Laterality

Asymmetries of Brain, Behaviour, and Cognition

ISSN: 1357-650X (Print) 1464-0678 (Online) Journal homepage: https://www.tandfonline.com/loi/plat20

On the Magnitude of Laterality Effects and Sex Differences in Functional Lateralities

Daniel Voyer

LATERALITY, 1996, *1* (1), 51–83

On the Magnitude of Laterality Effects and Sex Differences in Functional Lateralities

Daniel Voyer

St. Francis Xavier University, Canada

In the last 20 years, the hypothesis that men and women differ in functional lateralities has been used to account for sex-related differences in verbal and spatial skills. However, this hypothesis has not been clearly supported, with some reviewers confirming it (McGlone, 1980 for example), and others rejecting it (Fairweather, 1982 for example). The purpose of the present study was to provide a definite test of this hypothesis and to estimate the magnitude of overall laterality effects by means of a meta-analytic procedure. A total of 396 significance levels from a variety of studies on functional asymmetries utilising auditory, visual, or tactile presentation of verbal or nonverbal stimuli were sampled. Results showed that laterality effects tend to be large and significant but that they are heterogeneous in the visual modality. Homogeneity was generally achieved by a partition of the studies in terms of the specific task used. The results also showed sex differences to be significant in two modalities (visual and auditory). The data indicated the presence of sex differences in favour of men in functional asymmetries. However, it appears that the findings are not resistant to the file drawer problem. The results are discussed with regard to their implications for explanations of individual differences in cognitive abilities. The relation between functional lateralities and anatomical asymmetries is also discussed.

INTRODUCTION

The belief that sex differences in specific intellectual abilities exist was quite common even before they were empirically documented (Ellis, 1928). A large number of studies have also been conducted to test this belief and most of these studies were summarised by Garai and Scheinfeld (1968). Since then, other reviews and meta-analyses have demonstrated that men and women differ on specific cognitive abilities (Harris, 1978; Linn & Petersen, 1985; Maccoby &

Requests for reprints should be sent to D.Voyer, Department of Psychology, St. Francis Xavier University, P.O. Box 5000, Antigonish, Nova Scotia, Canada, B2G 2W5. Email: dvoyer @juliet.stfx.ca.

The author wishes to thank Susan Voyer for her assistance in collecting data for the present study. The author is also indebted to Pierre Cormier, Matthew J. Hoptman, Chris McManus, and Doug Wahlsten for their comments on previous versions of this paper.

Jacklin, 1974; Voyer, Voyer, & Bryden, 1995). Prominent in these reviews is the finding that sex differences are found in verbal and spatial abilities. Specifically, women generally perform better than men in verbal tasks, while the opposite pattern is found in spatial tasks. It is now commonly accepted that sex differences exist in verbal and spatial skills (but see Caplan, MacPherson, & Tobin, 1985, Feingold, 1988, and Hyde & Linn, 1988). Based on this conclusion, a number of hypotheses have been advanced to account for sex differences in these areas (see McGee, 1979, for a review). Several of these hypotheses have been tested but few have been conclusively rejected. Thus, a number of theories still remain.

One theory makes use of the fact that the areas of intellectual abilities where sex differences are found seem to parallel what is conventionally recognised as the basic hemispheric specialisation of the brain. A number of reviewers and theorists agree that the left hemisphere of the brain appears to be specialised for verbal functions, whereas the right hemisphere seems to be dominant for nonverbal, visuo-spatial functions (Bryden, 1982; Geschwind & Galaburda, 1987; Iaccino, 1993). Based on the parallel between the abilities where sex differences are found and the respective specialisation of the cerebral hemispheres, one obvious explanation of sex differences in verbal and spatial skills is that they may be due to sex differences in cerebral organisation. However, the exact nature of the differences in cerebral organisation is not clear.

