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# Personality and Individual Differences

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## Behavioral laterality advance: Neuroanatomical evidence for the existence of hemisity

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### ABSTRACT

The new context of “Hemisity” has recently emerged. Hemisity asserts that a person is inherently either left or right brain-oriented in their thinking and behavioral styles. Such a binary situation would necessarily be demanded if there were only a single executive “observer” element, imbedded either on the left or right side of the brain. Because the anterior cingulate cortex (ACC) is the site of a major executive element of the brain, the hypothesis of a unilateral observer would predict that some element of well-known ACC anatomical asymmetries should be congruent with a subject’s hemisity. Here, this hypothesis was confirmed by the MRI-based discovery that in 146 of 149 cases (98%), Areas 24 and 24’ of the ACC were on average almost 50% thicker on the same brain side as the subject’s predetermined hemisity. Based upon this, the localization of the larger side of the ACC was used as a primary standard to calibrate recently developed biophysical methods and derivative preference questionnaires as well-correlated secondary standards for the determination of hemisity in individuals and groups without the use of MRI.

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## 1. Introduction

### 1.1. Hemispheric dominance

Although Diocles of fourth century BC Greece may have been the first to write about brain laterality (Lockhorst, 1985), Dax (1785) was the first on record in the modern era to note a difference in function between the cerebral hemispheres. In 1836, he reported that victims of injury to the left hemisphere (LH), but not the right hemisphere (RH) could not speak. This hemispheric asymmetry for language was also thought to be tied to contra-lateral hand preference (Broca, 1863). Nearly a century passed before any further manifestations of hemispheric laterality were reported. Then, a large study by Weisenberg and McBride (1935) demonstrated a RH preeminence in visuospatial skills.

### 1.2. Hemispheric laterality–cerebral asymmetry

During that century, the *first* laterality term, “dominant hemisphere”, became inextricably tied to the language processing hemisphere, which was usually the LH, because of its association with the brain areas required for speech and dominant handedness. This forced the creation of a *second* set of terms not using the word,

“dominance”, such as “hemispheric laterality” or “cerebral asymmetry”, to describe the many, more-recently discovered non-language differences in cerebral structure and function, most notably found in “split-brain” subjects. These individuals had been produced by treatment for intractable epilepsy by cutting the corpus callosum, the only cerebral connection between the hemispheres, thus limiting the spread of seizures from one to the other (Gazzaniga, 2000; Gazzaniga, Bogen, & Sperry, 1962; Sperry, 1982).

Based upon the surprisingly different responses obtained from each of these isolated hemispheres of split-brain subjects (Gazzaniga, 2000; Gazzaniga et al., 1962; Geschwind et al., 1995), it was early proposed by investigators that the right and left cerebral hemispheres are characterized by inbuilt, qualitatively different and mutually antagonistic modes of data processing, separated from interference by the major longitudinal fissure of the brain (Levy, 1969; Sperry, 1982). In this model, the left hemisphere specialized in top-down, deductive, cognitive dissection of local detail, the right hemisphere in bottom-up, inductive, perceptual synthesis of global structure (Gazzaniga, 2000; Sperry, 1982). This context has been reinforced by known laterality differences between them. That is, there are striking differences in input to each hemisphere, differences in internal neuronal-columnar architecture, and differences in hemispheric output (Hutsler & Galuske, 2003; Jäger & Postma, 2003; Kosslyn, Chabris, Marsolek, & Koenig, 1992; Kosslyn et al., 1989; Schuz, & Preissl, 1996; Stephan, Fink, & Marshall, 2006).

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Supporting the above global view is a large body of detailed evidence that the left cerebral hemisphere in most right-handed individuals manifests facilities for language (Broca, 1863), has an orientation for local detail (Robertson & Lamb, 1991), has object abstraction-identification abilities (Kosslyn, 1987), and appears to possess a hypothesis-generating, event “interpreter” (Gazzaniga, 1989, 2000; Wolford, Miller, & Gazzaniga, 2000). In contrast, the right hemisphere has been demonstrated to excel in global analysis (Proverbio, Zani, Gazzaniga, & Mangun, 1994; Robertson & Lamb, 1991), object localization (Kosslyn et al., 1989), facial recognition (Milner, 1968), and spatial construction (Sperry, 1968).

### 1.3. Hemisphericity

Among those about 90% of humans who are right-handed (Cohen, 1992), language is located in the LH in over 95% of them (Smith & Moscovitch, 1979). Of the remaining about 10% of left handed individuals, some 60% of these also have language in their left cerebrum (Levy & Reid, 1976). Thus, the LH houses language ability in at least 9 of 10 humans.

It is of interest that within this huge group of right-handed, LH-dominant speakers, the existence of two major human sub-populations has repeatedly been inferred, whose characteristic thinking and behavior styles differ in a manner that appeared to mirror the putative properties of the asymmetric hemispheres. That is, in some right-handed, LH language individuals, putative *left* hemisphere traits were proposed to be ascendant, producing a “Left brain-oriented” thinking and behavioral style (Springer and Deutch, 1998; Fink et al., 1996). Such left brain-oriented persons are currently summarized as top-down, important detail, deductive, “splitters”. Yet, in other right-handed LH language persons, *right* hemisphere traits are thought to be more prominent, resulting in a contrasting “Right brain”-oriented style (Davidson & Hugdahl, 1995; Shiffer, 1996), currently viewed as bottom-up, big picture, inductive, “lumpers”.

Thus, original permanent assignment of the term “hemispheric dominance” to language laterality ultimately forced the creation of a *third* asymmetry term, that of “Hemisphericity” (Bogen, 1969; Bogen, DeZure, Ten Houten, & Marsh, 1969) in order to describe this third laterality phenomenon. This term was needed to refer to the differences in left and right brain thinking and behavioral style within individuals of constant language dominance and non-language asymmetries.

Why should hemisphericity exist? Upon what mechanism might these two thinking and behavioral styles of hemisphericity depend? Early studies of this phenomenon were doomed by misconception that hemisphericity was the result of hemispheric competition, where each person was located on some variable site on a gradient between left and right hemisphere extremes in functional asymmetry. This made it nearly impossible to develop usable quantitative methods to determine individual hemisphericity. Primarily due to this foundational misunderstanding and mis-definition, after thousands of conflicting reports, the field of hemisphericity finally collapsed in the 1980s (Beaumont, Young, & McManus, 1984).

Twenty-five years after the death of hemisphericity, a different, more intuitive context has emerged that demands the creation of yet a *fourth* laterality term. This is the new context of “Hemistry”, where an individual is inherently, unavoidably, and irreversibly either left, or right brain orientated in thinking and behavioral style. Within each of these two hemistry subtypes, individual differences exist that depend upon the complexities inherent in the expression of that subtype.

Such a context is consistent with the logic that there can be only one “Bottom-line”, “The buck stops here” executive element in any successful institutional organization, including that of the brain. The mammalian brain is completely bilateral, except for the pineal

gland, logically leading Descartes erroneously to propose this endocrine organ to be the “Seat of the Soul” (1637). Today, it rather appears that at least one important element of the executive system must be unilateral. It is important to note that this executive element is considered not to be a homunculus, but a preconscious (Libet, 1982) survival-optimizing subsystem of the brain.

