VARIETIES OF HUMAN BRAIN ORGANIZATION AND THE HUMAN SOCIAL SYSTEM

by Jerre Levy

The core of any social structure, from ant to man, is the differentiation of social roles such that each member of the group contributes his special skills and abilities while receiving from others the benefits of theirs. It is this role differentiation and mutual interdependence that constitute the definition of social organization and that provide for its maintenance, stability, and quality. In the case of the social insects we have a pretty fair understanding of the mechanisms responsible for the critical diversity of roles, but in the case of our own species there has been little attempt to acquire evidence since, for the most part, the answer has been assumed.

Typically man has been viewed as an infinitely plastic clay to be molded at will by social forces, and the diversity of human social roles has been seen as a direct consequence of the social system. Even from the perspective of sociobiology, although the social structure itself is attributed to evolutionary factors, the human infant born into that structure is perceived as having an invariant set of characteristics that define his species identity and that make it possible for him to be conditioned by the extant social forces into any role demanded by the culture. In this view the etiology of human social differentiation is assumed to differ little from that of the social insects. Indeed what we call moral or ethical behavior, or more narrowly "altruistic" behavior, is, as for the insect, a result of kin selection: There is no real altruism, only the selfish gene's attempt to preserve itself.

Social Organization and Behavioral Diversity

The idea that each human being is unique in his skills and propensities, that he seeks to find his own niche where his special abilities

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may be realized, that there is an inherent diversity in the human family that is primary and responsible for social evolution itself is an unpopular interpretation and is overtly denied by certain political philosophies. There are many reasons why such a notion has had little support in the scholarly community, some deriving from frightening Hitlerian visions, some deriving from the arrogance of social designers, and some from a conceptual difficulty in accounting for the concordance between social needs and available individuals to meet those needs.

The relative degrees of terror that may be invoked by the vision of a diversity imposed by our evolutionary history, versus a diversity imposed by social manipulators, will not be discussed here since the issue of concern is the nature of reality and not the popularity of various possible universes. Were people as plastic in response to social pressures as has been proposed, the congruence between the requirements of the social system and the ability of members of that system to meet those requirements would necessitate no explanation. If, however, as I would suggest, people are inherently variable in their propensities and skills to fill various social roles, and if they differ with respect to the nature of the activities that bring self-fulfillment, we are confronted immediately with the question of how individual and social needs can be simultaneously met. One possibility of course is that the individual does not have his needs fulfilled, that these are sacrificed for the "good" of the society. In this case, power relationships within the social system, whereby weaker members of the group, irrespective of their individual desires, are compelled to perform needed services, serve to maintain the social structure.

Although such societies have existed throughout human history, compulsory social ordering entails a constant threat of rebellion and is hardly conducive to social stability. Human history is replete with instances of collapse of rigid systems in which power relationships alone controlled the social order and in which no means were provided for individuals to realize their potentialities.

Another possibility is that individual needs are fully indulged, regardless of the necessities of the society. If, however, individual and social demands are incongruent, this would lead to total anarchy and social collapse. Being the social animal he is, the individual himself could not survive.

The final, most optimistic, and, I hope, most realistic possibility is that the social system conferring the greatest freedom on individuals to find their maximum fulfillment is also the system that best serves the group as a whole, that the diversity among people, if allowed to be manifested, would generate a beneficent and stable social organization. This would mean that evolution, acting over several millions of years, has achieved the development and preservation of human differences that are molded to human social needs. If so, we should observe genetically based individual differences that could not be classified along an inferior-superior dimension but rather would reflect qualitative differences in ways of perceiving the world, in strategies of thinking, that derive their value from within a social context. Additionally, if such variations are found, we would need to gain some understanding of how a mechanistic evolution could produce such a precise fit of man to society and of society to man.

In the next section I will discuss certain lines of evidence for inherent variations in human brain organization, and in the final section I will offer some speculations on the nature of selective forces that could create a true *Homo socialis*, a creature designed to generate a beneficent and stable social system that, in turn, would fulfill his humanity.

HUMAN BRAIN ORGANIZATION AND ITS VARIETIES

Over the last fifteen years or so, studies of human brain organization have begun to reveal a remarkable degree of variation from person to person in certain critical anatomical and functional patterns having direct relevance for cognition, emotion, and behavior. Further, the evidence that a significant portion of this variation derives from genetic differences is now compelling.

The Nature of Human Brain Asymmetry. The history of the scientific study of such differences began more than one hundred years ago in Montpellier, France. In 1836 Marc Dax reported that following damage to the left side of the brain, people suffer disorders of language. Dax failed to publish his findings, and they were lost to the scientific community for almost forty years. Unaware of this research, Paul Broca, another French neurologist, reported similar results in 1861, and only in 1865 did Dax's son belatedly publish his father's work.[1] The Dax/Broca conclusion, that language functions were localized to the left side of the human brain, was confirmed repeatedly in laboratories and clinical settings all over the world; there came to be a general acceptance that, even though the two cerebral hemispheres look grossly symmetric, their functions are profoundly different.

The left cerebral hemisphere was described as the "dominant" hemisphere on the assumption that if it is the seat of language it also must be the organ of thought, responsible for interpreting sensory input and for the planning and control of behavior. The right side of the brain was conceived to be nothing more than a relay station. Since the predominant sensory-motor connections of each cerebral hemisphere are with the opposite side of the body and the opposite side of space, the function of the right hemisphere, in this view, was to transmit signals from the left sensory field to the left hemisphere for processing and to convey commands from the last half of the brain to the muscles on the left side. By the end of the nineteenth century we had been reduced to a half-brained species, and this conception was to characterize neurological thinking until the middle of this century. Yet, beyond the purely biological pecularity of this perspective, there was direct empirical evidence against it.

