right-handed children had higher MLUs (and therefore a bigger chance of producing errors). The superior performance of RHF right-handed children occurred throughout the MLU range of the children. Thus, at the very young age studied here, it appeared that RHF right-handed children use fewer words per utterance but do so more grammatically.

Discussion

Our working hypotheses have received initial confirmation: RHF right-handers emphasize grammatical information and LHF right-handers emphasize other lexical information during language processing. There are a number of implications of such a difference.

The Distinct Operation of Linguistic Subsystems

In recent years it has been argued that the capacity to learn language is based on innate, skill-specific mechanisms. These mechanisms are most easily viewed as modules, distinct processing systems each with its own capacity and characteristics (Fodor 1983). For example, the mental representation of structural knowledge about language is distinct from the representation of lexical reference. The corresponding biological hypothesis is that there are distinct physiological mechanisms underlying the two kinds of knowledge. There are very few biological sources of data that confirm such a hypothesis. Most notably, the ways in which language is normally acquired and breaks down in aphasia have been argued to reveal the existence of linguistic subsystems. For example, anomias of specific kinds can occur without loss of grammatical capacity, and grammatical functioning can be lost without apparent loss of individual word denotations. Correspondingly, the acquisition of specific word denotations appears to occur parallel to, but distinct from, the acquisition of grammatical systems.

Systematic heritable variation offers a third kind of data confirming the hypothesis that there are distinct genetic mechanisms underlying

a skill. For example, the quantal nature of inherited defects of color vision was strong evidence for the existence of different kinds of color receptors. Heritable differences in the capacity to taste different chemicals is evidence for specific taste receptors. We may have found a difference between people who lay particular stress on structure in language processing and others who assign relatively greater weight to lexical information. The critical role of familial handedness in separating these groups suggests strongly that the difference in processing styles is biologically mediated. Confirmation of the heritability of this difference will support a polymorphic hypothesis about the biological basis for language. In particular, our results lend validity to the claim that grammatical mechanisms are neurologically distinct from referential mechanisms.

In psycholinguistics there is an ongoing debate between modularists and interactionists over the extent to which grammatical structure is processed independently of other kinds of knowledge (see papers in Garfield 1987). The role of referential knowledge in syntactic processing is a central topic in this controversy: interactionists claim that conceptual knowledge can guide immediate syntactic decisions; modularists argue that the two kinds of information are initially processed independently. Our research is aimed at demonstrating that there is heritable variation in the extent to which comprehension emphasizes one or the other of these kinds of linguistic knowledge. If our preliminary results are confirmed, it will demonstrate that the modular theory is correct, at least insofar as it claims that the two kinds of information can be behaviorally isolated as a function of a familial trait.

Individual Differences

A less important but serious implication of this research concerns the interpretation of many current lines of research on language processing: our research suggests that familial handedness is not merely a source of noise in the data; it is a *systematic* source of variability that bears directly on many of the controversial issues in the field. About 50 percent of right-handers have left-handed family members. Hence, many weak experimental effects of structure or referential knowledge may be obscured by chance variation of familial handedness in experimental subjects. This is not a happy fact for the field, but it must be recognized and attended to in future research.

These results may also shed some light on individual differences in style of language acquisition. Numerous authors have noted that children have different approaches to learning a first language. Some invoke such distinctions as analytic versus holistic learners or word

versus phrase learners (Bloom 1973; Nelson 1973; Peters 1983; Bates et al. 1988). We have found evidence that one contributing factor to such individual differences in linguistic style is the handedness of the child's family. Our preliminary analysis of the speech of young children suggests that LHF right-handed children may approach language behavior initially as a problem of mastering the words, while RHF right-handed children may focus initially on the acquisition of grammatical relations.

In our experiments RHF right-handers are clearly more immediately sensitive to grammatical structures than LHF right-handers. But it is less clear what typifies the language processing of LHF right-handers, or even whether a single characteristic pattern exists. We have reported evidence that LHF right-handers can access individual words during sentence comprehension better than RHF right-handers and that their sentence processing benefits when words are segregated for them. But LHF right-handers are not sensitive to all lexical information as such. The generalization that is supported by our results is that RHF right-handers are more sensitive to linguistic information in individual words (thematic-role structure, semantic category), while LHF right-handers are more sensitive to conceptual information. That is, during comprehension, LHF right-handers may access representations of lexical referents more immediately than RHF right-handers. This possibility has interesting implications for the apparent distribution of aphasias in response to left-hemisphere damage. For example, it may be that LHF right-handed patients with left-hemisphere damage are better able to mask loss of grammatical capacity by relying on their already well-developed lexical-referential strategies for language behavior. Conversely, LHF right-handed patients may show an apparent aphasia from right-hemisphere damage because it impairs access to their usual lexically based processing strategies (Kolk and van Grunsven 1985; Kolk 1987).

Underlying Mechanisms

We have noted that there are two major systems of knowledge involved in language behavior: grammatical structures and referential knowledge. We now turn to some speculations about why the LHF right-handers are relatively more sensitive to referential knowledge in language-processing style. One hypothesis is based on neurological distribution of the two kinds of language systems. Suppose that the neurological substrate for grammatical structures is always limited to a particular hemisphere, regardless of the overall growth or balance between the hemispheres. This would explain why almost

Furthermore, mental abilities in left-handers have often been reported to vary more than in right-handers. For example, left-handers have a relatively high incidence of language disabilities and also have a higher incidence of mathematical precocity (Benbow and Benbow 1984).

Previous research has occasionally suggested that familial left-handedness in right-handers is also associated with an exceptional neurological organization of cognitive abilities. For example, Luria (1947) noted that left-hemisphere wounds cause major aphasia in right-handers with left-handed family members less often than in right-handers with only right-handed relatives; like left-handers, LHF right-handers recover more quickly than RHF right-handers from aphasia caused by left-hemisphere damage; LHF right-handers also show aphasia more often in response to wounds to the right hemisphere. Consistent with this, Joanette et al. (1983) report that minor right-hemisphere lesions result in subtle language disturbances in LHF right-handed patients more often than in RHF right-handed patients. Furthermore, LHF right-handers have a higher incidence of dyslexia than do RHF right-handers (Orton 1925; Gordon 1980, 1983) and a higher incidence of mathematical precocity (Benbow and Benbow 1984; Benbow 1986).

