Line bisection-based hemisphericity estimates of university students and professionals: Evidence of sorting during higher education and career selection

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Abstract

Recently, hemisphericity has been assessed by six intercorrelated methods. Here, one of these, the "Best Hand Test," a two-hand line bisection-based biophysical method relatively independent of language, culture, or education, was applied to the measurement of hemisphericity distributions within large groups. Entering university students ($n = 402$) enrolled in three lower division courses were chosen as a reference population. Each of these classes contained about 56% left brain-oriented individuals. In contrast, mean student left-brain distributions in four specialized, upper level courses ($n = 180$), ranged from 35 to 68%, suggestive of hemisphericity sorting. Even more pronounced hemisphericity distribution differences were found within university representatives of 15 professions ($n = 421$) and within professional subspecialists ($n = 45$). For example, of biochemists ($n = 18$), 83% were left brain-oriented, while among astronomers ($n = 21$), only 29% were. These results are of intrinsic interest, and demonstrate the capability of the Best Hand Test to estimate hemisphericity in large groups.
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1. Introduction

With the advent of split-brain research (Gazzaniga, 1967; Sperry, 1961; Sperry, 1968), the word, hemisphericity (Bogen, 1969) came to be used, especially in popular psychology, as a convenient term to describe brain laterality differences thought to dictate whether a person's thinking and learning style (Bogen, DeZure, TenHouten, & Marsh, 1969) was right hemisphere-oriented (Ornstein, 1997; Schiffer, 1996) or left hemisphere-oriented (Fink et al., 1996; Springer & Deutsch, 1998). This information was applied in a later unsuccessful attempt to contrast certain occupations (Dumas & Morgan, 1975). From the beginning, attempts to determine a person's hemisphericity have been hampered by lack of agreement upon the meaning of the term, lack of a primary standard for comparison, lack of reliable measurement methods, and lack of certainty that the

phenomenon even exists (Beaumont, Young, & McManus, 1984).

Recently, six independent measures for hemisphericity have been developed, all of which correlated significantly with each another (Morton, 2001; Morton, 2002; Morton, 2003a, 2003b, 2003c), and also at a lower level with an older hemisphericity questionnaire (Zenhausern, 1978; Morton, 2002). This has reopened the topic of hemisphericity for renewed investigation. Some of these new methods required specialized equipment and at least half an hour to complete for each individual. Others required only pencil, paper, a minute or two, and had the potential to be administered to large groups simultaneously.

This paper describes the application of a two-handed, line-bisection test, The Best Hand Test (Morton, 2003b), to easily evaluate hemisphericity distributions within large groups. Unsorted incoming university students were chosen as the reference population. Within this group, and among two other lower division classes, it was found that the relative abundance of the four hemisphericity subtypes (right males, left females, right

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females, and left males) was approximately equal. The percentages of right- and left-brain orientations of these groups of lower division undergraduates were compared with that of groups of students within upper division more specialized classes and also with that of those found within various groups of mature professionals. Increasingly large reproducible differences in distributions between hemisphericity subgroups were present. These increasing distribution differences in hemisphericity suggested that an individual's career path might in some way be influenced by the behavioral laterality of his or her brain. Inspection of further hemisphericity distribution differences, measured among subspecialists within a profession, reinforced this idea.

2. Methods

2.1. Population

The 1048 subjects of this study were colleagues, students, and others in the University of Hawaii at Manoa (UHM) community. The study met the guidelines of Committee on Human Studies of the University of Hawaii Institutional Review Board and posed no significant risk to participants. The UHM faculty ($n = 2320$) was multiethnic, as were the students ($n = 27,189$, fall enrollment, 1997). In 1997 entering students were: 21.2% Japanese, 17.4% Mixed, 16.8% Caucasian, 11.1% Filipino, 11.0% Chinese, 10.4% Hawaiian-Part Hawaiian, 7.3% Other, and 4.8% Korean.

