Pseudoneglect and its Many Faces: Laterality of Motor Control Underpins Asymmetries in Line Bisection, Initial Visual Exploration, Optimal Viewing Position, Point of Subjective Equality and Visual Span

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Abstract: *Contrary to the accepted belief, incontrovertible evidence indicates that all commands are issued in one hemisphere (major, command center, speech hemisphere), with majority of people (~80%) left hemispheric in laterality of their command center. Thus, those commands intended for moving the nondominant side of the body, including the eyes, are first transmitted to the opposite hemisphere via the corpus callosum, before they are implemented by the minor hemisphere (which is devoid of any conscious awareness). This article reviews the many faces of the behavioural consequences of this one-way callosal traffic circuitry underpinning lateralities of motor and sensory control; including our inability to divide a line in exactly two halves without using a ruler (i.e. pseudoneglect). Review of the relevant time resolved data in the literature indicates that the well-known laterality indexed asymmetries in visual span (e.g. the right visual field advantage in lexical decisions), optimal viewing position in reading (OVP), point of subjective equality (PSE) and the tau effect are among the many faces of pseudoneglect, all based on the laterality of motor and sensory control which is unidirectional: from the major to the minor hemisphere for motor and from the minor to the major hemisphere for sensory signals (arising from the nondominant side of the body).*

Humanity possesses twin disabilities, for which the reason has been discovered recently. Firstly, we cannot divide a line precisely in halves and resort to a straight-edge or a tape measure for securing a valid result. This is not because we do not know that the middle is between the two halves; rather, we cannot determine exactly where the half mark must lie without actually measuring the line and deducing the middle mathematically. Short of this, depending on our neural handedness (i.e. see below for the distinction between neural hand behavioral handedness), we either deviate to the left or to the right of the veridical center by a percentage point of the length of the line without ever realizing that we have erred in the process [1]. Similarly, when viewing a target in the middle of our view, vast majority of right handed people will initiate a search to the left of the midline, focusing slightly to the left of the middle of a word target, or display a leftward point of subjective equality (PSE) when acknowledging the arrival of the stimuli just to the left of the midline using the right hand [2, 3]. It has been shown repeatedly that interference with this automatic process will result in diminished efficiency in the reading a text [4-6]. Whereas the first of these twin failings appears sensory in nature the second is more clearly motoric. Thus, starting from the same distance of a musical keyboard, humans are incapable of striking two keys at the very same time. Musicologists have known about this disability for a long time and since the melody of a tune is traditionally written for the right and the harmony for the left hand have formally named the phenomenon the "melody-lead of the right hand" in piano players [7]. Importantly, however, it has been known for over forty years that severing the anterior aspect of the corpus callosum (the neural bridge between hemispheres) intensifies the above described interlimb asynchrony by further prolonging the performance of left hand [8, 9].

The purpose of this article is to explore evidence that the twin phenomena mentioned above are based on the fact that the interhemispheric traffic, underpinning laterality of motor control, is one-way (from the major to the minor hemisphere, as here defined) and that the nature of signals employed for the purpose of activating the nondominant side is purely excitatory. It will be shown that the line bisection deviation mentioned above represents an automatic trading of “time” and “space” in the human mind as the motor command for moving the eyes to the left traverses the interhemispheric bridge (the corpus callosum) from the action hemisphere to its neighboring counterpart (minor hemisphere); which in turn implements the commands issued in the former, moving the eyes to the left (in a real right handed person, see below). Thus, the longer route imposed on the command for moving the eyes to the left is interpreted by the person clocking the event as a longer “time,” and by the subject as additional “space” (hence the over-estimation) [1, 10-12]. Accordingly, for the person who initiates looking to the left, the automatic “time-stamping” of the event begins after the emanation of the related commands from the major hemisphere [1, 13]. Because of the additional callosum-width routing imposed, however, an asymmetry occurs in the excursion of the two eyes, with those to the left coming out short (by an IHTT). In moving the extremities, on the other hand, when exactly the same excursion is imposed on the right and left arm, the latter must add the additional (callosum-width) extent to its journey’s length in order to accomplish the aim set forth by the decision-maker located in the major hemisphere [14].