The hemistry concept was also more in alignment with the qualitatively different and mutually antagonistic modes of data processing of the opposite cerebral hemispheres, and certainly was much easier to quantify (Morton, 2001, 2002, 2003a, 2003b, 2003c, 2003d; Morton & Rafto, 2006). That is, hemistry must result because an executive element, imbedded in the local specialized (top-down, important details) environment of the left hemisphere, will inevitably have a different perspective than one imbedded within that of the right (bottom-up, global perspective).

We then reported a first neuroanatomical difference between hemistry subtypes. That is, by use of MRI midline corpus callosal cross-sectional area measurements (Morton & Rafto, 2006), we found up to threefold differences in corpus callosal information transfer capacity between right and left brain-oriented hemistry subtypes.

Where in the brain is the major element of the executive system thought to reside? And, might this structure show signs of laterality directly related to a subject’s hemistry, thus supporting a relationship between the two? Much evidence supports the anterior cingulate cortex as a major structural element of the brain’s executive system (Devinsky, Morrell, & Vogt, 1995; Paus, 2001; Vogt, 2005; Vogt, Derbyshire, & Jones, 1996; Vogt, Finch, & Olson, 1992). Further, there are at least ten reports of structural asymmetries in both the paracingulate sulcus (PCS) and occasionally in the perigenual anterior cingulate and the anterior midcingulate region that alternated in an individually variable manner, especially in Areas 24, and 24’ (Palomero-Gallagher, Mohlberg, Zilles, & Vogt, 2008; Vogt, Nimchinsky, Vogt, & Hof, 1995).

These include the following: (Fornito et al., 2004, 2006, 2008; Huster, Westerhausen, Kreuder, Schweiger, & Whittling, 2007; Hutsler, Loftus, & Gazzaniga, 1998; Paus, Otaky, et al., 1996; Paus, Tomaiuolo, et al., 1996; Pujol et al., 2002; Yucel et al., 2001). Many of these reports have sought to identify behavioral consequences of these identified asymmetries, interestingly including their possible relationship to executive function.

The hypothesis driving the present research is the following: an individual’s hemistry subtype will be on the same side of the brain as some structural asymmetry of the ACC. We used MRI to inquire whether any known ACC asymmetry in Areas 24 and 24’ was associated with the predetermined right or left brain-oriented hemistry subtype of 149 subjects. Finding that such was indeed the case, the relationship of that ACC asymmetry to existing methods for the determination of hemistry was also investigated.

## 2. Methods

### 2.1. Subjects

This research was conducted in compliance with the Code of Ethics of the World Medical Association and the Committee of Human Studies at the University of Hawaii Institutional Review Board and posed no significant risks to participants. The 149 subjects of this study were non-patient colleagues, graduate students, and others from the University of Hawaii at Manoa community. Their age ranged from 18 to 74 years in age (43.8 years median age,  $\pm 14.2$  years SD). Of these, 74% were Caucasian, the remainder being primarily Asian. Eleven percent claimed left-handedness, a value near the 10% commonly reported (Hardyck & Petrinovich, 1977; although see Morton, 2003b; McManus, 2002).

Six independent methods for hemisity assessment (Morton, 2001, 2002, 2003a, 2003b, 2003c), briefly described below, had earlier been administered to each subject. The estimated hemisity for a subject was based upon the combined hemisity outcomes for each test converted from continuous to ordinal scores to give a final majority outcome, for example: R + R + L + R + L = R. An average of  $5.3 \pm 1.3$  SD of these tests were administered to each subject. No R – L numerical outcome ties occurred. Thus, there were 141 subjects who took three or more tests. The test outcomes for the remaining eight subjects were unanimous. Three of the assays were biophysical in nature and indeed reflected actual brain laterality consequences of hemisity. For example, about half of the right hander's, assessed by the Best Hand Test (Morton, 2003b), were more accurate bisecting lines with their left hands, as directed by their more controlling right hemisphere.

Among the 77 males, 38 were thus pre-identified as right brain-oriented (RMs), and 39 were left brain-oriented (LMs). Of the 72 females, 32 were right brain-oriented (RFs) and 40 were left brain-oriented (LFs). Thus, there were 70 right brain-oriented persons (RPs) and 79 left brain-oriented persons (LPs). Hemisity assessment was further addressed later in this report.

## 2.2. MRI setup for assessment of the anterior cingulate cortex asymmetries

MRI assessments were obtained employing a General Electric Signa 1.5 Tesla MRI instrument. A midsagittal plane setup calibration protocol was run for 3 min using a T1 weighted spin echo sequence (TR = 400 ms, TE = 1/Fr) to image 5 mm thick slices from the midline plane and two adjoining sagittal planes 6 mm on either side. The in-plane resolution was  $860 \times 980 \mu\text{m}$ . Whole-head photographic images (magnification =  $0.72\times$ ) were directly prepared from these three planes. These three exposures were printed on a single  $35 \times 43$  cm film sheet for each subject. This procedure enabled both cortical walls on either side of the midline fissure to be visualized and measured, thus allowing subelement lateralities of the ACC to be evaluated. Digital analysis processing equipment was not available. However, triplicate quantitative measurements

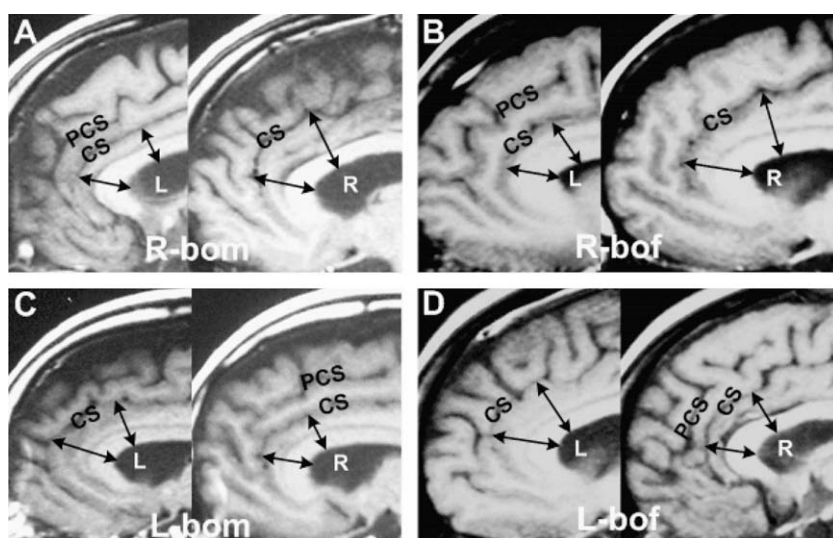
were made manually directly from the film with an intra-rater reliability of 0.96.

## 2.3. Quantification of paracingulate sulcus extent and laterality

Three categories were used to describe the presence on the MRI image of the paracingulate sulcus (PCS) of the ACC in Areas 24 and 24', as either absent (A), light (L), or heavy (H). These corresponded to the terms "absent", "present", and "prominent" of Paus, Tomaiuolo, et al. (1996). The use of the term "absent" is not meant to be taken literally, but as a qualitative statement to indicate any PCS that may have still been present was so light as to be dismissible. If the PCS was "absent" on both sides ( $n = 2$ ), light on both sides ( $n = 1$ ), or heavy on both sides ( $n = 1$ ), the side with the larger PCS could still be visually estimated by their relative film densities (even for the two "absent" cases). A PCS laterality score (from  $-3$  to  $3$ ) was created by assigning numeric values to the nine possible PCS laterality combinations observed as follows. The PCS index distributions from left to the right sides of the brain were weighted as follows: HA ( $-3.0$ ), HL ( $-2.0$ ), LA ( $-1.0$ ), HH, LL, or AA ( $0.0$ ), AL ( $+1.0$ ), LH ( $+2.0$ ), AH ( $+3.0$ ).

