CEREBRAL ASYMMETRIES IN HUMANS ARE DUE TO THE DIFFERENTIATION OF TWO INCOMPATIBLE PROCESSES: HOLISTIC AND ANALYTIC

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Cerebral localization is determined by the separation of incompatible mechanisms.
— Lashley[7]

Clinical and experimental evidence suggests that the left hemisphere of the brain is specialized for speech activity and the right hemisphere is specialized for many nonlinguistic functions. Jackson[1] related the hemispheric linguistic differences to differences in cognitive activity, suggesting that the left hemisphere is specialized for analytical organization, while the right hemisphere is adapted for "direct associations" among stimuli and responses. Modern researchers have substantially generalized this differentiation to encompass a wide range of behaviors in normal subjects. Experimental[2] and clinical[3] investigators of hemispheric asymmetry generally agree on the fundamental nature of the processing differences between the two sides of the brain: the left hemisphere is specialized for propositional, analytic, and serial processing of incoming information, while the right hemisphere is more adapted for the perception of appositional, holistic, and synthetic relations.

This asymmetry raises the question of whether there are essential differences in the way in which the two hemispheres organize behavior and process information. Several theories attribute hemispheric differences to a structural differentiation of some kind. Asymmetries might be due to differences intrinsic to each hemisphere: e. g., in the neurospatial organization of functions[4] or the existence of modality-specific differences in capacity,[5] or to some fundamental differences in the way the elementary neurological interactions occur. The structural difference might exist because of forces extrinsic to the brain, e. g., a muscular predisposition for handedness, asymmetries in sensory organs, or socially trained asymmetries in such observable traits as handedness and eyedness.

Each of these views supposes that there is some physical or social structure that specifically and directly causes functional asymmetry to occur; that is, these proposals are all extremely strong in that they make concrete claims about the nature of the phenomenon. Yet the apparent precision of each claim is of little use to us, since we do not know the relevant facts that would critically prove or disprove any of them.

I shall argue that unless we have evidence conclusively proving any of the more specific claims, we should view cerebral dominance as the result of certain general properties of the mind and of the relationship between the structures of the mind and the anatomy of the brain. The basic view underlying this proposal is that the mind is composed of a number of partially independent faculties, each of which has certain unique properties.* On this view the nature and existence of cerebral asymmetries are predictable, if there is any difference at all in the neonatal adaptability of the hemispheres. I will also discuss a number of surprising experimental results that follow from this view.

There are four statements (two are primarily theoretical and two are more immediately substantive), which combine to predict that analytic activity will tend to be localized in the left hemisphere and holistic activity in the right hemisphere.

Statement 1

The mind is self-organizing. In particular, it differentiates in mental space the location of analytic modes of processing from holistic modes of processing. Often we may have available two ways of organizing our behavior in response to a stimulus: we may analyze the stimulus in terms of component parts, or we may respond to the stimulus if it triggers a holistic behavioral "template." Consider, for example, the perception of a square. It may be analyzed either as four equal-length lines at right angles enclosing a space, or it may be directly perceived by triggering a template that is set for a □. Analogously, we can listen to a syllable, e.g., "bik," either by recognizing it in terms of its constituent phonemes or by setting up a complete template that is sensitive to that particular acoustic object as a whole. Finally, we can listen to a melody in terms of the individual intervals formed by successive notes or we can listen to the melody in terms of its entire gestalt. Much of this may seem to be a matter of terminology without behavioral implications. However, I will show that there are behavioral differences that reflect the two different modes of processing a stimulus. For the moment, one must simply accept the claim that a complex stimulus can itself be processed as a primitive whole or be analyzed in terms of its constituent parts, and that those processes are incompatible; in general, they cannot occur simultaneously in the same place.