The Line Bisection Test, Further Observations:

First described by Hall and Hartwell (1884) [15], deviations to the left in bisecting a line is seen in vast majority of normal right handed people. Only in more recent times the phenomenon was named “pseudoneglect,” by Bowers and Heilman [16]. According to 1-Way callosal traffic circuitry underpinning lateralities of motor and sensory control, the reason for the left deviation in bisecting lines in visual paradigms is that all movements occurring on or towards the nondominant side of the body are bi-hemispherical events requiring callosal participation. This delay applies to all movements of or toward the nondominant side, including the saccades (gaze) or those of the diaphragms for breathing. Thus, while conjugate eye movements to the dominant side do not require callosal participation, moving them to the left demands an intact corpus callosum [8, 9, 13]. Similarly, sensing from the nondominant side of the body requires callosal participation to convey those signals arising from the nondominant side of the body that have reached the right hemisphere to the left hemisphere before they are consciously apprehended. Accordingly, left sided movements incur a delay equal to the interhemispheric transfer time (IHTT) as the motor signals move from the left to the right hemisphere and the sensory signals incur a similar delay in the opposite direction [17]. Therefore, as expected, when drawing two straight lines with both hands simultaneously, the lines drawn by the two hands are unequal, with those by the dominant hand (the side in direct contact with the major hemisphere) being longer than those by the hand ipsilateral to the command center (regardless of the behavioral handedness of the person; see under fake (ostensible)-handedness for exceptions) [9].

To recapitulate, in assessing the middle of a line, it takes longer for a right handed person to move his or her eyes to the left than moving them to the right by an amount equal to IHTT. As a result of an automatic trading of space and time an overestimation of the left side of the line will occur, giving rise to the left deviation of the marking [1]. similarly, in the somatosensory realm, an overestimation of the size of an object occurs which is reported when judging the same size disks manipulated between our thumbs and index fingers simultaneously by both hands (with eyes closed). The disk on the left is judged as bigger due to automatic “time stamping” of motor events in measuring as the subject manipulates the disks [18, 19]. Here, therefore, the left deviation in “visual” line bisection has its “appendicular” counterpart, similar to the tau phenomenon described by Helson (1930) [20]. Turning to the abovementioned paper and pencil test, if the hands holding the pencils are moved from the side of the page to the middle, the lines drawn will meet on the left of the midline, reproducing the results of the line bisection test. Those who remain skeptical of the above explanation may take solace by attempting to draw two separate lines of the same length with each hand with their eyes closed as they count to a certain arbitrary number while drawing a line. It will again be noted that the line drawn by the neurally dominant hand is longer than that by the other hand by an amount equal to IHTT, again reflecting the aforementioned inevitable “trading of time with space” in the human mind [1, 9, 21]. Similarly, the right visual field advantage described in tachistoscopic experiments on naming latency, the wider excursion of the eyes to the right (which is based on the same anatomy just mentioned) “becomes more pronounced with the number of letters in the word” [22].

In the past, these visuo-motor asymmetries were erroneously accounted for by the faster speed of signals traveling from the minor to the major hemisphere compared to those moving in the opposite way (i.e. assuming a Newtonian division of visual half fields between the hemispheres) [23, 24]. The fact remains, however, that in right handed subjects laterality of tachistoscopically presented stimuli in Poffenberger paradigm is irrelevant to the reaction time of the dominant hand and the performances of both hands remain unchanged in response to stimuli appearing in the left visual field [23, 24]. [23]Finally, the absence of a role for the corpus callosum in vision is indicated by the fact that the asymmetries described above persist while performing the bimanual drawing task blindfolded [9, 21]. Additional observations point to the same conclusion [25-27].

