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Is There a Sex Difference in Human Laterality? III. An Exhaustive Survey of Tactile Laterality Studies from Six Neuropsychology Journals*

Merrill Hiscock[1], Roxanne Inch[2], Jenine Hawryluk[3], Paula J. Lyon[1], and Nancy Perachio[1]
[1]University of Houston, Houston, TX and Departments of [2]Psychiatry and [3]Psychology, University of Saskatchewan, Saskatoon, Canada

ABSTRACT

The contents of six neuropsychology journals (161 volumes, 612 issues) were screened to identify tactile laterality experiments. Of 73 experiments identified, 40% provided information about sex differences. Seventeen experiments yielded a total of 18 sex differences, of which 4 could be interpreted in terms of the hypothesis that functional cerebral lateralization is more pronounced in males. All 4 interpretable outcomes (constituting 5.5% of the population of experiments and 13.8% of the informative experiments) were found to be consistent with the differential lateralization hypothesis. The results, in isolation, do not justify rejecting the null hypothesis. However, when considered in conjunction with findings for auditory and visual laterality studies, the present results are compatible with a weak population-level sex difference.

A much-debated question in the literature on cerebral hemisphere specialization concerns the existence of a sex difference in the degree to which higher mental functions are lateralized. Despite an early claim that the female brain is more completely lateralized than the male brain (Buffery & Gray, 1972), most subsequent accounts have favoured the hypothesis of greater lateralization in males (Bryden, 1979, 1988; Harris, 1978; Levy & Reid, 1978; McGlone, 1980; Witelson, 1976). Nonetheless, the evidence is inconsistent across studies (Bryden, 1982) and some of the supportive outcomes may be attributed to differences in strategy rather than to differences in neurological organization (Inglis & Lawson, 1982). After reviewing the evidence, some authors have expressed scepticism about the existence of a sex difference in hemispheric specialization (Fairweather, 1982; Hiscock & Mackay, 1985; Kolb & Whishaw, 1996).

There is reason to question the magnitude and meaningfulness of any sex difference that may exist. A recent meta-analysis of 266 laterality studies (Voyer, 1996) yielded a sex difference that, even though statistically significant for aggregated data, is too small to be detected reliably in individual experiments with typical sample sizes. From his calculation of effect sizes, Voyer (1996) concluded that sex differences in laterality are susceptible to Rosenthal's (1979) ''file drawer problem''. In other words, one cannot rule out the possibility that the published sex differences are offset by a much larger number of unpublished negative findings.

Whereas it would be difficult to sample the population of unpublished studies, one could more readily ascertain the number of negative findings in a specified population of published studies. This approach is potentially informative because laterality studies typically are designed to address questions other than sex differences

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Address correspondence to: Merrill Hiscock, Department of Psychology, University of Houston, Houston, TX 77204-5341, USA. E-mail: MHISCOCK@UH.EDU.
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and hence are likely to be published irrespective of whether sex differences are found (or even considered). This is the rationale underlying studies by Hiscock and his colleagues (Hiscock, Inch, Jacek, Hiscock-Kalil, & Kalil, 1994; Hiscock, Israelian, Inch, Jacek, & Hiscock-Kalil, 1995), who suggested that the controversy about sex differences in laterality stems from haphazard sampling of findings from the literature. In other words, previous reviews of sex differences in laterality have highlighted positive findings selected from an unspecified population of laterality studies.

As a corrective measure, Hiscock, Inch, et al. (1994) and Hiscock, Israelian, et al. (1995) examined all auditory and visual laterality findings from a well-defined population of experiments. Among the 360 experiments that provided information about sex differences, the investigators found 61 significant sex differences in laterality, 48 of which were consistent with McGlone's (1980) hypothesis of greater lateralization in males. The proportion of confirmatory outcomes differs significantly from chance at $p < .001$. Hiscock, Inch, et al. (1994) and Hiscock, Israelian, et al. (1995) concluded that findings from auditory and visual laterality studies are compatible with the existence of a population-level sex difference that accounts for 1 to 2% of the variance in laterality.