The preceding surveys suggest that familial left-handedness is associated with a less-concentrated representation for language in the left-hemisphere. Some experimental studies suggest this as well. For example, in right-handers, verbal tasks interfere with rhythmic tapping by the right hand more than by the left hand, an effect that presumably reflects the competition for left-hemisphere resources between language processing and right-hand activity. This left-right asymmetry is smaller in LHF right-handers (Kee, Bathurst, and Hellige 1983). Furthermore, verbal-intelligence test scores correlate positively with right-ear dominance in a dichotic words task for RHF right-handers, while the verbal scores correlate negatively with right-ear dominance for LHF right-handers (Kraft 1983). Finally, RHF right-handers also show a much stronger hemispheric asymmetry than LHF right-handers in event-related brain potentials during silent reading (Kutas, VanPetten and Besson 1988). Such results suggest at the least that familial left-handedness is a phenotypic marker of a neurological organization for language and cognition different from that in purely right-handed families.[1] (See also the papers by McKeever and his colleagues listed in the bibliography.)

Geschwind and Galaburda (1987) present a theory of the development of cerebral lateralization that might predict the neurological

structure of LHF right-handers to be different from that of RHF right-handers. They note that in a standard anatomical pattern, certain structures in the language areas of the left hemisphere are larger than the corresponding structures of the right hemisphere. However, they estimate that about 35 percent of the population has "anomalous dominance," in which certain areas in the right hemisphere are unusually large compared to the standard, asymmetrical case. Anomalous dominance occurs in most left handers, but in an additional 25 percent of right-handers as well. Left-handers reveal most clearly that these anomalous anatomical patterns are associated with various behavioral phenomena, including dyslexia, other learning disorders, and special nonlinguistic talents. Geschwind and Galaburda (1987) also find that left-handedness is associated with an increased frequency of autoimmune disorders (Geschwind and Behan 1982, 1984; Benbow 1986; Searlman and Fugagli 1987).

The coincidence of autoimmune and allergic disorders with left-handedness is startling. Geschwind and Galaburda review evidence that one developmental cause of these disorders may be high activity of fetal testosterone. They further claim that normal hemisphere development can be inhibited by high testosterone activity at certain points in fetal cerebral growth. Since the structures that influence left-hemisphere dominance develop early (by hypothesis), high testosterone activity will often result in both autoimmune disorders and anomalous cortical representations for language. Furthermore, they suggest that the mechanisms underlying explicit handedness develop later and are less vulnerable to high testosterone activity. Thus, anomalous cerebral dominance for language will occur more often than explicit left-handedness.

On this view, familial left-handedness may be a phenotypic marker of the genetic substrate for high testosterone activity during gestation. Even when it does not result in overt left-ha: .dedness, it may result in distinct cortical representations for higher cognitive functions. This hypothesis predicts that even among right-handers few should be a strong statistical relations among autoimmune disorders, linguistic performance, and familial left-handedness. Relatively few data have been collected from normal right-handed people to determine the effects of familial left-handedness on them. We started our investigation of the relationship with a simple questionnaire of about 400 undergraduates at the University of Rochester. We found that 49 percent of LHF right-handed undergraduates report having some kind of allergy, while only 15 percent of RHF right-handed undergraduates do.*[2] Furthermore, the average verbal SAT score for RHF

right-handed subjects is 16 points higher than that of LHF right-handed subjects, (while the math SAT score is lower by about the same amount).[3] In addition, over the last decade we have frequently noticed that LHF right-handers respond to language stimuli in experiments differently from RHF right-handers (summarized in Bever 1983; see also Bever, Carrithers, and Townsend 1987). Such preliminary results indicate that there may be qualitative differences in language behavior that distinguish linguistically normal LHF and RHF right-handers.

How might styles of language behavior differ? Language behavior involves the exploitation of two kinds of knowledge: the structural system; which concerns syntactic, semantic, and phonological knowledge, and the conceptual system, which includes knowledge of the reference of words and conceptual knowledge of the world. Variation in language behavior might arise if different individuals can exploit these two kinds of knowledge to different degrees. In several studies we have found that utilization of syntactic structure during sentence processing is one dimension along which individuals can differ (Gerken and Bever 1986; Townsend et al. 1987). Since familial left-handedness has been associated with difficulties on specific language tasks, we developed the working hypothesis that LHF right-handers are less sensitive to grammatical structure than RHF right-handers, and LHF right-handers are more sensitive to conceptual and referential information than RHF right-handers. This hypothesis is presented with preliminary supporting data in Bever, Carrithers, and Townsend 1987.

Experimental Studies

In the research reported here, we attended directly to handedness background, using it as the basis for differentiating two groups of right-handed subjects matched on other variables such as age, sex, and verbal ability. The RHF subjects reported only right-handers in their family, while the LHF subjects reported at least one left-hander (the family included siblings, parents, uncles and aunts, and grandparents).[4]

Our first goal was to find out if the sensitivity to grammatical structures differs in RHF and LHF right-handers. We tested this by studying subjects' sensitivity during comprehension to two levels of structural constraints: the dominance relations between main and subordinate clauses and the thematic relation between phrases in canonical and noncanonical phrase order.

Subordinate and Main Clauses

There is considerable evidence that the clause is an important organizing unit in ongoing comprehension (Bever 1970; Fodor et al. 1974). Words in clauses are immediately segregated together and provide a framework for recoding into semantic propositions. Typically, a sentence involves both main and subordinate clauses. The intuitive and formal role of a subordinate clause is to modify the meaning of a main clause. Nonetheless, the relation between a main and a subordinate clause is a structural one, not a lexical or semantic one. For example, the three sentences below use the same words (except for the conjunctions *though* and *but*) and have the same meaning. But only in (1*a*) is the second clause subordinate to the first.[5]

(1*a*) Main-subordinate: Harry called up Bill, though he didn't want to.

(1*b*) Main-main: Harry called up Bill, but he didn't want to.

(1*c*) Subordinate-main: Though Harry called up Bill, he didn't want to.

The fact that the difference between main-main structures and main-subordinate structures does not necessarily involve a difference in meaning makes processing sensitivity to the main/subordinate clause distinction a useful probe of sensitivity to pure structure. Cowart (1987) found that RHF right-handed subjects read the beginning of final subordinate clauses more slowly than the beginning of main clauses, while LHF right-handers do not. This is consistent with the view that RHF right-handers are more immediately sensitive to the increased processing load associated with a subordinate clause. The following two studies suggest that RHF right-handed subjects are more sensitive to the main/subordinate distinction than LHF right-handed subjects.