Initial Visual Exploration (IVE), Optimal Viewing Position (OVP) and Point of Subjective Equality (PSE):

According to the abovementioned scheme (i.e. 1-way callosal traffic circuitry), what appears to be the center of a scene to an observer incurs a slight leftward shift compared to the veridical center of that scene. For example, in a paradigm employing targets made from texture numbers scattered to the right and left of the midline, 65 % of normal controls “started exploration in the left half of the arrays” and in a paradigm using overlapping figures, neurological control subjects (with lesions in the brainstem or below) displayed a strong tendency to identify first the parts of a composite diagram lying just to the left of the midline [2, 28]. On the other hand, in the studies mentioned, patients with right hemisphere damage displayed an initial directional bias to items ipsilateral to the damaged hemisphere, regardless of presence or absence of other signs of neglect (such as those seen in bilateral simultaneous stimulation, line cancellation and copying tasks); while measurements of the landing positions of the gaze while reading demonstrated a left of midline positioning of the gaze when viewing words (see Introduction). Lastly, using a speeded reaching task in thirteen right handed participants, Oliveira et al documented a leftward shift in their mean PSE in an experiment in which the participants chose the hand with which to respond to stimuli appearing in the right or left visual field [3]. The authors also documented faster response by the right hand to stimuli occurring in the right visual field compared to those of the left to stimuli appearing on the left side (p=0.0499). Nevertheless, the authors, following a conventional understanding of visual sense of space as well as that of motor control, the authors failed to provide a valid interpretation of their results (i.e. the callosum-width proximity of the dominant side of the body to the command center/macular vision in vast majority of right handed people) [9, 17, 26].

Asymmetry in Perceptual Span:

There is a substantial literature in which faster responses in moving the eyes to the right than moving them to the left, in vast majority of right handers is documented [11, 17, 22]. However, the relationship between this asymmetry to the asymmetry in visual perceptual span has never been explored [3, 11, 29-31]. Instead, the totality of the literature ascribes the right visual field advantage (RVFA) in lexical decision and naming tasks to the “specialization” of the left hemisphere for speech, without proving comments or specifications as to the mechanism underpinning the same. In this respect, Orbach’s [31] and Bub and Lewine’s [22] articles, by demonstrating a wider perceptual span to the left in two groups of left handed participants, provide solid evidence in favor of directionality in callosal traffic by documenting that abovementioned asymmetry is indexed to a person’s laterality of motor control as espoused in this article; as does the demonstration of a faster verbal response to right sided visual stimuli in a group of right handers studied by Melamed et al who also noted that participants displayed wider excursions to the right (RVFA) in an experiments involving lexical decision task [33].

Scrotal, Galvanic Skin Response and H-reflex Asymmetries:

There are numerous autopsy reports of patients with unilateral supratentorial lesions involving the dominant hemisphere associated with bilateral Babinski signs or with bilaterally absent abdominal and cremasteric responses associated with bilateral up going toes [34-38]. Importantly, only one of the eleven patients reported in the aforementioned five articles (the case by Adams et al) involved the right hemisphere of the patients described. Thus, the knowledge that traffic between hemispheres is one-way and that all transcallosal influences are purely excitatory [39] allow the clinicians familiar with the concept of interhemispheric diaschisis (separation shock) to properly interpret the above described findings; i.e. the diaschitic paralysis of contralateral hemisphere in lesions affecting the action/major hemisphere associated with paralysis of the contralateral side of the body directly connected to the action hemisphere.

