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A theory on the biology of lateral dominance

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Introduction

Despite the occurrence of a considerable volume of investigative and speculative literature on lateral dominance, the pertinent anatomical and neurological differences and physiological bases are not yet understood. Many widely-accepted generalizations, based on clinical observations, have not been substantiated by statistical analyses of pertinent clinical data. The fundamental biological mechanisms involved are obscure, and potential clinical applications may be unexploited.

The expression of hand preference apparently begins shortly after birth, when the child tends to take hold of objects most frequently with the "dominant hand" (8). The phenomenon of handedness probably involves hereditary factors which predospose an individual to use preferentially his right or left hand (41). Some extreme behaviorists, however, continue to simply classify handedness as an acquired trait, in the tradition of the Watson school (43). Pavlovian concepts have been invoked to support the belief that functional asymmetry of the hands is based entirely upon conditioned reflexes (6). Thus, Bushrova postulates that the direct causes of the phasic character of asymmetry formation are the development of the baby's body in relation to the physical support provided. Three major studies published previous to Bushrova's report, however, substantiate the involvement of pertinent genetic factores (9, 34, 36). More recent extensive studies of this phenomenon by Falek (14, 15) indicate the major involvement of both genetic and nongenetic factores, and considerable variation in the relative importance of the different factors in different subjects.

Discussion

Female subjects have indicated a relatively low intragroup variation in lateral dominance, compared to males (14). This observation is in marked contrast to studies of metabolic characteristics, in which females generally indicate greater variability and range of variation than males (23, 24). Falek reported the occurrence of differential social-psychological pressures by and on the different sexes, which may explain the observed sex differences. There is no basis for hypothesizing the involvement

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of sex-linked genetic factors relevant to the determination of lateral dominance; and a preliminary working hypothesis may suggest that observed sex differences are essentially non-genetic in etiology.

The problem of cerebral hemispheric dominance is much more complex than had previously been considered (5). The concept that the "manual skills, language functions, — sighting and pedal skills are controlled mainly by one side of the brain, the other side functioning in only a rudimentary manner" (1) has not been proved and is apparently an oversimplification. The available evidence does not support the concept of a simple generalized lateral cerebral dominance. In fact, the frequencies and correlations of right - and left-handedness have been shown to vary according to the criteria selected for defining handedness and footedness, as well as with the age and sex of the subjects studied (28). Apparently, pertinent correlations do not occur between hand dominance and localizations of speech centers in the brain (37, 45). Ascribed relationships between left-handedness and stuttering, and between imposed reversal of hand dominance and stuttering, are statistically unproved and disputed (30, 38). Reported correlations of hand dominance with eye dominance have varied from the profound to the insignificant, depending upon the investigators and the methods of study employed. The various popular methods of measuring eye dominance (10, 12) have been criticized as being essentially tests of eye-hand coordination and not necessarily correlated with the explicit phenomenon of eye dominance (19). The lack of a consistent correlation between hand dominance and eye dominance (42), and the inconsistency of definitions and reported criteria of eye dominance make questionable the hypotheses concerning correlations with hand dominance. The values of conclusions based upon alleged tests of eye dominance are further compromised by the fact that the eye which controls the interpretation of binocular vision is not necessarily the dominant (i.e., sighting) eye in essentially monocular functions (3).

Anthropomorphic explanations have been projected which speculate a physiological competition between different homologous parts of the central nervous system. Frauchiger, who asserts that the key to lateral dominance lies in the median structures of the thalamus, concludes that the observed laterality is the result of a "struggle for dominance between the two halves of the thalamus" which are neither anatomically nor functionally equal (16). There is no more objective basis for explaining the physiology of lateral dominance primarily in misused terms of 'social Darwinism' (21, 25), as Frauchiger postulates, than there is for dismissing all factors other than reflex conditioning, as Bushrova indicates (6). The dogmatic assertions in both of these extreme views have apparently been modulated by the authors' respective contextually prevalent social-cultural-political philosophies: in the former case, the concept that all natural organization literally involves a "struggle for dominance" between "unequal" protagonists; in the latter case, the concept that individual differences are explained only in terms of Pavlovian reflex conditioning.

