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Cerebral Lateralization, Cognitive Asymmetry, and Human Consciousness

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The study of cerebral asymmetries in humans has been a major area of growth in psychology for the past several decades. This is in part a result of the emergence of sophisticated experimental techniques that can be used with normal populations, and in part a result of medical technology which has provided spectacular cases of disconnected or absent hemispheres. Cerebral asymmetries are important because they are typically human and because they constitute an example of localization of function—crude as that localization may be. By studying simple asymmetries, one hopes, we will understand our own biology better, as well as gain insight into general laws governing the relation between brain and behavior.

Unfortunately, such hopes have been slow to be fulfilled, and our understanding of the phenomena recedes exactly as fast as new investigative techniques develop, or slightly faster. This chapter reviews some devastating problems that riddle the field, leaving us uncertain as to how to interpret most of the existing literature on normal subjects. These problems involve (*a*) subject variables, (*b*) task variables, and (*c*) the need for an independently motivated theory of congnitive behavior to test against functional asymmetries.

Cerebral asymmetries, in fact, constitute one of the most complex problems we could choose as an example of the relation between brain and behavior. Since, in fact, we have little choice, we must find ways to make the best of a nearly impossible situation. In this chapter I attempt to sharpen the empirical issues by embedding cerebral asymmetries in the context of a theory of cognitive activity and development. The main emphasis is that there are multiple sources for lateral asymmetries as they manifest themselves in normal and pathological behavior. I distinguish three sources of asymmetries—physiological, experiential, and cognitive. This clarifies a number of current controversies and alleviates some confusions in the field. Most important is that modern cognitive psychology affords a theory of consciousness that satisfies the intuition that consciousness depends on relational processes. This motivates the prediction that the left hemisphere, the seat of relational activity, is the usual seat of consciousness in normal people; we have confirmed this prediction experimentally by research on the interaction of levels of consciousness and cerebral asymmetries.

SUBJECT VARIABLES

Individual Genotype and Asymmetries

The brain is an extremely flexible organ, which produces similar behaviors in different ways. Yet, general references to so-called left-hemisphere and right-hemisphere activities presupposes that there is uniformity of the distribution of mental functions. The grossness of this neuro-geographical distinction lends confidence that there is relative constancy of the difference between hemispheres even if there is some variability in within-hemisphere organization. This confidence reflects the view that these differences must result from deep biological properties and therefore are genetically stable.

Nevertheless, we know of cases that demonstrate astounding resilience of behavioral organization in the face of major neurological differences: behaviorally normal people with one hemisphere damaged during childhood, or with a cortex that is virtually a thin layer lining the inside of the skull (Lewin, 1980). Given such evidence from extreme cases, why do we not expect a multiplicity of organizational differences among all people?

Variability in lateral organization has been studied to some extent. It is well documented that left-handed individuals can exhibit cerebral asymmetries that are different from those of right-handed people, if not the

reverse. A recent burst of papers has suggested that adult men and women have different asymmetries, though the literature has not settled on which sex is more lateralized for what.

Explicit handedness and sex are unambiguous variables, although it is not obvious why sex should interact with neurological organization in particular. There are also more subtle variables that effect behavioral asymmetries. In our work, we have systematically studied the different kinds of behavioral asymmetries that are revealed by right-handed people with and without left-handers in their genetic background. We have found that people with left-handers among their parents, siblings, or grandparents show a systematic reversal of asymmetries on certain kinds of tasks.

For example, the recognition of musical two-note intervals is traditionally viewed as a right-hemisphere-dominant task, which it is when averaged across subjects. Lucia Kellar and I found, however, that the average superiority for the left ear is actually produced by a very strong left ear superiority for people without familial left-handedness and a weak *right* ear superiority for people with familial left-handedness (Kellar, 1976, Kellar & Bever, 1981; see Table 2.1).

Simple visual identification is also a traditional right hemisphere task. For example, recognition that two briefly presented figures are identical should be faster in the left visual field than in the right visual field. In our lab, Leonard Huber found that, when people are first confronted with the task, this is strongly the case for people without familial left-handedness and weakly the reverse for those with familial left-handedness (Huber, 1981; see Table 2.2).

Relating words and pictures can also be a right-hemisphere-dominant task. For example, choice of which of two pictures goes with a simple sen-

Table 2.1
SUBJECTS' REPEATED CATEGORIZATION OF CONTINUOUSLY VARYING INTERVALS INTO THREE TARGET CATEGORIES: FIFTH, TRITONE, OR FOURTH[a, b]

	Left ear	Right ear	Right ear advantage
Pure	1.2	1.3	− .1
Mixed	1.4	1.2	+ .2

[a]From Kellar, 1976.
[b]The measure was the variability of the categorization assigned to each interval.