Hiscock, Inch, et al. (1994) and Hiscock, Israelian, et al. (1995) categorized laterality studies by ''filtering'' the data through a series of specified tests, for example, whether the analysis included sex as a variable, whether the sex difference was statistically significant, and whether the sex difference was manifested as a two-way interaction or a higher order interaction. This approach does not yield a direct estimate of effect size, as does quantitative meta-analysis, but it has some advantages. The stepwise decision rules allow the investigator to specify the sources of shrinkage in the number of informative studies as the data are passed through the various ''filters.'' The method also requires that experiments and outcomes be categorized according to explicit criteria despite complexities such as unusual sample characteristics, partially redundant analyses, higher order interactions, and atypical stimuli or experimental procedures.

Beginning with the same data base as that used by Hiscock, Inch, et al. (1994) and Hiscock, Israelian, et al. (1995) as a source of auditory and visual laterality studies, we updated the data base to include more recent studies and then identified all the tactile laterality studies. We subsequently determined (1) the number of tactile studies providing information about sex differences; (2) the proportion of studies showing a sex difference according to specified criteria; and (3) the direction of the sex differences reported, that is, whether males and females are equally likely to show the greater asymmetry.

METHOD

Data Sources

Six periodicals were examined: *Brain and Cognition*, *Brain and Language*, *Cortex*, *Developmental Neuropsychology*, *Journal of Clinical and Experimental Neuropsychology* (previously *Journal of Clinical Neuropsychology)* and *Neuropsychologia*. These periodicals were selected because they were thought, when the project began in the late 1980s, to be the richest sources of peer-reviewed laterality studies. Each issue, from the inception of the respective journal to December 1994, was included in the survey. Coverage included a total of 161 volumes, which comprised 612 issues. Table 1 shows the number of experiments from each journal.

Procedure

The sequence of decisions made for each experiment is summarized in Table 2. This series of tests is comparable to that used by Hiscock, Inch, et al. (1994) and Hiscock, Israelian, et al. (1995) in their survey of auditory and visual studies. 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 possibility 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 stimuli were presented (3) in the tactile modality and (4) unilater-

Table 1. Data Sources.

Source	Total Experiments	Informative Experiments	Percentage
Brain and Cognition	5	3	60.0
Brain and Language	5	2	40.0
Cortex	32	12	37.5
Neuropsychologia	28	11	39.3
Journal of Clinical and Experimental Neuropsychology[a]	1	0	0.0
Developmental Neuropsychology	2	1	50.0
Total	73	29	39.7

Note. [a] Includes all volumes of *Journal of Clinical Neuropsychology.*

ally. If the stimuli were not tactile, the experiment was not included in the present study. Experiments employing bilateral stimulation were included in the study but were compiled separately.

The next step (5) was to determine whether adults or children participated in the experiment; data for adults and children were tabulated separately. The next three steps entailed determining whether (6) the participant's sex was specified, (7) both females and males were included, and (8) sex of participant was included as a factor 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 two final steps were (9) to determine whether there was a statistically significant sex difference and (10) to categorize the significant sex difference according to the classification scheme depicted in Table 3.

Category A outcomes consist of significant main effects for sex of participant, that is, effects indicating a difference between females and males in overall performance. Even though Category A outcomes have no direct relevance to the hypothesis of greater lateralization in males, such outcomes may be of interest for other reasons. Category B findings consist of significant Sex × Hand interactions for raw scores as well as one comparable main effect for sex (from an experiment in which the right-minus-left difference score was used as the dependent variable). Category B outcomes are directly 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 outcomes, which entail four-way interactions, and Category E outcomes, which reflect separate analyses for females and males, sel-

Table 2. Sequence of Tests.

Step	Test	Positive Result	Negative Result
1	Laterality study?	Go to 2	Stop
2	Normal participants?	Go to 3	Stop
3	Tactile modality?	Go to 4	Record[a]
4	Unilateral presentation?	Go to 5	Go to 5
5	Adult participants?	Go to 6	Go to 6
6	Sex of participant specified?	Go to 7	Tabulate[b]
7	Both sexes included?	Go to 8	Tabulate[b]
8	Sex as factor in analysis?	Go to 9	Tabulate[b]
9	Significant sex difference?	Go to 10	Tabulate
10	Category of sex difference?	[Refer to Table 3]	

Note. [a] Data to be used in surveys of sex differences in other modalities.
[b] Study to be classified as uninformative with respect to sex differences.