2.2. Best Hand Test

A two-hand line-bisection task, derived from Schenkenberg, Bradford, and Ajax (1980), and named the Best Hand Test (Morton, 2003b) was obtained by typing the same set of 20 staggered horizontal lines (average line length, 115 mm) upon two vertical 215×280 mm ($8\frac{1}{2} \times 11$ in.) sheets of paper, each line being separated vertically by 1 cm. Line lengths ran from 70 to 160 mm, increasing in duplicate by 10 mm intervals. The resulting 20 lines were arranged so that each duplicate series of 10 horizontal lines alternated vertically on the page, one set progressing from short to long lines, the other from long to short. Each line was positioned laterally in a semi-random manner so as to avoid any obvious vertical midline patterns within the 165 mm page width used.

Beneath the title on the first page was a line recording the subject's identity or code, date of birth, sex, and parental ancestry. This was followed by the instructions: "Using your RIGHT hand, mark the center of each of the 20 lines below." Next, subjects were directed to mark with their left hand the same set of 20 lines on the second page. For those very few subjects who changed a midline mark, their first mark was the one used in grading.

At the bottom of the second page were questions regarding handedness (by self-report, Chapman & Chapman, 1987), whether subjects preferred using a left appendage for any process, and whether their pen grasp posture was non-inverted or inverted as illustrated by the examiner (Levy & Reid, 1976). Specifically, these questions were: "Please circle the following answers: Are you *Right or Left* handed? Do you do anything better with your left hand or foot, *Yes or No?* When you write with a pen, is its point: *away from you*? *across from you*?, or *toward you*?"

Rapid grading of the Best Hand Test was accomplished by use of a transparent overlay, as described by Morton (2003b). At the bottom of each page, the average of the individual's 20 midline estimates was computed to give the average right (+) or left (−) bisection deviation error for each hand, recorded as hundredths of mm. For the final score, the average midline estimation error (+ or − mm) of both the right and hand estimates were recorded, followed by the absolute directional difference between the averages of the two hands in mm, *importantly* with the right hand estimate used as the reference. For example, an overall result might be: +0.50R, −2.30L, and −2.80D, one of the four categorical possibilities. These categories are illustrated in Fig. 1, taken from Morton (2003b) and essential for understanding the method.

In the grading of group-administered Best Hand Tests when other hemisphericity tests were omitted, those subjects (about 15%) falling in Category 3 (ls) (Fig. 1A) were arbitrarily subdivided so that one third were left- and two-thirds were right brain-oriented persons, as described in Morton (2003b). The four possible marking patterns, illustrated in Fig. 1A, depend upon combinations of two elements: (1) which *hand is best* by marking closest to the true midline and (2) whether or not the *hands crossed* over each other, so that the left hand marked to the right of the right hand, for example.

In group testing, the four hand grasp position possibilities (Levy & Reid, 1976) were illustrated and emphasized at the beginning of the task in order to obtain as accurate a self-report as possible. This was important because Best Hand Test results for left but not right-handed subjects using an inverted writing grasp required reversal to match the hemisphericity of the five reference methods (Morton, 2001, 2002, 2003a, 2003c; Zenhausern, 1978). No phase correction was required for those rare left-handed subjects using a non-inverted hand posture, or right-handers using either posture. These issues are further elaborated in Morton (2003b).

