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Is There a Sex Difference in Human Laterality? IV. An Exhaustive Survey of Dual-Task Interference Studies From Six Neuropsychology Journals*

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ABSTRACT

The entire contents of six neuropsychology journals (161 volumes, 612 issues) were screened to identify dual-task laterality experiments. Of 112 experiments thus identified, 45.5% provided information about sex differences. Although 23 experiments yielded at least one significant main effect or interaction involving the sex factor, only 5 outcomes represented an unambiguous sex difference in laterality. All 5 of those sex differences support the hypothesis of greater hemispheric specialization in males. The confirmatory outcomes constitute less than 10% of the informative experiments and less than 5% of the total population of experiments. These data alone do not rule out the possibility that sex differences are chance findings (Type I errors). However, when considered along with similar results from perceptual laterality data previously examined, the dual-task data fit the pattern of a small but reliable population-level sex difference in human laterality.

Human sex differences (or gender differences) continue to be a source of scientific and societal interest (e.g., Becker, Breedlove, & Crews, 1992; Eagly, 1995; Kimura, 1999; Halpern, 1992; Harris, 1978; Hyde & Linn, 1988; Maccoby & Jacklin, 1974; Tavris, 1992; Voyer, Voyer, & Bryden, 1995). Even though there is little agreement regarding the nature, magnitude, origins and practical importance of cognitive sex differences, neuropsychologists nonetheless have looked for neural sex differences that might underlie cognitive differences. Among the most salient of putative sex differences in the brain is a difference in the degree of cerebral hemisphere specialization.

McGlone (1980), in a widely cited *Behavioral and Brain Sciences* paper, concluded that "Verbal asymmetries suggesting left hemisphere dominance appear to be more common and more marked in male than in female adult right-handers across several dichotic listening and tachistoscopic studies" (p. 226). These sex differences, together with findings from patients with unilateral cerebral lesions, led McGlone to conclude that men's brains may be organised more asymmetrically than women's brains.

This claimed sex difference in hemispheric specialization remains uncertain. Some of the supportive clinical evidence may be attributable to differences between males and females in the strategy used to accomplish nonverbal tasks (Inglis & Lawson, 1982), and claims of sex differences in laterality typically depend on a small number of positive findings selected from an

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unspecified population of studies (Bryden, 1988). A meta-analysis of perceptual laterality data (Voyer, 1996) yielded a sex difference consistent with McGlone's (1980) hypothesis, but the sex of participants was estimated to account for only 0.1% of the total variance in perceptual asymmetry.

After conducting exhaustive searches of the visual, auditory and tactual laterality studies published in six mainstream neuropsychology journals, we reached a conclusion similar to that of Voyer (1996), namely, that there is a weak population-level sex difference such that males show the greater asymmetry (Hiscock, Inch, Jacek, Hiscock-Kalil, & Kalil, 1994; Hiscock, Israelian, Inch, Jacek, & Hiscock-Kalil, 1995; Hiscock, Inch, Hawryluk, Lyon, & Perachio, 1999). The method employed for these literature searches entailed determining (1) the number of studies providing information about sex differences; (2) the proportion of studies showing a sex difference according to specified criteria; and (3) whether males are more likely to show the greater asymmetry. Of the 941 experiments examined, only 65 yielded sex differences directly relevant to McGlone's hypothesis. However, 80% of those 65 sex differences supported the hypothesis and only 20% ran counter to it.

The present study uses the same methods and criteria to enumerate sex differences in the literature on the laterality of interference between concurrent tasks. As in the previous reviews of the perceptual laterality data, the problem of selection bias is addressed by specifying precisely the population of experiments in which the positive findings are found. Given that the question of sex differences is ancillary to the primary objectives of the experiment in the large majority of instances, a failure to find a sex difference would not preclude publication of the findings (cf. Rosenthal, 1979). Consequently, the published literature should provide a relatively unbiased estimate of the actual prevalence of sex differences in laterality experiments.