Even before the end of the nineteenth century the English neurologist John Hughlings Jackson had noted that damage to the right side of the brain seemed to produce difficulties in recognizing objects, and he suggested that the right hemisphere was as specialized for certain perceptual operations as was the left for language.[2] During the next sixty years supporting observations accumulated, right-side damage being found to be associated with difficulties in recognizing faces (one French farmer even complained that he no longer could recognize the faces of his cows!), reading maps, drawing, doing jigsaw puzzles, and understanding three-dimensional relationships. Remarkably these data had little effect in dethroning the left hemisphere from its dominant position. Rather some suggested that the symptoms following right-hemisphere damage were a direct consequence of pathological overactivity in the left hemisphere resulting from its loss of inhibition by the right. Under such a model of course no amount of data from patients with right-sided brain damage could ever establish any special functions that this hemisphere might have.

Beginning in the early 1960s, however, a very special group of neurological patients became available for study, and investigations of the psychological characteristics of these people could leave no doubt that the right hemisphere, like the left, was a highly specialized organ of human thought.[3] These patients, all epileptics, had undergone total neocommissurotomy, in which all the bridges of fibers (commissures) connecting neocortical regions on the two sides of the brain were surgically sectioned. The surgery is highly effective in attenuating or abolishing epileptic seizures and seems to have few debilitating psychological or behavioral consequences for everyday life: Walking, talking, swimming, bike riding, piano playing, typing, and other typical presurgical activities remain at a normal level.

However, observations of these patients in a laboratory setting reveal that each hemisphere of split-brain individuals has a mind of its own that is completely out of conscious contact with the mind on the other side. Visual stimuli displayed in the left visual field, and projecting to the right hemiretinae of both eyes, are seen by the right hemisphere and vice versa for visual stimuli displayed in the right visual field. Similarly objects placed in the left hand are perceived by the right hemisphere, and objects placed in the right hand are perceived by the left hemisphere. In normal people the cerebral commissures convey information from one hemisphere to the other, so that both sides have access to information from both sides of space. However, split-brain patients have no means for such interhemispheric transfer, and information presented to one sensory half-field is restricted to the opposite hemisphere.

The differences in language capacity of the hemispheres are seen in the fact that pictures presented in the right visual field or objects placed in the right hand can be readily named, while pictures presented in the left visual field or objects placed in the left hand cannot be verbally identified. If patients are given the opportunity of choosing from among a set of pictures one that depicts what the left hand has felt or what was presented in the left visual field, the right hemisphere has no difficulty in selecting the correct picture. In other words, though mute, the right hemisphere knows what it has perceived and, given any nonverbal means for revealing its knowledge, will do so without hesitation.

In visual tests it is necessary to present stimuli for only a fraction of a second while patients are focused on a fixation point so that eye movements cannot shift the relative location of stimuli: Any stimulus to the left of fixation projects to the right hemisphere, and any stimulus to the right of fixation projects to the left hemisphere. If patients were to shift their point of fixation, a stimulus originally in one visual half-field could be displaced into the other. Voluntary eye movements require about one-fifth of a second, so if stimuli are flashed for a shorter duration they disappear before a refixation of the eyes can occur. This rapid-flash technique has been used in a large number of studies with split-brain patients and has been of great value in enabling us to gain an understanding of hemispheric differences.

By presenting different types of stimuli to the two sensory half-fields and asking patients to perform various tasks based on the information contained in those stimuli, it is possible to compare the abilities of the two sides of the brain. In one of our tests we flashed photographs of two different faces, one face to each hemisphere, and asked patients to point to the face they had seen from among a set of choices shown in free vision.[4] Since each hemisphere had seen a different face, it was possible that patients would point to two choices. Instead all patients made only one choice: They pointed to the face seen by the right hemisphere, totally ignoring the face seen by the left hemisphere. It was as if the left hemisphere were totally unconscious. We then flashed the faces again, this time removing the choice faces and asking patients to describe the face they had seen. A single face was described, and this was the face seen by the speaking, left hemisphere, an expected result since the right hemisphere is mute.

By requiring a verbal description we could compel the left hemisphere to respond, but when matching of faces was required—a response of which either hemisphere is capable—the right side of the brain totally dominated the processing of stimulus information and behavioral control. This finding is concordant with the observation that damage to the right hemisphere often produces difficulties in recognizing faces. The brain is a highly adaptive organ, and the hemisphere that is superior for a task typically becomes activated and takes control of behavior.

Right dominance also was seen for matching of nonsense shapes, various designs, and pictures of common objects. The left hemisphere assumed dominant control over behavior when patients were asked to select pictures named by flashed words, to select choice pictures having some functional relationship with flashed pictures (e.g., a knife and fork when the flashed picture was a cake), or to select choice pictures having names that rhyme with flashed pictures (e.g., a picture of a pie when the flashed picture is an eye).

These, as well as other studies, show the right hemisphere to be superior to the left in recognizing and remembering faces, shapes, and pictures, in mentally folding two-dimensional drawings into three-dimensional objects, in detecting whether an array of dots is aligned in rows or in columns, in matching arcs of circles with whole circles of the same diameter, and in detecting and noting invariants in spatial relationships or geometric or topological classes. Conversely the left hemisphere is found to be superior to the right not only in speech, as expected, but also in the understanding of complex syntactic structure, in phonetic analysis, in responding to conceptual similarities, and in arithmetic operations.

The investigations of split-brain patients, as well as investigations of normal individuals by means of specialized techniques, lead to the conclusion that the left hemisphere is asymmetrically involved in analytical, logical, and deductive reasoning, in understanding time and in discriminating temporal patterns, and possibly in understanding temporal causality, while the right hemisphere is asymmetrically important in the synthesis of overall form, in representing memories in terms of rich sensory experiences, in the understanding of space and spatial relationships, and in encoding and remembering stimuli and events that are resistant to verbal description. It appears that each hemisphere is predominant in and specialized for a set of functions complementary to those on the other side. Although it is almost certainly inaccurate to say that normal people, in whom the two hemispheres are in intimate contact and collaboration, have "two minds," it does appear to be the case that, by virtue of having two differently specialized hemispheres, people have available two very different ways of seeing the world, two types of strategies for apprehending and organizing reality. Moreover, because the two hemispheres can interact, normal people have the possibility of a creative and adaptive synthesis of the best that each hemisphere has to offer.