One attempt to clarify this issue was made by Levy (1969) who proposed that people with bilateral representation of language functions should perform relatively poorly on spatial tasks. Following this idea, Levy (1971) suggested that men are better than women on spatial tasks because they are more lateralised for spatial functions. According to Levy (1971), verbal functions are bilaterally represented in women, and they overlap with spatial functions. This presumably would explain why women perform better than men on verbal tasks, while men are superior to women on spatial tasks. The overlap of verbal functions with spatial functions impairs women's spatial abilities and increases their verbal abilities, while greater asymmetry of spatial functions in men leaves their spatial abilities intact, as compared to those of women. Levy (1971) explained the negative effect of overlapping of verbal functions on spatial functions as resulting from interference. That is, bilateral language competence produces a specific interference with spatial functions by forcing the two hemispheres to process information using a verbal approach. This interpretation implies that asymmetry of function allows an optimal performance of the right (spatial) hemisphere, as in this case, verbal functions do not interfere with spatial functions. This hypothesis predicts that men should show hemispheric advantages on specific tasks, whereas women should not.

Other attempts have been made to clarify the nature of sex differences in cerebral organisation. For instance, Buffery and Gray (1972) proposed a hypothesis that is virtually the opposite to that of Levy (1971). They claimed that women are more lateralised than men. In men, spatial functions are hypothesised to be bilaterally represented. This produces superior spatial abilities in men. These authors argued that bilateral representation is an advantage in one case (spatial functions), and asymmetry an advantage in another case (verbal functions). According to Buffery and Gray (1972, p.144), verbal skills require quick associations and serial ordering, which presumably demands fast and intricate neural mechanisms. ''Such mechanisms could benefit from being subserved by specific structures with a clearly lateralized and localized cerebral representation''. On the other hand, the three-dimensional nature of spatial tasks benefits from a bilateral cerebral representation. In this case, the authors assume a positive effect of bilateral representation of spatial functions. This is in obvious contradiction with Levy's (1971) model, as it predicts that women should show laterality effects on specific tasks, whereas men should not. It is worth noting that a more recent model of the development of cerebral lateralisation proposed by Geschwind and Galaburda (1987) also implies that men should be less lateralised than women in a variety of tasks.

One way to test these hypotheses is to look at anatomical sex differences in the brain. The rationale guiding this type of research is that if there are sex differences in functional asymmetries, they should have anatomical substrates. A number of anatomical studies have revealed the presence of sex differences in the shape and size of specific structures in the corpus callosum (Clarke, Kraftsik, Van der Loos, & Innocenti, 1989; de Lacoste-Utamsing & Holloway, 1982; Reinarz, Coffman, Smoker, & Godersky, 1988). In general, results show that women tend to have a larger corpus callosum than men. De Lacoste-Utamsing & Holloway (1982) claimed that their findings were compatible with the hypothesis that the female brain is less well lateralised than the male brain, a conclusion that can be applied to all the studies reporting a larger corpus callosum in women than in men. This means that it is plausible to assume that women engage in more interhemispheric communication than men do and, for that reason, they require a larger corpus callosum (Iaccino, 1993). Increased interhemispheric communication in women thus suggests that they are more likely than men to show bilateral representation of verbal and nonverbal functions, and this fits very well with Levy's hypothesis.

A number of reviews have examined sex differences in laterality. Bryden (1979), Fairweather (1982), Harris (1978), and McGlone (1980) are the most commonly cited ones. In three of these reviews (Bryden, 1979; Harris, 1978; McGlone, 1980) support was found for Levy's hypothesis. However, Fairweather (1982) reported that sex differences in laterality do not exist.

This inconsistency in the conclusions reached by different reviewers concerning the existence of sex differences in laterality is puzzling. A basic difference between Fairweather's review and the other three is that Fairweather only reviewed studies using a divided visual field paradigm. This might have produced a biased sample of studies and resulted in a false conclusion. However, the presence of a systematic bias is unlikely. A more likely possibility relates to the fact that these authors used a qualitative approach in reviewing the studies. Even though qualitative reviews allow a good understanding of conceptual and methodological issues which may account for differences in results among studies, they do not permit the quantification of the magnitude of sex differences in laterality. In examining the question of whether or not sex differences in laterality are significant, qualitative reviews only allow a count of the studies showing a significant effect, as compared to studies showing a non-significant effect. In the long run, this paradigm produces arbitrary decisions as to whether studies are more likely to produce one outcome rather than another.