In this study, a third page for self-analysis was attached, partly for motivational purposes. On it subjects were asked to judge their own hemisphericity, based upon a list of contrasts of putative right and left brain-oriented thinking and behavior, balanced for social desirability (derived from the Asymmetry Questionnaire

A The Four Possibilities for the Hands:
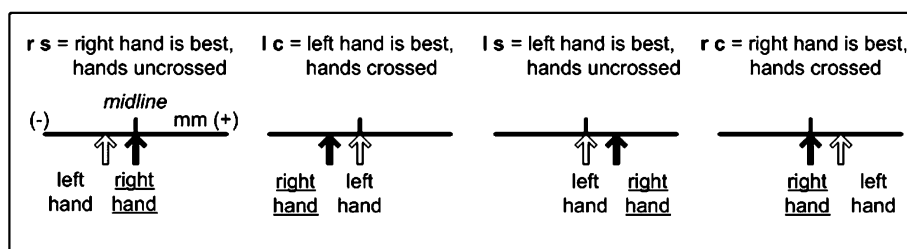
Best-Hand Test data to be recorded (plus true handedness and pen grasp posture) :
1. avg. mm error of right hand (reference hand)
2. avg. mm error of left hand
3. directional deviation (d) of l-hand from r-hand, +/- mm

B Group Percentages Observed,
n=412 (Morton, 2002c)

	s	c
	Category 1 **r s** 45%	**Category 4** **r c** 10%
r		
	Category 3 **l s** 15%	**Category 2** **l c** 30%
l		

C Polarity Questionnaire-Based
Hemisphericity Assignments

	s		c
	Category 1 **Lefts** all types 45%	**Rights** males 8%	**Category 4** **Lefts** females 2%
r			
	Category 3 **Rights** right-affect 10%	**Lefts** left-affect 5%	**Category 2** **Rights** all types 30%
l			

Examples: r s = 0.50r, -1.00l, -1.50d = left brain-oriented person
l c = -1.00r, 0.50l, 1.50d = right brain-oriented person
l s = 1.00r, -0.50l, -1.50d = right brain if right affect, left brain if left affect
r c = -0.50r, 1.00l, 1.50d = right brain if male, left brain if female

Fig. 1. Categories of best hand test results Derived from Morton (2003b). (A) Categories of groups, where right (r) or left (l) hand is more accurate and hands stay on the same side (s) or cross over (c) each other: right-same (rs), left-crossed (lc), left-same (ls) or right-crossed (rc). (B) The rs, rc, ls, and lc groups are from (A). (C) Right and left affect refer to from which brain side a subject's emotional reactivity was greater as determined by the Affective Laterality Test. Although males and females were represented in all groups, in group 4, "hemisphericity" was sex-dependent (Morton, 2003b). Similarly, only in group 3 was "hemisphericity" affect laterality-dependent (Morton, 2003a).

(Morton, 2003c)). This page was later returned to the subjects with their Best Hand Test hemisphericity outcome written on it next to their own guess. Because they were told to omit their names, essentially all students present completed the Best Hand Test. About 80% of these also made a self-estimate of hemisphericity.

3. Results

3.1. Hemisphericity distributions of entering and more advanced college students

The Best Hand Test was administered just before the scheduled lecture in three different classrooms containing a total of 228 entry-level college students taking History 152, Western Civilization, a core course re-

quired for graduation. The test included the above Best Hand Test, with the attached hemisphericity self-evaluation. The entire testing took less than 10 min of class time. Outcomes forms were returned to the students at their next class meeting. As may be seen (in Table 1), 57% of these students were left and 43% right brain-oriented.

This procedure was repeated with two other introductory classes: general chemistry ($n = 104$) and basic biochemistry ($n = 60$). In each of those, there were 56% left brain- and 44% right brain-oriented student groups, essentially the same distribution as in the Western Civilization class (Table 1). Together, these 402 lower division students appeared to be slightly enriched (56%) in left brain-oriented individuals.

Final grades for the history, chemistry, and biochemistry courses, gathered maintaining personal anonymity,

Table 1
Brain hemisphericity distributions in university classroom populations ($n = 572$)

Group	Percent participation	n	Left brain (%)	Right brain (%)	Left-handed (%)	Percent females
Western civilization	66	**228**	**57**	**43**	13	58% F
General chemistry	86	104	**56**	**44**	10	64% F
Basic biochemistry	79	60	**56**	**44**	11	49% F
Molecular biology laboratory	95	50	**49**	**51**	10	55% F
Home economics, family issues	97	69	**68**	**32**	13	88% F
Architecture, interior design	94	41	**41**	**59**	11	40% F
Civil engineering, grad. seminar	95	20	**35**	**65**	–	25% F

were coded with the student's brain-orientation. No significant interclass associations between student final grades and the four brain hemisphericity groups were apparent (data not shown).