## 2.4. Assessment of the laterality of the ventral gyrus in areas 24 and 24' of the ACC

At two ACC sites on each side of the brain, one in Area 24 and the other at Area 24' (Vogt et al., 1995), estimations of the relative thickness of the ventral gyri (vgACC) there were made. This abbreviation and these four ACC locations within Areas 24 and 24' are not to be confused with the more frontal ventral region of the perigenual ACC. The vgACC locations where these relative thickness estimations were made are illustrated by the arrows in Fig. 1. Two lines were extended outward perpendicularly from the inner edge of the CC, ending in one case at a more frontal point in Area 24 and in the other at a more dorsal point in Area 24'. Both points were in the plane of the cingulate sulcus and arbitrarily selected, based upon the sites in the region giving the largest thickness for each brain side involved. There were no points on the film where



**Fig. 1.** Asymmetries of the Anterior Cingulate Cortex. Three MRI sagittal images were taken for each of the 149 hemisity-calibrated subjects: 6 mm right, at midline, and 6 mm left of the midline. (R-bom or RM) right brain-oriented male subject with a larger right vgACC, (R-bof or RF) right brain-oriented female subject with a larger vgACC, (L-bom or LM) left brain-oriented male subject with a larger left vgACC, and (L-bof or LF) left brain-oriented female subject with a larger vgACC. Pairs of arrows reaching from the lower surface of the corpus callosum to the cingulate sulcus (CS) illustrate four measurements made for each subject. Corpus callosal thicknesses were also measured for each subject and subtracted from the four measurements to give thickness of the vgACC. The paracingulate sulcus (PCS), when present, is seen above the CS. Note that the distance to the cingulate sulcus was shorter on the side of the brain where the paracingulate gyrus was present, while the relative vgACC thickness was greater on the opposite side.

detectable boundaries were not present (Fig. 1). These vgACC measurements excluded dorsally to the paracingulate gyrus.

For about 20% of the subjects, the upper dorsal edge of the CC, the lower boundary of the vgACC was obscure, as illustrated in the right hemisphere panel of Fig. 1B. In order not to exclude these subjects, the always-sharp ventral edge of the CC was used as the lower reference point and accurate CC thicknesses were obtained from the other two sharp sections of the three vertical sections (–6, 0, and +6 mm). This was justified because when the CC boundaries in all three sections were sharp, the thickness along its length was invariant within each subject. These CC thickness measurements were subtracted from the overall measurement to give two estimates of the relative thickness of the vgACC on either side of the brain. All measurements were made in triplicate to the nearest mm by a single estimator. The average of these two lateral relative thickness estimates from the vgACC of each side were then used to determine upon which side of each subject's brain the vgACC was thicker. These data were also used to compute a left side/right side thickness ratio (L/R) of the vgACC for each subject. Also a vgACC Relative Thickness Laterality Index was compiled, defined as  $(L - R)100/(L + R)$ , where L and R are the averaged thicknesses in mm determined for the right and left side of each brain.

### 2.5. Hemisity determination methods

The following six independent hemisity methods, previously used to determine subject hemisity, were described in detail elsewhere:

*The Dichotic Deafness Test* (Morton, 2001, 2002; Morton & Rafto, 2006): utilized the "Tonal and Speech Materials for Auditory Perceptual Assessment", Disc 1.0 (1992), purchased from the Long Beach Research Foundation. This was used to measure minor ear deafness of 115 pseudo-randomly selected subjects during simultaneous and 90 ms-separated presentations of dichotic consonant–vowel syllables. Attention bias (Iaccino & Houran, 1989) was reduced by instructing subjects to write syllables heard in each ear.

*In The Phased Mirror Tracing* (Morton, 2003a), mirror tracings of pentagonal stars were produced by both hands of 131 subjects with the aid of a Lafayette Instrument, Mirror-drawing apparatus, Model 31010. Competitive mean elapsed time outcomes between

hands were phase-adjusted by use of the Affective Laterality Test (Morton, 2003a).

*In The Best Hand Task* (Morton 2003b, 2003d): forms containing 20 horizontal lines for each hand to bisect were completed by 142 subjects, measured, phased, and scored according to Morton (2003b).

*In Zenhausen's Preference Questionnaire* (Morton, 2002; Zenhausen, 1978), all subjects ranked 21 statements from "strongly agree to strongly disagree".

*The Polarity Questionnaire* (Morton, 2002) is a binary questionnaire of 11 statements, which were assessed by all subjects, using true or false answers.

*In the Asymmetry Questionnaire* (Morton, 2003c) all subjects selected between 15 binary statement pairs.

The above six methods were used earlier to determine each subject's individual hemisity (mean number of methods/subject was 5.3). The Best Hand Test alone has also been used to investigate the mean hemisity of academic and professional populations ( $n = 1048$ ; Morton, 2003d).

### 2.6. Statistical analysis

The Statistica 6.0 package was used to assess the strength of these data and their associations with the various hemisity methods, including the use scatter plotting and Pearson's correlational analysis.

## 3. Results

### 3.1. Replication of reported para cingulate sulcus asymmetries

The data in Table 1, replicates the usual finding that the para cingulate sulcus (PCS) is relatively more prominent in left hemispheres (70%) than in right hemispheres (60%). (Fornito et al., 2004, 2006, 2008; Hutsler et al., 1998; Ide et al., 1999; Paus, Otaky, et al., 1996; Paus, Tomaiuolo, et al., 1996; Yucel et al., 2001). Few if any gender differences were noted: the PCS was present in the right hemisphere in a higher percentage of females (65%) than males (53%), while on the left hemisphere the PCS was present in a lower percentage (62%) of females than males (65%). Because each hemisphere was tallied independently, not obvious from Ta-

**Table 1**  
Paracingulate sulci observed: frequency, laterality and extent.

	Heavy "prominent"	Light "present"	"Absent"	Present + absent = total (%)
Left hemisphere	13F + 14 M = 27 (18%)	31F + 47 M = 78 (52%)	27F + 17 M = 44 (30%)	105 (70%) + 44 = 149
Right hemisphere	14F + 22 M = 36 (24%)	32F + 21 M = 53 (36%)	25F + 35 M = 60 (40%)	89 (60%) + 60 = 149

Females = F, males = M.

**Table 2**  
Paracingulate sulcus of the anterior cingulate cortex: distribution and extent.

PCS location	Heavy on LH absent on R (HA)	Heavy on LH light on R (HL)	Light on LH absent on R (LA)	Absent light, or heavy on both sides	Light on RH absent on L (AL)	Heavy on RH light on L (LH)	Heavy on RH absent on L (AH)
Index value assigned	–3	–2	–1	0	1	2	3
Females 72	4	9	21	2	22	9	5
Males 77	5	8	28	2	13	19	2
Total 149	9 (6%)	17 (11%)	49 (33%)	4 (3%)	35 (23%)	28 (19%)	7 (5%)
Site of PCS		Mostly left	+	Ambiguous 4 (3%)	+	Mostly right	
<i>n</i>		75 (50%)				70 (47%)	

Abbreviations: PCS = paracingulate sulcus, RH = right hemisphere, LH = left hemisphere, H = heavy (PCS was "prominent"), L = light (PCS was "present"), A = absent (PCS was "absent").

ble 1 was the finding that 98% of subjects had a PCS visible on at least one side.