Table 2.2
LATENCY FOR SUBJECTS TO DECIDE WHETHER THE SECOND OF
TWO SIMPLE GEOMETRIC FIGURES WAS THE SAME AS THE FIRST[a]

	Left visual field	Right visual field	Right field advantage
Pure	1213	1281	− 68
Mixed	1318	1330	− 12

[a]From Huber 1981.

tence might be faster when the sentence is pesented to the left ear. Claudia
Leslie, Chava Casper, and I found that this is strongly the case for people
with no familial left-handers, but weakly the reverse for people with familial
left-handedness (Leslie, Casper, & Bever, 1983; see Table 2.3).

Identification of simple nonsense syllabic sounds might also be better in
the left ear. Huber and I found this to be true for people with no familial
left-handers and the reverse for people with familial left-handedness (Huber
& Bever, 1983; see Table 2.4).

By now, the reader must grasp the pattern: On many tasks that are gen-
erally assumed to be right hemisphere dominant, a weak reversal of that
effect occurs among subjects with familial left-handedness. I return later to
why this may be so, but for the moment it is clear how devastating this
finding is for the interpretation of the existing literature. Most studies still
do not control for handedness background—those that are worth inter-
preting at all will simply have to be redone.

Another implication of the effect of familial handedness is that neuro-
physiological variability in the organization of behavior is under individual
genetic control. That is, there are physiologically determined asymmetry

Table 2.3
LATENCY FOR SUBJECTS TO DECIDE WHICH PICTURE IS
APPROPRIATE FOR A SENTENCE[a]

	Left ear	Right ear	Right ear advantage
Pure	1614	1692	− 78
Mixed	1618	1494	124

[a]From Leslie, Casper, and Bever 1983.

Table 2.4
LATENCY TO RECOGNIZE A TARGET NONSENSE SYLLABLE IN
A SEQUENCE OF NONSENSE SYLLABLES (TWO PER SECOND)[a]

	Left ear	Right ear	Right ear advantage
Pure	669	705	− 36
Mixed	689	648	+ 41

[a]From Huber and Bever, 1983.

patterns that may have the same magnitude of sensitivity to genotype as eye color.

Individual Experience and Asymmetries

Subject-induced variability can also depend on a person's individual experience. For example, a number of studies contrast the ear asymmetries of musicians and nonmusicians. The traditional result from other laboratories is that nonmusicians process music better in the left ear. We have consistently replicated this and also found that musicians recognize melodies better when presented in the *right* ear. This finding has been replicated by numerous other researchers (for a review, see Bever, 1980, Appendix 1). In fact, one study reports that musicians show patterns of electrical activity on the scalp indicating left hemisphere processing of melodies compared with nonmusicians, who show evidence of right hemisphere processing (Hirshkowitz, Earle, & Paley, 1978). We have also found the right ear superiority in children who are regular choir singers. Our interpretation has been that musicians have learned to listen to music in an analytic way, which stimulates the kind of processing natural to the left hemisphere (see Table 2.5).

Whatever the reason, should we not expect that other kinds of special experience and training interact with asymmetries? For example, might not commercial artists and architects recognize geometric figures better in the right visual field? Might not members of the Audubon Society recognize bird calls better in the right ear? What visual field should be dominant for postage recognition in philatelists?

Again, the point should be clear. We know that subjects' laterality differs as a function of specific experiences and acquired skills. How are we to interpret a literature that does not control for such variables? Very cautiously.

Table 2.5
PROCESSING OF MELODIES BY MUSICIANS AS COMPARED TO NONMUSICIANS[a, b]

Study	Left ear	Right ear	Right ear advantage
Johnson[c]			
Musicians	16.0	19.8	+ 3.8
Nonmusicians	15.7	13.7	− 2.0
Musicians' advantage	0.3	6.1	
Johnson et al.[d]			
Musicians	4.9	4.5	+ 0.4
Nonmusicians	6.5	6.7	− 0.2
Musicians' advantage	1.6	2.2	
Gaede et al.[e]			
Musicians	10.87	10.00	+ 0.88
Nonmusicians	12.19	11.48	+ 0.71
Musicians' advantage	1.32	1.48	
Gates and Bradshaw[f]			
Musicians	0.83	1.10	+ 0.27
Nonmusicians	0.14	0.35	+ 0.21
Musicians' advantage	0.69	0.75	
Gordon[g]			
Musicians	15.3	17.6	+ 2.3
Nonmusicians	14.7	16.7	+ 2.0
Musicians' advantage	0.6	0.9	
Bever and Chiarello[b]			
Musicians	44	57	+ 13
Nonmusicians	54	36	− 18
Musicians' advantage	− 10	21	

