Laterality of Motor Control before the Advent of Experimental Psychology: Revisiting David Kinnebrook's "Error of Judgement" at Greenwich in 1796

Iraj Derakhshan, MD, Neurologist

Formerly, Associate Professor of Neurology, Case Western Reserve and Cincinnati Universities, Cleveland and Cincinnati, Ohio, USA

Currently, Private Practice of Neurology
415 Morris St, Ste. 401
Charleston, WV 25301
Tel 304 343 4098
Fax 304 343 4598

Abstract:

Background: The dismissal of David Kinnebrook as an astronomical laborer in 1796 has afforded him a special position in the history of experimental psychology: "a martyr of science." This is because he was "ushered away" from his work at the Royal Greenwich Observatory through no fault of his own. Here, using data available in the literature and insights from a new understanding in laterality of motor control (i.e. one-way callosal traffic circuitry) it is shown that Kinnebrook, though right handed, was wired as a left handed person would be; with delayed reaction times in noticing events arising from his right hemispace (delayed saccades to the right).

Keywords: Neurology, handedness, 1-way callosal traffic theory, reaction time, brain anatomy

1 Introduction

"In the 18th and early 19th centuries, astronomers were required to make difficult judgments, based on a combination of auditory and visual cues, in order to time stellar transits. A well-known story from the history of science is the firing in 1796 of Kinnebrook, an assistant to Maskelyne, the Astronomer Royal of England.

Kinnebrook was relieved of his job for giving inaccurate readings of stellar transits. Although he had provided readings in agreement with Maskelyne's 18 months prior to his dismissal, the hapless Kinnebrook by August 1795 had begun to give times that differed from Maskelyne's by one-half second. Subsequently, Kinnebrook's readings grew even more discrepant, so by the time of his firing they were almost a second later than Maskelyne's. This matter might not have attracted much interest had not Maskelyne recorded it in Astronomical Observations at Greenwich. Seventeen years later, in a history of Greenwich Observatory published in German, Kinnebrook's tribulation came to the attention of Bessel, an astronomer at Konigsberg. Bessel conducted a series of studies culminating in the notion of the personal equation [reaction time], the name given the systematic difference in recording times found to characterize the stellar transits of almost any pair of astronomers. From the perspective of reliability theory, the personal equation [reaction time] itself was not a highly significant discovery, for it refers to systematic error, not the random error treated by reliability theory. What interests us, instead, is Bessel's finding that the personal equation [reaction time] itself is a variable quantity, one that differs from one pair of astronomers to another. This variation suggests random or accidental errors in observations, errors that, if neither controllable nor amenable to elimination, at the least demand an explanation grounded in a theory or a scientific law." [1]

2 Methods and Results

In many of the accounts of the subject, David Kinnebrook is considered a "martyr of science" because of the role of his dismissal in inaugurating experimental psychology as a scientific discipline. [2, 3] As an assistant astronomer, Kinnebrook was constantly and regularly late (by 500-800 milliseconds) in marking down the transits of stars as they crossed the meridian; but only in his second year of employment and beyond. In the citation above, Traub asks for an explanation (scientific law) of the delay as shown by Kinnebrook as well as an explanation for the time line of its occurrence. The latter undertaking, however, has never been done before.

Based on time resolved anatomical data supporting 1-way callosal traffic theory[4,5], the present article provides an explanation for the widening of the gap between the performance of Kinnebrook and that of his superior Nevil Maskelyne (the royal astronomer) in the years of his employment as an assistant to Maskelyne.

From the neurological perspective, the key to explaining Kinnebrook's performance is the direction of motion of the stars monitored by the contestants and the number of such observations in each direction over the period under scrutiny. However, to my knowledge there are no published reports concerning the issue. We know that the procedure followed by observers in calibrating the clock called for single or multiple saccades in the direction of the appearance of the star (s) (right or left of the observer). According to the information available, Kinnebrook's performance variability over the two years of employment was contrary to the performance of other assistants working in the same observatory, as documented by a later Astronomer Royal (Sir Spencer Jones).[6] Spencer-Jones also recorded that two of his six assistants (R.C. & W.D) consistently lagged behind a "standard observer" in reacting to transiting stars as they watched a list of the so-called "clock stars." Clearly, therefore, we are not dealing with a very rare phenomenon though the physiological nature of the phenomenon has remained obscure thus far. Remarkably, this occurred despite the fact that astronomers had already discovered that "direction of star's motion could introduce a change in the personal equation."[7,8] Thus, while comparing his own reaction times with those of a colleague while using a chronograph in an observatory in Madras, a certain officer, named W.M. Campbell, became aware of his own tardiness in catching a glimpse of the objects appearing to his right compared to that of his colleague who clocked them that same way. In the words of Campbell, "Captain Heaviside observing in advance of me [by 64 milliseconds]." [8]