Table 1 also provides Best Hand Test data from different students in four more-specialized upper division courses. These were Molecular biology laboratory ($n = 50$), home economics-family issues ($n = 69$), architecture-interior design ($n = 41$), and civil engineering seminar ($n = 20$). Left brain-orientation distributions ranged from 35 to about 68%. This suggested that a entry-level population partially sorts itself in terms of hemisphericity subtype as it progresses on to more advanced studies.

3.2. Hemisphericity distribution outcomes for members of 15 professions

This idea of self-selection in higher education was tested farther by using the Best Hand Test to evaluate the brain hemisphericity distributions of 421 individuals employed in 15 selected professions. Most of these were well represented on the faculty of the University of Hawaii at Manoa. That brain hemisphericity selection had indeed occurred is evident in Table 2. There, it may be seen that some professional groups had a high proportion of left brain-oriented individuals, as in "reductionistic" sciences such as bacteriology and biochemistry (86 and 83%, respectively). At the other end of this

Table 2
Brain hemisphericity distributions within populations of 15 professions ($n = 421$)

Group	Percent participation	n	Left brain (%)	Left males (%)	Left females (%)	Right brain (%)	Right males (%)	Right females (%)
Unsorted college entrants		**228**						
Western civilization students	62	228	**57**	19	38	**43**	22	21
Specialist populations		**422**						
Microbiology professors	74	14	**86***	72	14	**14**	14	0
Biochemistry professors	95	18	**83***	72	11	**17**	17	0
Physics (particle) professors	80	15	**73**	73	0	**27**	27	0
Philosophy professors	73	11	**73**	54	19	**27**	27	0
Mathematics professors	93	27	**70**	70	0	**30**	30	0
Accountancy professors	75	9	**67**	44	22	**33**	22	12
Law professors	83	19	**63**	32	31	**37**	21	16
Art professors (vs. artists)	92	27	**63**	38	25	**37**	29	8
Civil engineering professors	89	17	**53**	53	0	**47**	41	6
Clin. psychologists (yel. pages)	75	29	**52**	24	28	**48**	28	20
Electrical engineering professors	75	16	**50**	50	0	**50**	44	6
Physicians (medical students)	80	178	**49**	25	24	**51**	26	25
Mechanical engineering professors	75	9	**44**	33	11	**56**	56	0
Architecture professors	100	12	**33***	26	4	**67**	61	9
Astronomy professors	66	21	**29***	30	0	**71**	60	10

yel. pages, American Psychological Society Members advertising in the yellow pages of the Honolulu phone directory.

Medical students, due to extremely low attrition rates of medical students, it was convenient to test them in mass rather than scheduling a separate appointment with each of them after they became clinicians.

* $p < .05$.

spectrum, an enrichment of right brain-orientation was found in the more "holistic," yet quantitative disciplines, such as architecture and astronomy. There, left brain-oriented practitioners were in the minority (33 and 29%, respectively). The hemisphericity subtype distributions of the bacteriologists and biochemists were significantly different from those of the architects and astronomers ($p < .05$).

3.3. Hemisphericity self-analysis outcomes for students and professionals

For both students and professionals, the overall self-analysis accuracy for brain hemisphericity was low (from the third page attached to the Best Hand Test). However, self analysis accuracy of both the right brain-oriented college freshmen (42%) and professionals (51%) was higher than that of the left brain-oriented freshmen (24%) and professionals (30%) when judged against Best Hand Test outcomes ($p < .02$), consistent with past traditions of right brain intuitiveness. There was also a small age effect in both groups consistent with the increased self-knowledge idealistically thought to be associated with maturation.