In dual-task studies, hemispheric specialization is inferred from findings that a concurrent activity – usually a nonmanual activity such as speaking or calculating – disrupts the simultaneous performance of one hand more than the other (Kinsbourne & Cook, 1971). Asymmetric interference typically is attributed to a difference between the efficiency of within-hemisphere and between-hemisphere time sharing (Hiscock, Kinsbourne, & Green, 1990; Kinsbourne & Hicks, 1978). For a person with left-sided speech representation, speaking and right-hand activity both require resources from the left hemisphere. Thus one would expect a fairly high degree of interference between the two tasks, especially when they are dissimilar and when they both demand attention (Kinsbourne, 1981). Less interference is expected when the same vocal task is accompanied by left-hand activity. In that instance, the left hemisphere again supports the vocal performance, leaving the right hemisphere free to control the left hand. In so far as a nonverbal task (e.g., a visuospatial task) engages the right hemisphere to a greater degree than the left hemisphere, the opposite pattern of interference would be expected. That is, more interference should occur when the nonverbal task is conjoined with left-hand activity than when it is conjoined with right-hand activity.

A summary of sex differences in the asymmetry of dual task interference is potentially interesting for two reasons. First, the concurrent-task method may be less susceptible than perceptual tasks to strategy effects. Attentional biases in a perceptual task (for example, dichotic listening) are likely to distort the "true" asymmetry because, as more processing resources are allocated to one side, fewer resources are available for perceiving the signal on the other side. An apparent sex difference in perceptual asymmetry may actually represent a differential bias on the part of females and males. Because the left and right hands are tested separately in dual-task research, an attentional bias might influence the allocation of resources between the two concurrent tasks but would have no direct effect on the asymmetry of interference (Kinsbourne & Hiscock, 1983). In addition, the dual-task data are interesting because the paradigm tests output asymmetries rather than input asymmetries, and there is some evidence that output processes are more clearly lateralized than are input processes (LeDoux, Wilson, & Gazzaniga, 1977; Searleman, 1977; Zaidel, 1978).

METHOD

Data Sources

The following six periodicals were examined: *Cortex*, *Brain and Cognition*, *Brain and Language*, *Developmental Neuropsychology*, *Journal of Clinical and Experimental Neuropsychology* (formerly *Journal of Clinical Neuropsychology)* and *Neuropsychologia*. Every issue from the inception of the respective journal to December 1994 (161 volumes, 612 issues) was included in the study. These periodicals were selected because they were considered to be the major sources of peer-reviewed laterality studies when the project began in the late 1980s. Table 1 shows the number of dual-task laterality experiments found in each journal.

Procedure

The sequence of decisions made for each experiment is comparable to that used previously in our surveys of perceptual laterality studies (Hiscock et al., 1994, 1995, 1999). Beginning with the table of contents for each issue of each journal, we identified all papers that might include laterality findings. When there was any doubt about the inclusion of laterality data in an article, the article was marked for examination. Each paper so identified was then inspected to determine whether (1) a measure of laterality was included in one or more experiments and (2) a sample of normal adults or normal children contributed data. Experiments meeting these two criteria were examined further to determine if (3) dual-task interference was measured.

The next step (4) was to determine whether adults or children served as participants; data for adults and children were tabulated separately. The subsequent three steps entailed determining whether (5) the participant's sex was specified, (6) participants of both sexes were included, and (7) sex of participant was included as a variable in the data analysis or separate analyses were performed for females and males. If the answer to any of these three questions was negative, the experiment was classified as uninformative.

The final two steps were (8) to determine whether there was a statistically significant sex difference and (9) to classify the significant sex difference into the categories depicted in Table 2.

Table 2. Categories of Sex Differences.

Category	Description
A	Incidental Sex Difference
B	Sex × Hand Interaction
C	Sex × Hand × Third Factor Interaction
D	Sex × Hand × Third Factor × Fourth Factor Interaction
E	Separate Analyses for Males and Females

Category A outcomes consist of significant sex differences that are unrelated to laterality, for example, findings that indicate a difference between females and males in overall manual performance or in the magnitude of interference between concurrent tasks. Even though Category A outcomes have no direct relevance to the hypothesis of greater lateralization in males, the information may be of interest for other reasons. Category B findings, which consist of significant Sex × Hand interactions in the analysis of interference between concurrent tasks, are potentially most relevant to the hypothesis of greater lateralization in males. Category C comprises significant Sex × Hand × Third Factor interactions. Such outcomes may or may not be interpretable with respect to the sex-difference hypothesis. Category D

Table 1. Data Sources.

Source	Total Experiments	Informative Experiments	Percentage
Brain and Cognition	19	10	52.6
Brain and Language	14	2	14.3
Cortex	17	7	41.2
Neuropsychologia	49	22	44.9
Journal of Clinical and Experimental Neuropsychology[1]	4	2	50.0
Developmental Neuropsychology	9	8	88.9
Total	112	51	45.5

Note. [1]Includes all volumes of Journal of Clinical Neuropsychology.

outcomes, which entail four-way interactions, were also tabulated even though such outcomes are unlikely to be readily interpretable. Category E outcomes reflect separate analyses for females and males. An alpha level of .05 level was set as the criterion for a statistically significant outcome in all instances.