This latter experiment performed in 1877 is equivalent to that of visual half-field paradigm conducted in today's laboratory, employing the so-called Poffenberger paradigm. [4]

To summarize, according to the 1-way callosal traffic circuitry (see below for details), by recording the fact that he was delayed in observing objects moving from right to left, Captain Campbell was documenting his own status as a neural left hander compared to his comrade in arms, Captain Heaviside, who was faster responding to the events appearing on his right side.

3 Discussion

The generally accepted view that each hemisphere controls the movement of the contralateral side has been questioned recently. There is overwhelming evidence that our handedness is a reflection of the fact that only one hemisphere houses the command center with the nondominant hemisphere engaged in carrying out the commands issued by the dominant for movements planned for the nondominant side of the body.

According to 1-way callosal traffic circuitry,[4,5] it is the directionality of callosal traffic (i.e. whether signals move from left to right hemisphere or the reverse) that determines the status of one hemisphere as that of action hemisphere (the command center, dominant hemisphere), where all commands are issued for movements occurring on either side of the body. According to this understanding, a person's behavioral (avowed) handedness is only a guide to his or her directionality of callosal traffic (i.e. neural handedness); the neural and behavioral handedness in an individual subject are in agreement in only ~ 80 percent of the population. In the remaining 20 percent of individuals display an avowed (behavioral) handedness opposite for which they are truly wired (see below for further explanation).

The above estimates as to the laterality of command center are derived from a variety of clinical sources. Thus, since the action hemisphere is the same as the speech hemisphere, the incidence of crossed aphasia and crossed nonaphasia in penetrating brain injuries does provide an estimate of the incongruities under consideration; [9] as do anomalous occurrences of neglect in lesions affecting the left hemisphere in ostensibly right handed subjects,[10] occurrences of aphasia after removal of supratentorial tumors of the right hemisphere in right handed subjects,[11] as well as occurrences of alien hand syndrome on the ostensibly dominant side of the subject following lesions affecting the minor hemisphere or its afferent callosal connection.[12,13] Experimentally, persons incongruous in neural and behavioral handedness display a faster manual reaction time to stimuli on their (ostensibly) nondominant side, or a negative crossed uncrossed differential (negative CUD) in applications of Poffenberger paradigm.[4,14]

According to 1-way callosal traffic circuitry, all actions originate in the major hemisphere, including those of moving the eyes to the side (saccades) and swallowing, with the command traversing the corpus callosum to activate the minor hemisphere which in turn moves the nondominant side of the body once it receives the command.[5,15] Electrophysiologically, the abovementioned callosally mediated delay has been repeatedly documented in bimanual "simultaneous" movements recorded with different techniques, indicating precedence of the neurally dominant side in moving when a simultaneous movement was intended.[16-18] For the saccades, a similar ratio of faster response to the stimuli from the left hemispace was found in two of the twelve (presumably) right handed subjects described by Honda,[19] confirming an earlier study by Hamers and Lambert in a lexical decision task on 15 right handed subjects (wherein three of the participants responded faster to stimuli from the left side). [20] Elsewhere, I have provided detailed explanation regarding the subjects reported by Honda.[4] To the above may be added the reports on those ostensible right handers who drew longer lines or larger geometrical designs with their nondominant hands, while drawing simultaneously with both hands[21,22] and the three of seventeen right handers who showed higher refractory cue-cost for their ostensibly dominant right hand (instead of the left) in a study by Buckingham et al.[23]

Since movements of the eyes to the sides is governed by the same circuitry that underpins hand movements, moving the eyes to the neurally dominant side occurs at a faster speed than moving them to the opposite direction; by an amount equal to the interhemispheric transfer time (IHTT, i.e. the time needed for transfer of the command signals issued in the action hemisphere for movements occurring on the nondominant side of the body). It has been shown that such commands are implemented by the minor hemisphere upon receiving the same via corpus callosum and anterior commissure.[4,5,22,24]

According to the above sketched circuitry, David Kinnebrook must have been a member of the above described neural-left but behavioral-right handers who saw the objects arising from his right hemifield at a significant delay compared to a real (neuro-behavioral congruent) right hander (such as Maskelyne). For objects arising from his left hemispace, however, Kinnebrook would have reacted faster than his superior Maskelyne. This provides a plausible explanation for his acceptable performance in his first year of employment at Greenwich. Accordingly, vast majority of transit trials performed by Kinnebrook in the years 1795 and 1796 must have been instances in which the transiting stars were moving from right to left, resulting in his ever worsening performance compared to Maskelyne as the time went on (leading to his eventual dismissal).