3.4. Evidence of further hemisphericity selection within certain professions

In Table 3 the Best Hand Test-based hemisphericity estimates of 58 practicing architects and civil engineers are shown. In both professions, the percentage of left brain-oriented field workers was comparable to that of their faculty colleagues. That is, faculty and practicing civil engineers were 53 and 56% in their left-brain proportions, while for faculty and practicing architects is was 33 and 38%, respectively. However, when the 45 practicing civil engineers were separated into design civil engineers and construction civil engineer categories and their Best Hand Test outcomes compared, a clear distinction between those two subspecialties was revealed. Among the design civil engineers, left brain-orientation was low (39%), similar to that of their natural collaborators, the practicing architects (38%). However, when compared to these right brain-abundant groups, the construction civil engineers were enriched with left brain-oriented workers (74%). This percentage was comparable to that found (Table 3) for physicists (73%) and mathematicians (70%), perhaps in keeping with the pressures of cost analysis demanded of construction engineers in the production of the final product within budget.

4. Discussion

The results reported here demonstrate that the Best Hand Test (Morton, 2003b) can be used to determine brain hemisphericity distributions within populations. That this was possible is fortunate because use of such biophysical methods avoids the potential bias for language, cultural, and education inherent in preference questionnaire methods. The method was quick and has the potential for machine grading.

A large population of unsorted incoming university students was chosen as the primary standard. About equal proportions of the four human hemisphericity subclasses were found in this group. However, in higher-level specialty courses, these ratios were significantly altered. Moreover, when groups of fully educated individuals practicing in 15 different professions were tested for brain-orientation distributions, even greater deviations from the hemisphericity distributions of the primary standard population were observed.

For example, only 29% (6/21) of astronomers tested from the Department of Physics and Astronomy at the UHM were left brain-oriented persons, while about 73% (11/15) of the particle physicists were ($p = .01$), in keeping with the popular "forest vs. trees" right and left orientation of hemisphericity tradition (Fink et al., 1996). However, another popular hemisphericity stereotype, that of a right brain-oriented person's lack of quantitative ability, appeared contradicted by the majority of right brain-oriented astronomers or architects whose disciplines also demand quantitative thinking. Nevertheless, it remains possible that quantitation may be easier for left brain-oriented persons, i.e., as the case of the production engineer subspecialists of Table 3 might suggest.

Table 3
Brain hemisphericity in civil engineering subspecialists and architects

Group	n	Left brain-oriented (%)	Right brain-oriented (%)
Faculty civil engineers	17	53	47
Practicing civil engineers	45	56	44
Practicing construction civil engineers	27	74	26
Practicing design civil engineers	18	39	61
Practicing architects	13	38	62
Faculty architects	12	33	67

Again seemingly against hemisphericity stereotypes, 63% (17/27) of the university Department of Art professors were left brain-oriented faculty. However, those faculty members included 10 specialists in art history and specialists in technical details, such as printmaking, etc., who were primarily left brain-oriented, as might be predicted. About half (8/17) the remaining professors who created more traditional works of art were right brain-oriented. A further survey of a dozen exhibiting artists from the Honolulu area indicated no significant preponderance of right brain-oriented persons (7/12). However, stereotypes are not easy to analyze. While these limited data could be interpreted to deny the validity of the hemisphericity stereotype that artists are right brain-oriented, such validity easily could be reasserted by arguing that these data only suggest the obvious: that less than half of art practitioners are truly artists.

Because the possibility of sampling error exists in the smaller professional groups, whose size raged from 9 to 178, mean = 29, $n = 467$, these data on the professions are offered with a great deal of skepticism and caution. However, there appeared to be an internal consistency between the subtypes of the more left or right hemisphericity-concentrated professions. That is, primarily "top-down" professions working at structural levels that are subvisible, such as microbiologists, biochemists, and particle physicists, were each found to be highly enriched with left-brain-"important-details" oriented individuals. In contrast, the more "bottom-up," macroscopic professions, such as architecture, civil engineering design, and astronomy, were enriched with right brain "big picture" oriented people.