Table 3. Categories of Sex Differences.

Category	Raw Scores	Laterality Index
A	Main Effect for Sex	Not Applicable
B	Sex × Hand Interaction	Main Effect for Sex
C	Sex × Hand × Other Factor	Sex × Other Factor
D	Sex × Hand × Two Other Factors	Sex × Two Other Factors
E	Separate Analyses	Separate Analyses

dom provide strong evidence of a sex difference. Nonetheless, our tabulation includes findings that fall into those categories. The $p = .05$ 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 73 experiments (49 with adults; 24 with children) satisfying the inclusion criteria, 29 (39.7%) yielded information about sex differences. Although a higher percentage of informative experiments was found among studies of children (54.2%) than among studies of adults (32.7%), the difference was not statistically significant by chi-square test. The percentage of informative experiments for each of the six journals is shown in Table 1.

Frequency of Significant Sex Differences

Frequency data are summarized in Table 4. Of the 29 informative experiments, 17 (58.6%) yielded at least one significant sex difference. The percentage of positive outcomes did not differ significantly between experiments with adults (56.3%) and those with children (61.5%), or between experiments that used unilateral stimulation (80.0%) and those that used bilateral stimulation (47.4%).

Categorization of Positive Outcomes

Table 5 shows the number of experiments falling into each of the five outcome categories (A, B, C, D, and E). Two positive outcomes in one experiment (Walch & Blanc-Garin, 1987, Experiment 1) caused the total of positive outcomes ($n = 18$) to exceed the number of experiments with positive outcomes ($n = 17$).

Table 4. Number of Experiments Yielding Positive and Negative Outcomes.

	Unimanual Presentation	Bimanual Presentation[a]	Total
Experiments with Adults			
Sex Difference	4	5	9
No Sex Difference	2	5	7
Experiments with Children			
Sex Difference	4	4	8
No Sex Difference	0	5	5
Adult and Child Experiments Combined			
Sex Difference	8	9	17
No Sex Difference	2	10	12

Note. [a]Experiments were included in the bimanual category if bimanual presentation was used at all in the experiment, i.e., bimanual only, or both bimanual and unimanual presentation in the same design.

Table 5. Positive Outcomes by Category.

	Number of Experiments[a]					
	Adults		Children		Combined	
Category	Unimanual	Bimanual	Unimanual	Bimanual	Unimanual	Bimanual
A	1	1	1	1	2	2
B	0	2	2	1	2	3
C	1	1	1	1	2	2
D	0	1	0	0	0	1
E	2	0	0	2	2	2
Total	4	5	4	5	8	10

Note. [a] Totals are inflated by one experiment with two positive outcomes.

Category A Outcomes

Four experiments (two with adults, two with children) yielded significant main effects for sex. Both of the findings for adults were qualified in some respect. Cohen and Levy (1986) found that men were more accurate than women in distinguishing stimuli on the basis of shape and texture, but the sex difference was found only with simultaneous bimanual stimulation. Hatta and Ejiri (1989) reported that men outperformed women in their ability to recall the order in which different fingers had been stimulated, but the sex difference was found only among pianists. Burden, Bradshaw, Nettleton, and Wilson (1985, Experiment 3) found that 5-year-old boys made fewer errors than did 5-year-old girls on a task requiring the reproduction of finger positions. In a longitudinal study of 120 children at ages of 11-15 years, Hassler and Birbaumer (1988) reported that males performed more accurately than females on Witelson's (1974) dichhaptic shapes test. Thus, all four Category A findings reflect superior performance by males.

Two other outcomes are noteworthy even though they failed to meet the criteria for inclusion in our final tabulation. In a preliminary experiment that did not include hand as a variable, Nilsson and Geffen (1987, Experiment 1) reported that women responded more quickly than men during a task requiring participants to rate the similarity of shapes explored independently with their left and right hands. Gibson and Bryden (1984) found a significant main effect for sex but only when the analysis included data from 19 deaf children as well as 20 hearing children. Males were more accurate than females in identifying letters and shapes.

Category B Outcomes

The five Category B outcomes are summarized in Table 6. Two of the outcomes were associated with unilateral presentation of stimuli and three with bilateral presentation. Two of the experiments involved adults as participants and three involved children.