When both sides of the cerebrum were considered together (Table 2), it may be seen that for 75 (50%) subjects the PCS still was predominantly on the left side of the brain, of these 34 were female and 41 male. The remaining 70 (47%) subjects were found to have their PCS mainly on the right side, of these 36 were female and 34 were male. Of the 72 females and 77 males in the group, only four subjects were ambiguous in terms of their PCS laterality: one male with both sides heavy, one female with both sides light, and two males with no PCS visible.

Based upon the existence within each subject of nine possible PCS distribution combinations, a PCS Laterality Index was created, illustrated in Table 2, using the terms “prominent (heavy, H), pres-

ent (light, L), or absent (absent, A)”. Subject distributions within these categories (Table 2) were HA (6%), HL (11%); LA (33%); HH, LL, and AA (3%); AL (23%); LH (19%); AH (5%).

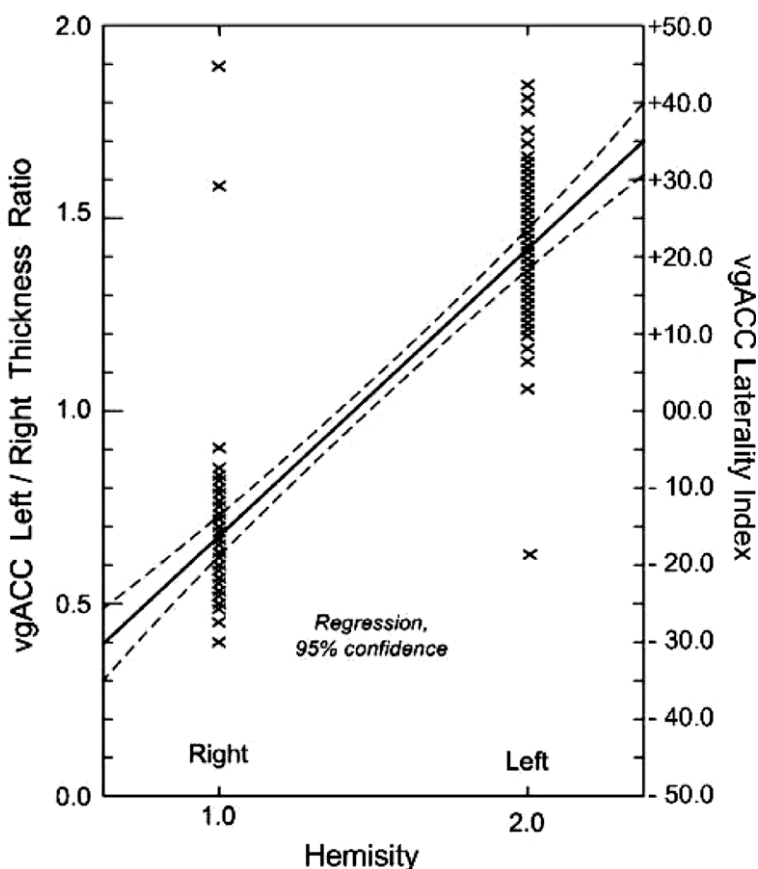
### 3.2. Asymmetries of the relative thickness of the ventral gyri of area 24–24' cingulate cortex

The relative thickness of the ventral gyri of the ACC in Areas 24 and 24' on both sides of each brain was directly measured from the MRI film, as detailed in Section 2 (see Fig. 1). Table 3 indicates that the vgACC average thickness for all subjects ( $n = 149$ ) was  $11.7 \pm 3.2$  SD mm on the right and  $11.8 \pm 3.2$  SD mm on the left side of the brain, giving a L/R ratio of 1.08. However, the subjects were then sorted into two groups, depending on whether their vgACC

**Table 3**  
Relative estimated thickness asymmetry of the vgACC.

Brain side, subjects $n = 149$	Left and right relative thickness, mm <sup>a</sup>	Relative thickness L/R ratio	Relative Thickness Laterality Index = $(L - R)100/(L + R)$
All subjects males 78, females 71	Left: $11.7 \pm 3.2$ SD Right: $11.8 \pm 3.2$ SD	$1.08 \pm 0.60$	$-0.48 \pm 20.9$ SD
Subjects with thicker left vgACC, $n = 78$ males 38, females 40	Left: $13.8 \pm 2.5$ SD Right: $9.5 \pm 2.2$ SD	$1.45 \pm 0.30$	$+17.8 \pm 8.4$ SD
Subjects with thicker right vgACC, $n = 71$ males 40, females 31	Left: $9.3 \pm 1.8$ SD Right: $14.1 \pm 2.5$ SD	$0.66 \pm 0.15$ average difference between sides = $48 \pm 22$ SD%	$-20.8 \pm 7.4$ SD

<sup>a</sup> Relative thickness was corrected to 1.0 $\times$  magnification.



**Fig. 2.** Distribution of Subjects by vgACC Left/Right Thickness Ratio and by vgACC Laterality Index. Of the 149 subjects, 70 had the larger vgACC located on the right side of their brains, as indicated by a L/R ratio of less than one. The other 79 had ratios above one, indicating the larger of the two vgACC occurred on their left. Of these 149, 146 were determined to have a hemisity located on the same side as the thicker vgACC. A similar plot results when the data are converted to a vgACC Relative Thickness Laterality Index, defined as  $= (L - R)100/(L + R)$ , where L and R are the averaged thicknesses in mm determined for the right and left sides of each brain. The three outlier subjects are visible on the combined double plot.

was relatively thicker on the left or right side of the brain. As illustrated in Table 3, the mean L/R ratio for the subjects whose gyri were larger on the left ( $n = 78$ , 38 males, 40 females) was  $1.45 \pm 0.30$  SD, compared a mean L/R ratio of  $0.66 \pm 0.15$  SD for those subjects ( $n = 71$ , 40 males, 31 females) whose gyri were larger on the right. Since the reciprocal of 1.45 is 0.68, within each brain there was the considerable size difference between the two adjacent vgACC of approximately 1.5-fold ( $48 \pm 16\%$ , SD,  $p = 0.000$ ). The vgACC Laterality Index =  $(L - R)100 / (L + R)$  was also shown in Fig. 2 where it may be seen that for all subjects the index was  $(-)\text{0.48} \pm 20.9$  SD, while for subjects with a thicker vgACC on the left side the index was  $(+)\text{1.78} \pm 8.4$  SD and for subjects with a thicker vgACC on the right it was  $(-)\text{20.8} \pm 7.4$  SD.

Table 4, shows the near congruence between the directly measured thicker brain side of the vgACC and the subject's predetermined hemisity subtype. In 146 of the 149 subjects, both variables were on the same side (=98%). The vgACC Relative Thickness Laterality Index was almost absolutely correlated with the vgACC L/R Relative Thickness Ratio ( $r = 0.99$ ,  $p = 0.000$ ,  $n = 149$ ), while the Laterality Index showed a slightly smaller correlation with the side of the brain upon which the vgACC was found to be thicker by direct measurement ( $n = 0.93$ ,  $p = 0.000$ ). Crucially, the vgACC Relative Thickness Laterality Index was very highly correlated with the subjects' predetermined binary hemisity ( $r = 0.90$ ,  $p = 0.000$ ,  $n = 149$ ).