Meaning Probes

A marked initial subordinate clause is always followed ultimately by a main clause that dominates it, but an initial main clause can stand alone. For example, the first clause in (1*c*) must be followed by the second clause; this is not true of (1*a*) and (1*b*). There are many well-known linguistic properties associated with this difference (Bever and Langendoen 1973; Ross 1967; Reinhart 1983). For example, a pronoun can occur in an initial subordinate clause with its antecedent in a later clause, but a pronoun cannot take an antecedent in a following subordinate clause;[6] initial subordinate clauses may be shortened by deletion, but initial main clauses may not be, and so on. In each case, it appears that information can be missing from a marked initial subordinate clause because the listener knows that there will follow a

main clause that will provide the missing information. An initial main clause may stand alone, so there is no guarantee that an additional clause will follow (Bever 1970). This difference explains the tolerance for linguistically degraded initial subordinate clauses. This difference also has a behavioral implication: during comprehension, initial main clauses can be recoded into a semantic form immediately, while initial subordinate clauses are temporarily retained in linguistic form attendant on subsequent integration with their main clauses (Townsend and Bever 1978; Bever et al. 1980).

We studied the form in which listeners immediately represent a clause, with a phrase-matching technique used in laboratory studies of language processing (Townsend and Bever 1978). In this experimental task a listener hears a word sequence that is part of a sentence, followed by a single probe phrase, as in (2):

(2) Sentence fragment Tone Probe phrase

Though Harry called up Bill yesterday—beep—talk on phone.

The listener must quickly respond verbally whether the probe phrase was related to the meaning of the just-heard sequence or not. In our study, the critical sentence fragments were both subordinate and main clauses.[7]

The overall prediction was that phrase probes would be recognized more quickly after a main clause than after a subordinate clause. This follows from the hypothesis that a main clause can immediately be 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 (Townsend and Bever 1978; Bever et al. 1980). This should facilitate recognition of a semantically related phrase after a main clause, in comparison with a phrase after a subordinate clause. The main-clause facilitated recognition in the study but only for RHF right-handed listeners: they responded more quickly to main-clause probes than to subordinate-clause probes (figure 12.1),* a response pattern different from that of LHF right-handed listeners,* whose latencies were the same for both kinds of clauses. This result is consistent with the hypothesis that RHF right-handed subjects are more sensitive than LHF right-handers to the main-clause/subordinate-clause distinction.

Word-by-Word Reading and Pronominal Anaphora

The next study involved the role of the syntactic relation between clauses in processing pronouns. The experimental materials were two-clause sentences with a pronoun (*they, he, she*) in the subject position of the second clause and a potential antecedent in the first

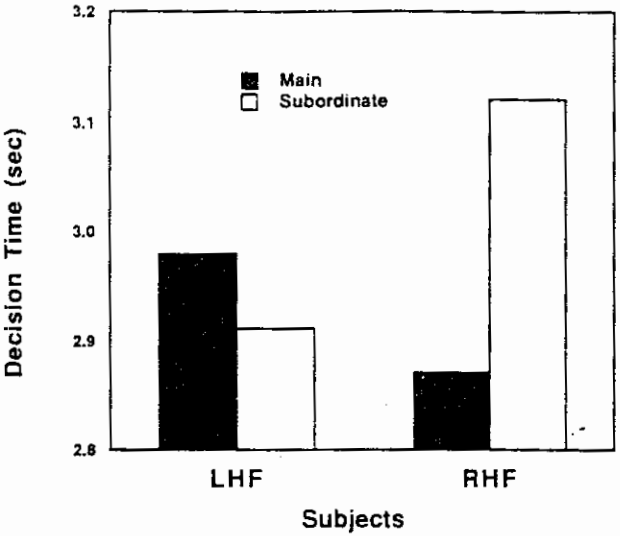

Figure 12.1
Time to decide that a phrase corresponds in meaning to the content of a just-heard main or subordinate clause sentence-fragment (Bever, Carrithers, and Townsend 1989).

clause. The potential antecedent could or could not actually serve as an antecedent according to whether it agreed with the pronoun in gender and number. The first clause was either subordinate to the second clause or the two clauses were main clauses, as in (3).[8]

(3) Samples of materials in pronoun reading time study

(*a*) Subordinate clause with antecedent present (or absent)
Even though *the librarian* (the librarians) made an awful lot of noise, *she* kept on working on her own material.

(*b*) Main clause with antecedent present (or absent)
The librarian (the librarians) made an awful lot of noise, but *she* kept on working on her own material.

Reading a pronoun and the material following it should be facilitated if the pronoun has a readily available antecedent. An initial subordinate clause must be integrated within its following main clause, while an initial main clause can be encoded as a distinct unit. This difference involves a higher degree of syntactic integration between clauses in the comprehension of subordinate-main constructions than of main-main constructions. Hence, the presence of an available antecedent should facilitate pronoun integration more strongly in subordinate-main constructions than main-main constructions for those subjects

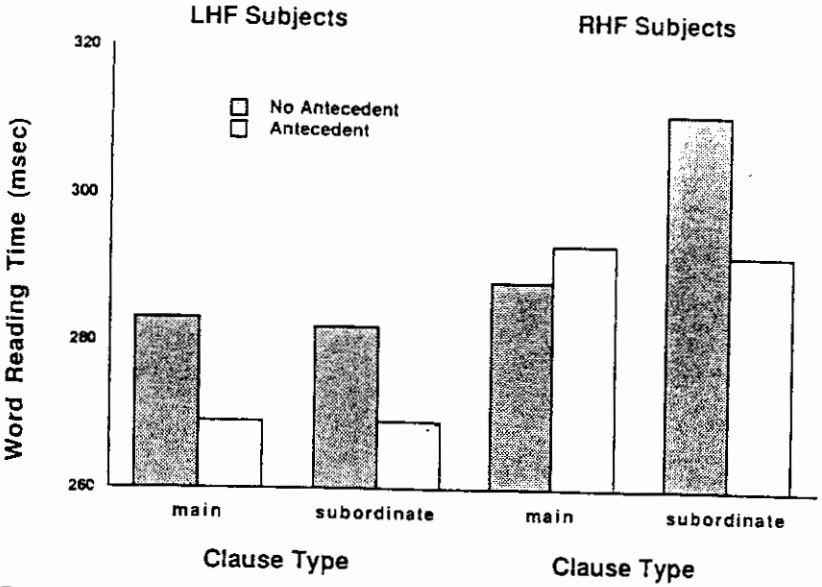

Figure 12.2
Word reading time for the three words following a pronoun in a final main clause, as a function of whether there is an antecedent in the initial clause and whether the initial clause is main or subordinate (Cowart 1988).

who immediately process an initial subordinate clause in a way that looks ahead to the coming main clause.