Meta-analysis has the advantage of allowing precise quantification of the magnitude of the effect in a series of studies (Rosenthal, 1991). Hence, it was used in the present study. However, it is important to keep in mind that a meta-analysis is only as good as the studies entering it, as it may be contaminated by poorly designed studies. To minimise the influence of this problem, an attempt was made in the present analysis to include only studies published in refereed journals. This approach was based on the assumption that methodologically flawed studies are less likely to appear in such publications. Studies published in non-refereed journals were included only when they were cited in the reviews previously mentioned (i.e. Bryden, 1979; Fairweather, 1982; Harris, 1978; McGlone, 1980).

Even when it is conducted carefully, a meta-analysis is not necessarily the perfect way to summarise literature, because it has its own flaws (see Sohn, 1995 and Eysenck, 1995, for examples). Nevertheless, meta-analysis provides a clear summary of the effects of interest and it also provides a definite test of significance of these effects. Therefore, based on the claim that its advantages outweigh its disadvantages (see Lipsey & Wilson, 1995), meta-analysis was used to provide a definite test of the hypothesis that there are sex differences in functional lateralities. Because the data were readily available along with the data pertaining to sex differences, the magnitude of the main effect of laterality was also examined.

A careful analysis of sex differences in laterality has recently been conducted by Hiscock et al. (1994). However, it concerned only auditory effects and it did not use a conventional meta-analytic approach. Specifically, these authors used a systematic counting procedure which allowed them to tabulate the frequency of significant sex differences in auditory laterality in studies drawn from a selective sample of neuropsychology journals. This procedure had both the advantages and disadvantages of a literature review, and it did not allow the authors to quantify the magnitude of sex differences in laterality. Nevertheless, it supported the notion that there are weak sex differences in laterality, indicating greater auditory lateralisation in men. Thus, based on the fact that laterality effects are consistently reported and that a number of reviews suggest the existence of sex differences, the hypotheses of the present analysis are that (a) overall laterality effects will be significant, and (b) sex differences in laterality will be significant.

META-ANALYTIC PROCEDURE

Selection Criteria for Inclusion in the Meta-analysis

The present meta-analysis includes only published studies presenting results obtained with dichotic listening, divided visual field, or dichhaptic (tactile) stimulation. Results obtained with samples of brain-damaged subjects were not included in the present analysis. The present study is thus concerned only with functional lateralities observed in brain-intact individuals. Another requirement was that the sex of subjects had to be considered as an independent variable in the data analysis of an individual study to warrant its inclusion in the sample of the present analysis. This is an important distinction, because in extracting the relevant information from the studies included in Fairweather's (1982) literature review, it was found that three studies were reported as showing no sex differences (Butler & Miller, 1979; Day, 1977; Martin, 1978), when the sex of subjects effect was in fact not tested in their analysis. Relevant published studies included in the reviews conducted by Bryden (1979), Fairweather (1982), Harris (1978), and McGlone (1980) were selected for inclusion in the present analysis. As previously mentioned, only studies published in refereed journals were included in the analysis. The only studies published in non-refereed journals which were included in the analysis were the ones cited in the Bryden (1979), Fairweather (1982), Harris (1978), and McGlone (1980) reviews. Furthermore, refereed journals likely to publish laterality studies were reviewed. Thus, all the issues of *Brain and Cognition*, *Brain and Language*, *Canadian Journal of Psychology*, *Cortex*, *Journal of Clinical and Experimental Neuropsychology*, *Journal of Experimental Psychology: Human Perception and Performance*, *Neuropsychologia*, and *Perception and Psychophysics* were systematically searched to extract laterality studies using sex of subject as a variable in their design. CD-ROM Psych-Lit searches were also conducted, and the reference list of recent papers was searched for relevant studies. Thus, the present meta-analysis provides a nearly exhaustive review of the published literature on sex-related differences in functional laterality in brain-intact subjects up to 1993. In most of those studies, the primary purpose was not to test the existence of sex differences in laterality. Sex of subjects was examined only because it was easily observable.

The studies selection procedure resulted in the sampling of 396 significance levels drawn from 266 studies. A list of the significance levels entered in the present analysis is available from the author on request. The studies included in the meta-analysis are listed in the Appendix.