There was also a high negative correlation between the larger side of these gyri and the more predominant PCS side and ( $r = -0.78$ ,  $p = 0.000$ ,  $n = 149$ ). Thus, the side of the brain both with the larger vgACC and subject hemisity subtype was generally opposite to that with the larger PCS. There was no relationship between either of these idiosyncratic ACC asymmetries to the sex ( $r = 0.08$ ,  $p = 0.309$ ) or handedness ( $r = -0.04$ ,  $p = 0.601$ ) of these subjects.

A scatter plot to illustrate the spread of the vgACC relative thickness data versus hemisity is shown in Fig. 2 where again 146 of the 149 subjects (98%) were found to have their predetermined hemisity on the same brain side as that of the larger vgACC. An almost identical plot resulted from the vgACC Relative Thickness Laterality Index. These data were also incorporated into Fig. 2. The three outlier subjects were clearly visible in this composite plot.

### 3.3. ACC laterality as a potential primary standard for binary hemisity

#### 3.3.1. Correlations of secondary standard methods for hemisity with vgACC laterality

Thus, laterality of the major side of the vgACC appeared to be as close to a neuroanatomical primary standard for hemisity as one might reasonably ask. In fact, due to the statistical nature of the earlier hemisity assignments, vgACC laterality could well be an absolute measure of hemisity.

By assigning laterality of vgACC as the primary standard for hemisity, the six earlier methods for individual hemisity determi-

nation (Morton, 2001, 2002, 2003a, 2003b, 2003c) could be then compared for relative accuracy. As shown for the three biophysical methods in Table 5, top, the Dichotic Deafness method (Morton, 2001, 2002) was significantly correlated with the MRI standard ( $r = 0.50$ ,  $p = 0.000$ ,  $n = 109$ ). The Mirror Tracing method (Morton, 2003a) was strongly correlated with the major side of the vgACC ( $r = 0.86$ ,  $p = 0.000$ ,  $n = 118$ ). Similarly, Best Hand Test (Morton, 2003b) correlation with the MRI hemisity standard was also high ( $0.83$ ,  $p = 0.000$ ,  $n = 142$ ).

In terms of the three Hemisity Questionnaire Methods (Table 1, bottom), scores from Zenhausern's earlier Preference questionnaire (Morton, 2002; Zenhausern, 1978) were modestly but significantly inversely correlated (Table 2) with the major vgACC side ( $r = -0.36$ ,  $p = 0.000$ ,  $n = 118$ ). However, higher correlations with ACC asymmetry were found for scores from the Asymmetry Questionnaire (Morton, 2003c) at  $r = -0.56$ ,  $p = 0.000$ ,  $n = 121$  and the Polarity Questionnaire (Morton, 2002) at  $r = -0.63$ ,  $p = 0.000$ ,  $n = 133$ .

#### 3.3.2. Validity of use of secondary standards for the determination of the binary hemisity of individuals and groups

Calibration of the intercorrelated secondary hemisity standards against this MRI-based primary hemisity standard (Table 3) is important because, due to cost and scheduling limitations, MRI determinations of individual hemisity are not readily accessible at present. It also permitted us to begin to address a central question: how many of these three biophysical and three questionnaire methods for hemisity are required to accurately determine the hemisity of an individual?

In Table 6, the binary hemisity outcomes of the 111 subjects who participated in all six methods are compared with predicted random probabilities. If the methods were not specific for hemisity, the number of subjects predicted to have the same outcome for all six instruments was only 1.6%. In contrast, 40% of our subjects had six identical hemisity determination outcomes. Similarly, only 9% of subjects would have the same outcomes for five of the six non-specific methods. Yet, here 39% of them received the same five hemisity outcomes. 20% of the subjects had the same outcome in four of the six tests and only 3% the same outcome for three of six methods. When those subjects having majority outcomes (4/6, 5/6, or 6/6) for the tests were assigned that hemisity, 99% of the subjects were correctly categorized.

**Table 4**  
Correlation of vgACC Laterality Index with other variables.

vgACC Laterality Index vs.	<i>r</i>	<i>p</i>	<i>n</i>
vgACC relative R/L thickness ratio	0.99	0.000*	149
Thicker side of vgACC	0.93	0.000*	149
Hemisity subtype <sup>a</sup>	0.90	0.000*	149
PCS laterality score	-0.76	0.000*	149
Sex	0.03	0.688	149
Handedness	-0.02	0.845	149

\* Significant.

<sup>a</sup> There were three discrepant subjects out of 146/149 = 98% congruence.

**Table 5**  
Correlations of laterality of the vgACC with outcomes of biophysical and questionnaire methods for hemisity.

Brain side with largest vgACC vs.	<i>r</i>	<i>p</i>	<i>n</i>
<i>Biophysical hemisity methods</i>			
Dichotic listening score	0.50*	0.000	109
Best hand test score	0.83*	0.000	142
Phased mirror tracing score	0.86*	0.000	118
<i>Questionnaire hemisity methods</i>			
Zenhausern's preference questionnaire score	-0.36*	0.000	118
Asymmetry Questionnaire score	0.56*	0.000	121
Polarity Questionnaire score	0.63*	0.000	133

\* Significant.

**Table 6**  
Outcomes for 111 subjects assessed by all six secondary hemisity tests.

Tests with same results	Outcome if random (%)	Outcome observed (%)
6/6	1.6	40
5/6	9.4	39
4/6	23.5	20
3/6	31	1

#### 4. Discussion

There were four major findings from this research. First, the mean estimated relative thickness of the bilateral vgACC, previously known to be asymmetric in Areas 24 and 24' (Fornito et al., 2008), was about 50% larger on one side than it was on the other side, in an idiosyncratic manner. Second, the hemisity subtype of each subject directly coincided with the larger side of the vgACC in 146 of 149 (98%) cases. Third, both hemisity and the larger side of the vgACC were negatively correlated with the major side of the para cingulate sulcus. By assigning vgACC laterality as a primary standard for hemisity, a fourth finding was that there were relatively high correlations between this anatomical feature and the six methods previously used to determine binary hemisity (Morton, 2001, 2002, 2003a, 2003b, 2003c).

##### 4.1. Evidence for an executive system element residing asymmetrically within the ACC

The ACC is believed to be a major executive structure in the brain, playing a critical role in assessing the motivational content of internal and external stimuli, and in regulating context-dependent decision, initiation, and evaluation of goal directed behaviors (Gehring & Willoughby, 2002; Kerns et al., 2004; Mars et al., 2005; Paulus & Frank, 2006). Further investigations of the function of the ACC in experimental animals and humans have reinforced the possibility that this ventral-medial, bilateral structure plays a crucial role in executive processes of the brain, and has resulted in unifying hypotheses (Devinsky et al., 1995; Paus, 2001).

The existence of major asymmetries in the ACC supports the hypothesis of the possible existence of a unilateral executive element. This idea, as developed in the introduction, is not new. When he learned that the bilateral ACC was the probable site of the executive system, Crick (1994) was led by similar logic, rhetorically but negatively to ask: "Could there be two centers of the Will?" (Sejnowski, 2004). In a "Postscript on the Will" within his book "The Astonishing Hypothesis", (1994), Crick states that he and Antonio Damasio arrived at the same negative answer to this question by noting about the ACC that the "region on one side projects strongly to the corpus striatum (an important part of the motor system) on both sides of the brain, which is what you might expect from a single Will." Parenthetically, neither their use of the term Will, nor the use of the term Executive System here were intended to invoke the idea of a decisional homunculus, but rather of a preconscious early response system (Libet, 1982) continually acting to optimize the survival of the organism.