Numerous anatomical and physiological variables have been reported to manifest correlations with differences in lateral dominance. The possibility of the occurrence of a correlation with the variations in dermatoglyphic patterns (13) has been suggested,

but is wanting in clarification and investigative corroboration. One of the most interesting physiological observations concerns the reported occurence, in left-handed individuals, of decreased electroencephalogram 'a' waves, and greater sensitivity to hyperventilation, compared to right-handers (42). While the reported correlations seem promising and provocative, their results are uncorroborated and their interpretations only speculative at the present time.

The organization of reciprocal relationships between two counterpoised sets of interacting functions is manifest by more or less periodic shifting ascendancies of the component functions with progressive integration and modulation of the resultant pattern (18). The term, laterality, does not refer to a unitary trait, and the observed lateral dominance for any particular trait is the dynamic result of an organic pattern that has been structured during development (4). Adherents to the hypothesis that lateral dominance or sidedness is a unit trait generally support the concept of lateral cerebral dominance as a basis for the "imbalance between the two halves of the body" (1). Extensive experiments have demonstrated that sidedness or lateral dominance is not unitary in character, and that the central balances related to different aspects of sidedness are not neurologically part of a unitary system (40). The studies of Smith and Akelaitis have demonstrated the complex character of sidedness, and that many different types of motor performance display varying degrees of sidedness and are not uniformly affected by lesions of the nervous system. Experimental cerebral lesions in rats reportedly have indicated that the rat's trait allegedly homologous to handedness may be under the control of a localized mechanism in the frontal region of the cerebral cortex (31). Large cortical destructions outside the frontal lobe, however, were ineffective in producing pertinent changes in the rat's "handedness". Other studies have failed to reveal any characteristics concerning locus, mass, or subcortical mechanisms responsible for the differences (32).

Two problems arise when handedness scores fall along a continuum (20): first, the magnitude of preference necessary to indicate significant laterality; and second, the constancy with which the degree of dominance is maintained. The former problem has not been objectively solved, but has been resolved for particular studies by arbitrary selections of criteria for categorization of 'right' and 'left' subjects. The latter problem has been studied extensively by Hillebrandt and Houtz (20). Basing their hypotheses on data from studies of the influence of physiological variations in stress on hand dominance, the following were among the conclusions reached:

1. the laterality distribution curve is unimodal and essentially normal in form;
2. the mean degree of functional superiority is moderate and falls to the dextral side of ambilaterality;
3. bimanual exercise tends to equalize functional performance;
4. both hands perform equally well under moderate stress, and differences in handedness cannot be evaluated;
5. fatigue augments asymmetry in functional capacity.

As a fundamental working hypothesis, manifestations of lateral dominance may be considered the results of the interactions of complex genetic potentialities and various

non-genetic variables. The genetic endowment sets the limits within which the environmental influences are able to act. In time, the complex strands of the organism's continuous adaptive responses to external influences are interwoven into patterns of functional lateral dominance (14, 15).

Problems and Hypotheses

Lateral dominance is not an absolute quality and signifies, rather, a conglomoration of degrees of functional preference which are subject to the multiple influences accounting for normal physiological variability. The lack of significant correlations between the results of numerous motor tests, as utilized to determine hand dominance (7), indicates that the different motor activities do not involve merely a single general or central laterality factor. These observations are compatible with the hypothesis of a multiplicity of laterality factors, in contrast to the concept of generalized unitary organismic laterality. The latter concept (17), while unsubstantiated experimentally, apparently has been more generally accepted.

Data which support the concept that training differences lead to differences in performance where timing or the serial organization of muscle activity is required (33), and data which indicate that "innate anatomical structure" is involved in determining limb preference (11), need not be considered mutually exclusive. The application of general genetic principles relevant to the etiology of individual differences (23, 26) would support the hypothesis that muscular training and development may emphasize existing constitutional differences. In other words, while training and use improve the strength of musculature of both limbs, they may increase the differences between them. A corollary of this interpretation would be that the training which brings about increased development of both limbs has a greater effect on the side which is constitutionally predisposed to respond more profoundly. The pressures of a society in which mechanical design is oriented to fit its right-handed members may act on left-handed individuals to decrease the developmental differences between the constitutionally-predisposed dominant and non-dominant hand. The same social pressures, however, would manifest effects synergetic with constitutional predisposition in the right-handed subjects.