The ''file drawer problem'' (see Rosenthal, 1979)—the possibility that published studies are a biased sample of the studies that are actually carried out, as it is presumed that only experiments with significant results are published—is one problem associated with the inclusion of only published studies in a meta-analysis. The exclusive use of published studies is likely to result in an overestimation of the effects under study. The number of studies averaging null results that would be necessary to offset the significance of the findings at the 0.05 level (fail-safe number, see Rosenthal, 1991) is usually computed to cope with this problem. In the present study, the fail-safe number will be calculated to assess the resistance of the meta-analytic results to the file drawer hypothesis. The fail-safe number will be compared with the criterion of 5 × the number of the sampled studies + 10 ($5k+10$), suggested by Rosenthal (1980, 1991), to evaluate its significance and allow rejection of the hypothesis that significant results are due to the exclusive sampling of published studies.

Analysis Procedure

The present analysis followed the procedure presented by Rosenthal (1991). This author presented meta-analytic techniques designed for the combination and comparison of significance levels. Comparison of the significance levels allows for the conclusion that the results in a specific sample of studies are homogeneous and were drawn from the same population. In other words, homogeneity of the significance levels indicates that the studies included in a specific meta-analysis can be considered as replications of each other, and that a pooled estimate of the results provides a valid summary of the findings from the sample of studies. However, when heterogeneity is detected, it is likely that the pooled estimate is not representative of the state of affairs in a sample. When this is the case, further partitioning of the studies is required.

Following Rosenthal's (1991) recommendations, significance testing was conducted by obtaining the standard normal deviate (Z) associated with each significance level. Zs in disagreement with the bulk of the results were given a negative sign. Following this procedure, a positive Z value represented a left hemisphere advantage for verbal tasks and a right hemisphere advantage for nonverbal tasks, while a negative Z value indicated a right hemisphere advantage for verbal tasks and a left hemisphere advantage for nonverbal tasks in the analysis of the main effect of laterality. In the analysis of sex differences in laterality, a positive Z value represented a greater lateralisation in men than in women, while a negative Z represented a greater lateralisation in women. Studies that reported non-significant effects and provided no statistics concerning these effects were assigned a Z value of zero, as recommended by Rosenthal (1991). There are several reasons why this approach was used. One such reason is that the direction of the effect remains undefined under these conditions. The logic underlying this approach makes the assumption that the negative and positive outcomes are equally represented in cases where relevant statistics are not provided. Therefore, assigning a value of zero to the corresponding *Z*s reflects the average of all these outcomes. This approach is also the most conservative procedure and it is least likely to lead to erroneous conclusions. Finally, the mere exclusion of these cases would contribute to the file drawer problem.

The test of significance of the combined *Z* values was computed using a modified Stouffer's method (Rosenthal, 1980, 1991), in which each significance level was weighted by its error degrees of freedom (N–2). This approach clearly gives more weight to the results obtained in studies with a large sample of participants than to the results of small sample studies (Rosenthal, 1991).

Cohen's *d* (Cohen, 1977) was used as an estimate of effect size. This index represents the standardised difference between the mean of the groups under study. It was chosen because it allows a direct interpretation of the results in standard deviation units. *Z* values were transformed into *d*s by using the formula provided by Rosenthal (1991).

The present analysis followed an hierarchical approach in evaluating the magnitude of the main effect of laterality and sex differences in functional asymmetries. In both cases, an analysis was first conducted separately for each modality (auditory, visual, tactile) to compare and combine the significance levels in these broad groupings. Following this procedure, the significance levels were partitioned into type of task (verbal, nonverbal) when heterogeneity was detected. Tasks were defined as verbal or nonverbal by the present author, on the basis of the type of cognitive processing involved. When homogeneity was still not achieved with those clusters, a partition based on specific task was performed. The classification of specific tasks was based on the description provided in the individual studies. Tasks with similar descriptions were classified under the same label by the present author.

The analysis of the main effect of laterality was performed first, followed by the analysis of sex differences in laterality. Because homogeneity of significance levels tends to be difficult to achieve in a meta-analysis (Linn & Petersen, 1985), a criterion similar to that used by Voyer, Voyer, and Bryden (1995) was used to classify significance levels as close to homogeneity. This means that when the obtained homogeneity statistic (chi-square) was significant at the 0.05 level, but not at the 0.005 level, significance levels were considered to be close to homogeneous. This range is arbitrary, but sets clear limits to what can be considered as satisfactorily homogeneous.