[a]From Bever, 1980. Sources: Johnson (1977, table 1); Johnson, Bowers, Gamble, Lyons, Presbrey, and Vetter (1977, table 1); Gaede, Parsons, and Bertera (1978, table 1); Gates and Bradshaw (1977, table 2); Gordon (1978, table 1); Bever and Chiarello (1974, table 10.3).

[b]Note: Advantage scores compensate for whether the raw scores are based on correct responses or errors.

[c]Scores are the mean numbers of correct positive responses.

[d]Musicians are their groups 1 and 2; nonmusicians are their group 4. Scores are the mean number of errors.

[e]Groups are means of their high-aptitude and low-aptitude subjects. Scores are the mean number of errors.

[f]Groups the means of male and female subjects, responding to long and short excerpts, from their unfamiliar melodies. The scores are means of presented d's.

[g]Excludes subjects performing at chance level. Scores are number correct (out of possible 24) on dichotic melodies differing in rhythm.

[b]Percentage correct, corrected for guessing.

RELATIONAL AND UNITARY PROCESSES IN TASKS

The dominant theories about the differences between the two hemi-spheres have evolved in several stages during recent decades. First it was thought that the difference between the hemispheres depended on the mo-dality of behavior: The left hemisphere was viewed as normally specialized for language and reasoning, the right as specialized for such modalities as music and vision. (Kimura, 1973; Scheid & Eccles, 1975). This view became generalized into the distinction between a calculatingly "rational" or "an-alytic" hemisphere on the left and a creatively "intuitive" or "holistic" one on the right (Bever, 1971; Levy, 1969). On this view, language is left-hemisphered because it is analytic and vision is right-hemisphered because it is holistic, and so on. Specific modalities were viewed as asymmetric, but this in turn was viewed as the result of the kind of activity each modality involves.

The literature reveals considerable confusion about how to distinguish analytic and holistic processing, independent of observing facts about la-teralization—some studies even use the lateralization pattern to differen-tiate the processing style. We can avoid this circularity by referring to a technical definition of the two kinds of activities from theoretical cognitive psychology (Bever, 1975, 1980).

It is a generally accepted notion that mental activity involves the pro-cessing of information. This point of view is espoused by researchers who agree on little else: Human thought involves the transformation of repre-sented information in one form into another form. Of course, there are controversies about the forms of mental representation and the mechanisms of its transformation. Even on the latter question, though, there is general agreement that there are two types of processors: special purpose ones which carry out habitual functions and a "central" one that utilizes general prob-lem-solving mechanisms (Anderson, 1980; Chomsky, 1980; Norman & Ru-melhart, 1975; Pylyshyn, 1981; Simon, 1979).

The relative importance and the source of the special purpose processors are not constant. In some theories, special purpose processors play a minor role and are basically task dependent (Simon, 1979); in other theories, they account for almost all rational activity and are genetically prestructured (Chomsky, 1980; see Carroll, 1981, for a general discussion of these issues). Whatever the resolution of such controversies, it is generally claimed that the human mind operates, at least in part, in semiautonomous "faculties" or "modules," which carry out complex processes (Bever, 1975; Fodor, 1975; Pylyshyn; 1981). The mechanism for speech perception is one such module,

that for visual object recognition another. The output of a module is relatively simple, and is expressed in units that are relatively accessible. In speech, it provides us with a meaning that corresponds to the sound, in vision with an object that corresponds to the visual array.

Whether general purpose or specific purpose, each module is an information-processing system—it performs operations on one form of representation that pair it with other forms. These operations can be complex internally, compared with their input or output. This contrasts the inner workings of a representational module with the result of relating those units into integrated schemata that present the accessible output of the module. For example, the computations involved in visual recognition of a square may require sensitivity to separate angles and lines, whereas the output of those computations is the gestalt of a square. Similarily, recognition of a word may involve considerable manipulation of acoustic and phonological features, but the accessed output is the percept of the word as a whole.

