In defense of the sinistrals: anatomy of handedness and the safety of prenatal ultrasound

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Once again there is a flurry of interest in handedness, this time in the guise of a question: whether a demonstrated increased 'risk' of left-handedness among those exposed to prenatal ultrasound denotes brain damage in such babies1,2.

This is an old debate in a new vernacular in the sense that left-handedness has always been viewed with suspicion as far as the integrity of the brain of its practitioners is concerned (note the negative meaning of the word ‘sinistral’), and not always on cultural or religious grounds3. The genesis of handedness itself is subject to controversy with a recent review concluding, for example, that handedness is all acquired4. An ugly fact, however, serves as nature’s sobering remark: the congenitally blind displays the same statistics of hand preference as do the sighted5,6. The fundamental problems hampering resolution of any laterality questions are as follows. First, the precise anatomy of handedness as a unique and ubiquitous human characteristic, which would also provide an insight as to its skewed distribution. Second, the fact that the use of one hand or the other in performing a task is entirely subject to a person’s volition, in turn subject to improvement by practice. Because of its technical nature the second aspect will not be examined here in detail but it is important to note that the saying ‘practice makes perfect’ has a neural basis within the motor cortex, i.e. activity-dependent synaptic modification7.

The first issue, which is intimately related to cerebral laterization of motor control, has been clarified recently with significant implications for the subject under review (the safety of prenatal ultrasound). The novel understanding is that the callosal traffic underpinning lateralities of executive functions of speech and handedness is one-directional, with the direction of callosal traffic displayed/codified as handedness. The theory is buttressed by unequivocal clinical and experimental evidence8–11. While highlighting the dichotomous nature of neural handedness (as opposed to manifest or self-declared handedness, see below), the theory provides verifiable answers as to the nature of hitherto unresolved laterality questions (some of which are to be touched upon later). It discards the notion of pathological left-handedness as the return of old superstitious beliefs in scientific garbs, unworthy of attention.

The hemisphere that houses the controlling moiety of the neuronal aggregate devoted to executive functions is the major hemisphere with the hand opposite to it the dominant hand. (This contralaterality is due to the crossing of the pyramidal tracts, a grossly visible anatomical landmark, in the medulla oblongata.) Physiologically this means that the dominant hand, because of its direct connection to the major hemisphere, where all commands are planned and executed, flings into action faster than the non-dominant when called upon to perform. Those commands to be carried out by the non-dominant hand require an extra step, and thus additional time, taken by the command to reach from the command center on the left to the exclusive motor apparatus for the left, located in the right hemisphere. There is thus a callosum-length distance by which the non-dominant hand is farther away from the command center than the dominant. This anatomical scheme is supported by the fact that the activity of motor cortices in bimanual actions is strikingly similar to that seen with movements of the non-dominant limb alone, as documented in emission technology9–11 as well as in electromagnetic studies.
wherein sequential activity involving both hemispheres is seen when moving the non-dominant side, always beginning in the major hemisphere. This translates into a lag (synchronization gap) between the performances of the two sides, by an amount equal to the interhemispheric transfer time (IHTT, see below). The clinical support for the above arrangement is summarized in the trilogy described below. The evidence also suggests the same laterality bias to include other organs such as the lips and eyes, vocal cords, trunk and diaphragm, and swallowing.

Clinical representation of this scheme is reflected in the following three laterality-indexed cortical syndromes. (1) Paralysis of the dominant side, inability to do things by volition with the non-paralyzed limb while being able to perform the same automatically as the occasion calls for them (the neurological jargon for this is apraxia; frequently observed examples of this are cussing, waving the hand to say bye, and drawing a cross across the chest, all of which may be done spontaneously but not on request by the examiner). (2) Less common than the above is the weakness of the non-dominant side when callosum is transected. (3) Weakness on the same side as the major hemisphere in certain insults involving the same. Any insult that renders the callosum non-functional will result in non-functioning of the minor hemisphere that is otherwise grossly intact, resulting in contralateral weakness (ipsilateral to the major hemisphere). This is due to a separation shock (diaschisis, deafferentation) imposed on the minor hemisphere as a result of a deactivation, which may be permanent.