Subjects read sentences in a self-paced, cumulative, word-by-word task. Every time the subject pushes a button, the next word appears on a computer screen in its correct location. We averaged the reading time on the three words following the pronoun as a measure of the effect of the presence or absence of an antecedent. RHF right-handed subjects read the words following the pronoun faster when an antecedent was present, but only in subordinate-main constructions, not in main-main constructions* (figure 12.2). LHF right-handed subjects, however, were equally helped by the antecedent in subordinate-main and main-main structures. The difference of construction type on the effect of the antecedent is significantly larger for RHF right-handed subjects than for LHF right-handed subjects.*[9] It appears that RHF right-handed subjects encode potential antecedents in a way that makes them available for the following main clause only if they occur in an initial subordinate clause. LHF right-handed subjects retain potential antecedents in initial clauses with equal accessability, regardless of clause type.

The preceding two experiments support the hypothesis that com-

prehension processes in RHF right-handers are relatively sensitive to the difference between main and subordinate clauses. They immediately encode an initial main clause in a form that makes its meaning more quickly accessible than that of an initial subordinate clause. They encode an initial subordinate clause in a form that prepares it for integration with the following main clause. LHF right-handers do not encode initial subordinate clauses in a form different from initial main clauses. In sum, RHF right-handers may be relatively sensitive to structural relations between clauses within a sentence.

Canonical and Noncanonical Assignment of Thematic Roles

Let us now turn to a study of RHF and LHF right-handers' relative sensitivity to structures within clauses. In English the canonical phrase order of noun phrase, verb, noun phrase conveys the basic thematic relations agent, predicate, patient. Agent status is assigned to the initial noun phrase and patient status to the second noun phrase, as in (4*a*) and (4*b*). There is considerable evidence that during comprehension, people attempt to assign thematic relations based on this standard word order: for example, noncanonical word orders, as in (4*c*) and (4*d*), can be relatively hard to understand (McMahon 1963; Bever 1970; Slobin and Bever 1982; Carrithers 1988).[10]

(4*a*) John hit Sam.

(4*b*) It's John who hit Sam.

(4*c*) Sam was hit by John.

(4*d*) It's Sam who John hit.

The next study explores sensitivity to canonical word order in two ways: with noncanonical sentence constructions such as the passive and with particular verbs that assign noncanonical thematic relations to subject and object phrases. In each case, we found that RHF right-handers are more sensitive than LHF right-handers to canonical/noncanonical order manipulation.

We used a self-paced word-by-word reading task similar to that employed by Aaronson and Scarborough (1976): 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 experimental materials included sentences with the canonical agent-verb-patient order (active constructions) and those without that order (passive sentences). These sentences were semantically reversible; that is, the subject and object could be exchanged, and the result would be a sensible sentence.[11]

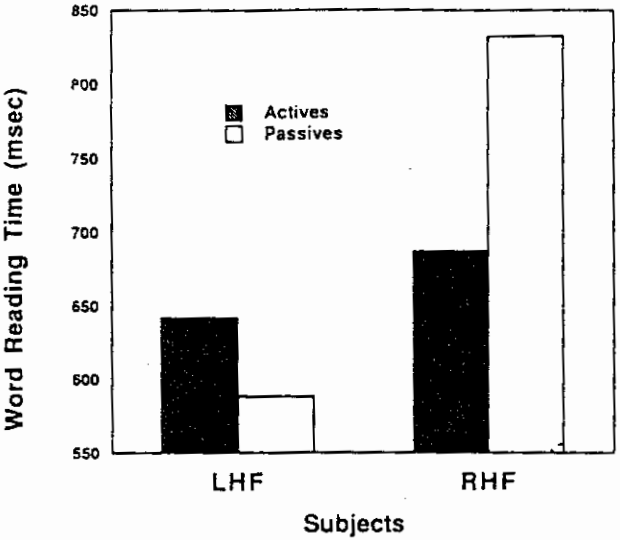

Figure 12.3
Final word reading time for active and passive sentences (see Carrithers 1988).

We used reading time on the last word of each sentence as a measure of its difficulty, scoring responses for each subject only when he correctly answered a subsequent comprehension question. The results showed that RHF readers are more sensitive to the difference between active and passive word order than LHF readers (figure 12.3).* RHF right-handed subjects spent a longer time on the last word of passive constructions than on active constructions.* LHF right-handed subjects did not show any differences as a function of word order.[12]

Canonical and Noncanonical Verbs

In this study we used two types of verbs to explore whether RHF readers are relatively sensitive to structural information conveyed by single words, as well as to variations in word order. One type of verb was a simple transitive verb such as *hit, see,* or *love.* These verbs maintain a canonical identity between grammatical object and thematic patient: in (5*a*) *Sam* is the direct object of *hit,* and Sam is the thematic patient (the one affected by the action). (The asterisk indicates peculiar or ungrammatical English.)

(5*a*) John hit Sam easily

(5*b*) John scared Sam easily

(5*c*) Sam scared easily for John

(5*d*) *Sam hits easily for John

The second type of verb inverts that relation, e.g., *scare*, *upset*, or *please* (Postal 1971; Carrithers 1988; Belleti and Rizzi 1988). Intuitively, the grammatical object of this second class of verb is the thematic agent of an intransitive form of the verb. Thus, the object of (5*b*) can become the apparent subject, as in (5*c*), a variation that cannot occur with standard transitive verbs, hence the ungrammaticality of (5*d*). This and other facts suggest that the apparent direct object of such verbs is thematically an experiencer or agent. This violates the usual confluence of grammatical and thematic object. The distinction between simple transitive and inverse thematic verbs is reflected differently in different linguistic theories. But, however it is correctly represented, it is a structural property, not a conceptual one: the fact that the object of *scare* is the experiencer is a grammatical fact, 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 canonical relation between syntactic and thematic relations. In fact, final words of sentences with thematically inverse verbs were read more slowly than those of sentences with normal transitive verbs.* This difference was larger for RHF right-handers than for LHF right-handers (figure 12.4).*

Lexical-Conceptual Sensitivity

The preceding studies all suggest that RHF right-handers are more immediately sensitive than LHF right-handers to syntactic structures during processing. This confirms the first working hypothesis—that comprehension processes in RHF right-handers are more dependent on grammatical information than in LHF right-handers. We now turn to the complementary hypothesis, that LHF right-handers are more sensitive to conceptual information in words. Words are the interface in memory between structural and conceptual information. So we predicted that LHF right-handers would be more sensitive to individual word presentation and to nonlinguistic conceptual information that relates words to each other. The following studies suggest that LHF right-handers may indeed be more sensitive to word-based conceptual information.