The largest series of similar cases, i.e. paralysis ipsilateral to a lesion affecting the major hemisphere, remains the classical study by Kernohan and Woltman where only one half (17 of the 35) of patients with supratentorial lesions displayed ipsilateral pyramidal signs, regardless of presence or absence of a Kernohan notch [40]. Failure to consider or understand the above-described mechanism (i.e. interhemispheric diaschisis) as the cause of ipsilateral paralysis in lesions affecting the major hemisphere has led to numerous expressions of bewilderment by some the most distinguished luminaries of clinical neurology upon confronting similar findings in their patients [38, 41], or has prevented well known clinicians from correctly interpreting the numerical results obtain in their otherwise excellent clinical research [14].

The circuitry described above also provides a plausible explanation for other laterality indexed findings such as the asymmetrical positioning of testicles in response to gravity [42, 43] and the longer latencies of the nondominant side to electrical stimulation in Huffman and Galvanic skin response measurements [44, 45]; i.e. a callosum-width proximity of the body's dominant side to the command center located in the major hemisphere.

Fake (ostensible)-handedness:

The footprints of one-way callosal circuitry is visible in all circumstances in which laterality of motor control plays a role in our daily lives, as in dueling sports [26] and the laterality of seizure onset [46, 47].There is a caveat, however, as follows: Statistically, it has been shown that one in five persons display a behavioral handedness opposite for which the person is wired (see above). Thus, about one half of the left handed people and 20 % of right handers are wired in the opposite direction as judged from the laterality of their speech or the speed of their movements [9, 48-50]. Neurologists have long known about this disparity starting with Bramwell's article on "crossed aphasia" in a left hander who lost his speech and became agraphic after a right sided hemiplegia [51]. According to observations supporting 1-way callosal traffic scheme, it is the higher speed of the side contralateral to the command center, relative to the side ipsilateral to the same, that unmistakably points to the laterality of motor control in any individual, regardless of his/her declared handedness [17, 52, 53].Understandably, there are no data on manual reaction times of those who later become crossed aphasics. Nevertheless, since the incidence of crossed aphasia among the right handers is about 20 percent [48, 49] there is a likelihood of running into one or two of such person with "anomalous brain organization" in any gathering of 10 right handers; i.e. persons who react more quickly to a signal, or tap faster in a short span of time, with their left hand than their right hands despite their avowed handedness to the opposite [9, 12, 21, 50, 54-56]. Historically, the Imperial Counselor described by Liepmann [56], the famous neuroanatomist Alf Brodal, whose description of his own aphasic performance when writing with his right hand [58] and David Kinnebrook whose consistent 500-800 milliseconds tardiness in responding to events in his view finder compared to those of his superior (Nevil Maskelyne, Royal Astronomer) cost him his job as an assistant at Greenwich observatory [59, 60]. At the same time, it appears that ostensible right handers may have played a role in the early twentieth century drama unfolded after Pierre Marie's attack "on the basic tenets of Broca's aphasia," by the absence of "left third frontal lesion without l'Aphasie de Broca" [61] Finally, reference must be made to the syndromes of crossed nonaphasia [62, 63] and occurrences of right sided neglect in ostensibly right handed subjects after insults to their left hemisphere to complete the list of behavioral surprises seen in those with "anomalous brain organization" [46, 47, 55, 62, 63].

Conclusion:

Much harm has come from the blind faith in the Newtonian hypothesis of contralateral representation of vision and its counterpart in the motor realm as opined by Valsalva. Neither the right visual field advantage in perceptual span nor the right hand advantages in timed movements can be explained by the Newtonian and Valsalva's schemes (leaving aside for now the issue of macular sparing in hemianopia). Nor can these dogmas account for the known asymmetries in initial visual search, line bisection or optimal viewing point as reviewed above. In this article I have reviewed critical studies that support the existence of 1-way callosal traffic circuitry, underpinning lateralities of motor and sensory controls as represented in our daily lives. Bimanual simultaneous drawing test reveals the laterality of motor control in all those who are able to perform the test by allowing the brain to speak for itself in a simple paper and pencil test. The test allows identification of members of that minority of humans who for over a century have wreaked havoc in our understanding of brain structures underpinning the laterality of motor control and consciousness.

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