META-ANALYTIC RESULTS

Laterality Effects

The meta-analytic results for the laterality effects are presented in Table 1. In the visual modality, laterality effects were highly significant. The fail-safe analysis indicated that 65,447 studies with non-significant results would be needed to offset the significance of the results at the 0.05 level. However the significance

TABLE 1
Meta-analytic Results for Laterality Effects as a Function of the Testing Modality and the Nature of the Task

Partitioning Factor	*N*	*Weighted Estimator of Effect Size (d)*	*Test of Significance (Z)*[c]	*Fail-Safe*	*Homogeneity Statistic* (χ^2)
Visual Modality	235	0.531	21.84	65,447	486.71*
Verbal Tasks	123	0.674	19.94	25,170	241.66*
Nonverbal Tasks	112	0.388	10.94	9340	216.38*
Auditory Modality	120	0.499	17.72	27,102	143.73[a]
Verbal Tasks	94	0.519	17.04	19,298	79.58[a]
Nonverbal Tasks	26	0.391	4.96	621	50.21*
Tactile Modality	41	0.353	5.20	650	81.46*
Verbal Tasks	17	0.257	2.65	18	21.24[a]
Nonverbal Tasks	24	0.390	4.59	389	37.32[b]

*$P < 0.05$
[a] Homogeneity achieved
[b] Close to homogeneity
[c] All $P < 0.01$

levels were not homogeneous. This means that the studies using the visual modality included in the present analysis are not all drawn from the same population.

In the auditory modality, laterality effects were also highly significant. In this case, the fail-safe analysis indicated that 27,012 studies with non-significant results would be needed to offset the significance of the results at the 0.05 level. In this modality, the significance levels were found to be homogeneous. This means that the studies included in the auditory modality are basically replications of each other, in spite of the variety of tasks used in the studies included in the sample. It is thus legitimate to state that laterality effects are clearly significant and homogeneous in the auditory modality, regardless of the nature of the task or the specific task used.

Finally, in the tactile modality, the analysis revealed that laterality effects were significant. The fail-safe value indicated that 650 studies with non-significant results would be needed to offset the significance of the results at the 0.05 levels. However, as was the case in the visual modality, the significance levels were found to be heterogeneous. This means that the studies included in the tactile modality sample are not all drawn from the same population and require further partitioning.

In an attempt to achieve homogeneity, significance levels were partitioned based on the nature of the task material (verbal, nonverbal). Results of this analysis are also presented in Table 1. Note that the significance levels were partitioned as a function of the nature of the task in the auditory modality as well, even though the overall analysis revealed homogeneous effects in this modality. This partition was performed to allow comparison with the results obtained in the other two modalities. When the results obtained in the visual and tactile clusters are examined, Table 1 shows that homogeneity of the significance levels was obtained in the tactile modality after partitioning by nature of the task. It thus appears that the tactile modality produces significant and homogeneous laterality effects when verbal and nonverbal tasks are considered separately. In the visual modality, however, a partition by nature of the task did not allow for homogeneity to be achieved. This means that even though verbal and nonverbal tasks used in the visual modality show significant laterality effects, these effects are not all drawn from the same population. For this reason, they required further partitioning.

Significance levels in the visual modality were partitioned by specific task to assess the effect of this division on homogeneity. Results of this partition are shown in Table 2. This analysis showed that most tasks demonstrated significant laterality effects. In fact, all the verbal tasks showed significant effects (at least when a one-tailed test of significance was used), while only dot localisation and mental rotation did not show significant effects in nonverbal tasks. This partition achieved homogeneous significance levels in most clusters. Only lexical decision studies and study-specific tasks (classified as others) showed heterogeneous effects in the verbal tasks, while studies using faces did not achieve homogeneity in the nonverbal tasks. Further partitioning in terms of dependent variable (accuracy, reaction time, etc.), scoring procedure, handedness, age, or selectivity of the participants (see Hedges & Olkin, 1985) did not achieve homogeneity in these clusters. Nevertheless, it is legitimate to conclude that laterality effects are generally significant and homogeneous when the studies are partitioned in terms of the specific task used in the visual modality.