RESULTS

Proportion of Experiments Yielding Information About Sex Differences

Of the 112 experiments (95 with adult participants, 17 with child participants) satisfying the inclusion criteria, 51 (45.5%) yielded information about sex differences. The percentage of informative experiments was higher among studies of children (88.2%) than among studies of adults (37.9%), χ^2 (1, $N=112$) $=12.77$, $p<.001$. The percentage of informative experiments for each of the six journals is shown in Table 1.

Frequency of Significant Sex Differences

Of the 51 informative experiments, 23 (45.1%) yielded at least one significant sex difference. The percentage of positive outcomes did not differ significantly between experiments with adults (52.8%) and those with children (26.7%), $p>.10$.

Categorisation of Positive Outcomes

Table 3 shows the number of experiments falling into each of the five outcome categories (A, B, C, D, and E). Multiple positive outcomes in several experiments, for example, a main effect for sex and a Sex × Hand interaction, caused the total number of positive outcomes ($n=39$) to exceed the number of experiments with positive outcomes ($n=23$).

Table 3. Number of Positive and Negative Outcomes, With Positive Outcomes Listed by Category.

	Participants		
Outcome	Adults	Children	Combined
Positive			
Category A	17	3	20
Category B	4	3	7
Category C	8	0	8
Category D	2	0	2
Category E	2	0	2
Total[1]	33	6	39
Negative			
Total	17	11	28

[1]The number of positive outcomes exceeds the number of experiments yielding a positive outcome because many experiments yielded multiple positive outcomes. The total number of experiments yielding at least one positive outcome was 23 (19 experiments with adults and 4 experiments with children).

Category A Outcomes

Twenty of the 39 positive outcomes (17 with adults, 3 with children) were irrelevant to the hypothesised sex difference in the asymmetry of interference between tasks. These Category A outcomes include main effects for sex, Sex × Hand interactions in single-task data or in pooled single- and dual-task data, and an interaction between sex and a variable other than hand.

Of 10 main effects for sex in the analysis of manual performance, all were found in experiments with adult participants and 9 of the outcomes favoured males. In 7 instances, men's overall manual performance in single- and dual-task conditions exceeded that of women (Ashton & McFarland, 1990; Green, Nicholson, Vaid, White, & Steiner, 1990; LaBarba, Bowers, Kingsberg, & Freeman, 1987, Experiments 1 and 2; Lomas & Kimura, 1976, Experiment 1; Sergent, Hellige, & Cherry, 1993, Experiment 2; van Strien & Bouma, 1988, Experiment 2). In 2 other experiments, men performed better than women on the manual task in the single-task condition (Sergent, Hellige, & Cherry, 1993, Experiment 1; van Strien & Bouma, 1988, Experiment 1). In only 1 experiment did the manual performance of women exceed that of men (Lomas & Kimura, 1976, Experiment 2). The most salient difference between Lomas and Kimura's experiment and the others was its use of a sequential (four-finger) tapping task. In the other experiments, the manual task consisted of either dowel-rod balancing or else repetitive or alternating tapping with the index finger or the entire hand (as when holding a pen).

The remaining 10 Category A outcomes do not conform to any simple pattern. Whereas women performed better than men on the nonmanual task used by Botkin, Schmaltz, and Lamb (1977), boys performed better than girls on the nonmanual task used by Hiscock, Antoniuk, Prisciak, and von Hessert (1985, Experiment 2) and men and women showed dissimilar patterns of performance across the three nonmanual conditions of Lempert's (1987) Experiment 2. Men showed the greater amount of interference, irrespective of hand, in 2 experiments (Lomas & Kimura, 1976, Experiment 1; van Strien & Bouma, 1988, Experiment 1), but females showed more interference than males in 1 experiment with adults (Simon & Sussman, 1987) and 1 experiment with children (Hiscock et al., 1985, Experiment 2). Girls showed greater single-task manual asymmetry in an experiment by Hiscock (1982), but boys showed greater asymmetry in Hiscock et al.'s (1985) Experiment 2. The final Category A outcome was an interaction between sex and familial sinistrality for overall manual performance by left-handed adults (van Strien & Bouma, 1988, Experiment 2). The finding that males tapped faster than females (included in our previous summary of main effects) applied only to familial left-handers.