Statement 2

Analytic processing requires more mental activity than holistic processing. This point is essentially a necessary truth whenever it applies to a stimulus that offers both a holistic and analytical level of organization. There is a sense in which recognition of a figure through analysis of its constituent parts must include the recognition of the whole figure as well. For example, I may recognize the syllable sequence "bik" as "b," "i," "k," but in so doing I ordinarily will also perceive the stimulus sequence as the syllable "bik." There is a related substantive claim, namely, that when instructed to perceive analytically, subjects nevertheless tend to start by perceiving a stimulus as a whole and then use additional processing to break the whole into constituent parts. This latter result is not itself the only possible consequence of the relative difficulty of analytic processing, but it does seem to be true. For example, suppose we ask a listener to respond as soon as he hears the syllable "bik" in a list of syllables presented one per second. The listener does so considerably faster than if he is listening for a syllable that begins in the sound "b" (even though he knows that the first such syllable *is* "bik").[6]

Statement 3

The dynamic mapping of mental processes onto functional brain structures is maximally simple. This is a substantive point, claiming that mental activities of the same kind tend to be represented anatomically in the same part of the brain. For

*See my discussion paper in this annal for a fuller presentation of this view. If the reader is concerned about the use of the word "mind," it may be glossed as "higher integrative functions." See the discussion of Statement 3 in this paper.

the purposes of this discussion I do not need to specify how this occurs, in particular, whether the higher order functions have this effect on the brain or vice versa. All I must claim is that there is some flexibility in the neurological localization of function that allows for maximal localization in the same area of the brain of similar mental functions.

This view may appear to be dualistic, in the sense that it distinguishes the operation of "the brain" from that of "the mind." The distinction, however, does not render the notion of "mind" mystical or unscientific. The model that sets the framework for this discussion is the following:

(A) Physiological properties of the brain make possible certain fundamental operations, and combinations of those operations.

(B) These operations organize modality-specific activities (e.g., audition, vocalization. . .) integrating receptive and productive behavior in response to limits set by other physiological structures (e.g., the ear, the mouth). Such kinds of activities differentiate into modality systems. An independent differentiation occurs in terms of the organization of the capacities (e.g., "language", "music". . .).

(C) The representation of these higher-order functions segregates in the brain according to similarity of function, *and* according to adaptation of the particular brain structures for that kind of function. (Note that such "adaptation" can be due to intrinsic properties of a brain structure or to its anatomical connectedness to the stimulus-response organs that ordinarily carry out the activities.)

There is nothing magical about this view, nor does it strike me as particularly novel. It is a commonplace that mechanistic systems combine to produce functions that no system alone could serve. Futhermore, it is a commonplace in biology that the operations of individual systems are phylo- and ontogenetically shaped by the larger functions in which those systems participate. The view presented here simply combines these two simple notions, as part of the explanation of cerebral localization of function in general and hemispheric dominance in particular.

An explicit example of the sort of view I have in mind is discussed by Lashley.[7] He argues that fundamental properties of brain systems make it impossible for the same neurological area to serve different kinds of functions. Separate localization of functions is determined by the existence of diverse kinds of integrative mechanism that cannot function in the same nerve field without interference. For example, neurological "fields in which [temporal order] is dominant cannot also serve in other space systems." Lashley gave special attention to potential physiological morphogenesis of functional localization. However, he also emphasized the need to understand any brain area in relation to the entire brain. "On anatomical grounds alone there is no assurance that cerebral localization is anything but an accident of growth."

Statement 4

The left hemisphere is more "adaptable" at birth. This principle is not intended to mean that the left hemisphere is either more or less "mature," since relative maturity might predict greater capacity, but it also might predict less flexibility. There is evidence that certain anatomical areas of the left hemisphere are, in fact, larger at birth.[8] It would be premature, however, to rest this part of my syllogism on the functional relevance of that fact. Furthermore, there are alternate claims that the right hemisphere functionally matures earlier than the left.[9] Notice that this claim is not a claim about the nature of the organization of activities in the left hemisphere, nor is it a claim about the specific neurochemical interactions in the left hemisphere. Rather, it simply proposes that at birth the left hemisphere is more able to deal with and to develop mastery over mental activity. The reason for that might be an intrinsic property of differing maturation rates, or an extrinsically imposed asymmetry (e.g., asymmetric pressure *in utero*).†

Conclusion

The mentally more demanding kind of activity (analytic) will become localized in the more adaptable hemisphere (the left hemisphere). This conclusion involves no claim about the relative frequency of holistic and analytic processing in the child. All it claims is that proportionately more of the analytic processing will be taken over by the left hemisphere and proportionately more of the holistic processing will be left to the right hemisphere.