In this way, the modular concept provides technical definitions that can be used as the basis for explaining the difference between "holistic" and "analytic" processing. To avoid confusion with previous literature, I use the terms *unitary* and *relational*. Unitary processing accesses the output or input of a module; relational processing accesses the computational language normally intrinsic to a module. Another way of putting this is that relational processing involves the interrelation of more than one output of a module. For example, conscious recognition of a square is unitary, recognition that a line is part of the square is relational; intended production of a whole syllable is unitary, intended production of the same syllable as an ordered sequence of phonetic sounds is relational. This theoretical differentiation reformulates the concept of "analytic" processing as a special case of "relational" processing, the case in which the relation is that between a part and a whole. Other relational activities may not have this property—for example, the relations of actor to action and action to object do not involve inclusion.

The contrast between unitary and relational processing rests on differentiating the kind of output of a module. This formulation resolves a conundrum that we would otherwise face. Clearly, recognition of a square requires computation of equal sides and angles, itself a relational activity; therefore, we might argue that *no* activity is unitary. What is at issue in our definition, however, is the units and processes that are *accessed* in a cognitive domain—a unitary activity accesses only single units, a relational activity accesses units that bear some relation to each other.

In brief, cognitive theory offers a motivated differentiation of two kinds

of processes, unitary and relational; we can postulate that this distinction is reflected in the difference between the activities that each hemisphere is most adapted to. This distinction is now formulated in terms provided by a cognitive theory, rather than by a generalization across observed hemispheric differences. It is not the case that speech is univocally lateralized to the left because it is analytic, nor is vision immovably lateralized to the right because it is holistic. Rather, we can show that even behavioral modalities can shift their lateral pattern if we shift the kind of cognitive processing that is required.

We can test the correctness of this distinction by showing that behaviors are not lateralized as modality defined kinds, as was previously thought. One demonstration of this is the fact that the same kind of material is processed preferably on the left or right as a function of the kind of task, not the modality. For example, Huber's figure-matching task would be classified as unitary, on the grounds that no internal analysis of the figures was required. Indeed, he found an overall superiority for left visual field presentations. He then paired the same kind of figures in such a way that the first member of each pair either was or was not a component part of the second figure. On this task, people performed better to stimuli presented in the right visual field (Huber, 1981; a similar finding is independently reported by Hurtig, 1982). We can intuitively recognize that the part–whole matching task is "analytic" in the sense that the whole figure must be recognized as made up of component parts.

We can demonstrate a similar effect on lateralization as a function of the way acoustic stimuli are processed. For example, Huber and I showed that overall there is a bias to respond more quickly to target nonsense syllables presented to the left ear than to the right ear. But the same stimuli elicit a right ear superiority if subjects are only told to recognize the first phoneme of the syllable. When a syllable is identified metonymously, in terms of its first component sound, then the processing is relational and better performed in the left hemisphere (see Table 2.6).

If the same stimuli can be processed in different ways, with opposite resulting lateralization patterns, we now have two possible explanations of the laterality patterns that differ according to such subject variables as handedness background and special training. Subjects might have differing neurological organization, as a function of, for example, familial sinistrality. Alternatively, at least in the case of subjects with special training, subjects might have different ways of approaching a stimulus; for example, musicians may listen to melodies relationally, and thereby perform better on stimuli presented to the right ear. Evidence for the latter interpretation

Table 2.6
LATENCY TO RECOGNIZE THE FIRST PHONEME OF A TARGET
SYLLABLE IN A SEQUENCE[a]

	Left ear	Right ear	Right ear advantage
Pure	760	716	44
Mixed	759	736	23

[a]From Huber and Bever, 1983.

comes from the fact that the difference between musicians' and nonmusi-
cians' performance lies almost entirely in the relative superiority of the right
ear performance in musicians, rather than in a decrease in their left ear
performance (see Table 2.5). That is, they have learned to listen to music
relationally, rather than actually shifting their overall neurological organi-
zation of music from the right to the left hemisphere.