But what does the asymmetry of the human brain have to do with human social organization and, in particular, with the differentiation of social roles? Before considering this question I shall discuss the evolution of brain asymmetry.

The Evolution of Brain Asymmetry. In many animals, including birds, the hemispheres are asymmetric, but these are not homologues of the asymmetries found in man and are highly unlikely to have similar behavioral consequences. It is within the primate line that clues to the evolution of cerebral asymmetry in man can be found.

Because the two hemispheres look grossly symmetric, it was thought for many years that anatomical correlates of the functional differences between the two sides of the brain must be too subtle to be detected. However, N. Geschwind and W. Levitsky found that in the majority of human brains the left planum temporale, on the superior surface of the temporal lobe and in the heart of the language area, was larger than the homologous region on the right.[5] S. F. Witelson and W. Pallie and J. A. Wada, R. Clarke, and A. Hamm subsequently observed the same asymmetry in infant brains.[6] M. LeMay and A. Culebras reported that the left parietal operculum, at the superior border of the posterior Sylvian fissure and also part of the language region, was larger than the right parietal operculum in the majority.[7] Following these reports, a number of researchers described morphologic asymmetries of the hemispheres, in width or length of various lobes, in length and pattern of the Sylvian fissure, and in branching and patterning of cerebral blood vessels.

When it became clear that there were anatomical differences between the two sides of the human brain that appeared to be related to functional lateralization, the question arose as to whether primates other than man displayed similar asymmetries. LeMay and Geschwind, in examining the brains of great apes, found differences between the two sides of the brain resembling those seen in people.[8] G. H. Yeni-Komshian and D. A. Benson observed that in chimpanzee brains the Sylvian fissure was longer on the left than on the right, as it is in people, but that monkeys did not display a significant difference in fissure length (although the left Sylvian fissure was somewhat longer than the right fissure).[9]

The Yeni-Komshian and Benson study suggested that hemispheric asymmetry was confined to the hominoids among primates; this is congruent with C. R. Hamilton's failure to detect any functional lateralization for visual tasks in split-brain monkeys.[10] However, it now appears that monkeys, like apes and people, have morphologic and other functional differences between the two sides of the brain. D. P. Cain and Wada examined seven baboon brains and determined that in six the right frontal pole was longer than the left, an asymmetry observed in the human brain also.[11] Additionally M. R. Petersen et al. tested the discrimination of the left and right ears (reflecting, respectively, discrimination by the right and left hemispheres) of five Japanese macaques and five other Old World monkeys for a communicatively relevant conspecific call of the Japanese monkeys.[12] All five Japanese monkeys had a right-ear (left-hemisphere) superiority, but the other monkeys, for which the stimulus was a meaningless sound, showed no ear asymmetry. Similarly the Japanese monkeys had no ear asymmetry for a communicatively irrelevant stimulus. The left-hemisphere specialization in Japanese macaques for the analysis of communicatively significant sounds is strongly analogous, and perhaps homologous, to the lateralized mechanisms used by people for analyzing speech.

No functional studies that investigate lateralization of processing in apes have yet been reported.

That monkeys are lateralized with respect to the discrimination of conspecific communication signals but evidently are not lateralized with respect to visuospatial analysis means that different processes evolved asymmetrically at different rates and that "lateralization of function" does not describe some unified characteristic applicable to any higher cognitive process. In people the evidence is overwhelming that, regardless of the sensory modality utilized for receiving information and regardless of the nature of processing requirements, most higher cognitive operations are asymmetrically dependent on one side of the brain or the other. Evidently then, although some aspects of lateralization characterized the common ancestor of monkeys, apes, and man, this was not true of all, and there were considerable evolutionary changes in brain lateralization following the monkey-hominoid separation.

Additionally, since various cognitive processes appear to have become lateralized at different rates and therefore are at least partially independent with respect to cerebral representation, there is no necessary concordance between either the direction or the degree of functional asymmetry of one type of cognitive process and another. Although it may be that a majority of people have one hemisphere specialized for speech, language comprehension, reading, temporal analysis, and deductive reasoning, and the other hemisphere specialized for visuospatial analysis, memory for nonverbal sounds, face memory, and a variety of other nonverbal functions, this would not necessarily have to hold for all. The degree of asymmetric representation for speech, for example, might be considerably greater than that for reading, or speech might be specialized in one hemisphere, while reading is specialized in the other.

The evolution of cerebral asymmetry, as inferred from studies of monkeys and apes, suggests that many different patterns of brain lateralization might be found in the human population. Although the lateralizing of cognitive processes—entailing as it does a deduplication of function that would be found in a perfectly symmetric brain—would be expected to provide a more efficient use of neural space, greatly increasing the informational complexity of a fixed amount of neural tissue and yielding greater cognitive power than would be possible for a symmetric brain of the same size, there are no obvious reasons for supposing that one particular type of laterality pattern invariably must characterize all human brains. If people vary in their patterns of cerebral asymmetry, this variation may be the neurological manifestation of differences in ways of perceiving the world, in skills, or in propensities.