Category B Outcomes

The 7 Category B outcomes are summarised in Table 4. Four of the outcomes were obtained from experiments with adults and 3 were obtained from experiments involving children.

Three findings support the hypothesis of greater lateralization in males. Johnson and Kozma (1977) and Hiscock and Kinsbourne (1980) reported that recitation of sentences and nursery rhymes, respectively, produced right-greater-than-left interference in males but not females. Dalby (1980) found that a spatial task produced left-greater-than-right interference in males but not in females. The first and third of these experiments involved adult participants; the second experiment involved children.

The other 4 Category B outcomes (Hiscock, Antoniuk, Prisciak, & von Hessert, 1985, Experiments 2 and 3; Kee, Matteson, & Hellige, 1989; Wolff & Cohen, 1980) were categorised as ambiguous with respect to the hypothesised sex difference. In the two experiments reported by Hiscock et al., judging the slope of line segments produced at least a tendency toward right-greater-than-left asymmetry in boys and the opposite tendency in girls. Similarly, in the Kee et al., experiment, a block-design task yielded greater right-than-left interference in men and a tendency toward the opposite asymmetry in women. In the Wolff and Cohen experiment, a recitation task yielded greater left-than-right interference in men and greater right-than-left interference in women. These four outcomes were classified as ambiguous because each of them entails opposite asymmetries for males and females rather than a significantly greater degree of asymmetry for males, as predicted by the differential lateralization hypothesis. Nonetheless, in every instance it is the females' asymmetry that conforms more closely to expectations based on generally accepted concepts of "right- and left-hemisphere tasks." Interpretation of the Kee et al. findings is complicated by evidence that block-design performance is likely to be impaired by lesions to either hemisphere (Lezak, 1995). The Wolff and Cohen findings are difficult to interpret because they were obtained only when a novel bimanual tapping task was used; the more conventional unimanual tapping task, when performed by the same participants, yielded no sex differences.

Category C Outcomes

Table 5 summarises the 8 experiments that yielded significant interactions among sex, hand, and a third variable. Two of the outcomes were partially redundant with 2-way interactions in Category B, and none of the remaining 6 interactions could be interpreted unambiguously in terms of the differential lateralization hypothesis. All 8 experiments involved adult participants.

The 3-way interactions reported by Dalby (1980) and by Wolff and Cohen (1980, Experiment 1) led the respective authors to perform more specific analyses that yielded 2-way interactions as described in Table 4. Although we included the 3-way interactions in our count of positive outcomes (Table 3), the redundancy between the 2-way and 3-way interactions precludes us from counting the 3-way interactions as additional evidence of relevance to the differential lateralization hypothesis.

Three of the other Category C outcomes indicate that the Sex $\times$ Hand interaction varies with a third variable that would not be expected to influence a true sex difference in laterality. In the study by Kee, Bathurst, and Hellige (1984, Experiment 1), the direction of the sex difference reversed from one trial to the next. Sergent, Hellige, and Cherry (1993, Experiment 2) reported a sex difference that varied with the order in which two tapping tasks were administered. Lempert

Table 4. Experiments Yielding a Significant Sex × Hand Interaction in Magnitude of Interference or an Equivalent Outcome.