It should be clear that the statements in this argument are constructed to be either logically true or consistent with known or testable phenomena. On this view behavioral asymmetries emerge as a dynamic function of the self-organizing properties of the mind and the brain in differentiating the mental activities and segregating them neurophysiologically. The further question is whether this way of interpreting cerebral asymmetries makes predictions beyond the claim that the right hemisphere is dominant for those activities that involve holistic processing (e.g., perception of simple visual figures) and the left for analytic tasks (e.g., language).

My proposal argues that asymmetries result from a *process* of mental and neurological differentiation that operates initially at the highest and most central levels. A general prediction from this interpretation is that lateral asymmetries should occur with unilateral stimulation, rather than requiring bilateral sensory inhibition at the peripheral sense-organ level. Unilateral asymmetries have usually been found in visual studies, in which the stimuli are characteristically presented only to one visual field. In auditory studies, however, most researchers present their stimuli dichotically; in fact, some argue that it is only with dichotic presentation that asymmetries should occur.[10] Nevertheless, a growing number of experiments have found monaural differences,[11] and I shall review several others. (All experiments in the present paper used right-handed subjects.)

Consider as a simple example the fact that if a list of random words is followed by a three-second interference task, the right and left ears perform identically. However, when those same random words are respliced into a sentence order, then sequences presented to the right ear are recalled significantly better than sequences presented to the left ear (TABLE 1). In the general view outlined above, the processing asymmetry in this paradigm occurred only when the sequences had syntactic structures, because it is the syntactic structures that make possible processing the word sequences in an analytic mode.[12]

In addition to the general prediction that monaural asymmetries should occur, the nature of asymmetry sketched above makes other somewhat surprising predictions, which turn out to be true.

Prediction 1

The kind of processing that subjects are asked to perform should determine which side is dominant in processing a stimulus. This would be the strongest way of testing the claim that indeed it is the *kind* of processing that determines behavioral asymmetry, not the modality in which the processing is categorized (e.g., language, music, vision, etc.). To show this, Richard Hurtig, Ann Handel, and I ran monaurally the initial-phoneme vs. syllable-recognition experiment described in *Statement 2*.[13] We

†Of course, such externally imposed asymmetries might trigger early structural differentiation as well.

TABLE 1

RESULTS OF IMMEDIATE RECALL OF WORDS IN ARRANGED SENTENCE ORDER AND IN RANDOM ORDER*

	Words in Sentence Order		Words in Random Order	
	% sequences totally correct	% words correct	% sequences totally correct	% words correct
Sequence heard in				
Left ear	54	94	4	57
Right ear	65	96	4	57

*From Bever,[2] Table II.

found that the time taken to recognize a syllable beginning in "b" is shortest when the materials are presented to the right ear and the subject responds with the right hand compared with other hand/ear configurations. There was no difference in amount of time to recognize the entire syllable, e. g. "bik." We checked this result in two ways; we alternated whether listeners were listening for an entire syllable, target, or an initial phoneme target, and in a second group of subjects we held the task constant but alternated the ear to which the stimulus was presented. Both experiments gave the same results. (See TABLE 2). This investigation shows that the same stimulus can be differentiated according to the kind of processing the subject must carry out on the stimulus. If the subject must analyze the stimulus internally, then the condition in which only the hemisphere is involved (right-ear/right-hand) is more facilitating than the other conditions. The task in which the subject listens holistically shows no overall differences in this case. (It remains to be seen whether one can show a statistically reliable favoring of right-ear input with a linguistic stimulus.)