Variations in Cerebral Asymmetry: Handedness. The first evidence that not all people have the laterality pattern typical of the modal individual came from studies of left-handed neurological patients suffering damage of either the left or right hemisphere. Some were found to develop language disorders after left-hemisphere lesions, as is usually the case in right-handers, but some were found to manifest aphasic symptoms after damage to the right side of the brain—an extremely rare occurrence in right-handers. Additionally a substantial proportion of left-handers seemed to be at risk for aphasia regardless of which side of the brain was injured. Thus, in a random sample of neurological patients having damage on one side of the brain, no more than 50 percent would be expected to display linguistic disorders if language is strictly unilaterally organized; yet, among left-handers, from some 70 percent to 80 percent develop an initial aphasia that, in a large fraction, is transient. These observations imply that in left-handers, much more frequently than in right-handers, there is a bilateral representation of language: Damage to either side therefore can produce a temporary disruption of function, but with time the intact hemisphere can assume control of processing.

In recent studies in which one side of the brain is inactivated briefly by intracarotid injection of an anesthetic drug, many more left- than right-handers became aphasic after injections on either side or failed to become aphasic after injections on either side, again indicating bilateral language representation.[13] Also, confirming inferences from patients with unilateral brain damage, many more left- than right-handers developed aphasia after right-side, but not left-side, injections. It appears that left-handers not only differ from right-handers but are highly variable among themselves in the degree and direction of lateral asymmetry for speech and possibly for other cognitive functions as well.

Investigations utilizing noninvasive techniques of normal people confirm and expand inferences drawn from observations of neurological patients. The typical right-hander is more accurate or faster at identifying words briefly flashed in the right visual field (left hemisphere) or heard in the right ear (left hemisphere), compared to those presented in the left sensory field (right hemisphere). Conversely a left-sensory-field superiority emerges for nonverbal tasks such as face recognition, detecting the location of a flashed dot, or discriminating musical chords or various environmental sounds that are not easily verbally describable. Although the cerebral commissures permit transmission of information between the two hemispheres, there is an information loss and/or time delay entailed by transcommissural communication that is reflected in the perceptual asymmetries that have been observed.

Thus it is possible to infer the direction and degree of hemispheric specialization from the direction and magnitude of perceptual asymmetries manifested on different types of cognitive tasks. When studied by these techniques, left-handers display much variation in their patterns of cerebral organization: A significant fraction show considerably smaller asymmetries than do right-handers; some are strongly lateralized but in the opposite direction from right-handers;

and others seem to differ little from the dextral pattern. Further, in a recent study, language functions in left-handers, as assessed by asymmetric suppression of the electroencephalogram (EEG) alpha rhythm during performance of various tasks, were found to be nonunitary.[14] For some left-handers one hemisphere was more active during writing or reading, while the other hemisphere was more active during speaking. Similarly there were dissociations between verbal and nonverbal tasks with one hemisphere being more engaged in the nonverbal task and the same hemisphere being also more engaged in one or more verbal tasks.

I. Gloning et al. examined fifty-seven non-right-handed patients, all of whom had been trained to write with the right hand and seventeen of whom reverted to left-hand writing after leaving school.[15] They found an extremely strong association between the probability of developing disorders of reading and writing and the writing-hand/hemisphere-of-lesion relationship: Many more patients became agraphic or alexic when the damaged hemisphere was contralateral to the writing hand than when it was ipsilateral. A much weaker association was found for disorders of speech: Some 40 percent of patients with damage to the hemisphere on the same side as the writing hand suffered loss of speech. The Gloning et al. observations reveal the nonunitary character of language representation in the brains of left-handers.

Further evidence for the dissociation of different linguistic functions in left-handers is provided by the relationship between the lateralization of language functions and the hand posture adopted during writing (either noninverted [*N*] in which the hand is held below the line of writing and the tip of the pen tends to point toward the top of the page or inverted [*I*] in which the hand is held above the line of writing and the tip of the pen tends to point toward the bottom of the page). We found that, in left-handers adopting the *N* posture, reading was specialized in the right hemisphere and visuospatial functions in the left hemisphere, the reverse being observed in those adopting the *I* posture.[16] Herron et al. found similar associations of hand posture with laterality as indexed by asymmetric alpha EEG suppression measured over the occipital lobes.[17]

However, L. C. Smith and M. Moscovitch observed no associations of hand posture with laterality for discriminating spoken words, Herron et al. found no associations for alpha EEG picked up from central or parietal leads, and B. Milner found no associations for speech localization indexed by the hemispheric-inactivation procedure.[18] These results mean that visually lateralized functions display one asymmetry pattern in left-handers, while speech and auditory discrimination of language have an unrelated lateralization pattern.

Some researchers have suggested that the modal laterality pattern observed in right-handers is a species-specific trait and that any deviations from this pattern are a result of undetected pre- or perinatal brain damage that induced a developmental reorganization of the brain. Although unusual patterns of brain asymmetry may be due in some cases to pathological factors, this cannot be the case for all left-handers. First, among right-handers, the family handedness pattern has effects on cerebral laterality: Dextrals with sinistral relatives display smaller perceptual asymmetries on tests of functional asymmetry than do dextrals from purely dextral families. Moreover, among neurological patients, familial right-handers only very rarely recover from aphasia concomitant with left-hemisphere lesions, but right-handers with left-handed relatives have a good probability of recovery.

Infants display a wide variety of behavioral asymmetries at birth, in addition to the morphologic asymmetries of the brain that have been previously mentioned. Most babies have a bias for rightward turning, and the direction of the turning bias is correlated with handedness at age two and ten. Of importance with respect to the etiology of these biases is the fact that babies having two right-handed parents display the right-turning bias, while those with one left-handed parent display no bias in either direction, independently of whether it is the mother or the father who is left-handed. This observation demonstrates beyond any reasonable doubt that genetic factors play a significant role in determining neonatal turning biases, handedness, and related asymmetric traits.