Two findings, both based on bimanual stimulation of adults, support the hypothesis of greater lateralization in males. Duda and Adams (1987, Experiment 3) found that men, but not women, showed left-hand superiority for identifying Witelson's (1974) shapes presented bilaterally. The effect, however, disappeared after the initial 10 trials (the number of trials used by Witelson); there was no indication of a sex difference across the full 40 trials of the experiment. The second supportive finding (Nilsson & Geffen, 1987, Experiment 2) also consisted of a left-hand advantage for men and no asymmetry for women on a task requiring the identification of shapes on the basis of bimanual palpation.

The other three Category B outcomes, derived from studies of children, are ambiguous with respect to the sex-difference hypothesis. Hatta, Yamamoto, Kawabata, and Tsutui (1981) found a right-hand advantage for girls and no asymmetry for boys in identifying shapes. The

Table 6. Experiments Yielding a Significant Sex × Hand Interaction or the Equivalent Main Effect when a Laterality Index Was Used as the Dependent Measure

Experiment	Participants	Stimuli	Results and Task
Hatta, Yamamoto, Kawabata, & Tsutui (1981)	48 RH children (8 M and 8 F at ages 8, 10, and 12 years)	Plywood shapes of common objects; unimanual palpation with 20-s time limit; pointing response with opposite hand	Sex × Hand interaction, $F(1, 42) = 4.10$, $p < .05$, in analysis of accuracy. RHA for females but no asymmetry for males
Gibson & Bryden (1984)	20 RH children (10 M and 10 F at 11 years)	Letters and shapes made of sandpaper and cardboard; bimanual palpation for 2 s; pointing response with each hand in random order	Sex × Hand interaction, $F(1, 18) = 13.58$, $p < .01$, in analysis of accuracy. Males tended to show LHA; females tended to show RHA
Hatta & Yamamoyto (1986), Experiment 2	24 RH children (12 M and 12 F at 6 years)	Steel bars of different lengths presented on participant's midline or in left or right hemispace; participant estimated midpoint of bar from unimanual palpation; manual response	Sex × Hand interaction, $F(1, 22) = 5.46$, $p < .05$, in analysis of one of three error scores. Males showed RHA but females showed no hand difference
Duda & Adams (1987), Experiment 3	26 RH adults (12 M, 14 F)	Cardboard shapes identical to those used by Witelson (1984); bimanual palpation of shapes for 4 s with index and middle fingers; participant responded by pointing to black patterns in visual array; responding hand counter-balanced between participants	Sex × Hand interaction, $F(1, 22) = 10.49$, $p < .004$, in analysis of accuracy during first 10 trials. LHA for males and trend toward RHA for females. No sex difference in data for all 40 trials
Nilsson & Geffen (1987), Experiment 2	16 RH adults (8 M, 8 F)	Aluminum shapes mounted on cardboard; bimanual palpation for 4 s with index and middle fingers; participant indicated whether one of the shapes matched a target previously palpated; participant responded by pressing front or rear of a rocker switch with both feet	Sex × Hand interaction, $F(1, 12) = 5.57$, $p < .05$, in analysis of correct responses. LHA for males but no asymmetry for females
Hatta & Ejiri (1989), Experiment 1	40 RH adults (10 M and 10 F pianists; 10 M and 10 F controls)	Random sequences of 5, 7, or 9 electrical pulses delivered to the fingers of each hand; left and right hand stimulated unimanually in randomized order; participants responded by lifting fingers in the order in which they had been stimulated	Main effect for sex, $F(1, 18) = 8.28$, $p < .01$, in analysis of difference between hands in number of correct responses by pianists. Females showed larger LHA than did males. No sex difference for control group

Note. 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; RHA = right-hand advantage; LHA = left-hand advantage.

asymmetry shown by girls was opposite to the expected asymmetry and largely attributable to the youngest girls in the sample. Gibson and Bryden (1984) reported that hearing boys were more accurate with the left hand, whereas hearing girls were more accurate with the right hand, on a bilateral tactile identification task. The finding is ambiguous because the sex difference was observed irrespective of whether the stimuli were letters or shapes. The authors, in describing a similar Sex × Hand interaction in an earlier study with a larger sample, attributed the finding to a ‘‘differences in a task-independent bias favouring the left hand…’’ (Gibson & Bryden, 1983, p. 142). An experiment by Hatta and Yamamoyto (1986, Experiment 2) yielded a right-hand advantage for boys but no asymmetry for girls on a task that entailed tactile bisection of a steel bar. This finding reflected not asymmetries of overall accuracy but, rather, asymmetries in the displacement of estimated midpoints from the actual midpoint of the bar. The investigators suggested that strategy differences might account for sex differences on this task.