Subject-Paced Reading Time for Individual Words

On our view, LHF right-handers access individual words during comprehension more readily than do RHF right-handers. This explains a

structure that causes a shift to the right from equipotentiality (and a related shift to the left hemisphere for higher functions like language). Annett suggests that the developmental mechanism for the expression of the genetic structure actually involves *suppression* of the right hemisphere. On one view, the right-shift gene may express this suppressive effect developmentally via increased fetal-testosterone activity (Geschwind and Galaburda offer this as a potential interpretation of the right-shift theory). In any case, Annett (1985) notes that since about a third of all right-handers should have a double signal for right-hemisphere suppression, familial handedness may have effects on cerebral organization among right-handers. Thus, the right-shift hypothesis for dominance is at least consistent with our findings.

So much for speculations about mechanisms. Whatever its basis turns out to be, we believe that the heterogenous studies reviewed here are initial indicators of an effect of familial handedness on language processes. This brief review is intended to alert cognitive scientists and neurologists interested in the study of language behavior to a subject variable that may affect their work and theories: RHF right-handers show significantly more sensitivity to syntactic structure than do LHF right-handers, while LHF right-handers show more ready access to individual words and conceptual relations between words.

There is much to do. First, we have not systematically explored the interaction of handedness background with sex, though we have controlled for this in most of our research. Second, we have not studied left-handers themselves, simply because it is much more difficult to find and match them for sex, handedness background, and manifest verbal ability. There are also important questions about the impact of the immediacy of familial left-handedness. We do not know to what extent LHF right-handers whose nearest left-handed relative is a grandparent or an aunt or uncle are different from RHF right-handers. If the effect of familial handedness is basically genetic, then the size of the LHF/RHF differences should correlate with the extent and closeness of left-handers in LHF families.

A Cautionary Note on Neophrenology

We conclude this report by emphasizing the preliminary, statistical, and experimental nature of our findings. Clearly, there are many factors that influence an individual's neurological organization and behavioral style. We may have isolated an effect of one of them, using laboratory techniques that reveal small but significant differences in performance on specially constructed tasks. But we do not yet under-

stand the true nature of these effects, we do not have a general theory of how they interact with other factors, and we have no idea how they are expressed in ordinary contexts.

The scientific and popular literature today is littered with neophrenologic studies that focus on alleged individual differences between 'right-brained' and 'left-brained' individuals. Even relatively conservative scholars sometimes link the kinds of differences we are reporting to talents for different professions. We, on the other hand, are more impressed by the enormous organizational resilience of the human brain and the remarkable cognitive similarities among people, despite occasional extreme anatomical differences. The kinds of studies we have carried out do not demonstrate that there are two right-handed talents that could provide the basis for assessing a person's functional capacity. Rather, our specialized experimental techniques show that there can be different processing styles underlying the same manifest abilities. This result may provide helpful insights for understanding the multiple nature of the relations between brain, knowledge, and behavior, but it leads to no obvious prescriptions for pedagogy or any other practical concern. Human behavior is the product of many factors, among which the organization of the neonate brain is just one.

Notes

1. There are numerous reports of nonlinguistic effects of familial left-handedness in right-handers, e.g., Deutsch 1983; Yeo and Cohen 1983; Burnett, Lane, and Dratt 1982; Tinkcom, Obrzut, and Poston 1983; Melamed and Arnett 1984; McKeever et al. 1983; Kraft 1983; Xintian, Minggao, Huikun, and Kuihe 1984; Bryden, Hecaen, and DeAgostini 1983. These studies are quite heterogenous, so we concentrate on those studies that we think potentially involve the role of grammatical relations and lexical knowledge in language comprehension.
2. Each of the experimental studies summarized here has been published elsewhere or is being prepared for separate publication with full experimental details and statistical analyses. Unless otherwise noted, every result marked in this paper with an asterisk (*) is statistically reliable at least at the $p < .05$ level. Almost all results are actually $p < .01$.
3. Subjects filled out a variant of the Edinburgh handedness questionnaire, used in all our research reported in this paper. In addition, they filled out a familial handedness questionnaire, which asks about the handedness of all family relations, including immediate family, grandparents, uncles and aunts: the questionnaire distinguishes blood relations from others; it also distinguishes the handedness categories of left, right, ambidextrous, and "right handed but switched from left." The allergy question on the survey was simply whether the subject had any allergies. Because of the association of left-handedness with mathematical ability, we note that University of Rochester undergraduates have a mean score of around 550 on the verbal SAT, and a mean of 625 on the math SAT.

12. A word about theory and results is in order here. The effect of canonical word order was almost entirely due to sentences with verbs discussed in the next section. Thus, the active/passive difference was statistically significant by subject for RHF right-handers, but there was only a marginal difference by items. The active/passive difference was significantly larger for RHF right-handers than for LHF right-handers when the two groups were compared, but marginally so when items were compared. Recently Carrithers (1986, 1988) and Bever et al. (1988) have argued that the passive construction with transitive verbs should be easier to apprehend than actives with certain verbs, which may explain why Carrither's results varied so by verb.
13. We should note that the RHF right-handed readers were slightly better at answering the questions correctly. There was, however, no speed-versus-accuracy trade-off across subjects ($r = .04$). Overall accuracy was about 80 percent. In the cumulative word-by-word reading studies, the LHF and RHF reading rates are much more similar to each other. This may be because the accumulating series of words on the screen allows the RHF right-handed subjects to integrate larger units than a single word.
14. Srinivas and Bever, in preparation. Sixteen LHF and RHF right-handed subjects read 20 two-clause sentences presented on a standard computer screen and were asked to paraphrase each sentence right after reading it. Subjects were drawn from the University of Rochester undergraduate subject pool. Groups were balanced for verbal SAT score and were roughly balanced by sex.
15. Iverson and Bever 1989. There were 16 RHF and 16 LHF right-handed subjects balanced for sex and verbal SAT score. Subjects were drawn from the University of Rochester undergraduate subject pool. Each subject heard eight short essays, four monaurally and four with content and function words presented to different ears. The essays were about 40 words long and were recorded from a slow but natural reading of the essay, with content and function words recorded on different tracks of a tape recorder. The presentation rate was then electronically sped up to about 1.5 words per second. Monaural presentations mixed the two separate tracks. There were weak interaction effects of sex and which ear heard the content words, but further research is needed to assess these effects.
16. Burgess and Bever 1989. There were 17 LHF and 17 RHF right-handers balanced for sex and verbal SAT, drawn from the University of Rochester subject pool. There were 15 trials of each of four types (two with related primes and two with unrelated control primes). There were also 60 pronouncable nonword trials. The semantic primes were controlled to be low associates of their following probes.
17. Our examination is based on 43 children studied by Gerken (1987), ages 23 to 30 months, with a mean length of utterance (MLU) of 1.3 to 5.0. Only children who passed a pretest of their ability to imitate a three-word sentence were included in this study, so the population sample may be biased in a crucial way. We also excluded children who had a clear preference for the left hand. The mean MLU for RHF children was 2.6, while for LHF children it was 3.3; the proportion of structurally well-formed multiword sequences for RHF children was 59 percent, while for LHF children it was 47 percent. The group MLU differences we report are signifciant by chi-square tests, as are the grammaticality differences. We accept these results with caution, however, because of the possibility of subject bias and because we can not be sure of the children's ultimate handedness. By chance, almost all of the children were first-born offspring of highly verbal parents. Also, note that our measure of grammaticality counted as grammatical every sentence that *could* be grammatical in some context even if it was not grammatically or socially acceptable in the context of the child's use of it.