The human population evidently is genetically variable in handedness and in the degree and direction of cerebral asymmetry. Also left-handers are far too numerous (about 10 percent to 12 percent of the population) to be explained as random mutants. Hence while all human beings, to one degree or another, have brain asymmetry, we are confronted with the problem of accounting for the fact that there is considerable genetic variation in both its direction and degree and in the unity or dissociation of various cognitive representations.

Variations in Cerebral Asymmetry: Gender. The variations in laterality patterns that distinguish left-handers from right-handers, and those using the noninverted hand posture from those using the inverted hand posture, occur in both males and females, but there are other differences in brain asymmetry that distinguish the two sexes. A number of laboratories have found that females display smaller perceptual asymmetries on laterality tests than do males on both verbal and nonverbal tests, suggesting that functional differentiation of the hemispheres is less extreme in girls and women. This inference is supported by observations of neurological patients that reveal greater symptom differentiation as a function of which hemisphere is damaged in males compared to females.

Left-hemisphere damage results in less severe linguistic disorders in women than in men and in a greater probability of perceptual disabilities. Similarly right-hemisphere damage has a smaller probability of disrupting visuospatial function in women than in men and a greater probability of interfering with certain logic-verbal tasks.

The rate of maturation of the two hemispheres also may differ for boys and girls. Although the hemispheres are functionally distinct at birth, each gains progressively greater competence within its domain of specialization as development proceeds. Prior to a certain level of maturation, the child either is totally incapable of certain cognitive tasks or performs them poorly and relies on primitive and unlateralized strategies. It is thus possible to investigate the age at which the child first manifests asymmetric hemispheric capacity for various tasks as an index of the rate of hemispheric maturation.

A right-hemisphere superiority for visuospatial tasks typically emerges earlier in boys than in girls, while a left-hemisphere superiority for verbal and related cognitive tasks has been found in some studies to emerge earlier in girls than boys. A possible interpretation of these maturational differences is that verbal skills are selectively encouraged in girls, while spatial-mechanical skills are selectively encouraged in boys. This would say that the two sexes do not differ biologically in hemispheric maturation rate but instead develop differently due to different cultural experiences.

This interpretation is, however, contradicted by data gathered by Marylou Reid on left-handed children with the mirror pattern of brain organization (i.e., lateralization is in the opposite direction from that of typical right-handers).[19] In these children the left, visuospatial hemisphere matured more rapidly in girls, and the right, verbal hemisphere matured more rapidly in boys. Under the cultural-conditioning hypothesis, the reverse maturational pattern would be expected. Evidently the female left hemisphere and the male right hemisphere develop more rapidly, independently of the nature of their cognitive specializations. Although cultural factors could affect directly the maturation of cognitive functions, they could not selectively affect whether it is the left or right hemisphere that has the developmental advantage. Biological differences in the two sexes apparently control hemispheric maturation rates through undetermined mechanisms.

It is probable that the fetal sex hormones play a significant role in brain lateralization. Women with Turner's syndrome, having an *XO* sex-chromosome complement and gonadal dysgenesis, display less hemispheric asymmetry than normal *XX* women. Although it is generally thought that the normal female fetal ovaries are hormonally inactive, this is almost certainly incorrect. The pituitary hormone, FSH, is under feedback control from ovarian hormones and is found to be at a significantly higher level in Turner's fetuses than in normal fetuses—an observation that is only easily explained by the assumption that the normal female fetus can regulate FSH output via ovarian activity, while the absence of ovaries in Turner's fetus makes this impossible.

Recent data from our laboratory also suggest that women whose mothers were treated with diethylstilbesterol (DES) during pregnancy are less lateralized than other women. DES is a nonsteroidal synthetic estrogen, and its presence may suppress normal steroidal estrogen output. To the extent that cerebral lateralization may depend on the presence of fetal steroids, the reduced lateralization of both Turner's patients and women whose mothers were treated with DES is explainable. Also the normal male fetus has much higher steroid levels than the female fetus, and this may play a role in differentiating the sexes with respect to brain asymmetry.

Correlates of Variations in Brain Asymmetry. The fact that people are found to vary in brain lateralization patterns indexed from specialized laboratory tests, and the evidence that these variations are, to a significant degree, genetic in origin, nevertheless would have no sociobiological implications if the neurological differences had no consequences for normal psychological and behavioral function. Although the data are far from complete at this point, those that are available indicate that differences in laterality patterns result in differences in behavior and psychological structure.

Left-handed university students have been observed to be equal or superior to right-handers in verbal processes but significantly inferior in certain visuospatial skills. In contrast, among architecture students, left-handedness is associated with unusually high visuospatial skills and the frequency of left-handedness increases from freshman through senior years. In other words, it appears that a substantial fraction of left-handers are cognitive specialists, either being especially able at verbal functions or especially able at visuospatial functions—a conclusion that is concordant with the fact that many are weakly lateralized. If verbal functions are bilateralized into both hemispheres, high verbal and depressed spatial abilities would be expected; if, on the other hand, spatial functions are bilateralized into both hemispheres, high spatial and depressed verbal abilities would be expected.

There is an unusually high frequency of sinistrality among law students, as well as among music and art students, again indicating a great variation within the left-handed population with respect to neurological and psychological organization.[20] Interestingly J. M. Peterson found an unusually low frequency of left-handedness among science students, although I found that left-handed graduate students in science at the California Institute of Technology surpassed right-handers on certain aspects of verbal reasoning.[21] D. Deutsch found that weakly left-handed individuals surpassed all other groups in pitch discrimination, possibly accounting for the high frequency of left-handers among music students.[22]

With Reid, I found that left-handed males were highly variable in their performance patterns, some performing well on the verbal test and poorly on the spatial test, and vice versa for others.[23] Reid, in her doctoral research, found that children typically performed best on standardized tests that measured the specialized functions of the earlier-developing hemisphere.