A second experiment of this type has been done by Victor Krynicki at Columbia University.[14] Characteristically, previous studies have shown that the recognition of nonlinguistic visual stimuli is best when the stimuli are presented to the left visual field. Since visual stimuli must be presented off the fovea to be completely lateralized anatomically, these experiments characteristically use simple visual stimuli which can be differentiated in the visual periphery (e.g., angle of line, recognition of a face, recognition of a simple geometric figure.) Overall performance on complex stimuli in the periphery can be so low that laterality differences might not be meaningful. Consequently, the experimental requirement that the visual discrimination task must be simple when stimuli are in the visual periphery may account for the apparent right-hemisphere dominance vision that is claimed in the literature.

To test this, Krynicki used a figure-recognition task with brief presentations of irregular eight- and sixteen-sided geometric figures. In one situation the subjects had to recognize rapidly presented stimulus figures from a target set of twenty (20 msec, 2°

TABLE 2

MEAN RT (msec) TO IDENTIFY A SYLLABLE IN TERMS OF THE INITIAL PHONE, OR THE WHOLE SYLLABLE*

	Left Hand			Right Hand		
	Left Ear	Right Ear	Difference	Left Ear	Right Ear	Difference
Initial Phone	360	354	6	377	342	35
Syllable	257	254	3	261	262	−1

*From Bever *et al.*,[13] combining experiments 1 and 2.

off fovea; a nonius fixation task and EOG monitoring ensured correct fixation). Although the success rate was low, the sixteen-sided figures were identified better in the right visual field (the eight-sided figures showed no differences). Krynicki suggests that the subjects must recognize the complex figures in terms of isolated configurational features (e.g., a jagged edge), thus leading to a left-hemisphere superiority. The basis for this assumption is that a large number of complex and similar figures would be easiest to differentiate, identify, and recognize in terms of some criterial visual feature that distinguishes it from the others in the target set. In a second task the stimulus figures were always rotated 90° or 180°. This task was even more difficult. Nevertheless, there was a left visual field superiority for both eight- and sixteen-sided figures. This result was predicted by the view that holistic processing is relegated to the right hemisphere and the assumption that recognizing a figural rotation is a holistic task that can operate on the gross contour of the stimulus. It is an important fact that in this condition *both* eight-and sixteen-sided figures showed a left visual field superiority, suggesting that figure complexity was not an effective variable. If these results hold up in other paradigms, they will show that the frequent claim that *vision* (of nonlinguistic stimuli) is dominant in the right hemisphere was based on research that involved holistic processing; analytic processing can stimulate left-hemisphere dominance in visual recognition of nonlinguistic stimuli.

Prediction 2

If one shifts ontogenetically from holistic to analytical ways of perceiving a stimulus, one should also shift from being right-hemisphere dominant to being left-hemisphere dominant for that stimulus. Up to now, the perception of music has been a well-documented exception to the differentiation of the hemispheres according to analytic vs. holistic processing. Melodies are composed of an ordered series of pitches, and hence should be processed analytically by the left hemisphere, rather than the right. Yet the recognition of simple melodies has usually been reported to be better in the left ear than the right.[15] This finding is *prima facie* evidence against the functional differentiation of the hemispheres proposed by Jackson; rather, it seems to support the view that the hemispheres are specialized according to stimulus-response modality, with speech in the left, vision and music in the right, and so forth.[16] Such conclusions however, are simplistic, since they do not consider the different kinds of processing strategies that listeners use as a function of their musical experience.[17]

Psychological and musicological analysis of processing strategies resolves the difficulty for a general theory of hemispheric differentiation posed by music perception. It has long been recognized that the perception of melodies can be a "gestalt" phenomenon. That is, that fact that a melody is composed of a series of isolated tones is not relevant for naive listeners—rather, they focus on the overall melodic contour.[18] The view that musically experienced listeners have learned to perceive a melody as an articulated set of relations among components rather than as a whole is suggested directly by Werner.[19] "In advanced musical apprehension a melody is understood to be made up of single tonal motifs and tones which are distinct elements of the whole construction." This is consistent with Meyer's[20] view that recognition of "meaning" in music is a function not only of perception of whole melodic forms but also of concurrent appreciation of the way in which the analyzable components of the whole forms are combined. If a melody is normally treated as a gestalt by musically naive listeners, then the functional account of the difference between the two hemispheres predicts that melodies will be processed predominantly in the right hemisphere for such subjects. It is significant that the one investigator who failed to find a superiority of the left ear for melody recognition used college musicians as subjects,[21] the subjects in other studies were musically naive (or unclassified).