Experiment	Participants	Tasks	Results
Johnson & Kozma (1977)	18 RH adults (9 M, 9 F)	Manual task: balancing a dowel rod on the index finger; Concurrent tasks: (1) repeating a sentence and (2) humming a melody	Sex × Hand × Condition interaction, $F(2, 32) = 5.52$, $p < .01$, in analysis of balancing duration. Sentence repetition interfered selectively with right-hand balancing of males but no interference was found for females
Dalby (1980)	30 RH adults (15 M, 15 F)	Manual task: speeded sequential finger movement (keyboarding); Concurrent tasks: (1) repeating a sentence, (2) reading a list of words, (3) solving items from Raven's Matrices test, (4) solving items from the Space Relations test.	Sex × Hand interaction, $F(1, 28) = 4.38$, $p < .05$, in analysis of manual interference from performance of Space Relations. Males showed more interference in the left hand than in the right hand, but females showed no asymmetry
Hiscock & Kinsbourne (1980)	155 RH children (84 M and 71 F at ages 3–12 years)	Manual task: speeded tapping of telegraph key with index finger; Concurrent tasks: (1) reciting a nursery rhyme and (2) reciting a list of animal names	Sex × Hand interaction, $F(1, 119) = 4.55$, $p < .05$, in analysis of manual interference from recitation of rhyme. Males showed more right-hand interference than left-hand interference but females showed no significant asymmetry
Wolff & Cohen (1980), Experiment 1	30 RH adults (7 FS − M, 8 FS + M, 7 FS − F, 8 FS + M)	Manual tasks: (1) unimanual paced tapping of an electronic key and (2) alternating bimanual paced tapping of 2 electronic keys; Concurrent task: reciting a nursery rhyme	Sex × Hand interaction, $F(1, 26) = 6.7$, $p < .05$, in analysis of manual interference as indexed by variability in bimanual tapping. Males showed more left-hand interference than right-hand interference whereas females showed more right-hand interference than left-hand interference
Hiscock, Antoniuk, Prisciak, & von Hessert (1985), Experiment 2	64 RH children (8 M and 8 F from Grades 2, 3, 4, and 5)	Manual task: speeded tapping of microswitch tapping device with index finger; Concurrent tasks: (1) judging orientation of lines and (2) silent reading	Sex × Hand interaction, $F(1, 56) = 4.30$, $p < .05$, in analysis of manual interference from judging line orientation. Males tended to show more right-hand interference than left-hand interference, whereas females tended to show the opposite asymmetry
Hiscock, Antoniuk, Prisciak, & von Hessert (1985), Experiment 3	64 RH children (8 M and 8 F from Grades 2, 3, 4, and 5)	Manual task: speeded alternating tapping of 2 microswitch tapping devices with index finger; Concurrent task: judging orientation of lines	Sex × Hand interaction, $F(1, 56) = 7.82$, $p < .01$, in analysis of manual interference. Males showed significantly more right-hand interference than left-hand interference, whereas females tended to show the opposite asymmetry

Table 4. (*Continued*)

Experiment	Participants	Tasks	Results
Kee, Matteson, & Hellige (1989)	40 RH adults (20 M, 20 F)	Manual task: speeded tapping of a microswitch tapping device with index finger; Concurrent task: mentally solving block design problems	Sex × Hand interaction, $F(1, 38) = 4.94$, $p < .05$, in analysis of manual interference. Males showed significantly more right-hand interference than left-hand interference, whereas females tended to show the opposite asymmetry

Note. [1]Abbreviations: M = male; F = female; RH = right-handed; LH = left-handed; RHM = right-handed male; LHM = left-handed male; RHF = right-handed female; LHF = left-handed female; FS−M = male with no familial sinistrality; FS+M = male with familial sinistrality; FS−F = female with no familial sinistrality; FS+F = female with familial sinistrality; RHA = right-hand advantage; LHA = left-hand advantage.
[2]When raw scores are used as the dependent measure in lieu of interference scores, a Sex × Hand × Condition (single- versus dual-task) interaction is equivalent to a Sex × Hand interaction in the analysis of interference scores.

Table 5. Experiments Yielding a Significant Sex × Hand × Third Factor Interaction in Magnitude of Interference or an Equivalent Outcome.

Experiment	Participants	Tasks	Results
Dalby (1980)	30 RH adults (15 M, 15 F)	Manual task: speeded sequential finger movement (keyboarding); Concurrent tasks: (1) repeating a sentence, (2) reading a list of words, (3) solving items from Raven's Matrices test, (4) solving items from the Space Relations test.	Sex × Hand × Concurrent Task interaction in omnibus analysis of the interference associated with the 4 concurrent tasks. Data for each concurrent task were subsequently analysed separately
Wolff & Cohen (1980), Experiment 1	30 RH adults (7 FS−M, 8 FS+M, 7 FS−F, 8 FS+F)	Manual tasks: (1) unimanual paced tapping of an electronic key and (2) alternating bimanual paced tapping of 2 electronic keys; Concurrent task: reciting a nursery rhyme	Sex × Hand × Mode interaction, $F(1, 26) = 5.6$, $p < .05$, in analysis of manual interference as indexed by tapping variability. The sex difference in direction of asymmetry (greater LH interference for males and greater RH interference for females) was obtained for bimanual tapping but not for unimanual tapping
Kee, Bathurst, & Hellige (1984), Experiment 1	24 RH adults (12 M, 12 F)	Manual task: speeded tapping of a microswitch tapping device with index finger; Concurrent task: mentally solving block design problems	Sex × Hand × Trials interaction, $F(1, 22) = 10.39$, $p < .005$, in analysis of manual interference. The predominant pattern of LH facilitation and RH interference was more marked for males on Trial 1 and for females on Trial 2
Lempert (1987), Experiment 1	96 RH adults (30 M, 66 F)	Manual task: speeded tapping of telegraph key with index finger; Concurrent task: listening to sentences and encoding content for subsequent recall using imagery, overt rehearsal, or silent rehearsal	Sex × Hand × Strategy interaction, $F(2, 84) = 4.64$, $p < .05$, in the analysis of manual interference. Males showed right-greater-than-left interference only in the silent-rehearsal condition, and females showed right-greater-than-left interference only in the overt-rehearsal and imagery conditions