Although almost all right-handers have speech specialized in the left side of the brain, like left-handers, they are variable in the degree of hemispheric asymmetry as indexed either from behavioral laterality tests or from EEG measures. P. K. Oltman, H. Ehrlichman, and P. W. Cox and P. Zoccolotti and Oltman found that the degree of perceptual asymmetry manifested on either verbal or nonverbal tests was related to cognitive style: Subjects with large asymmetries had a field-independent cognitive style, characterized by relative autonomy from external referents, high spatial restructuring ability, and relatively autonomous interpersonal behavior, the reverse, field-dependent cognitive style being observed in those with small perceptual asymmetries.[24] Oltman, C. Semple, and L. Goldstin measured the correlation between hemispheres in EEG amplitude fluctuations over time, finding more similarity (higher correlation) between hemispheres for field-dependent right-handed males (females and left-handers were not included in the subject sample) than for field-independent subjects.[25]

People are highly variable in the extent to which they rely on one hemisphere or the other when confronted with a cognitive problem or with an emotional situation, independently of whether the activated hemisphere is necessarily the more appropriate. One index of hemispheric usage is the direction of lateral eye deviation when an individual is asked a reflective question. Most people, when asked a reflective question, momentarily break eye contact with the questioner, look toward the left or the right, and then recenter their gaze before answering the question. In a face-to-face situation, people are consistent in their lateral deviations and can be classified as "right-movers" or "left-movers." R. C. Gur and R. E. Gur have found a number of dimensions on which right-movers and left-movers differ and provide a review of similar observations reported by others.[26] Right-movers perform better than left-movers on tasks requiring focused visual attention, but left-movers report clearer visual images. Left-movers have more waking EEG alpha activity, more frequently major in the humanities and social sciences, and score better on the verbal than on the quantitative section of the Scholastic Aptitude Test (SAT). Right-movers are less likely to display waking EEG alpha, more often major in the natural sciences, and have higher scores on the quantitative than on the verbal section of the SAT. Left-movers are more hypnotizable than right-movers, regardless of the nature of hypnotic induction, but the former show relatively superior induction when instructions are phrased in a passive and emotional style, while the latter show relatively superior induction when instructions are phrased in an active and intellectual style.

The psychological correlates of eye directionality show opposite patterns for right-handed males and left-handed females, providing support for the view that eye directionality is related to hemispheric activation. Further support is provided by the observation that when the experimenter is outside the subject's line of vision, and eye movements are recorded by camera or by electrooculograms, eye directionality, instead of being an individual-difference dimension, reflects the nature of the question asked. For right-handers verbal questions induce rightward eye movements, and spatial questions induce leftward eye movements. The Gurs have proposed that the face-to-face situation is anxiety inducing and causes subjects to rely on a habitual mode of response, independently of its appropriateness for the situation, whereas when the experimenter is outside the subject's line of sight, anxiety is reduced, and individuals adaptively activate the more apropriate hemisphere for the task at hand.

Orientation reflexes (eye turning, head turning, whole-body turning) are related to hemispheric activation in all vertebrates that have been studied. Typically lateral orientations are induced by the appearance of a stimulus in one or the other sensory field, the stimulus projecting to the contralateral hemisphere, producing a momentary higher activation of that hemisphere, and resulting in an orientation reflex toward the source of stimulation. Stimulation of a hemisphere by an electrode also produces contralateral turning, while, conversely, destruction of portions of a hemisphere (which reduces its activity level compared to the intact side) often results in ipsilateral turning. In people in whom the two hemispheres are functionally asymmetric differential activation of the hemispheres and the concomitant contralateral orientation reflex can be induced by thinking itself.

Differences among people in hemispheric activation patterns that are related to cognitive performance also have been observed with EEG measures. C. J. Furst found that there was a substantial correlation between subjects' ability on a spatial task and the relative activity levels of the right and left hemispheres: The greater was right hemisphere activity compared to left hemisphere activity, the better was spatial performance, and this was true not only of hemispheric activity patterns observed during task performance but also of baseline hemispheric activity.[27] The fact that good and poor performers differed in baseline activity patterns indicates the existence of stable individual differences in the lateralization of hemispheric activity that are present even when subjects are not engaged in the cognitive task.

R. C. Gur and M. Reivich measured regional cerebral blood flow in normal subjects by having then inhale ^{133}xenon while sodium iodide crystal emission detectors measured the clearance rate from cerebral blood vessels.[28] Subjects were all right-handed and a verbal task induced increased left-hemisphere blood flow, but a spatial task induced only a nonsignificant increase in right-hemisphere blood flow. However, subjects showing an increased right-hemisphere flow performed better on the spatial task than subjects showing either no change in flow or an increased left-hemisphere flow, and those having an increased right-hemisphere flow were typically left-movers.

The eye-movement, EEG, and blood-flow studies are all consistent in suggesting that people differ in the activation of the two cerebral hemispheres and that these individual differences have major effects on cognitive, emotional, and personality function. The within-sex variations in brain laterality are evidently important factors in psychological differences.

Gender Differences in Behavior. The psychological literature is replete with studies showing that males and females differ on a number of psychological dimensions, but there is a great deal of controversy regarding whether these differences are biological or cultural in origin and whether they are related to the observed differences in the sexes in brain asymmetry. In general males have been found to be superior to females in map reading, three-dimensional visualization, understanding of physical principles, and mathematical reasoning, while females have been found to surpass males in reading skills, verbal fluency, noting of fine visual details, incidental memory (i.e., noting and remembering of aspects of experiences that have no direct bearing on a particular well-structured task), pure associative memory (where a well-structured cognitive framework is not available for the organization of new information), and understanding of social relationships.