The validity of 1-way callosal traffic circuitry has been confirmed in several recent studies. [24-28] The criticism raised by Goble, [29] is based on a failure to fully understand the import of the circuitry, i.e. that the "critical" issue as to dominance of one limb over its counterpart is the comparative speed with which the two arms move, *regardless of the subject's claim as to his/her own handedness*. Thus, in addressing the problems of classification of handedness by employing a dexterity evaluation method (i.e. the speed of performance), Satz et al [30] found that "roughly 69 per cent of the left-handers showed superior performance on the left hand, and 75 per cent of the dextrals showed superior right hand performance. In this study, "self-classified right-handers displayed less variable and better performance with their preferred right hand." In the same vain, Wyke in an experiment involving speed of performance concluded that *"handedness influences the speed of arm movements, and the results are in line with previous observations showing that tests of rapid repetitive movements of the arms might provide a more critical index of handedness than is obtained from observations of non-repetitive arm movements."*[31] The above described motor asymmetry is reflected as an asymmetry in perceptual span in experiments involving the oculomotor system; and as a wider excursion of the neurally dominant side of the body in bimanual simultaneous drawing test (a simple paper and pencil test for determining the laterality of motor control in those able to hold a pen in each hand and draw a line simultaneously with both).[32,33]

Finally, the clinical import (validity) of the above mentioned time-resolved observations in the motor realm is corroborated by the hitherto ignored observation that only one-half of the 35 supratentorial cases of cerebral herniation described by Kernohan and Woltman in their 1929 article displayed (false localizing) pyramidal signs ipsilateral to the tumor; corroborating the fact that callosal interhemispheric transfers are one-way in directionality and excitatory in nature (i.e. form the major to the minor hemisphere).[34]

4 Conclusion

Approximately one in five people in society displays a handedness for which he or she is wired in the opposite direction. The dismissal of Kinnebrook by Astronomer Royal of England was based on an assumption that all right handers are created equal. Kinnebrook was in fact wired as a left hander. Bimanual simultaneous drawing task, an inexpensive and very accurate method, based on the existence of laterality in motor control, has shown quantitatively that this assumption has been flawed. Similarly flawed was Maskelyne's methodology, i.e. failure to control for the direction of motion of objects that the two observers were tracking at the time; thus the sad outcome for the "hapless" David Kinnebrook.

5 References

[1] Traub RE. Classical test theory in historical perspective. Educ Meas Issues Pract 1997: 16:8–14.

[2] Brooks GP, Brooks RC. The improbable progenitor. J Roy Astron Soc Can 1979; 73: 10-23.

[3] Schaffer S. Astronomers Mark Time: Discipline and the Personal Equation. Sci Context 1998; 2: 115-145.

[4] Derakhshan I. Handedness and macular vision: laterality of motor control underpins both. Neurol Res 2004; 26: 331-337.

[5] Derakhshan I. How do the eyes move together? New understanding help explain eye deviations in patients with stroke. CMAJ 2005; 172: 171-173.

[6] Spencer-Jones H. The measurement of time. Rep Prog Phys 1937; 4:1-26 (table 2)

[7] Sanford EC. Personal equation; ii variations in the mount of personal equation. Am J Psychol 1889; 2: 271-298.

[8] Campbell WM. On a peculiarity of personal equation. Monthly Notices of the Royal Astronomical Society 1877; 37: 283-284. (suppl)

[9] Mohr JP, Weiss GH, Caveness WF, et al. Language and motor disorders after penetrating head injury in Viet Nam. Neurology 1980; 30: 1273-1279.

[10] Beis JM, Keller C, Morin N, et al. Right spatial neglect after left hemisphere stroke. Qualitative and quantitative study. Neurology 2004; 63: 1600-1605.