Inter-group Differences. The analyses reported so far only concerned the magnitude and significance of laterality effects. They did not address the question of whether or not differences in the magnitude of laterality effects exist between modalities and types of task. One might suggest that a factorial analysis of variance (ANOVA) would provide an answer to this question. However, Hedges and Becker (1986) argued that ANOVA is not appropriate for effect sizes, and they suggested an analogue to analysis of variance for effect sizes. Unfortunately, in its present form, this approach does not allow a test of the interaction between variables. For this reason, the weighted regression procedure proposed by Hedges and Becker (1986) was used. The unbiased estimate of effect size (d) was the dependent variable, and testing modality (visual, auditory, tactile) and type of task (verbal, nonverbal) were the independent variables. Because testing modality and type of task are categorical

TABLE 2
Meta-analytic Results for Laterality Effects as a Function of Specific Task in the Visual Modality

Partitioning Factor	*N*	*Weighted Estimator of Effect Size (d)*	*Test of Significance (Z)*	*Fail-Safe*	*Homogeneity Statistic (χ^2)*
Verbal Tasks					
Lexical Decision	65	0.579	12.75*	5106	120.99*
Letters	19	0.653	6.45*	547	31.47[b]
Naming	25	1.040	13.77*	2310	28.05[a]
Category Judgment	2	0.285	1.73[c]	0	2.09[a]
Digits	6	0.629	4.82*	23	11.30[b]
Picture–Word Matching	4	0.500	2.84*	17	5.65[a]
Others	2	0.672	1.90[c]	4	4.50*
Nonverbal Tasks					
Dot Detection	7	0.261	1.98*	9	9.11[a]
Dot Localisation	6	<0.001	<0.001	0	<0.001[a]
Dot Enumeration	8	0.649	2.05*	82	9.66[a]
Shapes	6	0.362	2.66*	21	13.50[b]
Faces	56	0.486	9.67*	3293	106.09*
Mental Rotation	7	0.211	1.33	0	16.23[b]
Objects	7	0.295	2.19*	25	17.79[b]
Line Orientation	8	0.339	3.33*	23	11.65[a]
Others	7	0.529	2.74*	24	9.22[a]

* $P<0.05$
[a] Homogeneity achieved
[b] Close to homogeneity
[c] $P<0.05$, one-tailed

variables, they were transformed by the use of effect coding (Pedhazur, 1982), to make them adequate for regression analysis. The interaction vectors were computed by cross-multiplying the vectors representing the task and modality variables. The regression weights were the same values that were used to calculate the weighted estimates of effect sizes presented in Table 1. These weights are the inverse of the variance associated with each effect size ($1/v_i$). A computational formula for these weights can be found in Hedges and Becker (1986). The regression procedure involved the forced entry of the main effect of modality (represented by two vectors), followed by the main effect of type of task. The interaction vectors were entered last.

According to Hedges and Becker (1986), the conventional test of significance reported for regression coefficients (t-test) is incorrect. For this reason, the calculation of a Z score, representing a corrected test of significance (Hedges & Becker, 1986) was required in the present analysis. This approach revealed a significant effect of modality, $Z=3.01$, $P>0.01$, and a significant effect of type of task, $Z = 6.43$, $P < 0.01$. These main effects were qualified by an interaction between modality and type, $Z = 3.76$, $P < 0.01$. Simple main effect analyses indicated that the effect of task was significant both in the visual and auditory modality ($Z = 7.04$, $P < 0.01$, and $Z = 2.14$, $P < 0.05$, respectively). In both cases this finding reflected the fact that effect sizes were significantly larger in verbal tasks than in nonverbal tasks (see Table 1). In the tactile modality, the effect of type of task was not significant, $Z = -1.14$, ns.

Sex Differences in Laterality[1]

The same approach used to analyse laterality effects was applied to the analysis of sex differences in laterality. Results of this analysis are presented in Table 3. In the visual modality, this analysis revealed a significant mean weighted *d* of

TABLE 3
Meta-analytic Results for Sex Differences in Functional Asymmetries as a Function of Testing Modality and Nature of the Task

Partitioning Factor	*N*	*Weighted Estimator of Effect Size (d)*	*Test of Significance (Z)*	*Fail-Safe*	*Homogeneity Statistic (χ^2)*
Visual Modality	235	0.067	2.49*	1155	269.27[a]
Verbal Tasks	123	0.058	1.47	0	136.56[a]
Nonverbal Tasks	112	0.076	2.06*	302	132.41[a]
Auditory Modality	120	0.063	2.73*	207	98.42[a]
Verbal Tasks	94	0.062	2.26*	119	86.34[a]
Nonverbal Tasks	26	0.070	1.78[c]	0	12.06[a]
Tactile Modality	41	0.148	1.80[c]	136	81.46*
Verbal Tasks	17	0.129	0.89	0	40.50*
Nonverbal Tasks	24	0.155	1.59	0	40.09[b]