Literally, thousands of reports have invoked the concept of an ACC-based executive, some even asking which side of the ACC was required to maintain executive function. Assuming that a unilateral executive system did exist within the asymmetries of the ACC, if that executive was in the same hemisphere as language, there should be less need for trans colossal communication than if the executive were in the opposite non-language hemisphere. Evidence supporting this concept has been supplied by Morton and Rafto (2006) who showed that in right-handed subjects, 95% of whom have language on the left (Smith & Moscovitch, 1979), the midline corpus callosal cross-sectional areas were significantly smaller in left brain-oriented subjects than in right brain-oriented subjects, both in males and females. Further support for a unilateral executive "Observer" has been supplied by hemisometry results (Morton, unpublished) where a single light flash submitted to each hemisphere, either by temporal or nasal retinae only, was perceived as two flashes, due to the delay caused in the travel from the observerless side across the corpus callosum to the side of

the observer (Klemm, 1925; Ringo, Doty, Demeter, & Simard, 1994).

##### 4.2. Unilaterality of the executive system and the existence of binary hemisity

Such laterality of an executive system element provides the missing mechanism for the existence of hemisphericity (Beaumont et al., 1984), and specifically for hemisity. Depending upon within which of the functionally very different hemispheres this executive module is embedded, local environmental conditions resulting from differences in hemispheric structure, connectivity, and function would seem to demand the existence of the contrasting thinking and behavioral style differences between right and left brain-oriented individuals as inevitable.

##### 4.3. Use of ACC laterality as a primary standard for the determination of binary hemisity

The near congruity of the larger side of the vACC and side of individual hemisity suggests that MRI scans could be used as a primary standard for the estimation of individual hemisity. There was enough variability in the earlier methods to accommodate the 2% of subjects so misidentified. Since all six of the previous hemisity procedures were well correlated with the primary standard, it would appear reasonable they could continue to be used in combination as secondary standards. When all five of these six were used (5.3 average) the combined outcome for the 149 subjects was 146/149 (98%) correct. For the 111 subjects assessed by all six secondary methods, the accuracy rose to 99%.

Yet, no single secondary method can be used to absolutely identify subject hemisity, each being correct only about 80% of the time. However, the combined use of at least four methods (e.g., the Best Hand Task, and three questionnaires) allows for the fairly accurate measurement of the hemisity of individuals. In contrast, use of only one biophysical method was found sufficient to determine the mean hemisity of a group, if the group was large enough. Using only the Best Hand Task (Morton, 2003b) for 1048 university students and professionals, it was found that a substantial amount of hemisity sorting-selection had occurred during higher education and career selection (Morton, 2003d). In another population ( $n = 703$ ), the Polarity Questionnaire was compared to the Best Hand Task and found to give comparable hemisity results among English-speaking subjects (Morton & Svard, unpublished).

Confirmation that the three earlier biophysical methods developed to assess hemisity were well correlated with a putative primary standard for hemisity, based upon brain structure asymmetry, could be viewed as a validation of some of the assumptions used in their development. For example, in the Dichotic Deafness Test (Morton, 2001), it was necessary to make arbitrary decisions as to where to draw cutoff lines. In the Phased Mirror Tracing Method (Morton, 2003a) it was necessary to assess a portion of the subjects as to which was the more emotional side of their brain. This was based upon the examiner's interpretation of the subjective judgment of the subject in response to peripheral presentation of pictures containing emotion-invoking content. In the Best Hand Task (Morton, 2003b) a certain portion of the population required redefinition of handedness and the sometimes-difficult assessment of pen grasp hand posture. It is paradoxical that it was necessary to develop the secondary methods first in order to calibrate the hemisity of a sufficiently large group of subjects even to begin to search for and recognize actual brain structural differences between left and right brain-oriented individuals.



#### 4.4. Interpretation of earlier reports of ACC behavioral asymmetry from the perspective of hemisity

Hemisity may account for earlier results of attempts to find behavioral or other consequences paired to the brain side with the largest paracingulate sulcus. For example, Pujol et al. (2002) reported that in their Barcelona subject population, a prominent right anterior cingulate was more frequent in women than men. Further, both men and women in this category defined themselves as experiencing greater worry, fearfulness, and shyness than those with a prominent anterior cingulate on the left. Since this research group counted the para cingulate gyrus as part of the ACC (Paus, Otaky, et al., 1996), whereas we and others did not (Fornito et al., 2008), their subjects with “prominent right anterior cingulate” correspond to our left brain-oriented subjects. It is our finding that often the members of the left brain-oriented hemisity subtype are indeed the more anxious of the two categories. Morton, 2002, 2003c; Morton, McLaughlin, & Rafto, unpublished).

In studies to investigate the behavioral consequences of the individual variability of the larger side of the PCS, a set of putative executive cognitive tests were administered by Fornito et al. (2004, 2008). They found that the leftward pattern of PCS asymmetry was associated with better performance across verbal and non-verbal executive tasks, but that PCS variability had no effect on tasks thought to be less dependent upon executive functions (Fornito et al., 2004). Since we find that the side PCS predominance occurred on the opposite side as the hemisity of our subjects, it would appear that the best performers on their executive tasks were right brain-oriented individuals. In 2008, Fornito et al., reported that similar subjects (who also had a greater vgACC thickness on the right, thus further confirming them to be right brain-oriented), performed better on a test of spatial working memory ability. Their observation is consistent with the greater spatial skills demonstrated by the right hemisphere (Weisenberg & McBride, 1935), and which manifests itself in the more global orientation of the right brain hemisity subtype (Morton, 2002, 2003c) and for propensity of this hemisity subtype to select spatially-oriented professions, such as astronomy, architecture, and mechanical engineering (Morton, 2003d).

#### 4.5. Limitations

It became feasible for us to conduct this research at our (non-academic) hospital MRI facility when we found we could obtain vgACC relative thickness information by use of a triple sagittal MRI calibration requiring only a three minute scan per subject. Our results are qualitatively similar to others using more extensive, but much more costly approaches requiring large numbers of coronal scans to produce extensive anatomical reconstruction maps. Similarly, the use of manual quantification methods, rather than computerized thickness and area estimations requiring elaborate instrumentation and software, greatly reduced the magnitude of effort required for its quantification in terms of personnel and other costs.

However, it is acknowledged that use of this approach markedly reduced the flexibility and scope of options available. For example, it is not possible to speak of the absolute thickness of the vgACC, because, cortical thickness is determined from the pial surface to the border with the white matter, not its surface distribution, as done here, which can only give an estimate of relative thicknesses. Fortunately, extensive work by others providing control information on such topics as the relationship of cortical thickness to intracranial and anterior cortical volumes, grey matter amounts, sulcal depths, surface areas, etc., preceded this work (Fornito et al., 2006, 2008). For example, intracranial volume was found not to be a significant covariant with ACC cortical thickness (Fornito et al., 2008).