[11] Thomson AM, Taylor R, Whittle IR. Assessment of communication impairment and the effects of resective surgery in solitary, right-sided supratentorial intracranial tumours: a prospective study. Br J Neurosurg 1998; 12: 423-429.

[12] Derakhshan I. Lateralities of motor control and the alien hand always coincide: further observations on directionality in callosal traffic underpinning handedness. Neurol Res 2009; 31: 258-264.

[13] Jeannerod M. The origin of voluntary action. History of a physiological concept. C. R. Biologies 2006; 329: 354-362.

[14] Derakhshan I. Crossed-uncrossed difference (CUD) in a new light: anatomy of the negative CUD in Poffenberger's paradigm. Acta Neurol Scand 2006; 113: 203-208.

[15] Teismann IK, Rainer D, Steinstraeter O, Pantev C. Time-Dependent Hemispheric Shift of the Cortical Control of Volitional Swallowing. Hum Brain Mapp 2009; 30:92–100.

[16] Kristeva R, Keller E, Deecke L, Kornhuber HH. Cerebral potentials preceding unilateral and simultaneous bilateral finger movements. Electroencephalogr Clin Neurophysiol 1979; 47: 229-238.

[17] Shen YC, Franz EA. Hemispheric competition in Left-Handers on bimanual reaction time tasks. J Mot Behav 2005; 37: 3-9. (tables 1-3)

[18] Walsh RR, Small SL, Chen EE, Solodkin A. Network activation during bimanual movements in humans. Neuroimage. 2008; 43: 540–553.

[19] Honda H. Idiosyncratic left-right asymmetries of saccadic latencies: examination in a gap paradigm. Vision Res 2002; 42: 1437-1445.

[20] Hamers JF, Lambert WE. Visual field and cerebral hemisphere preferences in bilinguals. In Language Development and Neurological Theory, Sj Segalowitz and FA Gruber (Eds.). Academic Press, New York, 1977 (PP 57-62)

[21] Derakhshan I. Right sided weakness with right subdural hematoma: motor deafferentation of left hemisphere resulted in paralysis of the right side. Brain Inj 2009; 23: 770-774.

[22] Semjen A. Summers JJ Cattaert D. Hand Coordination in Bimanual Circle Drawing. J Exp Psychol: Human Perception and Performance 1995; 21: 1139-1157. (subject DA)

[23] Buckingham G, Main JC, Carey D. Asymmetries in motor attention during a cued bimanual reaching task: Left and right handers compared. Cortex 2010, 45: 1-9. (Fig. 4a)

[24] Ioannides AA, Fenwick PB, Pitri LI, Liu E. A step towards non-invasive characterization of the human frontal eye fields of individual subjects. Nonlinear Biomed Phys 2010; 4 suppl 1: S 11

[25] Azémar G, Stein SF, Ripoll H. Effects of ocular dominance on eye-hand coordination in sporting duels. Sci & Sports 2008; 23:263-277.

[26] Thummler P, Karnath HO. Eye deviation after left hemispheric stroke. Tubingen University School of Medicine, 2009. (suppl)

[27] Badoud S, Rouiller EM. Relation between hand preference and hand dominance in human: A behavioral study. University of Fribourg School of Medicine, 2009. (suppl)

[28] Becker E. Karnath HO. Neuroimaging of eye position reveals spatial neglect. Brain 2010; 133: 909-914.

[29] Goble D. Validity of using reaction time as a basis for determining motor laterality. J Neurophysiol 2007; 97: 868.

[30] Satz P. Achenbach K. Fennell E. Correlations between assessed manual laterality and predicted speech laterality in a normal population. Neuropsychologia 1967; 5: 295-310.

[31] Wyke M. Influence of direction on the rapidity of bilateral arm movements. Neuropsychologia 1969; 7: 189-194.

[32] Lindell AK, Nicholls MER, Kwantes PJ, Castles A. Sequential processing in hemispheric word recognition: The impact of initial letter discriminability on the OUP naming effect. Brain Lang 2005; 93: 160-172.

[33] Derakhshan I. Attentional asymmetry or laterality of motor control? Commentary on Buckingham et al. Cortex 2011; 47: 509-510.

[34] Derakhshan I. The Kernohan-Woltman phenomenon and laterality of motor control: Fresh analysis of data in the article "Incisura of the crus due to contralateral brain tumor". J Neurol Sci 2009; 287: 296

.