* $P < 0.05$
[a] Homogeneity achieved
[b] Close to homogeneity
[c] $P < 0.05$, one-tailed

[1] Preliminary results obtained in the present analysis were presented in Voyer (1994), *Brain and Cognition*, *26*, pp. 211–216. The meta-analytic procedure used in this preliminary report was based on an approach to cumulation of effect sizes that resulted in a conservative estimation of significance tests. Because of this, the initial procedure revealed non-significant sex differences in laterality. Problems were noted with this approach as it did not provide an accurate test of significance. Specifically, the likelihood of a Type II error increased with the size of the sample of studies (I.C. McManus, personal communication, November 18, 1994). The approach used in the present analysis corrected this problem and provided an adequate test of significance.

0.067, demonstrating that, based on these figures, men tend to be more lateralised than women in this modality. The fail-safe analysis showed that 1155 studies with non-significant results would be needed to offset the significance of the present findings at the 0.05 level. Furthermore, the significance levels were found to be homogeneous. This means that the pooled estimate of effect size is representative of the state of affairs in this sample. Sex differences are thus clearly significant in this modality, regardless of the task used.

In the auditory modality, a significant mean weighted *d* of 0.063 was found, indicating the presence of sex differences in laterality in this modality as well. The fail-safe analysis revealed that 207 studies with non-significant results would be required to offset the significance of the results at the 0.05 level. Once again, the significance levels were found to be homogeneous. Sex differences in laterality are thus significant and homogeneous in this cluster.

Finally, in the tactile modality, the mean weighted *d* of 0.148 only achieved significance when based on a one-tailed test. The fail-safe analysis showed that 136 studies with non-significant results would be needed to offset the significance of the effect at the 0.05 level. The significance levels were heterogeneous in this cluster and required further partitioning.

Significance levels in the tactile modality were partitioned based on the nature of the task in an attempt to achieve homogeneity. Results of this partition are also presented in Table 3. Note that, as was done in the analysis of laterality effects, the significance levels were partitioned as a function of the nature of the task in the visual and auditory modalities as well, even though the significance levels were homogeneous in these clusters. This allowed comparison with the results obtained in the tactile modality. Examination of the tactile cluster in Table 3 shows that sex differences were not significant in verbal and nonverbal tasks, while they remained heterogeneous in the verbal cluster. Further partitioning by specific task was thus warranted in the tactile modality. The results of this partitioning are presented in Table 4. It appears that homogeneity of significance levels was achieved (or nearly achieved) in the tactile modality when partitioning was based on the specific task used. In most clusters, sex differences were non-significant in spite of the relatively large *d*s reported in Table 4 but they were homogeneous. Line orientation was the only partition that demonstrated nearly significant sex differences ($P = 0.08$, two-tailed). However, with only three significance levels sampled in this cluster, the fail-safe value was negative and indicated essentially non-significant results. Finally, the digits grouping was the only one that showed heterogeneous effects. The small sample size in this cluster made further partitioning meaningless.

Inter-group Differences. As was the case with the analysis of the main effect of laterality, the analyses reported so far did not examine differences in the magnitude of laterality effects between modalities and types of task. The weighted regression procedure proposed by Hedges and Becker (1986) was used

TABLE 4
Meta-analytic Results for Sex Differences in Functional Asymmetries as a Function of Specific Task in the Tactile Modality

Partitioning Factor	*N*	*Weighted Estimator of Effect Size (d)*	*Test of Significance (Z)*	*Homogeneity Statistic* (χ^2)
Verbal Tasks				
Letters	11	0.212	1.14	20.36[b]
Digits	6	–0.039	–0.20	18.12*
Nonverbal Tasks				
Shapes	19	0.129	1.30	35.37[b]
Line Orientation	3	0.403	1.75[c]	2.56[a]
Bisection	2	0.416	1.39	1.92[a]

* $P<0.05$
[a] Homogeneity achieved
[b] Close to homogeneity
[c] $P<0.05$, one-tailed

once again to investigate this aspect. As before, the unbiased estimate of effect size (*d*) was the dependent variable, and testing modality (visual, auditory, tactile) and type of task (verbal, nonverbal) were the independent variables. Testing modality and type of task were once again coded by the use of effect coding (Pedhazur, 1982), to make them appropriate for regression analysis, and the interaction vectors were computed by cross-multiplying the vectors representing the task and modality variables. The regression weights were the same values that were used in the regression analysis reported in relation to the main effect of laterality.