References

Aaronson, D., and Scarborough, H. 1976. Performance theories for sentence coding: Some quantitative evidence. *Journal of Experimental Psychology: Human Perception and Performance* 2:56–70.

Annett, M. 1983. Hand preference and skill in 115 children of two left-handed parents. *British Journal of Psychology* 74 (1): 17–32.

Annett, M. 1985. *Left, right hand and brain: The right shift theory.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Bates, E., Bretherton, I., and Snyder, L. 1988. *From first words to grammar: Individual differences and dissociable mechanisms.* New York: Cambridge University Press.

Belleti and Rizzi, L. 1986. Psych-verbs and Th-theory. Lexicon Project Working Paper no. 13. Center for Cognitive Science, MIT.

Benbow, C. P. 1986. Physiological correlates of extreme intellectual precocity. *Neuropsychologia* 24 (5): 719–725.

Benbow, C. P., and Benbow, R. M. 1984. Biological correlates of high mathematical reasoning ability. In G. J. De Vries et al., eds., *Progress in brain research*, vol. 61. Amsterdam: Elsevier Science Publishers.

Benbow, C. P., and Stanley, J. C. 1980. Sex differences in mathematical ability: Fact or artifact? *Science* 210:1262–1264.

Benbow, C. P., and Stanley, J. C. 1983. Sex differences in mathematical reasoning ability: More facts. *Science* 222:1029–1031.

Bever, T. G. 1970. The cognitive basis for linguistic structures. In R. Hayes, ed., *Cognition and language development*, pp. 277–360. New York: Wiley and Sons.

Bever, T. G. 1983. Cerebral lateralization, cognitive asymmetry, and human consciousness. In E. Perecman, ed., *Cognitive processing in the right hemisphere*, pp. 19–39. New York: Academic Press.

Bever, T. G., Carrithers, C., and Townsend, D. 1987. A tale of two brains, or The sinistral quasimodularity of language. In *Proceedings of the Ninth Annual Cognitive Science Society Meetings*, pp. 764–773. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Bever, T. G., Carrithers, C., and Townsend, D. 1989. Sensitivity to clause structure as a function of familial handedness. University of Rochester, Cognitive Sciences Technical Report no. 43.

Bever, T. B., Garrett, M. F., and Hurtig, R. 1973. The interaction of perceptual processes and ambiguous sentences. *Memory and Cognition* 1:277–386.

Bever, T. G., Kirk, R., and Lackner, J. 1970. An autonomic reflection of syntactic structure. *Neuropsychologia* 7:23–28.

Bever, T. G., and Langendoen, T. 1971. A dynamic model of the evolution of language. *Linguistic Inquiry* 2:433–463.

Bever, T. G., Straub, R. O., Terrace, H. S., and Townsend, D. S. 1980. The comparative study of serially integrated behavior in humans and animals. In P. Jusczyk and R. Klein, eds., *The nature of thought: Essays in honor of D. O. Hebb.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Bloom, L. 1973. *One word at a time.* The Hague: Mouton.

Bouma, A., VanStrien, J. W., Bekker, C., and Tjerkstra, A. 1984. Dichotic listening and tactual mental rotation in females as a function of familial sinistrality and strength of handedness. *Journal of Clinical Neuropsychology* 6 (2): 171–188.

Bradsahw-McNulty, G., Hicks, R. E., and Kinsbourne, M. 1984. Pathological left-handedness and familial sinistrality in relation to degree of mental retardation. *Brain and Cognition* 3 (4): 349–356.

Broca, P. 1961. Remarques sur le siège de la faculté de la parole articulée, suivies d'une observation d'aphémie. *Bulletin de la Société d'anatomie* (Paris) 36:330–357.

Brown, R. 1973. *A first language*. Cambridge: Harvard University Press.

Bryden, M. P., Hecaen, H., and DeAgostini, M. 1983. Patterns of cerebral organization. *Brain and Language* 20 (2): 249–262.

Burgess, C., and Bever, T. G. 1989. Lexical access and familial handedness. University of Rochester, Cognitive Science Technical Report no. 44.

Burgess, C., and Simpson, G. B., 1988. Neuropsychology of lexical ambiguity resolution. In Small, S. C., Cottrell, G. W., and Tonenhaus, M. K., eds., *Lexical ambiguity resolution*. San Mateo, Calif.: Morgan Kaufmann Publishers.

Burnett, S. A., Lane, D. M., and Dratt, L. M. 1982. Spatial ability and handedness. *Intelligence* 6 (1): 57–68.

Carrithers, C. 1986. The special status of non-canonical sequences. Ph.D. dissertation, Columbia University.

Carrithers, C. 1988. Canonical sentence structure and psych-ergative verbs. *Journal of Psycholinguist Research*.

Carrithers, C., Townsend, D. J., and Bever, T. G. 1988. Sentence-processing in listening and reading among college and school-age skilled and average readers. In R. Horowitz, and S. J. Sammuels, eds., *Comprehending spoken and printed language*. New York: Academic Press.

Channon, L. D. 1985. The relationship between laterality indices, inversion of the writing hand, and some demographic variables. *Australian Journal of Psychology* 37 (1): 89–96.

Chiarello, C. 1985. Hemisphere dynamics in lexical access: Automatic and controlled priming. *Brain and Language* 26:146–172.

Cowart, W. 1987. Relation to neurophysiological variation. *Proceedings of the Ninth Annual Conference of the Cognitive Science Society*, pp. 811–823. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Cowart, W. 1988. Familial sinistrality and syntactic processing. In J. M. Williams and C. J. Long, eds., *Cognitive approaches to neuropsychology*, pp. 273–286. New York: Plenum.

Deutsch, D. 1983. The octave illusion in relation to handedness and familial handedness background. *Neuropsychologia* 21 (3): 289–293.