But we remain in doubt about the basis of the behavioral effects on man-
ifest asymmetries of such variables as sex and familial handedness. It could
be the case that different sexes approach problems differently, which is then
reflected in different patterns of manifest laterality. It could even be that
familial left-handedness has its reversing effects indirectly, through a ge-
netically controlled change in the ease of accessing different processing strat-
egies rather than direct reversal in asymmetries. For example, familial left-
handedness may underlie a more diffuse asymmetric organization, which
makes all tasks easier to approach relationally. This would lead to the ob-
served right-side advantage for people with familial left-handedness, with-
out meaning that they actually perform unitary tasks better in the left
hemisphere.[1]

Developmental Shifts in Asymmetries

The preceding discussions emphasize the importance of individual dif-
ferences in genetic background and experiences. There are also general de-
velopmental patterns that are related to cerebral asymmetries. Three stages
occur in a typical sequence in the development of a capacity: an initial "syn-
cretic" stage, a later "analytic" stage, and a final "integrative" stage. The

[1]Such a speculation can be tested, for example by specifically studying relational and unitary
processing styles in different groups of subjects. We have begun to do this but the preliminary
results are downright terrifying: It seems that handedness background and processing style
interact with lateral asymmetries in opposite ways in men and women.

terms for these stages differ widely according to the connotative desire of different theorists. Nevertheless, there is general agreement that the first stage is one in which a skill is carried out "globally," "holistically," or, in the terms of the current discussion, "unitarily." That is, the skill is based on fixed schemata or action patterns. The second stage is typically characterized as "analytic" or "relational"; the skill is broken down into component parts, typically resulting in a temporary regression in the manifest capacity. The third stage involves a new integrated balance between unitary and relational processes. (See Bever, 1982, for a general discussion of such sequences at various ages.)

Intuitively, one can see how such stages might result from a quantitative development of the complexity of individual cognitive modules—at first, they act unitarily, then they are assembled (interrelated) into more complex modules, which in turn act unitarily, and so on. Despite the appeal of such a model, I do not see how one can derive this pattern from formal considerations alone; most attempts to derive developmental phenomena in this way have failed, albeit nobly (the most noble being that of Piaget, see Piatelli-Palmerini, 1980). We must accept the fact that, like evolution, development is an empirical accident, constrained by certain boundary conditions, the result of happenstance and current history.

Consider the development of sentence perception with special reference to the assignment of the semantic relations, such as agent, action, and patient (see Slobin & Bever, 1982, for a full discussion). At an early age (around 2 years), children interpret sentences by way of a unitary schema. This schema accommodates to the unambiguous properties of the native language. In English, this schema is "Noun Verb. . ." = "agent, action. . ."; in Turkish, it is ". . .Noun + Suffix. . ." (i.e., an inflected noun, whatever it precedes) = "patient"; in Serbo-Croatian, it is "Noun + Suffix Verb . . ." = "patient + verb." Sentences that do not conform to the schema are simply not understood, in one way or another. At a later age (around 4 years), children show a sensitivity to word order (in those languages where it is relevant, e.g., English and Serbo-Croatian); they interpret the first noun as the agent. This leads to a temporary regression in performance on those sentences in which this is not the case (e.g., the passive in English, and the object-first constructions in Serbo-Croatian).

The emergence of the relational word-order strategy is associated with an emergence of cerebral lateralization. In English, children who show a relative dependence on the word order strategy are also those who are relatively lateralized for dichotic word recognition (see Table 2.7; a large difference between actives and passives indicates sensitivity to word order; the original

Table 2.7

CHILDREN ACTED OUT SIMPLE SENTENCES, ACTIVE (*THE DOG KISSES THE PIG*) AND PASSIVE (*THE PIG IS KISSED BY THE DOG*), AND RESPONDED TO A "DICHOTIC ANIMALS" TEST TO ASSESS EAR PREFERENCE

Percentage of correct-reversible actives	79	96	94	90	95	87	86	97	90	91	90
Percentage of correct-reversible passives	70	63	48	61	76	78	73	72	55	35	62
Difference	9	33	46	29	19	9	13	25	15	56	28
N	11	9	5	7	6	24	20	12	13	12	20
Ear preference	All left					No preference				All right	

experimental details are presented in Bever, 1971). This is consistent with the view that the word order dependence reflects the emergence of relational processing of language, which in turn is lateralized.

We do not have any collateral evidence, or counterevidence, that the younger children, who use the unitary comprehension strategy, are right-hemisphered for language. It is extremely difficult to obtain laterality measures with children at this age. There are, however, suggestions in the literature on older children that an early stage of learning a second language involves relative dependence on the right hemisphere (Obler, 1981). This is consistent with the view that the unitary stategies themselves are right-hemisphered. Children at the third stage (by age 6) appear to remain left-hemisphered for language, rather than switching back to the right hemisphere. As most language tasks involve comprehension, typically a cross-modal problem which requires relational processing, we can expect that left hemisphere dominance will remain.