Table 5. (*Continued*).

Experiment	Participants	Tasks	Results
Simon & Sussman (1987)	140 RH adults (35 FS−M, 35 FS+M, 35 FS−F, 35 FS+F) 120 LH adults (30 FS−M, 30 FS+M, 30 FS−F, 30 FS+F)	Manual task: speeded tapping of a microswitch tapping device with index finger; Concurrent task: speaking (describing a picture, reading aloud and speaking extemporaneously)	Significant Sex × Hand × Handedness interaction (*F*- and *p*-values not provided in report) in analysis of manual interference. Male and female RHs showed right-greater-than-left interference. Male LHs showed left-greater-than-right interference, and female LHs showed no significant asymmetry of interference
van Strien & Bouma (1988), Experiment 2	60 LH adults (15 FS−M, 15 FS+M, 15 FS−F, 15 FS+F). Within each group, 10 participants wrote with a noninverted hand posture and 5 wrote with an inverted hand posture	Manual tasks: (1) speeded tapping of a response key with index finger; (2) speeded sequential tapping of 4 keys with 4 fingers; Concurrent task: speaking (verbal fluency and reading aloud)	Significant Sex × Hand × Handedness × Load interaction, $F(1, 52) = 4.06$, $p < .05$, in analysis of single-finger tapping speed. All groups except male inverters showed left-greater-than-right interference
Sergent, Hellige, & Cherry (1993), Experiment 2	31 RH adults (16 M, 15 F)	Manual tasks: (1) paced tapping of a microswitch tapping device with index finger, (2) speeded tapping of the same tapping device with index finger; Concurrent task: solving anagrams	Sex × Hand × Task Order × Condition interaction, $F(1, 27) = 4.65$, $p < .05$, in analysis of the motor-implementation component of intertap variance. Males and females showed differential patterns of interference asymmetry that depend on the order in which speeded and paced tapping tasks were performed
Bathurst & Kee (1994)	32 RH adults (16 M, 16 F) and 64 LH adults (32 M, 32 F). All RHs wrote with a noninverted hand posture; half of M and F LHs wrote with an inverted hand posture	Manual task: speeded tapping of a microswitch tapping device with index finger; Concurrent tasks: (1) solving anagrams silently, (2) solving anagrams with vocalization, (3) solving items from Raven's Matrices test, (4) encoding 4 forms for subsequent reproduction	Sex × Hand × Condition interaction, $F(1, 84) = 4.10$, $p < .05$, in analysis of interference associated with the 2 anagram tasks for LHs with noninverted writing posture. Follow-up analyses yielded no significant Hand x Condition interaction for either M or F groups

Note. [1]Abbreviations: M = male; F = female; RH = right-handed; LH = left-handed; RHM = right-handed male; LHM = left-handed male; RHF = right-handed female; LHF = left-handed female; FS−M = male with no familial sinistrality; FS+M = male with familial sinistrality; FS−F = female with no familial sinistrality; FS+F = female with familial sinistrality; RHA = right-hand advantage; LHA = left-hand advantage.
[2]When raw scores are used as the dependent measure in lieu of interference scores, a Sex × Hand × Third Variable × Condition (single- versus dual-task) interaction is equivalent to a Sex × Hand × Third Variable interaction in the analysis of interference scores.

(1987, Experiment 1) found that the direction of the sex difference differed according to whether the concurrent task involved overt or silent rehearsal of verbal material.