An adjunct hypothesis would consider the occurrence of a relatively large left cerebral hemisphere in a significant proportion of the population (27, 35, 44), which may be assumed to be related to lateral muscular dominance. The reverse anatomical situation has not been reported. Thus, apparently, a part of the right-dominant population manifests a correlated cerebral lateral hemispheric volume difference; and no such anatomical correlation has been observed which may be ascribed to the left-dominant population. These observations may be indicative of an ontogenetic predisposition to generalized left lateral cerebral and right lateral muscular dominance. The occurence, then, of a high proportion of independent genetic factors for right lateral somatic (and left lateral cerebral) dominance in an individual would manifest effects either cumulative or synergetic with the ontogenetic predisposition and cause a marked

lateral dominance. On the other hand, however, the occurence of a high proportion of genetic factors for left lateral somatic (and right lateral cerebral) dominance in an individual would tend to decrease and even outweigh the ontogenetic predisposition, to which they are opposed. The above hypothesis is consistent with claims that markedly extreme cerebral dominance is "unique to the left hemisphere" which is "found to be involved in practically all subjects studied" whereas individuals commonly regarded as left-handed are "relatively ambidextrous" (2). Additional support for a concept of physiological interaction between various independent laterality factors for right and left lateral dominance and an ontogenetic predisposition to right lateral dominance may be extrapolated from reports of unilateral occipito-parietal brain injury. Left-handed victims of cerebral damage are said (29, 39) to have a relatively high rate of recovery, compared to right-handed victims; and the latter group indicate markedly better prognoses when the right hemisphere is damaged rather than the left one. Statistical analyses of clinical data, based on right-and left-handed patients with damage to right and left sides of the brain may substantiate and clarify such beliefs. The literature contains several descriptions of the effects of left occipito-parietal lesions in right-handed subjects, all of whom suffered permanent extensive loss of higher functions; and one report of a left-handed patient with a right occipito-parietal lesion who, by contrast, manifest nearly complete recovery after his injury (22). The unusual degree of restitution exhibited by the latter patient may have been an expression of his incomplete lateral cerebral dominance. In accordance with the above hypothesis, it might be inferred that right cerebral dominance in this case had never been established as completely as the tendency in cases of the left hemisphere in right-handed individuals. The left-dominant individual is relatively plastic and ambidextrous, since his predominance of multiple genetic factors for left somatic (and right cerebral) dominance is opposed by the generalized ontogenetic tendency to right somatic (and left cerebral) dominance.

Summary

The literature and results of studies on the subject of lateral dominance have been reviewed and discussed, and pertinent hypotheses advanced. The various known facts need not be considered contradictory if multiple genetic factors are hypothesized, interacting with an ontogenetic predisposition to left cerebral (and right somatic) dominance, and with various psychological-social factors.

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RIASSUNTO

Sono stati riesaminati e discussi la letteratura ed i risultati degli studi sull'argomento della dominanza laterale e sono state avanzate alcune ipotesi pertinenti.

I vari fatti noti non vanno considerati contradittori, se si faccia l'ipotesi di fattori genetici multipli, agenti in collaborazione ad una predisposizione ontogenetica a dominanza cerebrale sinistra (e somatica destra) ed a svariati fattori psicologico-sociali.

RÉSUMÉ

La littérature et les résultats des études sur la dominance latérale ont été réexaminés et discutés en faisant quelques hypothèses possibles.

Les faits divers connus ne sont pas en contradiction entre eux si l'on fait l'hypothèse de l'existence de facteurs génétiques multiples, agissants en collaboration avec une prédisposition ontogénique à dominance cérébrale gauche (et somatique droite) et avec plusieurs facteurs psychologiques-sociaux.

ZUSAMMENFASSUNG

Die Litteratur und die Ergebnisse von Untersuchungen über die Seitendominanz werden wiederuntersucht und diskutiert und einige Hypothesen vorgestellt.

Die verschiedene bekannte Vorfälle werden nicht als widersprechende betrachtet, wenn man vielfache genetische Faktoren annimt, die mit einer ontogenischen Neigung zu linker Gehirn- (und rechter somatischen) Dominanz und zu verschiedenen psychologisch-sozialen Faktoren arbeitet.