Music does not ordinarily involve cross-modal activity. Accordingly, we might expect that musicians would reveal an increase in the extent to which they use the right hemisphere for unitary musical tasks. The fact that musicians are more strongly right-hemisphered for unitary musical tasks supports this prediction (Table 2.8). We might expect that with increased musical experience, musicians and nonmusicians would build up a balanced representation of musical function—more complex musical motives would be treated in a unitary fashion, while relational processes bind them together. Some evidence for this has been found by Wagner and Hannon (1981); they replicated our results contrasting late adolescent musicians and nonmusicians, but found that 40-year-old adults—"musicians" and "non-musicians" alike—do not have an asymmetry for monaural melody recog-

Table 2.8
UNITARY MUSICAL TASKS AS PERFORMED BY MUSICIANS VERSUS
NONMUSICIANS[a,b]

Study	Left ear	Right ear	Right ear advantage
Gordon[a]			
Musicians	16.9	14.6	− 2.3
Nonmusicians	15.1	14.3	− 0.8
Musicians' advantage	1.8	0.3	
Gaede et al.[b]			
Musicians	8.21	9.00	− 0.79
Nonmusicians	9.94	10.08	− 0.14
Musicians' advantage	1.73	1.8	
Gates and Bradshaw[c]			
Musicians	1.88	1.56	− 0.32
Nonmusicians	0.61	0.65	+ 0.04
Musicians' advantage	1.27	0.91	
Johnson et al.[d]			
Musicians	4.6	5.7	− 1.1
Nonmusicians	6.7	7.0	− 0.3
Musicians' advantage	2.1	1.3	
Zatorre[e]			
Musicians	73	67	− 6
Nonmusicians	63	59	− 4
Musicians' advantage	10	8	

[a]From Bever, 1980. Sources: Gordon (1978, table 3); Gaede *et al.* (1978, table 1); Gates and Bradshaw (1977, table 2); Johnson *et al.* (1977, table 1); Zatorre (1978, figure 2).
[b]Note: Studies and subjects are the same as in the corresponding studies in Table 2.5 except where noted.
[c]Scores are number correct on chord recognition.
[d]Scores are mean errors on note discrimination in chords.
[e]Scores on familiar melodies.
[f]Errors on short random-pitch sequences.
[g]Scores are the percentage correct recognition of short, repeatedly presented dichotic melodies.

nition (Table 2.9).[2] This is one of those results that must be replicated with explicit attention to subject variables: If it holds up, it may demonstrate

[2]A word about their adult subjects is in order. All were college professors; the musicians were taken from a department of music, the nonmusicians from other academic departments. As Table 2.9 shows, the overall performance of the nonmusical adults was similar to that of the musicians. This suggests that on this task *all* artistically aware adults develop an integrated ability to recognize tonal melodies.

Table 2.9
PROPORTIONAL EAR DIFFERENCES IN MELODY
RECOGNITION[a]

	Left − Right
College	
Musician	− .07
Nonmusician	+ .10
Adult	
Musician	+ .02
Nonmusician	+ .01

[a]From Wagner and Hannon, 1981.

the gradual reintegration in all musically aware adults of a coherent single
cognitive module for melody perception, thus eradicating ear differences.

I am presenting a picture in which at various points in development the
left hemisphere can act as a construction of unitary schemata and action
patterns, building up relational representational systems of increasing com-
plexity; as some of these systems become modules in their own right, they
can create unitary processes of corresponding complexity. It may be difficult
to bring this out in language (because of its habitual cross-modal involve-
ments), and we have not yet studied it in music. There is, however, some
evidence for a lateral shift back and forth in facial recognition that may
reflect the alternation between relational and unitary processing, with the
latter becoming more complex at each stage (see Bever, 1980, for discus-
sion). The salient facts are that at the ages of entering primary and secondary
school, American children actually show a temporary drop in the ability to
recognize new faces, and (at the latter age) show a loss of the usual right
hemisphere dominance for the task (this has not been tested at the younger
age). On the present view, the temporary changes occur at points when the
child is attempting to master a new and larger set of faces; he or she reor-
ganizes a new canonical set of unitary facial schemata—the period of
reorganization is associated with a drop in the growth of the skill, and a
relative left hemisphere superiority, since the reorganizational activity itself
is relational. Carey (1980) and Diamond, Carey, and Back (in press) have
presented some evidence showing that the onset of puberty is a critical factor
in the temporary loss of right hemisphere dominance. This is consistent with
the view that when the child becomes particularly interested in mastering
new faces and new kinds of facial features (on Carey's data, because of pu-
berty), a period of relative left-hemisphered reorganization occurs.