If music perception is dominant in the right hemisphere only insofar as musical form is treated holistically by naive listeners, then the generalization of Jackson's proposals about the differential functioning of the two hemispheres can be maintained. To establish this we conducted a study with subjects of varied levels of musical sophistication that required them to attend to both the internal structure of a tone sequence and its overall melodic contour.[22] The listener's task is sketched below:

hear melody	2 sec pause	hear excerpt	say if excerpt was from melody	say if melody was heard before in the experiment

We found that musically sophisticated listeners could accurately recognize isolated excerpts from a tone sequence, whereas musically naive listeners could not. However, musically naive people could recognize the entire tone sequences, and did so better when the stimuli were presented in the left ear; musically experienced people recognized the entire sequence better in the right ear (TABLE 3). This demonstration of the

TABLE 3
PERCENTAGE CORRECT ON RECOGNITION OF WHOLE AND OF EXCEPTS FROM THE MELODIES*

	Relative Percentage Correct			
	Musically naive subjects		Musically experienced subjects	
	Left ear	Right ear	Left ear	Right ear
Excerpt recognition	−7	−22	27	31
Melody recognition	54	36	44	57

*Percentages are corrected for guessing, from Bever & Chiarello,[20] Table 1.

superiority of the right ear for music shows that it depends on the listener's being musically experienced; it explains the previously reported superiority of the left ear as being due to the use of musically naive subjects, who treat simple melodies as unanalyzed wholes.

We also compared the performance of a group of choir boys with nonmusical boys from the same school on a similar task.‡ Here, too, the choirboys performed more effectively on stimuli presented to the right ear, while the musically naive boys performed better on the left-ear stimuli. Since half the choir boys cannot read music (they memorize their parts), this could not be due to mapping the music onto a score or note-names. It is also possible, in principle, that developing musical ability is not the cause of left-hemisphere dominance but its result: it might be that those boys who are *already* left-hemisphered for music are thereby more musical, and that is why they sign up for the choir. This is inconsistent with several facts. First, the boys join the choir for a mixture of social and financial reasons (choirboys receive a scholarship to their schools). Second, the longer a boy was in the choir, the more pronounced his right-ear dominance (compared with non-choirboys in the same age and grade). Recently, a similar relation between the musical ability of the subject and right-ear superiority was confirmed by Gordon,[23] who reanalyzed data from an experiment on melody and chord recognition. He found that listeners who recognized more melodies overall tended to be more right-eared.

‡We used a "yoked subject" design: for every choirboy there was a corresponding non-choirboy (who was also not studying an instrument) of the same age and grade.

Our interpretation is that musically sophisticated subjects can organize a melodic sequence in terms of the internal relation of its components. This is supported by the fact that only the experienced listeners could accurately recognize the two-note excerpts as part of the complete stimuli. Dominance of the left hemisphere for such analytic functions would explain dominance of the right ear for melody recognition in experienced listeners; as their capacity for musical analysis increases, the left hemisphere becomes increasingly involved in the processing of music.

The shift to left-hemisphere processing does not occur for all aspects of music perception. For example, musically sophisticated listeners continue to show left-ear superiority for recognition of chords (also found by Gordon[21]). Recently L. Kellar and I tested this on our adult population by asking listeners to identify a two-note chord as a musical fourth, augmented fourth, or a fifth:§ we presented musically naive and sophisticated listeners with two-note intervals that were acoustically intermediate between the musical intervals. There is an overall left-ear superiority for all subjects in the consistency of judging intermediate intervals; this tendency was even stronger in musicians.¶ Thus, being musically sophisticated does not involve shifting *all* music processing to the left hemisphere, but only these aspects that require analytic processing.