There have been recent suggestions that males are superior in right-hemisphere processes and females in left-hemisphere processes, with others suggesting the opposite. However, a consideration of the nature of male-female differences makes it apparent that these cannot be explained by a hemispheric dichotomy. Figural completion, in which subjects must identify an object from its fragmentary representation in a picture, is a right-hemisphere process, but males are not superior to females at such completion tasks. The superiority of males to females on three-dimensional visualization, another right-hemisphere task, suggests that the intrahemispheric organization of the right hemisphere differs in the two sexes. This conclusion is supported also by the observation that females surpass males in understanding the meaning of facial expression, another right-hemisphere process.

The organization of the left hemisphere also seems to differ between the two sexes. Although females, as mentioned, are superior to males in reading skills and in verbal fluency (left-hemisphere processes), they are not superior to males in verbal reasoning (also a left-hemisphere process) and are inferior to males in mathematical reasoning. Mathematics is a formal language and differs from natural languages in that its content is purely denotative and in that there are no metalinguistic factors (tone of voice, actual concrete referents, etc.) that affect its meaning.

In brief, there are some right-hemisphere processes in which males surpass females, others in which the sexes do not differ, and still others in which females surpass males. The same holds with respect to left-hemisphere processes. The smaller degree of asymmetry between the female hemispheres seems to be related to a field-dependent cognitive style which is more prevalent in females than males. The admixture of verbal and perceptual processes within the same hemisphere in females, versus their extreme separation into different hemispheres in males, may play a critical role in the psychological differences in the sexes.

With an admixture of functions, it would not be unlikely that there could be a more intimate integration of verbal with nonverbal processes that is not dependent on some formal mapping function between the two. With separation of functions in the two hemispheres, and integration dependent on transcallosal communication, more highly structured verbal and nonverbal representations may be required. This is to suggest that in males there may be a serious difficulty in integrating experiential representations that bear a close resemblance to the original perceptual experiences: The "languages" of the two hemispheres would be too disparate to permit such direct experiential integration. Rather it may be necessary for representations to be transformed into highly abstract codes that can be mapped from one hemisphere to the other.

Both hemispheres of the female may be able to retain and integrate all the richness and variation of experience, whether capable of being put into a formal, abstract structure, while both hemispheres of the male, unable to deal with continuously varying sensory input, may ignore "irrelevancies" in favor of abstract invariants that persist even as context varies. In this view females would show deficiencies, relative to males, in reading maps because of their sensitivity to the radical differences between the world of experience and its representation as abstract lines on a map; for males the invariants between maps and the world they represent would be easily perceived since the world in the first place was encoded as a set of abstract relationships.

The superiority of females to males in understanding the social world would derive from their ability to note, remember, and integrate a wealth of information that is relevant for appreciating social interactions. For the male a "theory" guides his perception of social events that directs his attention to only a subset of events from which he attempts to extract some "principle" that represents his understanding. Males in general may be disposed to seek rules and invariances that provide summaries of the physical world and constitute their conception of reality, while females may be disposed to note and remember all the richness and variety of experience that then can be utilized to draw accurate conclusions, even when those conclusions may not be susceptible to formal proof.

If these descriptions of the male and female orientations to the world are valid, they would suggest that females are specialized for understanding the social world (requiring a capacity for incorporating, remembering, and integrating all the rich details of experience that have no a priori, necessary relationships among themselves) and males are specialized for understanding the physical world (requiring the abstraction of formal context-independent principles from which relations among events can be deduced). The "field dependence" of females, limiting performance in some situations, becomes a "context sensitivity" in other situations which greatly benefits performance. Similarly, although field independence is valuable for males in facing many problems of the physical world, it becomes a context insensitivity leading to invalid conclusions in other, and particularly in social, situations.

Some of the communicative difficulties between males and females may derive from this source. Women expect men to be as sensitive as they in understanding emotions, psychological needs, and human behavior, and when such understanding is not displayed it is often interpreted as a lack of caring on the part of the man. When the inevitable emotional scene occurs, the bewildered male often says, "Well, just tell me what you want!" The problem of course is that females think they are communicating clearly (and are doing so, in fact, if it is another female with whom they are communicating) and attribute (correctly) the communication failure to deficiencies in the male. It rarely occurs to most women that most men need much more direct communication of psychological needs and emotions than is required by women.

Men, in trying to understand women, suffer just as many frustrations. They perceive the female's inability to provide a rational (from the male viewpoint) justification for conclusions she reaches as some sort of cognitive defect and typically merely remain puzzled when those conclusions prove to be valid. At best, men laughingly call the female ability "women's intuition," as if there were no experiential basis whatsoever for the conclusions. The fact that people (especially women) are capable of drawing accurate inferences from situations that are vastly too complex for an analytic specification (and therefore too complex to be given a verbally satisfactory justification) is difficult to accept especially by men but even by those women who are unusually skilled in such activities.

An understanding by women that most males are simply not so capable as they would wish at reading the emotional and psychological states of others accurately, and an understanding and acceptance by men that women may not be able to provide a satisfactory "justification" for their conclusions because of the inferential complexity on which those conclusions are based, might go a long way toward decreasing the frustrating miscommunications that often mark male-female interactions.

Although many more data need to be gathered, it appears that the fetal sex hormones have a significant role in conditioning the differences in the brains of males and females. The effect of Turner's syndrome on brain laterality has been mentioned. These women, in addition to having weakly lateralized brains, manifest high verbal and extremely depressed spatial abilities: Both hemispheres, to some extent, are organized for verbal functions. As also previously noted, women whose mothers were treated with DES during pregnancy are more weakly lateralized than other women. J. M. Reinisch found that, compared to their unexposed siblings, children whose mothers received estrogens during pregnancy were more group oriented than individualistic and more group dependent than self-sufficient (characteristics of field-dependent individuals), while those exposed to progesterones (which generally have masculinizing effects on the fetus) were more individualistic and self-sufficient than their unexposed siblings (characteristics of field-independent people).[29]

Although proof is not yet available regarding the causal relationships between cerebral and psychological differences between the sexes and the causal role of biological versus cultural factors, certain conclusions seem justified: (1) The sexes differ in degree of brain asymmetry, males being more lateralized than females, (2) degree of brain laterality is affected by fetal sex hormone status, (3) cognitive style is related to degree of brain asymmetry and is affected in the same direction by fetal sex hormone status, and (4) the nature of the psychological differences between the sexes is congruent with the nature of the sex difference in brain laterality. These conclusions imply that to a significant extent the differences between the sexes in brain organization and the correlated psychological traits are biological in origin. Sociocultural factors almost certainly serve to magnify and reinforce whatever biological differences are present, but of course one then must account for the social system that encourages differentiation of sex roles.