In view of the critical role of the callosum in the genesis of handedness, the one-directional view of the callosal traffic underpinning executive functions suggests that the reason for the asymmetrical distribution of handedness in humans may be the death (before birth) of the vast majority of those individuals destined to be neurally left-handed for reasons as yet unknown. This prediction and may reflect an improvement of care of the premature babies occurring between the two era. It is also consistent with findings of the more recent era that ‘the prevalence of left-handedness increased with decreasing gestation’. It is to be noted that in the absence of other anomalies and complications, the cognitive achievement of the sinistral group is related to presence or absence of periventricular white matter damage occurring around the birth, and to nothing else.

It is worth noting that agenesis (absence) of the callosum, whether partial or complete, has been associated with a large and growing number of chromosomal abnormalities and anomalies, attesting to the pivotal role of the callosum in mammalian life, since it first appeared on the evolutionary scene.

Thus, for an agent to affect neural handedness (see below) it must affect the neuronal population involved in forming the callosum at the critical juncture of its appearance as the fetus is forming. Such occurrences are on record, experimentally and naturally. While substantial information exists as to the nature of damage to the premature brains involving the white matter of periventricular region, resulting in cognitive deficits, there is no evidence of their selective involvement indexed to laterality of the subjects studied.

Therefore, given the role of the callosum in mediating handedness as described above and the fact that the vast majority of humanity is right-handed, it should not come as a surprise that proportion of mentally retarded individuals who survived the calamities destined for the left-handers become so solely on the anatomical grounds sketched above.

To say it differently, the retardation (brain damage) is not contingent on their handedness but on the fact that they survived the odds as left-handers. The fact that not all left-handers are cognitively impaired, therefore, bespeaks of the existence of other factors (as yet unknown) necessary for completing the puzzle as to the reason(s) for the adverse intrauterine milieu affecting this large segment of humanity who all used to die unborn until recent times.

With the biological implausibility of such associations (prenatal ultrasound/brain damage/handedness) discussed and refuted, I now return to the issue of ostensible laterality in humans. Here, one can begin with corollaries (predictions) of the proposed one-directional callosal traffic underlying handedness as seen in everyday life. As mentioned previously, the theory predicts and experiments confirm the existence of a lag (asynchrony) of the non-dominant hand compared to the dominant hand by an amount equal to the time it takes for a command from the dominant hemisphere to traverse the callosum and for those movements to be carried out by the non-dominant hand. This IHTT, which varies from 10 to 60 ms depending on other factors such as the speed of the performance, is the biological reason for the so-called melody lead of the right hand in piano players, wherein the right hand precedes the left when the intention is simultaneous delivery of a musical chord. This is one of the objective tests for neural handedness, as revealed in an investigation by Savage and Thomas designed to test the validity of a particular inventory of handedness. In an experiment in which the designated dominant hand was switched from that assigned by an inventory to the one the subjects used for writing, they found a change in the IHTT sign from negative to positive.
indicating the risk of misclassifying handedness when any arbitrary inventory is used. Clinically, incongruities of neural (speech) and behavioral handedness, seen more often in sinistrals, are represented by cases of crossed aphasia and crossed non-aphasia, where in an expected language disorder in the context of hemiparesis does or does not occur.\textsuperscript{31,32} Forcing a left-hander to adopt the manners of right-handers leaves the anatomy unchanged, as shown in bilateral cortical activity when moving the neural non-dominant limb (in this case the right hand), as predicted by the model sketched above, as documented\textsuperscript{13} and discussed\textsuperscript{11} recently.

As a result of the lagging mentioned earlier, left-handers do not make professional musicians of keyboard instruments as the melody is always written for the right handers do not make professional musicians of keyboard instruments as the melody is always written for the right hand. Advances in neonatal care may increase the likelihood of survival of left-handers even further.

Such corollaries of handedness in daily life are mentioned here to indicate the pervasiveness of the anatomy’s effect in circumstances devoid of clinical significance and in order to dismiss as fable that left-handedness is somehow ‘pathological’. Rather, it represents a distinct mode of motor control in humans with as much anatomical validity as right-handedness, the remarkable difference being the control of the left motor apparatus by the right hemisphere; a role reversal within the neuronal aggregate devoted to executive functions. The elucidation of the genetics of this reversal awaits future studies.

In summary, left-handedness requires the same sophisticated neural apparatus and circuitry as does right-handedness. Sinistrality is not a back-up mechanism of motor control. Its unique and ubiquitous minority status in human society is biologically determined, as detailed in the preceding paragraphs. The one-directional theory of callosal traffic underpinning lateralities of speech and handedness has revealed the biological legitimacy of left-handedness. Advances in neonatal care may increase the likelihood of survival of left-handers even further.

REFERENCES