That segregation of hemisphericity types continues beyond career selection was illustrated by the data on the civil engineers where the design engineers were much more right brain-oriented than their predominantly left brain-oriented production engineer colleagues. This observation bears directly upon the well known traditional tension between production engineers with design engineers and architects (Johnson & Singh, 1999; Singh & Johnson, 1998). It would be interesting to compare subspecialists within the practice of medicine and law in terms of further brain hemisphericity segregation within those professions.

On still another topic, less than half of the entire student-professional population at the university was correct in assessing their own brain hemisphericity. Yet, self-assessment by both the right brain-oriented college freshmen and professionals was more accurate than that of the left brain-oriented members of both groups. Also, self-assessment accuracy for brain hemisphericity improved with maturity for both groups. These differences were significant ($p < .02$).

A weakness in administering the Best Hand Test in groups, rather than with individuals, is the inability of the examiner to individually confirm the handedness and pen grasp posture information given by each participant. Accurate information in this regard was required so as to phase correct those with native left-inverted hand orientation (Morton, 2003b). However, because of the attention given to this issue by the examiner immediately before the test, it is assumed that most subjects with left hand, inverted postures were able to identify themselves. Self-report of handedness has been found to correlate with outcomes of objective questionnaires (Chapman & Chapman, 1987).

While use of the group data of this report is appropriate due to the numbers of subjects involved, it would be invalid to assign the hemisphericity of an individual on the basis of the outcome of a single Best Hand Test. Reasonably accurate estimations of individual hemisphericity require the use of at least four of six independent methods (Morton, 2001, 2002, 2003a, 2003b, 2003c).

That the unsorted college freshmen standard population contained about 56% left brain-oriented individuals, yet in upper division specialty courses, that distribution varied from 35 to 68%, while among the 15 professions tested it ranged between 29 and 86%, has led to the following career selection speculation: in higher education, outside of a few required core courses, such as the Western Civilization course here, students are free to select their own courses and ultimately their own major areas of concentration as they continue. These choices appear to be based primarily upon the student's own preferences. In general, it would appear that one enjoys more rewards from, and ultimately prefers to do, those activities at which one is most successful. Of the wide range of courses offered at an institution of higher learning, it is speculated that left brain-oriented students would excel over their right brain-oriented competitors in the many unrecognized but inherently left brain-oriented courses, and vice versa.

Thus, it is further postulated that the drive to maximize immediate personal rewards would ultimately lead the student to select a career path consisting primarily of what he or she was more successful at doing, and thus found most enjoyable. For example, if right brain global-spatial skills were rewarded in architecture courses, it would to be predicted that more right brain-oriented students would become architects. Such would be so, even if left brain-oriented students were strongly attracted or committed to architecture for reasons unrelated to native talent. Unless they strongly compensated for their relative weakness, they would be less competitive than their associates at right brain-oriented architecture courses, and could not afford to sustain consequent continuing lowered grade point averages in terms of career self-marketability. In general, this ultimately would lead to student segregation into the available career tracks that were among those more compatible with their inherent hemisphericity skills.

Nevertheless, many notable professional niches exist for individuals with the less common hemisphericity. For example, globally oriented astronomers are dependent upon telescope builders and other instrumentalist who are more oriented to important details. This complimentarity allows both hemisphericity subtypes to thrive together within the same profession. That this is true in general, is supported by the Civil Engineer subclass distribution data of Table 3.

Lastly, a fourth independent biophysical hemisphericity method, an analysis of the relationship of hemisphericity to sex, and the separate discovery of a neuroanatomy-based primary standard for hemisphericity will be topics of later reports.

Acknowledgments

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