CONSCIOUSNESS AND THEORIES
OF COGNITIVE ACTION

I have outlined current cognitive theory, in which different capacities are represented in relatively distinct cognitive systems, or "modules." The modular concept provides a technical basis for differentiating relational and unitary processing. Unitary processing normally accesses the output or input of one module; relational processing normally accesses the input or output of several modules.

Modular cognitive theory also offers a technical description of consciousness, and therefore a theory of why consciousness exists. Suppose that during ordinary wakefulness a number of modules operate simultaneously on their appropriate intero- and extero-receptor inputs. Different modules can provide different representations, which are either orthogonal to each other or in conflict. For example, the visual representation of a dog is of a different kind than the representation of a bark. But the two representations are properly unified, under simple circumstances in which they both have the appropriate magnitude and direction. In such cases the information is orthogonal; there are also cases in which it might conflict—for example, if the dog appeared retinally small, and to one side of the apparent location of the bark. One resolution of this relative disparity is that the dog is distant and the bark is being partially reflected. Such a percept might be immediate when presented with these two kinds of information. That is, we can reconcile apparently conflicting information by way of "inferences" about a possible world. These inferences occur so rapidly and automatically that one is tempted, like Helmholtz, to refer to them as "unconscious."

It is also tempting to suggest at this point that there is a central mental "executive" which actively mediates all representational conflicts by way of inferences. Clearly, some decision must be made at each moment as to which module to attend, and how to integrate it with other outputs. The result of such decisions appears to be what we think of as consciousness. Accordingly, it would be further tempting to call this executive "consciousness." In fact, I will succumb to this temptation, with one important exception— consciousness is not itself an independent mental module. Rather, it is an inner representation of reality that mediates conflicting information yielded by different modules. In this sense, consciousness is an automatic consequence, which resolves conflicting computational output of modules. It is the inference of reality. It is *automatic,* not autonomous, for without that property it would merely have the status of a junior executive modular homunculus.

The reader will recognize that this sort of view resonates with proposals by Piaget and others about the development of models of reality in general. The child builds up internal representations that mediate conflicts in individual systems of perception and knowledge. For example, the child builds up a theory of immutable quantity, which establishes a reconciliation between conflicting kinds of information about quantities. The child builds up a theory of the structure of the language that reconciles disparities created by habits of talking and listening. Just so for consciousness itself. It offers an internal representation of reality which carries us through representations of otherwise incoherent objects and events in relation to each other. Consciousness *must* exist in a complex computational system with many independent sources of representational information.

If we turn to traditional investigations of consciousness, we find that this treatment resonates loudly with what has been observed since Hippocrates. Virtually everybody argues, albeit in unique ways, that consciousness involves relating one kind of information to another. That is, the sensing of oneself or ones' something requires a setting-in-relation of more than one entity.

This requirement does find a reflex in the technical characterization of cerebral asymmetries. The processes underlying the empirical phenomena that distinguish the hemispheres are either unitary or relational. The effect of that difference is that the left hemisphere is more relational and hence more conscious, in the technical sense discussed here. This offers a theoretically motivated prediction for a claim that has already been made on the basis of clinical facts (Sperry, 1974; Gazzaniga, 1970) or anthropological speculation (Jaynes, 1977): The right hemisphere (as a complex organ) has some consciousness but in a physiologically integrated brain the left hemisphere is the seat of consciousness.

I do not wish to dwell on the philosophy of consciousness because I would like to believe that it is an empirical phenomenon. But it is difficult to know to get an empirical handle on it. We cannot compare directly beings whom we know have consciousness, like us, and beings whom we know not to have it. First, we cannot be sure that other animals do not have it; indeed, the cognitive theory of consciousness suggests they do have it to some degree. Second, their general intelligence may differ, thereby confounding any experimental comparisons. But we can manipulate a person's level of self-awareness (i.e., his self-consciousness) and examine the effects of that manipulation. In what follows I discuss a few effects of that manipulation on cerebral asymmetries.

Social psychologists have noticed that the way to increase a person's self-

consciousness is to put him in front of a mirror (Duval & Wicklund, 1972). A variety of measures show that in such circumstances people think of themselves more as social entities, as others see them. For example, when people are in front of mirrors, they conform more to norms describing the behavior of others. This can be shown by having a subject rate the performance of somebody else on a task, such as digit recall, after telling the subject how other people rated that individual's performance of the task. When subjects are in front of a mirror, their judgment is much more influenced by what they are told other people thought than when they are not in front of a mirror.