Lastly, the relationship of the thinking and behavioral differences between left and right brain-oriented individuals of hemisity to the many subelements of existing personality models remains to be determined. In this regard, propensity to report paranormal or mystical experiences and religiosity in general come to mind (Lange, Irwin, & Houran, 2000; Persinger, 1983, 1984, 1993). The hemisity subtype abundances within mental illnesses are also ripe topics for research. It is here predicted that left brain-oriented individuals will be found to be overrepresented in victims of post-traumatic stress disorder, in poor responders to SSRI antidepressants, and almost absent among individuals with developmental dyslexia.

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#### References

- Beaumont, G., Young, A., & McManus, I. C. (1984). Hemisphericity: A critical review. *Cognitive Neuropsychology*, 1, 191–212.
- Bogen, J. E. (1969). The other side of the brain II. An appositional mind. *Bulletin of the Los Angeles Neurological Society*, 34, 135–162.
- Bogen, J. E., DeZure, R., Ten Houten, W. D., & Marsh, J. F. (1969). The other side of the brain. IV. The A/P ratio. *Bulletin of the Los Angeles Neurological Society*, 37, 49–61.
- Broca, P. (1863). Localisations des fonctions cerebrales. Seige de la faculte du langage articule. *Bulletin de la Societe d Anthropologie*, 4, 200–208.
- Coren, S. (1992). *The left-hander syndrome: The causes and consequences of left-handedness*. New York: Free Press.
- Crick, F. (1994). *The astonishing hypothesis: The scientific search for the soul* pp. 265–268. New York: Charles Scribner and Sons.
- Davidson, R. J., & Hugdahl, K. (1995). *Brain asymmetry*. Cambridge, MA: MIT Press.
- Dax, M. (1785). Lésions de la moitié gauche de l'encéphale coincident avec moublé des signes de la pensée. *Gazette Hebdomadaire de Medécine et de Chirurgie*, 2(2eme serie), m 2. (read at Montpellier in 1836.).
- Descartes, R. (1637). La dioptrique. In *Discours de la Methode, Leiden, Ian Maire*. Adam and Tannery (1964–74), Vol. VI.
- Devinsky, O., Morrell, M. J., & Vogt, B. A. (1995). Contributions of anterior cingulate cortex to behavior. *Brain*, 118, 297–306.
- Fink, G. R., Halligan, P. W., Marshall, J. C., Frith, C. D., Frackowiak, R. S., & Dolan, R. J. (1996). Where in the brain does visual attention select the forest and the trees? *Nature*, 382, 626–628.
- Fornito, A., Whittle, S., Wood, S. J., Velakoulis, D., Pantelis, C., & Yucel, M. (2006). The influence of sulcal variability on morphometry of the human anterior cingulate and paracingulate cortex. *Neuroimage*, 33, 843–854.
- Fornito, A., Wood, S. J., Whittle, S., Fuller, J., Adamson, C., Saling, M. M., et al. (2008). Variability of the paracingulate sulcus and morphometry of the medial frontal cortex: Associations with cortical thickness, surface area, volume, and sulcal depth. *Human Brain Mapping*, 29, 222–236.
- Fornito, A., Yucel, M., Wood, S., Stuart, G. W., Buchanan, J., Proffitt, T., et al. (2004). Individual differences in anterior cingulate/paracingulate morphology are related to executive functions in healthy males. *Cerebral Cortex*, 14, 424–431.
- Gazzaniga, M. S. (1989). Organization of the human brain. *Science*, 245, 947–952.
- Gazzaniga, M. S. (2000). Cerebral specialization and interhemispheric communication: Does the corpus callosum enable the human condition? *Brain*, 123, 1293–1326.
- Gazzaniga, M. S., Bogen, J. E., & Sperry, R. W. (1962). Some functional effects of sectioning the cerebral commissures in man. *Proceedings of the National Academy of Sciences, USA*, 48, 1765–1769.
- Gehring, W. J., & Willoughby, A. R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. *Science*, 295, 2279–2282.
- Geschwind, D. H., Iacoboni, M., Mega, M. S., Zaidel, D. W., Cloughesy, T., & Zaidel, E. (1995). Alien hand syndrome: Interhemispheric motor disconnection due to a lesion in the midbody of the corpus callosum. *Neurology*, 45, 802–808.
- Hardyck, C., & Petrino, L. F. (1977). Left-handedness. *Psychological Bulletin*, 4, 385–404.
- Huster, R. J., Westerhausen, R., Kreuder, F., Schweiger, E., & Whittling, W. (2007). Morphologic asymmetry of the human anterior cingulate cortex. *Neuroimage*, 34, 888–895.
- Hutsler, J., & Galuske, R. A. W. (2003). Hemispheric asymmetries in cerebral cortical networks. *Trends in Neurosciences*, 26, 428–435.
- Hutsler, J. J., Loftus, W. C., & Gazzaniga, M. S. (1998). Individual variation of cortical surface area asymmetries. *Cerebral Cortex*, 8, 11–17.
- Iaccino, J. F., & Houran, J. (1989). Influence of stronger attentional manipulations on the processing of dichotic inputs in right-handers. *Perceptual and Motor Skills*, 69, 1235–1240.

