Liepmann's Imperial Counselor Re-visited: The First Documented Case of Disparity of Neural and Behavioral Handedness

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After more than a century, Hugo Liepmann continues to hold a special position in elucidating the anatomy that underpins laterality of motor control (handedness). In this note, I will provide data as to the reason behind the right-sidedness of the apraxia in this patient, elucidating the exceptional laterality of his symptom (apraxia). Introduced to us as The Imperial Counselor, [1] the patient had been right handed all his life. Liepmann's observations and the interpretations he advanced to explain them, linked the two hemispheres in the following manner:

1. As shown in the drawings of the year 1900 (Figs.1, 2), Liepmann recognized for the first time that motor signals between the two hemispheres had directionality (from the left to the right).
2. He also recognized that the major hemisphere plays a special role in the planning and execution of motor commands on both sides of the body. He was puzzled, however, by the "exceptional" right sidedness of apraxia in this patient; the only **exception** among remainder of his cases, where the apraxia had affected the left hand (in 21 out of the 40 cases with left hemispheric lesions). [2]
3. Liepmann knew that directionality of callosal traffic he was espousing was related to handedness of his subjects and believed that the Counselor's exceptional laterality of symptom (apraxia) might be due to the subject's (latent) left handedness, as the Counselor had dealt cards with his left hand. It remains a puzzle as to why Liepmann did not take the logical step of distinguishing neural from behavioral handedness in his patient since he knew the anatomical distinction between the dominant and nondominant side of the body as they related to the laterality of command center, as seen in his drawings (Figs. 1, 2). Further, Liepmann realized that Counselor's drawings were perfect when drawn by the left hand, while those drawn by the right were mere squiggles. The photographs taken of the Counselor's use of a brush held with the right hand (rubbing his ear), and that of drinking water from a glass held with the same (Figs 3, 4) demonstrated the right sidedness of the apraxia; as did his abnormal performance in moving the right foot. The same movements by the left hand were performed correctly.

Addressing the laterality of apraxia in usual circumstances Liepmann remarked: "Part of what left hand "can do" is not is not a possession of the right hemisphere which directs its mobility, but a possession which is borrowed from the left hemisphere. The right hand center [right hemisphere] …. remains during the whole life in a certain dependency on the left hemisphere."

There was no complaint or comment regarding unruliness of the right hand in the Counselor's case but Liepmann's photograph clearly indicates the presence of "enabling synkinesis", described in some cases of alien hand syndrome of callosal variety. [2, 3]As seen in Fig. 4, the Counselor moved both hands when attempting to drink from a glass with the right hand. In the sensory domain, Liepmann wrote, "the localization of pinprick and light touch is very poor indeed on the right side of the body. On the left side he accurately points to the spot stimulated with his left hand…He is totally inaccurate, however, as regards to right arm and leg." Since the right arm was no longer under

volitional control of the Counselor, “naturally the left hand was used in all these tests for indicating the spot stimulated.”
Given the above findings, and in light of the insight provided by 1-way callosal traffic circuitry, the Imperial Counselor was displaying crossed apraxia in a behavioral right and neural left hander, as elaborated below and detailed elsewhere. [4-7] (The subject of “latent” or “natural” left handedness has a long history in cortical neurology, always raised in the context of crossed aphasia and crossed nonaphasia.[8])

Anatomy of Handedness

According to the circuitry sketched above (Figs. 1, 2), handedness is a code for the laterality of the hemisphere that controls the other via an excitatory pathway. The major hemisphere is the seat of the cell bodies of a bi-hemispherically distributed ensemble devoted to movement. While all commands are issued from the major hemisphere, as just defined, the moiety in the minor hemisphere carries out the commands related to the contralateral side (the side ipsilateral to the major hemisphere). In vast majority of the public it is the left hemisphere which controls the right via the callosum. In a minority of the population, however, the controlling moiety is in the right hemisphere, majority of those being left handers. Thus, the validity of behavioral handedness is statistical while that of neural handedness is anatomical and unchanging.
Proof of the above arrangement comes from a variety of evidence. The most reliable among those are the ones with sufficient temporal resolution to show the earlier performance of the dominant side when we press push buttons with both hands. The latter interval is commensurate with the interhemispheric transfer time (IHTT). Elsewhere, I have reviewed the experimental and clinical (diaschitic) data substantiating the anatomy delineated above. [4-7] I note here an exception corroborating the rule; the reaction time for sterno-cleido-mastoid muscle is the reverse of that for other effectors on the same side (i.e. it is shorter on the left side than the right, in right handers). The reason for this is the special arrangement for the above-said muscle which turns the head **away** from its insertion site. [9] It is important to note that the laterality of callosal traffic is reverse in the sensory domain; it runs from the minor to major hemisphere. This explains the inability of the neurally left handed Counselor to appreciate the whereabouts of his **right limbs** with his eyes closed, as sensing from the nondominant side of the body is (as it is in the case of moving it) a bi-hemispheric affair. [10] This means that signals arising from the nondominant side are apprehended exclusively in the major hemisphere. Experimentally, this is verified by the activation of both hemispheres when moving or sensing the left side of the body.[4, 7, 11] Employing the paradigm of bimanual response to bilateral stimulation, Muram and Carmon showed that the performance of the dominant hand always occurs before the nondominant by an interval commensurate to two IHTTs; indicating that tactile apprehension and command initiation arise from the same hemisphere.[12] Absence or amelioration of neglect when drawing or copying with nondominant hand has in the past been erroneously interpreted as indicative of the dominance of the minor hemisphere in spatial domain. [11] There is, however, no documented amelioration of neglect upon moving the nondominant side without an extant anterior callosum, indicating that the said effect is the result of activation of a dormant (injured) right hemisphere by the excitatory signals arising from the command center on the left. [7, 13]