An undergraduate colleague at Columbia, T. Engelmann, suggested that we examine the impact of this technique on cerebral asymmetries. We started with the view that has been outlined here, that consciousness is an automatic conflict-resolving representation of reality. We predicted several results. First, on a task that simply involves individual performance, such as recall of digit strings, we expected that the mirror would reduce any cerebral asymmetries. Our reasoning was that if the behavioral superiority of the right ear is related to the role of automatic processes in the left hemisphere, then increasing a person's total self-awareness would reduce the isolated operation of that hemisphere and thereby reduce behavioral asymmetries.

This prediction was borne out by our study, the results of which are given in Table 2.10. Subjects (who, of course, were controlled for all the variables mentioned in the previous section, and more), performed better in the right ear than the left on ordered recall of digit strings. However, when they were in front of a mirror, they performed equally on the two ears—primarily due to a relative increase in their left ear performance.

A second prediction is that in a socially interactive task the left hemisphere is more influenced than the right. To test this we used a social influence paradigm. Experimental subjects were presented with a recording

Table 2.10
PERCENTAGE CORRECT ON RECALL OF ELEVEN
DIGIT SEQUENCES[a]

	Left ear	Right ear	Right ear advantage
No-mirror	57.0	60.0	− 3.0
Mirror	58.8	57.5	+ 1.2

[a]From Engelmann and Bever, 1983.

of another subject attempting to recall strings of digits. After each trial, the experimental subjects had to rate how well the recalling subject had done. Experimental subjects were informed on each trial as to how other people had rated the recalling subject—though the ratings were, in fact, constructed by us. Experimental subjects heard the recalling subject in either the right or left ear. As predicted by the view that the left hemisphere is the seat of relational consciousness, we found significantly more conformity to the social standard when they heard the recalling subject in the right ear (see Table 2.11). This increase interacted with the effect of the mirror: The degree of social conformity was very strongly increased by the mirror when the recalling subject was heard in the right ear, but not when he was heard in the left. This is further evidence that the effect of thinking of oneself in relation to society is primarily a left hemisphere activity.

These experiments are preliminary, and I stipulate that they are somewhat outlandish. But they do demonstrate that levels of self-consciousness interact systematically with cerebral asymmetries.

CONCLUSION: THE BASES OF ASYMMETRIES

I have argued that an assiduous application of cognitive theory can guide us through the maze of subject and task variables that permeate research on asymmetries in normal people. It also motivates specific predictions about the interaction of asymmetries and consciousness, which we have tested. The view of the basis of cerebral asymmetries has become more general. I have outlined examples of three factors that govern the appearance of asymmetries—genetic, experiential, and cognitive.

Researchers who theorize about cerebral asymmetry always end up theorizing about its evolutionary basis. If we are constrained to believe that

Table 2.11
MEAN ABSOLUTE DISTANCE OF RATED PERFORMANCE FROM SOCIAL STANDARD[a]

	Left ear	Right ear	Right ear advantage
No-mirror	.23	.14	+ .09
Mirror	.20	.07	+ .12
No mirror advantage	.03	.07	

[a]From Engelmann and Bever 1983.

everything that evolved did so because it was good for us at the time, then I wish to bow out of the game, since it is exquisitely circular. It would be more encouraging to be able to look at our behavioral phylogenesis and conclude that we are like our ancestors only slightly more so, so far as fundamental capacities are concerned. I am not suggesting that one animal's brain is like another, only bigger or smaller; among other things, size of an organ rarely changes without some structural implications. But I do think that we can frame a nonapocalyptic view of what might have happened, a view that leaves intact the notions that evolution proceeds slowly and that small increments can have drastic implications for morphology and behavior (see Bever, 1975, 1980, for fuller presentations).

Many animals have the capacity to learn symbols. Many seem to have some relational capacities, even in the technical sense defined here. Suppose humans simply have more of each. Suppose, further, that the left hemisphere is usually computationally advanced over the right in the young child. The result will be that relational activities—the relatively more complex— end up being represented and executed in the more capable hemisphere. The epigenetic implications of this result we can only guess at. But it does allow us to understand the difference between the hemispheres as rooted in an early quantitative difference in a general capacity. The result for adults is the sharp differences in the ordinary activities of the two sides of the brain, ranging from the performance of special tasks, to language and consciousness itself.

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