A finding that runs counter to the differential lateralization hypothesis (Hatta & Ejiri, 1989, Experiment 1) was excluded from our tabulation because it pertained to a sample of skilled pianists but not to control participants or to the sample as a whole.

Category C Outcomes

Four experiments yielded significant three-way interactions among sex, hand, and a third factor. The experiments are summarized in Table 7. Two of the experiments entailed unilateral presentation of stimuli, one entailed bilateral presentation, and one entailed a combination of unilateral and bilateral stimulation. Two of the experiments involved adults as participants and two involved children.

None of the four outcomes could be related unambiguously to the differential lateralization hypothesis. Lenhart and Schwartz (1983) reported that the left-hand performance of men, but not women, was enhanced by instructions to use an imagery strategy for matching shapes. In light of evidence that image generation is not primarily a right-hemisphere function (Farah, 1984), the association between imagery and left-hand performance in males is difficult to interpret. In the other study of adults, Hatta and Yamamoyto (1986, Experiment 1) found that men bisected a steel bar more accurately when it was palpated with the right hand than with the left hand, but only when the bar was presented on the participant’s midline. The bisection accuracy of women varied with the hemispace in which the bar was presented but not with the hand used to feel the bar. In the two experiments involving children, Burden et al. (1985, Experiments 1 & 2) also found interactions among sex, hand, and hemispace. In Experiment 1, the crossed-hands conditions proved to be disadvantageous for texture matching in girls but not in boys. A Sex × Presentation Hand × Response Hemispace interaction in Experiment 2 was based on data from 3 left-handed boys and 3 left-handed girls. The investigators acknowledge that this interaction ‘‘cannot be safely interpreted’’ (Burden et al., 1985, p. 520).

Category D Outcomes

The single outcome in this category is derived from a study of adolescents and young adults that employed bilateral presentation of letters and nonsense shapes (Tinkcom, Obrzut, & Poston, 1983). Analysis of scores for the nonsense shapes yielded a significant Sex × Hand × Handedness × Familial Sinistrality interaction, which reflected left-hand superiority for left-handed males with familial sinistrality and right-hand superiority for right-handed females with no familial sinistrality. We consider this interaction to be uninterpretable with respect to the differential lateralization hypothesis.

Category E Outcomes

We identified three experiments in which four sex differences were suggested by separate analyses for males and females (Benton, Varney & Hamsher, 1978; Fagot, Lacreuse, & Vauclair, 1993; Walch & Blanc-Garin, 1987, Experiment 1). The two sex differences in adults were based on unilateral presentation of stimuli, and the two sex differences in children were based on bilateral stimulation. This category does not include any experiment in which the analyses were un-

Table 7. Experiments Yielding a Significant Sex × Hand × Third Factor Interaction or the Equivalent Two-Way Interaction When a Laterality Index Was Used as the Dependent Measure.