In the case of Counselor, the minor (left) hemisphere had been disconnected from the major in both the sensory and motor realms. Post mortem examination of the Counselor's brain showed destruction of anterior two thirds of the corpus callosum. [2]

The disparity of and behavioral handedness occurs in no less than one in five persons in the populace. [6] Such disparities has long been a major source of confusion in classical neurology assuming various names, such as crossed aphasia, crossed nonaphasia, crossed apraxias and, most recently, crossed right hemisphere syndrome. [14-16] I have provided a review of nine left handers elsewhere, pointing out the fact that the laterality of the hand with apraxia (i.e. the right hand) in those cases was the same as that of the apraxic hand in a series of nine right handers with crossed aphasia (injury to the right hemisphere).[6, 14] Absence of aphasia and apraxia in lesions affecting the left (major) hemisphere in (behavioral) right handers have generally been ascribed to "anomalous," "atypical," "crossed" or "bilateral" distribution of neural substrate sustaining motor functions in these patients; [14-18] contrary to the dichotomous lateralization of the command structure in motor and sensory realms, documented on clinical and electrophysiological grounds. [4-7] Kobayashi et al have reached a similar conclusion (i.e. absence of any ipsilateral corticospinal influence on either side) utilizing transcranial magnetic stimulation technique. [19]

Conclusion

The validity of behavioral handedness is statistical while that of neural handedness is biological and unchanging. The latter represents the proximity of the dominant side to the command center by a callosum width. Measurement of the reaction time of any symmetrically located effectors of the body is a robust and noninvasive way of lateralizing the major hemisphere. The effectors on the dominant side fling into action earlier than the nondominant by an amount commensurate with IHTT.
Liepmann should be credited for his clinical acumen and attending to significant details. Interest in this subject, however, is not merely historical. For example, there is evidence that the minor hemisphere per se is incapable of generating epilepsy; except if associated with raised intracranial pressure thus affecting the hemisphere sitting next door, since intrinsic lesions in the minor hemisphere (as defined above) are associated with diminished excitability of both hemispheres. [20, 21, 22]
Thus, measuring the reaction times of two symmetrically located effectors constitute a robust and noninvasive method in lateralizing the onset hemisphere in epileptics who are candidates for seizure surgery. The effector with shorter latency is located contralateral to the major hemisphere.

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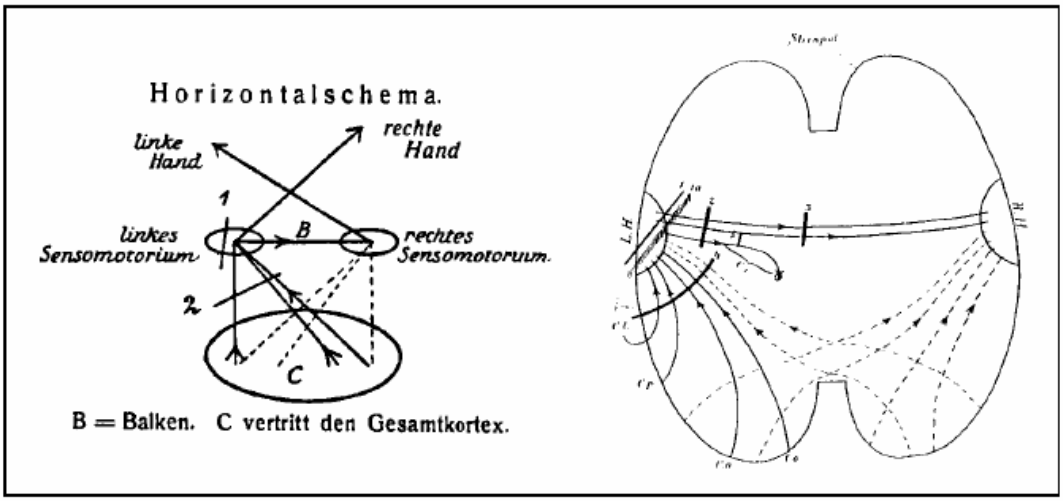

Figures 1 and 2. Schematic drawings of callosal motor traffic by Hugo Liepmann, 1900. Note the direction of arrows between two hemispheres, from left to right. Evidence shows that directionality of sensory signals arising from the left side of the body is the opposite of that of motor signals; from right to left hemisphere in right handers. (See text for explanation).

Figure 3.

Figure 4.

Figures 3 and 4. Very simple tasks are not successfully accomplished because the purposeful activity of the left hand (enabling synkinesis) is thwarted by the faulty interaction of the right hand. For example, he is asked to brush the examiner's coat. He grasps its lower corner properly with his left hand and picks up the brush correctly with his right hand, but he lifts it repeatedly in rhythmic movements upwards and back wards above his right ear (see Fig. 3). He is asked to pour from a jug into a glass. His left hand takes the jug and wants to pour, but, simultaneously, his right hand lifts the empty glass to his mouth (Fig. 4). When the glass is held by another person the left hand succeeds in pouring without any difficulty. [1] See text for further explanation. Figures from Liepmann's text.