The 3 remaining Category C findings are based on left-handers. The sex difference described by Bathurst and Kee (1994) applied only to a subset of left-handed participants, and follow-up analyses indicated that neither females nor males showed a significant asymmetry. Simon and Sussman (1987) and van Strien and Bouma (1988, Experiment 2) described sex differences that arose in the context of overall left-greater-than-right interference between verbal and manual activity amongst left-handers. Because the overall asymmetry is opposite to that expected, sex differences in asymmetry are difficult to interpret (see Hiscock, Kinsbourne, & Green, 1991). In the Simon and Sussman study it was the male left-handers who showed left-greater-than-right asymmetry, but van Strien and Bouma reported that male left-handers with inverted writing posture were the only group who failed to show left-greater-than-right asymmetry.

Category D Outcomes

The 2 Category D findings are based on studies of adults. Both findings are ambiguous with respect to the differential lateralization hypothesis. Bathurst and Kee (1994) reported a significant Sex $\times$ Hand $\times$ Condition $\times$ Familial Handedness interaction in their analysis of the manual interference attributable to concurrent performance of an anagrams task. This 4-way interaction applied only to left-handers who wrote with an inverted hand posture. Within this subgroup of 16 men and 16 women, only the 8 women who had left-handed relatives showed asymmetric interference, and this asymmetry was manifested only when the concurrent task was performed silently. Green, Nicholson, Vaid, White, and Steiner (1990), in a study of Spanish-English bilinguals, described a result that is equivalent to a 4-way interaction among sex, hand, language and group (interpreters vs. bilingual controls). In men but not in women, the degree to which concurrent verbal tasks disrupted right-hand performance more than left-hand performance varied between groups and between the languages in which the concurrent tasks were performed.

Category E Outcomes

Category E contains sex differences based on separate analyses for females and for males. The category excludes experiments in which the separate analyses were undertaken to follow up a significant interaction involving the sex factor. The 2 Category E outcomes, which stem from studies of adults, both support the differential lateralization hypothesis.

Lomas and Kimura (1976, Experiment 1) found that repetition of nursery rhymes disrupted right-hand dowel-rod balancing but not left-hand balancing in men, whereas no significant interference for either hand was found in women. Dalby (1980) reported that men made fewer correct responses on items from Raven's Progressive Matrices test when tapping with the left hand than with the right hand. Females showed no asymmetry of interference.

It should be noted that separate analyses for males and females do not verify the existence of a statistically significant sex difference. Even if subjects of one sex show a significant asymmetry and subjects of the other sex do not, the *difference* between males and females may not be statistically significant.

Composite Data

Combining the interpretable outcomes in Categories B, C, D, and E, we find that all 5 outcomes are consistent with the differential lateralization hypothesis and none is contrary to the hypothesis. This proportion differs significantly from chance at $p = .05$ by the binomial test (Siegel, 1956). Three findings are based on a conjunction of verbal and manual tasks, and 2 are based on a conjunction of nonverbal and manual tasks. Four findings are derived from studies of adults.

Only 2 of the 5 interpretable outcomes were described in such a way that effect sizes could be estimated. The proportion of variance accounted for by the participant's sex in the Category B outcome reported by Hiscock and Kinsbourne (1980) was .04, and the proportion of variance accounted for by sex in the Category B finding reported by Dalby (1980) was .14. These coefficients of determination correspond to effect sizes of $d = 0.4$ and 0.8, respectively (Cohen, 1988).

DISCUSSION

If only Category B outcomes are accepted as sex differences relevant to the differential lateralization hypothesis, then 3 of the 39 sex differences are relevant and all 3 outcomes are consistent with the hypothesis. Addition of Category C, D and E outcomes adds 2 more findings, both of which support the hypothesis of greater laterality in males. The 5 confirmatory outcomes represent 9.8% of the informative experiments and 4.5% of the total population of 112 studies. No outcomes run counter to the hypothesis even though one would expect at least one contrary outcome on the basis of chance.

The literature concerning dual-task asymmetry resembles the perceptual asymmetry literature with regard to sex differences. In particular, (1) only a minority of studies provide information about sex differences; (2) most of the reported sex differences are not directly relevant to the differential lateralization hypothesis; and (3) at least 80% of the outcomes that can be interpreted in terms of McGlone's hypothesis show a sex difference in the predicted direction.

The strong resemblance of dual-task sex differences to the sex differences observed in perceptual studies is especially interesting because the respective methods are based on different principles. Dual-task laterality represents output asymmetries whereas perceptual laterality represents input asymmetries. Dual-task asymmetries are derived from competition between two concurrent tasks whereas perceptual asymmetries are derived from competition between stimuli on opposite sides of space. Even if some extraneous factor could account for the sex difference in perceptual laterality, it is difficult to see how that factor could produce a corresponding sex difference in the asymmetry of dual-task interference.