Prediction 3

Variation in the complexity of syntactic structures should stimulate greater correlations in behavioral complexity when heard in the right ear than in the left. This prediction follows from the view that if the left hemisphere carries out analytic processing, the perceptual strategies that listeners use to analyze relations among the words in sentences will be indigenous to the left hemisphere. A common strategy of speech perception is one that maps an "NVN" sequence onto the grammatical relations "actor, action, object."[24] This strategy accounts for the fact that a sentence like (A) is easier to compare with a picture than sentence (B).[25] In sentence (A) the NVN pattern conforms

(A) They are fixing benches. (Progressive construction.)
(B) They are performing monkeys. (Participial construction.)

to the expectation expressed by the strategy, whereas in (B) it does not. We tested the comprehension of these sentences monaurally to see if the comprehension time between sentences like (A) and sentences like (B) would differ more in the right ear than in the left (listeners heard five sentences structurally like (A) or five sentences like (B); and matched each one to a picture; the sentences were always presented to the same ear for a particular subject). The results are summarized in TABLE 4. The predicted differences occurred for sentences heard in the right ear, but the results were actually the reverse, numerically, for those heard in the left ear.[26] It should be noticed that the average comprehension time for the two constructions together was similar in the two ears; however, the right ear presentation differentiated the constructions according to their conformity with the perceptual strategy, while the left ear presentation did not.

If the left-ear presentation does not show evidence of perceptual strategies, how are the sentences understood at all? One possibilty is that the information is transmitted to the left hemisphere via the callosum, thus circumventing the application of the strat-

§The notes were pure sine waves lasting for one second. Listeners were first presented a reference set (pure fifth, augmented fourth, pure fourth) and then a series of intermediate cases.

¶A puzzling fact is that right-handed subjects who reported left-handers in their family appeared to differ on these tasks from other subjects.

TABLE 4
MEAN LATENCY (sec) TO MATCH PICTURES TO PROGRESSIVE AND PARTICIPIAL SENTENCES IN LISTENERS WITHOUT EXPERIENCE AT THE TASK*

	Left Ear	Right Ear
Participial	.98	1.29
Progressive	.96	.79
Difference	.02	.50

*From Carey *et al.*,[23] Table 2.

egies but leaving intact other mechanisms of perception. A second possibility is that the monotony of the task of hearing the same construction type repeatedly allows for the formation of a holistic *schema* in the right hemisphere. (The results in Prediction 4 are consistent with this interpretation.)

Prediction 4

It should be possible to shift analytical processing to the right hemisphere, at least temporarily. This follows from the view that cerebral asymmetry is maintained in part by the dynamic self-organizing properties of the mind and brain.[27] In particular, it is presupposed that the right hemisphere *can* carry out analytic processing at birth, but that it does not ordinarily do so during development (and perhaps cannot readapt to do so after adolescence). If one forces the left ear to continue processing, then it is at least possible on this view of asymmetries that continued monaural stimulation would shift some analytical processing to the right hemisphere and predicts that the left ear would start to show responses with the same pattern as the right ear. This was in fact observed in the experiment involving the two types of sentences, (A) and (B). TABLE 5 presents the mean reaction time for the two constructions in the second half of the experiment. In this task listeners continued to hear the sentences in the same ear as before, but now heard the set of five sentences that they had *not* heard in the first half of the experiment. (The delay between the first and second half was less than a minute.) Listeners continue to find construction (B) more difficult than construction (A) in the right-ear presentation, although the difference is reduced from the first half. What is striking is that the left-ear presentation now shows the relative complexity of construction (B).