The Evolution and Maintenance of Human Diversity

It is evident from recent studies on lateral asymmetry that there are large differences in the patterns of organization both within and between sexes; that these differences, to a major extent, are due to genetic variations; and that they have important consequences for psychological and behavioral function. Strongly asymmetric people seem to be cognitive generalists, and weakly asymmetric people seem to be cognitive specialists; some individuals rely predominantly on the left hemisphere and view the world from its perspective, while others rely predominantly on the right hemisphere having a perspective conditioned by the specialties of that side of the brain; those having a cognitive style that may be described as field independent or context insensitive have an extreme separation of verbal and nonverbal functions in the two hemispheres, and those who are field dependent or context sensitive have an admixture of processes within the same hemisphere. For the majority of right-handers there is a congruence in lateral representation of the various types of verbal or nonverbal functions, but in many left-handers processes within the verbal or nonverbal domains are laterally dissociated. The male brain organization seems to be designed to extract formal relational principles as these pertain to spatial or logical organization but in consequence seems to suffer a deficiency in contextual integration; the reverse is seen in female brain organization where the richness of experience is retained and integrated, but the sensitivity to subtle experiential variations interferes with formal structuring in terms of abstract invariants.

Although the neuropsychological variation of the human tapestry surely would serve social organization and stability, the question still remains as to how a mechanistic evolution could have preserved such variety. I would like to suggest that the concordance between social needs and the distribution of individuals available to fill those needs derived from the social structure itself. Most of the selective pressures that differentiated us from apes emerged not from the external physical environment but from the human social structure.

Much has been written in recent years regarding the effects of genes on social organization, but much less attention has been devoted to the effects of social organization on genes. While our genes condition the way we behave in a social group, the nature of the society we develop feeds back on the human gene pool and has strong selective consequences. The discovery that stones could be shaped at will into useful tools and weapons surely conferred new advantages on those skilled in the art of chipping stones and reduced the advantages of those whose skills lay mainly in recognizing stones of the proper shape. A social discovery, in other words, would change the selective forces acting on the gene pool. The development of medical science has changed radically the fitness differentials of various genotypes, resulting in a rapidly changing genetic structure since these medical innovations were introduced.

The evolution of altruistic and ethical behaviors has been attributed to either kin selection or to an expected reciprocity, but the existence of a social organization can generate a genetically encoded altruism that does not depend on an ultimate selfishness. The individual who, with no thought of achieving special rewards and with no thought of preserving his genes, is propelled to risk his life for others, thereby reducing his biological fitness, nevertheless may achieve higher fitness through fitness-enhancing social rewards that are bestowed. The social benefits obtained, though not sought and not playing any motivating role in his behavior, may outweigh greatly the fitness-reducing aspects of his altruistic acts. If so, altruistic behaviors will be selected. This would not be an altruism selected through kin selection or one predicated on an expected reciprocity: The neurological organization through which the behavioral effects of genes is manifested would be one propelling pure altruism and one that would be selected solely because the social group awards fitness-conferring benefits that outweigh the fitness-reducing consequences of the altruistic act.

However, were a population to evolve in which all members were equally altruistic, it may be expected that the social rewards conferred would be greatly reduced or even absent since there would be no special qualities to reward (and indeed no genetic variation on which selection could act). The rarity of a socially valuable trait would be expected to determine the extent of fitness-conferring awards bestowed. Fitness of the genotype would be frequency dependent, and when a genotype became prevalent its fitness, as determined by social benefits, would become reduced and its prevalence in future generations would decrease. The same would be expected with respect to cognitive and behavioral skills: When genotypes appropriate to fill needed social niches are underrepresented, social benefits should increase their fitness above the mean of the population; but when these genotypes are overrepresented, social constraints should reduce their fitness below the mean of the population. By such means a balanced polymorphism of various genetic types is achieved that brings into concordance the needs of the social structure with the genotypes available to fulfill those needs.

The genetic and the social structure coevolve so as to remain in congruence; as the genetic structure changes, so too does cultural evolution, bringing with it new selective pressures that act on the gene pool itself. Thus we have a very intimate, two-way causal interaction that results in an ever-increasing complexity of social organization which selects for genetic variation that is necessary to maintain social stability.

From this perspective it is obvious that there cannot be any "ideal" human being. We are defined by our variations that make possible a social system, and it is the system itself that gives us our humanity. Certain current ideas that all individuals are biologically identical and susceptible to being molded into some "perfect" type is a denial of our evolution, a denial of our social nature, and a denial of our mutual interdependencies. If there is any ethic at all that can be derived from our evolutionary history, it is that we must value and encourage the differences among us that simultaneously offer the possibilities of self-fulfillment and a stable, noncoercive, and beneficent social organization. Such a society, where each individual is valued for the unique contributions he can make, is in no danger of anarchy from the conferral of human freedom. A consideration of our evolutionary history and of the diversity it has provided should be sufficient to inform us that any social system that can maintain itself only through coercive power relationships contains the seeds of its own destruction. Each individual is embedded in a hierarchy of living organization, and if we can understand this with adequate wisdom we can maximize simultaneously the welfare of each human individual, of the human species as a whole, and of the entire planetary ecology.

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