Fischler, I. 1977a. Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance* 3:18–26.

Fischler, I. 1977b. Semantic facilitation without association in a lexical decision task. *Memory and Cognition* 5:335–339.

Fodor, J. A. 1983. *The modularity of mind*. Cambridge: MIT Press.

Fodor, J., Bever, T. G., and Garrett, M. 1974. *The psychology of language*. New York: McGraw Hill.

Garfield, J., ed. 1987. *Modularity in knowledge representation and natural language understanding*. Cambridge: MIT Press.

Gerken, L. A. 1987. Telegraphic speaking does not imply telegraphic listening. *Papers and Reports on Child Language Development* 26:38–46.

Gerken, L. A., and Bever, T. G. 1986. Linguistic intuitions are the result of interactions between perceptual processes and linguistic universals. *Cognitive Science* 10:457–476.

Geschwind, N., and Behan, P. 1982. Left-handedness: Association with immune disease, migraine, and developmental learning disorder. *Proceedings of the National Academy of Sciences* (U.S.A.) 79:5097–5100.

Geschwind, N., and Behan, P. 1984. Laterality, hormones, and immunity. In N. Geschwind and A. Galaburda, eds., *Cerebral dominance: The biological foundations*. Cambridge: Harvard University Press.

Geschwind, N., and Galaburda, A. M. 1987. *Cerebral lateralization*. Cambridge: MIT Press.

Gordon, H. W. 1980. Cognitive asymmetry in dyslexic families. *Neuropsychologia* 18:645–656.

Gordon, H. W. 1982. Learning disabled are cognitively right. In M. Kinsbourne, ed., *Topics in learning disabilities* 3:29–39. Rockville, Md.: Aspen Systems Corp.

Healy, J. M., and Aram, D. M. 1986. Hyperlexia and dyslexia: A family study. *Annals of Dyslexia* 36:237–252.

Hécaen, H., and Albert, M. 1978. *Human neuropsychology*. New York: Wiley.

Iverson, P., and Bever, T. G. 1989. Auditory lexical segregation, comprehension, and familial handedness. University of Rochester, Cognitive Science Technical Report no. 45.

Joanette, Y., Lecours, A. R., Lepage, Y., and Lamoureux, M. 1983. Language in right-handers with right hemisphere lesions: A preliminary study including anatomical, genetic, and social factors. *Brain and Language* 20:217–248.

Kee, D. W., Bathurst, K., and Hellige, J. B. 1983. Lateralized interference of repetitive finger tapping: Influence of familial handedness, cognitive load, and verbal production. *Neuropsychologia* 21 (6): 617–624.

Kennedy, A., and Murray, W. S. 1984. Inspection times for words in syntactically ambiguous sentences under three presentation conditions. *Journal of Experimental Psychology: Human Perception and Performance* 10:833–849.

Koff, E., Naeser, M. A., Piendiadz, J. M., and Foundas, A. L. 1986. Computed tomographic scan hemisphereic asymmetries in right- and left-handed male and female subjects. *Archives of Neurology* 43 (5): 487–491.

Kolk, H. 1987. A theory of grammatical impairment in aphasia. In G. Kempsen, ed., *Natural language generation*. Dordrecht: Martinus Nijhoff Publishers.

Kolk, H. H. J., and van Grunsven, M. M. F. 1985. Agrammatism as a variable phenomenon. *Cognitive Neuropsychology* 2:347–384.

Kraft, R. H. 1983. The effect of sex, laterality, and familial handedness on intellectual abilities. *Neuropsychologia* 21 (1): 79–89.

Kutas, M., Van Petten, C., and Besson, M. 1988. Event-related potential asymmetries during the reading of sentences. *Electroencephalography and Clinical Neurophysiology* 69:218–233.

Lupker, S. J. 1984. Semantic priming without association: A second look. *Journal of Verbal Learning and Verbal Behavior* 23:709–733.

Luria, A. R. 1947. *Traumatic aphasia: Its syndrome, psychopathology, and treatment* (Russian). Moscow: Academy of Medical Sciences. Translation, The Hague: Mouton, 1970.

McKeever, W. F., and Hoff, A. L. 1982. Familial sinistrality, sex, and laterality differences in naming and lexical decision latencies of right-handers. *Brain and Language* 17 (2): 225–239.

McKeever, W. F. 1983. Interacting sex and familial sinistrality characteristics influence both language lateralization and spatial ability in right handers. *Neuropsychologia* 21 (6): 661–668.

McKeever, W. F., Nolan, D. R., Diehl, J. A., and Seitz, K. S. 1984. Handedness and language laterality: Discrimination of handedness groups on the dichotic consonant-vowel task. *Cortex* 20 (4): 509–523.

McLaughlin, J. P. 1986. Aesthetic preference and lateral preferences. *Neuropsychologia* 24 (4): 587–590.

McMahon, L. 1963. Grammatical analysis as part of understanding a sentence. Ph.D. dissertation, Harvard University.

McManus, I. C. 1985. *Handedness, language dominance, and aphasia: A genetic model*. Psy-

chological Medicine Monograph, supplement 8. New York: Cambridge University Press.

Melamed, L. E., and Arnett, W. B. 1984. The effect of familial sinistrality on perceptual learning. *Neuropsychologia* 22 (4): 495–502.

Minggao, L., Xintian, L., Huikun, G., and Xiaoqin, W. 1984. A study of hand preference in children. *Information on Psychological Sciences* 2:1–7.

Nelson, K. 1973. Structure and strategy in learning to talk. *Monographs of the Society for Research in Child Development* 38.

Orton, S. T. 1925. "Word-blindness" in school children. *Arch. Neurol. psychiat.* 14:581–615.

Peters, A. 1983. *The units of languge acquisition*. Cambridge: Cambridge University Press.

Postal, P. 1971. *Cross-over phenomena*. New York: Holt, Rinehart, and Winston.

Pringle, G. F., Anderson, S. W., and Jaffe, J. 1985. Speed of color naming and degree of familial sinistrality: Correlation in girls, no correlation in boys. *Journal of Communication Disorders* 18 (1): 59–62.

Reinhart, T. 1983. *Anaphora and semantic interpretation*. Chicago: University of Chicago Press.

Ross, J. R. 1967. Constraints on varibles in syntax. Ph.D. dissertation, MIT. Published as *Infinite syntax* (Norwood, N.J.: Ablex Publishing Corp., 1986).

Russell, W. R., and Expir, M. L. E. 1961. *Traumatic aphasia*. Oxford: Oxford University Press.