- Ide, A., Dolezal, C., Fernández, M., Labbé, E., Mandujano, R., Montes, S., et al. (1999). Hemispheric differences in variability of fissural patterns in parasylvian and cingulate regions of human brains. *Journal of Comparative Neurology*, *410*, 235–242.
- Jager, G., & Postma, A. (2003). On the hemispheric specialization for categorical and coordinate spatial relations: A review of the current evidence. *Neuropsychologia*, *41*, 504–515.
- Kerns, J. G., Cohen, J. D., MacDonald, A. W., 3rd, Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science*, *303*, 1023–1026.
- Klemm, O. (1925). Über die wirksamkeit kleinster zeitunterschiede [On the effect of the smallest time differences]. *Archiv Gesamter Psychologie*, *50*, 204–209. 03, pp. 504–515.
- Kosslyn, S. M. (1987). Seeing and imagining in the cerebral hemispheres: A computational approach. *Psychological Review*, *94*, 148–175.
- Kosslyn, S. M., Chabris, C. F., Marsolek, C. J., & Koenig, O. (1992). Categorical versus coordinate spatial relations: Computational analyses and computer simulations. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 562–577.
- Kosslyn, S. M., Koenig, O., Barrett, A., Cave, C., Tang, J., & Gabrieli, J. D. E. (1989). Evidence for two types of spatial representations. *Journal of Experimental Psychology: Perception and Performance*, *15*, 723–35.b.
- Lange, R., Irwin, H. J., & Houran, J. (2000). Top-down purification of Tobacyk's revised paranormal belief scale. *Personality and Individual Differences*, *29*, 131–156.
- Levy, J. (1969). Possible basis for the evolution of lateral specialization of the human brain. *Nature*, *224*, 614–615.
- Levy, J., & Reid, M. (1976). Variations in writing posture and cerebral organization. *Science*, *194*, 337–339.
- Libet, B. (1982). Brain stimulation in the study of neuronal functions for conscious sensory experiences. *Human Neurobiology*, *1*, 235–242.
- Lockhorst, G. J. (1985). An ancient Greek theory of hemispheric specialization. *Clio Medica*, *17*, 33–38.
- Mars, R. B., Coles, M. G., Grol, M. J., Holroyd, C. B., Nieuwenhuis, S., Hulstijn, W., et al. (2005). Neural dynamics of error processing in medial frontal cortex. *Neuroimage*, *28*, 1007–1013.
- McManus, C. (2002). *Right hand, left hand: The origins of asymmetry in brains, bodies, atoms, and cultures*. Boston: Harvard University Press.
- Milner, B. (1968). Visual recognition and recall after right temporal lobe excision in man. *Neuropsychologia*, *6*, 101–209.
- Morton, B. E. (2001). Large individual differences in minor ear output during dichotic listening. *Brain and Cognition*, *45*, 229–237.
- Morton, B. E. (2002). Outcomes of hemisphericity questionnaires correlate with unilateral dichotic deafness. *Brain and Cognition*, *49*, 63–72.
- Morton, B. E. (2003a). Phased mirror tracing outcomes correlate with several hemisphericity measures. *Brain and Cognition*, *51*, 294–304.
- Morton, B. E. (2003b). Two-hand line-bisection task outcomes correlate with several measures of hemisphericity. *Brain and Cognition*, *51*, 305–316.
- Morton, B. E. (2003c). Asymmetry Questionnaire outcomes correlate with several hemisphericity measures. *Brain and Cognition*, *51*, 372–374.
- Morton, B. E. (2003d). Hemisphericity of university students and professionals: Evidence for sorting during higher education. *Brain and Cognition*, *52*, 319–325.
- Morton, B. E., & Rafto, S. E. (2006). Corpus callosum size is linked to dichotic deafness and hemisphericity, not sex or handedness. *Brain and Cognition*, *62*, 1–8.
- Palomero-Gallagher, N., Mohlberg, H., Zilles, K., & Vogt, B. (2008). Cytology and receptor architecture of human anterior cingulate cortex. *Journal of Comparative Neurology*, *508*, 906–926.
- Paulus, M. P., & Frank, L. R. (2006). Anterior cingulate activity modulates nonlinear decision weight function of uncertain prospects. *Neuroimage*, *30*, 668–677.
- Paus, T. (2001). Primate anterior cingulate cortex: Where motor control, drive, and cognition interface. *Nature Reviews of Neuroscience*, *2*, 417–424.
- Paus, T., Otaky, N., Caramanos, Z., MacDonald, D., Zijdenbos, A., D'Avirro, D., et al. (1996). In vivo morphometry of the intrasulcal grey matter in the human cingulate, paracingulate, and superior-rostral sulci: Hemisphericity asymmetries, gender differences, and probability maps. *Journal of Comparative Neurology*, *376*, 664–673.
- Paus, T., Tomaiuolo, F., Otaky, N., MacDonald, D., Petrides, M., Atlas, J., et al. (1996). Human cingulate and paracingulate sulci: Pattern, variability, asymmetry, and probabilistic map. *Cerebral Cortex*, *6*, 207–214.
- Persinger, M. A. (1983). Religious and mystical experiences as artifacts of temporal lobe function: A general hypothesis. *Perceptual and Motor Skills*, *57*, 1256–1262.
- Persinger, M. A. (1984). Propensity to report paranormal experiences is correlated with temporal lobe signs. *Perceptual and Motor Skills*, *59*, 583–586.
- Persinger, M. A. (1993). Vectors of cerebral hemisphericity as differential sources of the sensed presence, mystical experiences, and religious conversions. *Perceptual Motor Skills*, *76*, 915–930.
- Proverbio, A. M., Zani, A., Gazzaniga, M. S., & Mangun, G. R. (1994). ERP and RT signs of a rightward bias for spatial orienting in a split brain patient. *Neuroreport*, *5*, 2457–2461.
- Pujol, J., Lopez, P. J., Deus, J., Cardoner, N., Vallejo, J., Capdevila, A., et al. (2002). Anatomical variability of the anterior cingulate gyrus and basic dimensions of human personality. *Neuroimage*, *15*, 847–855.
- Ringo, J. L., Doty, R. W., Demeter, S., & Simard, P. Y. (1994). Time is of the essence: A conjecture that hemispheric specialization arises from interhemispheric conduction delay. *Cerebral Cortex*, *4*, 331–343.
- Robertson, L. C., & Lamb, M. R. (1991). Neuropsychological contributions to theories of part/whole organization. *Cognitive Psychology*, *23*, 299–330.
- Schuz, A., & Preissl, H. (1996). Basic connectivity of the cerebral cortex and some considerations on the corpus callosum. *Neuroscience and Biobehavioral Reviews*, *20*, 567–570.
- Sejnowski, T. J. (2004). In memoriam: Francis H.C. Crick. *Neuron*, *43*, 619–621.
- Shiffer, F. (1996). Cognitive ability of the right hemisphere: Possible contributions to psychological function. *Harvard Review of Psychiatry*, *4*, 126–138.
- Smith, L. C., & Moscovitch, M. (1979). Writing posture, hemispheric control of movement and cerebral dominance in individuals with inverted and noninverted hand postures during writing. *Neuropsychologia*, *17*, 637–644.
- Sperry, R. (1968). Hemispheric disconnection and unity in conscious awareness. *American Psychologist*, *23*, 723–733.
- Sperry, R. (1982). Some effects of disconnecting the cerebral hemispheres. *Science*, *217*, 1223–1226.
- Springer, S. P., & Deutch, G. (1998). *Left brain, right brain: Perspectives from cognitive neuroscience* (5th ed.). New York: Freeman.
- Stephan, K. E., Fink, G. R., & Marshall, J. C. (2006). Mechanisms of hemispheric specialization: Insights from analysis of connectivity. *Neuropsychologia*, *45*, 209–228.
- Vogt, B. A. (2005). Pain and emotion interactions of the cingulate cortex. *Nature Reviews of Neuroscience*, *6*, 533–544.
- Vogt, B. A., Derbyshire, S., & Jones, A. K. P. (1996). Pain processing in four regions of human cingulate cortex localized with co-registered PET and MR imaging. *European Journal of Neuroscience*, *8*, 1461–1473.
- Vogt, B. A., Finch, D. M., & Olson, C. R. (1992). Functional heterogeneity in cingulate cortex: The anterior executive and posterior evaluative regions. *Cerebral Cortex*, *2*, 435–443.
- Vogt, B. A., Nimchinsky, E. A., Vogt, L. J., & Hof, P. R. (1995). Human cingulate cortex: Surface features, flat maps, and cytoarchitecture. *Journal of Comparative Neurology*, *359*, 490–506.
- Weisenberg, T., & McBride, K. E. (1935). *Aphasia: A clinical and psychological study*. New York: Commonwealth Fund [cited in Springer, S.P., & Deutsch, G. (1999). *Left brain, right brain: Perspectives from cognitive neuroscience* (5th ed., p. 361). New York: W.H. Freeman.]
- Wolford, G., Miller, M. B., & Gazzaniga, M. (2000). The left hemisphere's role in hypothesis formation. *Journal of Neuroscience*, *20*(RC64), 1–4.
- Yucel, M., Stuart, G. W., Maruff, P., Velakoulis, D., Crowe, S. F., Savage, G., et al. (2001). Hemispheric and gender-related differences in the gross morphology of the anterior cingulate/paracingulate cortex in normal volunteers: An MRI morphometric study. *Cerebral Cortex*, *11*, 17–25.
- Zenhausen, R. (1978). Imagery, cerebral dominance, and style of thinking: A unified field model. *Bulletin of the Psychonomic Society*, *12*, 381–384.