Experiment	Participants	Stimuli	Results and Task
Lenhart & Schwartz (1983)	90 RH adults (45 M, 45 F)	Wooden shapes; bimanual palpation with middle 3 fingers of each hand for 3 s; participants assigned randomly to verbal, imagery, or no strategy conditions; manual response to indicate whether a single shape, palpated with one hand, matched either of the previously presented shapes	Sex × Presentation Hand × Strategy Condition interaction, $F(4, 168) = 3.17$, $p < .05$. For left-hand matches, males in the imagery condition outperformed males in the other two strategy conditions, whereas females tended to show the opposite pattern across conditions
Burden, Bradshaw, Nettleton, & Wilson (1985), Experiment 1	32 RH children (8 M and 8 F at ages 3 and 5 years)	Circles of different textures presented in same or opposite hemispace to the same hand twice or sequentially to different hands; stimuli were rubbed across tip of the index finger; oral ‘‘same’’ vs. ‘‘different’’ response	Sex × Presentation Hand × Presentation Hemispace interaction, $F(1, 28) = 4.24$, $p < .05$. Girls performed better when hand and hemispace were congruent (e.g., right hand in right hemispace) than when hand and hemispace were incongruent. Boys showed no corresponding difference
Burden, Bradshaw, Nettleton, & Wilson (1985), Experiment 2	30 children at age 8 years (12 RHM, 12 RHF, 3 LHM, 3 LHF)	2 or 3 fingertips were touched sequentially with a small plastic rod; pointing responses were made by either the stimulated hand or the opposite hand, within the same or opposite hemispace as the stimulation	Sex × Presentation Hand × Response Hemispace interaction, $F(1, 4) = 21.99$, $p < .01$ in analysis of errors for LHs. Boys made a large number of errors when responding in right hemispace following left-hand stimulation. The authors declined interpretation because of small sample size ($n = 3$ for each sex)
Hatta & Yamamoyto (1986), Experiment 1	24 RH adults (12 M, 12 F)	Steel bars of different lengths presented on participant’s midline or in left or right hemispace; blindfolded participant estimated midpoint of bar from unimanual palpation; manual response	Sex × Hand × Spatial Condition interaction, $F(2, 44) = 4.83$, $p < .025$, in analysis of absolute error. Males showed RHA in midline condition but females showed Hand × Spatial Condition interaction. Females tended to show LHA in left hemispace and RHA in right hemispace

Note. 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; RHA = right-hand advantage; LHA = left-hand advantage.

dertaken to follow up a significant interaction involving the sex factor.

Benton et al.'s (1978) study supports the differential lateralization hypothesis. Men showed a significant left-hand superiority on a task requiring the matching of steel rods for orientation in space, whereas women showed a nonsignificant difference favoring the left hand. The sex difference reported by Fagot et al. (1993) is ambiguous with respect to the differential lateralization hypothesis. In this study, men differed from women in the way in which they palpated geometric forms composed of cubes joined together. Men touched more cubes simultaneously with the left hand than with the right hand; women showed no significant difference between hands.

Both Category E findings for children are found in Experiment 1 of Walch and Blanc-Garin (1987). The investigators found a significant left-hand advantage for 6-year-old girls but not for 6-year old boys when letters were used as stimuli. When the stimuli consisted of shapes, only the boys showed a left-hand advantage. The first finding was classified as ambiguous with respect to the differential lateralization hypothesis, and the second finding was classified as supportive.

Two additional outcomes that might be invoked to support the differential lateralization hypothesis were disregarded because the outcomes applied only to subgroups of musically talented children and not to the entire sample of children (Hassler & Birbaumer, 1986).

It should be noted that separate analyses for males and females do not verify the existence of a statistically significant sex difference. Even if participants of one sex show a significant asymmetry and participants 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 four outcomes are consistent with the differential lateralization hypothesis and none is contrary to the hypothesis. The number of outcomes is insufficient for significance testing using the binomial test (Siegel, 1956). Three findings are based on bimanual stimulation, and three findings are derived from studies of adults.

DISCUSSION

The hypothetical sex difference in laterality, which has been difficult to document in auditory and visual studies, appears to be equally infrequent in the tactual modality. Of the 28 significant sex differences identified in the present study, only 2 satisfy the most stringent criteria (i.e., Category B criteria) for relevance to the differential lateralization hypothesis. One of those findings disappeared after the initial 10 trials of a 40-trial experiment (Duda & Adams, 1987), leaving one unequivocal sex difference (Nilsson & Geffen, 1987, Experiment 2) gleaned from a total of 73 experiments. This difference reflects greater asymmetry in males than in females. Considered in isolation, this finding provides little support for the hypothetical sex difference in functional specialization of the cerebral hemispheres.

When the inclusion criteria are relaxed so as to admit two- and three-way interactions as well as results of separate analyses for males and females, the number of relevant sex differences increases from two to four. All four of the relevant sex differences support the hypothesis of greater functional lateralization in males. Nonetheless, the four confirmatory experiments constitute only 5.5% of the original population of studies, and could plausibly be attributed to chance.