Searleman, A., and Fugagli, J. 1987. Suspected autoimmune disorders and left-handedness: Evidence from individuals with diabetes, Crohn's disease, and ulcerative colitis. *Neuropsychologia* 25:367–374.

Searleman, A., Herrmann, D. J., and Coventry, A. K. 1984. Cognitive abilities and left-handedness: An interaction between familial sinistrality and strength of handedness. *Intelligence* 8 (4): 295–304.

Slobin, D. I. 1966. Grammatical transformations and sentence comprehension in childhood and adulthood. *Journal of Verbal Learning and Verbal Behavior* 5:219–227.

Slobin, D. I., and Bever, T. G. 1982. Children use canonical sentence schemas in sentence perception. *Cognition* 12:229–265.

Spiegler, B. J., and Yeni-Komshian, G. H. 1983. Incidence of left-handed writing in a college population with reference to family patterns of hand preference. *Neuropsychologia* 21 (6): 651–659.

Srinivas, K., and Bever, T. G. In preparation. Lexical and decompositional representations of idioms.

Tan, L. E. 1983. Handedness in two generations. *Perceptual and Motor Skills* 56 (3): 867–874.

Tinkcom, M., Obrzut, J. E., and Poston, C. S. 1983. Spatial lateralization: The relationship among sex, handedness, and familial sinistrality. *Neuropsychologia* 21 (6): 683–686.

Townsend, D. J., and Bever, T. G. 1978. Interclausal relations and clausal processing. *Journal of Verbal Learning and Verbal Behavior* 17:509–521.

Townsend, D. J., Carrithers, C., and Bever, T. G. 1987. Listening and reading processes in college- and middle-school-age readers. In R. Horowitz, and S. J. Samuels, eds., *Comprehending oral and written language*, pp. 217–242. San Diego: Academic Press.

Xintian, L., Minggao, L., Huikun, G., and Kuihe, J. 1984. Experimental study on grasping with left or right hand by 6 months to 3-year-old children. *Acta Psychologica Sinica* 16 (2): 214–222.

Yeo, R. A., and Cohen, D. B. 1983. Familial sinistrality and sex differences in cognitive abilities. *Cortex* 19 (1): 125–130.

Editor's Comments

Heretofore both biology and psychology have concentrated on extracting from their observations and experiments those characteristics that are universal among living organisms, e.g., DNA, the simple reflex, memory. More recently neurobiologists and psychologists are beginning to address the issue of individual differences and are trying to discover universal principles underlying the generation of diversity, as evidenced by several chapters in this volume. The present chapter looks at functional diversity in language processing as constrained by biological factors such as hand preference. What emerges is a remarkable set of preliminary data on the effects that family handedness in right-handers have on the extent to which the latter rely on structural or conceptual-lexical knowledge during language processing. Specifically, those right-handers with left-handed family histories (LHF) rely more heavily on conceptual-lexical factors, while right-handers with a right-handed family history (RHF) rely more on structural information.

Right- and left-handers differ in the anatomy of language-relevant cortical regions, a fact that has not yet been checked for RHF and LHF right-handers. Right-handers more often than left-handers tend to show the expected population distribution of Sylvian-fissure asymmetry, which is about 65 percent with longer left sides, about 25 percent symmetrical, and about 10 percent with longer right sides. Left-handers instead show a substantial and significant increase in the frequency of symmetrical Sylvian fissures (up to 66 percent of all cases). Symmetry of the Sylvian fissures reflects to a great extent symmetry of the planum temporale, a language-related area on the temporal lobe. And symmetry of the planum temporale in turn reflects greater development of the right planum temporale in comparison to those brains in which the planum temporale is leftward asymmetrical. Related work shows that compared to asymmetrical equivalents, symmetrical brain regions contain more neurons and greater densities of more diffuse interhemispheric connections than asymmetrical brain regions (see Sherman et al. and Galaburda et al. in this volume). These anatomical facts, together with the observation that the right planum varies in size to a much greater extent than the left, support the speculation of Bever et al. that left-hemisphere linguistic activities may be comparable among RHF right-handers and LHF right-handers (and perhaps right- and left-handers?), while right-hemispheric nonlinguistic contributions to language function may vary more and be more important in individuals with atypical cerebral dominance. Whether the functional and anatomical findings of

the present chapter appear equally well in left-hander and right-hander comparisons as in comparisons of RHF and LHF right-handed subjects remains an empirical issue, as the authors warn. But it does appear that handedness plays a role in both anatomical and functional architectures related to language.

An interesting set of questions arising from this research is whether the described processing biases of RHF and LHF right-handers lies along a continuum and whether there are extremes of this continuum that constitute developmentally pathological states. Are there individuals who must rely so much on one strategy or the other that situations in which the required strategy is not adequate lead to failure? One such situation may be reading, for which only a limited amount of conceptual-lexical information is available and reliance on structure is important to extract meaning efficiently. When learning to read, small children (who by adult standards have only a limited knowledge of the world) have a greater need to rely on structural aspects of language than later on when world knowledge increases. Either absolute or relative increases in the need to rely on structural knowledge might, therefore, lead to disorders of reading acquisition and reading competence.

Many dyslexia experts have raised the issue of grammatical abnormalities in developmental dyslexics. My co-workers and I have learned that functional and anatomical lateralization is so altered in this population that there are excess anomalous patterns of asymmetry. A tempting hypothesis stemming from these observations is that some dyslexics rely exceptionally on conceptual-lexical knowledge for extracting meaning from print, which tends to favor those with advanced structural skills. Hence, their reading acquisition is slow and improves only insofar as they become more efficient with experience at extracting the maximum lexical knowledge from texts. Any interference with the process of deriving contextual information from texts should lead to a reading disability. Thus far the brains of severely dyslexic individuals have shown absence of asymmetry and another anatomical difference as well: male brains studied show multiple instances of laminar disorganization and many ectopic neurons (together termed *microdysgenesis*) in the perisylvian cortex of both hemispheres, but more on the left. The perisylvian cortex contains language-relevant areas. What we are witnessing in the most severe dyslexics may thus be a relatively physiological difficulty in using structural information, which is related to the lack of asymmetry, coupled with sluggishness in deriving lexical knowledge from print, which is related to the microdysgenesis. This hypothesis is speculative in that we cannot as yet assess the effects of microdysgenesis on

language processes and we do not have a clear understanding of the relationship between linguistic capacities and cerebral asymmetry (as opposed to handedness). To confirm or reject this hypothesis, we need to isolate the two anatomical findings in dyslexic populations. High resolution neuroimaging coupled with cognitive assessment remains the most promising for progress in this regard.