It might be that this result occurs because information is now being transmitted from the left ear directly to the left hemisphere, in such a way that the left-hemisphere perceptual strategies can apply. However, this would predict that during the second half of the experiment the differences between the two sentence constructions should be the same in the right and left ear (or should be less in the left ear than the right, on the assumption that the information transfer or unaccustomed application of the strategies is imperfect). The fact is, however, that the left-ear difference in the second

TABLE 5
MEAN LATENCY (SECONDS) TO MATCH PICTURES TO PROGRESSIVE AND PARTICIPIAL SENTENCES IN LISTENERS WITH EXPERIENCE AT THE TASK*

	Left Ear	Right Ear
Participial	1.27	1.08
Progressive	.72	.91
Difference	.55	.17

*From Carey *et al.*,[23] Table 2.

half of the experiment is *larger* (significantly) than the right-ear difference in the second half of the experiment.

Prediction 5

Attention should be shifted laterally as a function of the kind of processing that subjects use. This prediction also follows from the claim that asymmetries emerge from self-organizing properties of mind and brain. If sensory information is routed to the left hemisphere during analytical processing, this will have the consequence of giving relative priority to information from all the right sensory organs. This prediction has been confirmed by a number of experiments[28] showing that attention to the right side of the body is enhanced during speech processing. We have extended this in our laboratory** to the finding that during dichotic stimulation, speech sounds presented to the right ear are perceived as *physically* louder than those presented to the left ear. That is, even a simple *sensory* judgment about the speech stimuli is affected by the processing asymmetries.

If the asymmetry emerges in part as a function of self-organizing *functional* properties as opposed to isolated neurological ones, then we would also predict that any stimulus perceived by the subject to be to the right would be treated differentially. This should occur even if both ears are receiving the input, as is the case when a listener hears two signals from two loudspeakers, one to the left and one to the right. Morais and Bertelson have confirmed this prediction (1974).[29] They showed that verbal material presented from a right loudspeaker is recalled better than verbal material presented simultaneously to a left loudspeaker. Morais[30] has extended this finding by showing that the lateral position of a dummy loudspeaker (which the listener *thinks* he is hearing) can influence the recall of verbal material actually presented from a central speaker. That is, it is not the lateral sensory organ of input alone that determines asymmetry, but also the perceived location of input. We tested this kind of finding in an experiment similar to the preceding one on perceived loudness, except that the different diotic words were presented over speakers to the subjects left and right. In this study, the words coming from the right loudspeaker were perceived as louder than those from a left loudspeaker.

These results are crucial to our general view because they invalidate the claim that asymmetries result from a low-level neurologically based routing of information to one hemisphere or the other. Rather, the proposed process must be something like the following: input stimulus information is routed to the left or right hemisphere for initial processing according to its perceived relative location. Once the sensory information is routed in this way, the intrinsic advantages (or disadvantages) of the specific hemisphere determines the results.

Conclusion

I have argued that organizational processes account for the existence of functional hemispheric asymmetries in humans. The substantive claim is that the left hemisphere becomes the locus for analytic processing because it is more flexible during childhood. This is the weakest claim that is compatible with the facts we currently have. The general view I have sketched also predicts facts about asymmetry that would be surprising on more structural theories of its basis.

Part of the difficulty in isolating an ultimate cause for such a complex phenomenon is that it is embedded in many manifestations of human psychology and culture. The

**The listener's task was to adjust the loudness of a word in one earphone to be equally loud to a different word in the other earphone (both earphones were adjusted in different phases of the experiment).

result of this is that the emergence of cerebral asymmetry in an individual is overdetermined. Whatever its "original" biological basis, it is shaped by explicit social patterns and artifacts, as well as by implicit patterns of thought. In order to disentangle the problem it is necessary to apply logical principles to isolate the minimum substantive claims.

The most general reason to study asymmetries is that brain structures are generally symmetrical in animals except for the higher functions in humans. This could lead to speculation about the ultimate evolutionary "advantage" of asymmetric function. The near universality of symmetry in nature suggests that asymmetry is *disadvantageous*, given that it makes any difference at all. If the present discussion is correct, asymmetries emerge because of the human ability to differentiate holistic and analytic processing: the advantage of that implicit differentiation seems intuitively clear, although its evolutionary and ontogenetic cause is obscure. Nevertheless, the present formulation of the problem argues that hemispheric asymmetry is the *result* of the evolution of a general mental capacity, not the cause.

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