Although the population of tactile experiments is much smaller than the corresponding populations of auditory and visual laterality experiments (Hiscock, Inch, et al., 1994; Hiscock, Israelian, et al., 1995), the percentage of experiments providing information about sex differences (approximately 40%) is almost identical across modalities. For the informative experiments, however, the number of significant sex differences per experiment is somewhat greater in the tactile laterality literature (0.62) than in either the auditory (0.39) or visual (0.42) literature. Most sex differences, irrespective of modality, are difficult to interpret in terms of the differential lateralization hypothesis. Nonetheless, when readily interpretable sex differences are found, they usually support the hypothesis of greater lateralization in males. Of 65 interpretable sex differences (Categories B, C, D, and E) in all three modalities, 80% suggest greater lateralization in males.

Three explanations were considered by Hiscock, Inch, et al. (1994) in light of the auditory evidence: (1) a population-level sex difference that is obtained only with certain stimuli or tasks (Bryden, 1982); (2) a population-level sex difference that accounts for little variance and is observed only sporadically (Bryden, 1988; Hiscock & Mackay, 1985); and (3) biased reporting of chance findings, that is, an instance of Rosenthal's (1979) ''file drawer problem.'' Hiscock, Inch, et al. (1994) argued that the auditory laterality results--though failing to rule out the third model (the null hypothesis)--tend to support the second model, that is, a weak sex difference in hemispheric specialization. Consideration of the visual laterality literature (Hiscock, Israelian, et al., 1995) strengthens the argument for the second model while diminishing the plausibility of the third model. Neither the auditory nor the visual laterality studies lend substantial support for the first model. The tactile findings, though limited in number, are consistent with the conclusions based on auditory and visual studies. 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.

Voyer's (1996) meta-analysis of 120 auditory, 235 visual, and 41 tactile laterality effects led him to conclude that (1) men show greater asymmetries in all modalities, (2) sex differences are much weaker than overall laterality effects, and (3) sex differences are sufficiently weak as to be susceptible to the file drawer problem. The largest significant effect size for sex accounted for only 0.1% of the total variance in laterality. Although this estimated effect size is one order of magnitude smaller than the 1-2% figure offered by Hiscock, Israelian, et al. (1995), the estimates are encouragingly similar when one considers the different assumptions and dissimilar procedures underlying the respective estimates. For instance, Voyer (1996) assigned a Z value of zero to nonsignificant sex differences for which the authors reported no additional information. This is a conservative decision rule that might have underestimated the actual effect sizes. Hiscock, Israelian, et al. (1995), on the other hand, used power tests to infer the magnitude of a population-level sex difference that would be necessary to yield the sex differences obtained in their sample of experiments. This indirect procedure, which requires a number of simplifying assumptions (e.g., regarding sample size and the complexity of the experimental design), may have overestimated the magnitude of the sex difference in the population.

Both Voyer's (1996) meta-analysis and Hiscock, Israelian, et al.'s (1995) frequency counts lead to the conclusion that a weak sex differences exists at the population level, and that males are more asymmetric than females. Moreover, both approaches converge on the conclusion that sex differences in tactile laterality resemble sex differences in the auditory and visual modalities.

As in our previous examinations of auditory and visual laterality studies (Hiscock, Inch, et al., 1994; Hiscock, Israelian, et al., 1995), the conclusions are constrained by certain limitations of our method, which include its concern with the statistical significance of mean sex differences rather than differences in the distribution of left- and right-sided advantages within each experiment (cf. Bryden, 1983). Also, since no attempt was made to categorize studies according to participant characteristics other than age, caution must be used in generalizing the results to populations that differ (e.g., with respect to handedness, ethnicity, language, or socioeconomic status) from the samples represented in our review.

It has been suggested by Harshman, Hampson, and Berenbaum (1983) that sex differences in brain organization interact with handedness, and that the Sex × Handedness interaction may be reversed in people with different levels of reasoning ability. If so, the question of sex differences in laterality, as raised by McGlone

(1980) and other writers, may be excessively simplistic. Given the relative paucity of laterality data from left-handers and the rarity of cognitive-ability data in laterality studies, it may not be feasible to test more complicated hypotheses using tabulations or meta-analyses of available data. In addition, questions about Sex × Handedness interactions may be confounded by the heterogeneity of left-handedness, for example, by the existence of subgroups that differ reliably in the consistency of left-hand preferences (Peters & Servos, 1989).

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