Three explanations for the sex differences in perceptual asymmetry have been considered previously: (1) a population-level sex difference that is demonstrable only with certain stimuli or tasks (Bryden, 1982); (2) a weak population-level sex difference that is observed only sporadically (Bryden, 1988; Hiscock & Mackay, 1985); and (3) selective reporting of chance findings (Voyer, 1996; Hiscock et al., 1994). Perceptual laterality findings are compatible with the second model but fail to support the first and third models (Hiscock et al., 1994, 1995, 1999; Voyer, 1996). Dual-task findings, though limited in number, lead to similar conclusions. There appears to be a weak population-level sex difference in laterality, the direction of which is consistent with McGlone's (1980) differential lateralization hypothesis.

Another explanation for the weakness of sex differences across methods and modalities is that the laterality paradigms are deficient in validity. Voyer (1996) calculated that laterality of input accounts for only about 10% of the total variance in performance on visual, auditory and tactile tasks. If 90% of the variance in performance on these tasks is error variance or a combination of error variance and variance from extraneous sources, then one would expect sex differences to be attenuated accordingly. For instance, if the size of the laterality effect were limited by the unreliability of the dependent variable, the magnitude of the sex difference in laterality would be reduced for the same reason.

A recent finding implies that a laterality test may be invalid even when the retest reliability of the asymmetry scores is above .90 (Hiscock, Cole, Benthall, Carlson, & Ricketts, 2000). In this study a highly reliable dichotic listening test yielded a right-ear advantage (REA) in 82% of normal right-handed adults, which is substantially lower than the expected range of 95–99%. The ear asymmetry failed not only to differentiate females from males but also to differentiate left-handers from right-handers. Thus, irrespective of the reliability of the asymmetry score, the presence or absence of the expected asymmetry apparently does not constitute a satisfactory basis for classifying normal individuals with respect to underlying brain lateralization (see Satz, 1977). Given inadequate classification accuracy, the failure to find a strong or consistent sex difference in laterality must be interpreted with caution.

On the other hand, the weakness of the sex difference in laterality may simply reflect the small magnitude of the underlying difference between females and males in brain organization. That underlying sex difference, in turn, would be commensurate in magnitude with at least some cognitive sex differences. For example, Plomin and Foch (1981) used data obtained from over 67,000 children (Maccoby & Jacklin, 1974) to determine that sex accounts for only 1% of the variance in verbal ability. Consequently, even if the small sex difference in cerebral lateralization accounted for 100% of the difference between boys and girls in verbal ability, it would account for only 1% of the total variance in children's verbal ability. No biological sex difference can account for more than a trivial amount of variance in a behavioural characteristic if females and males differ only trivially with respect to that characteristic (Plomin & Foch, 1981).

The sex differences reported most consistently in the dual-task literature are incidental to the differential lateralization hypothesis. Males typically are faster than females at speeded repetitive and alternate finger tapping and better able to balance a dowel rod for a sustained period. It has been reported that females are substantially faster than males in sequential (four-finger) tapping (Lomas & Kimura, 1976, Experiment 2) and better at establishing and maintaining a steady rhythm (Wolff & Hurwitz, 1976). Even though sex differences in manual performance presumably are irrelevant to the hypothesised sex difference in lateralization, they may influence the asymmetry of interference in the dual-task condition. The most striking example of this potential confound is found in Experiment 1 of the Lomas & Kimura (1976) study. First, more women than men (9 versus 2) were eliminated as participants because their mean balancing times failed to exceed 5 s. Then, the remaining 12 women achieved a mean balancing time in the control condition of 19 s, as compared with 48 s for the remaining 12 men. The women's mean balancing times actually increased slightly when the concurrent speaking task was introduced. The difference between men and women in interference asymmetry thus might be attributable to the lack of interference in women, and this lack of interference might be attributable in turn to poor performance in the control condition.

As in our previous examinations of sex differences in perceptual laterality studies (Hiscock et al., 1994, 1995, 1999), the present conclusions are constrained by certain limitations of our method, which include its concern with the statistical significance of mean sex differences rather than on differences in the distribution of asymmetrical performance within each experiment. Also, caution must be used in generalising the results to populations that differ (e.g., with respect to ethnicity, language, or socioeconomic status) from the populations represented in our review.

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