In the analysis of sex differences in laterality, this approach revealed no significant effects and no interaction (all *P*s >0.10). This means that the magnitude of sex differences did not vary in a significant way between the different modalities and types of tasks.

DISCUSSION

The results of the present analysis suggest conclusions relevant to laterality effects in general, and sex differences in laterality in particular. Even though the findings concerning these two types of effects are related, they will be discussed separately.

Laterality Effects

Concerning laterality effects, it appears that they tend to be highly significant, particularly when verbal tasks are used in the visual and auditory modalities.

Furthermore, they are homogeneous when the auditory modality is used. In the tactile modality, a partition in terms of the nature of the task (verbal, nonverbal) produced homogeneous effects, whereas a partition by specific task used produced a satisfactory level of homogeneity in the visual modality. Only two clusters (dot localisation and mental rotation) showed non-significant laterality effects. It is thus possible to conclude that laterality effects are clearly significant and homogeneous in most contexts in which they are studied. This conclusion supports the first hypothesis of the present study stating that laterality effects are significant. However, it is worth noting that in several clusters—i.e. tactile verbal in Table 1; digits, picture–word matching, dot detection, shapes, objects, line orientation, and the two study-specific tasks (others) categories in Table 2—the fail-safe value is much smaller than the criterion of $5k+10$ suggested by Rosenthal (1991). This means that the results obtained in these clusters are not resistant to the file drawer problem.

The finding that verbal tasks produce larger laterality effects than nonverbal tasks in the visual and auditory modalities suggests that the type of tasks is relevant if one wants to maximise the likelihood of detecting laterality effects. Specifically, the present results indicate that the use of a verbal task would increase this likelihood in the visual and auditory modalities. This finding is compatible with the notion that nonverbal tasks produce effects that are not as consistent as those obtained with verbal tasks (Bryden, 1982).

Sex Differences in Laterality

The results of the present analysis suggest that sex differences in laterality are significant in the visual and auditory modalities, and in the tactile modality when a one-tailed test of significance is used. In fact, the prevalence of positive effect sizes indicates that men generally obtain larger laterality effects than women. The second hypothesis of the present study, which predicted that sex differences in laterality would be significant, is therefore confirmed. The present results thus extend the conclusion reached by Hiscock et al. (1994) to the visual and tactile modalities. Furthermore, the results of the present analysis argue for the plausibility of an explanation of sex differences in cognitive abilities in terms of sex differences in cerebral organisation. Specifically, the present findings provide evidence in agreement with Levy's (1971) hypothesis, but they contradict predictions made on the basis of the models proposed by Buffery and Gray (1972), and Geschwind and Galaburda (1987). It thus appears that sex differences in verbal and spatial abilities can be explained, at least in part, by the fact that men tend to be more lateralised than women.

The results of the present study also suggest that reported anatomical sex differences in the brain seem to relate to functional brain asymmetries. However, even though a number of studies have found sex differences in the size and shape of specific structures in the corpus callosum (Clarke et al., 1989; de

Lacoste-Utamsing & Holloway, 1982; Reinarz et al., 1988), many authors reported a failure to replicate this finding (Demeter, Ringo, & Doty, 1985; Kertesz, Polk, Howell, & Black, 1987; Oppenheim, Lee, Nass, & Gazzaniga, 1987; Witelson, 1985). It is worth noting that the study conducted by de Lacoste-Utamsing and Holloway (1982), often cited as demonstrating sex differences in the size of the splenium, only found a marginal difference between men and women ($P = 0.08$). An alternative hypothesis stating that within-sex individual differences may be more striking than between-sex differences (Bleier, Houston, & Byne, 1986; Byne, Bleier, & Houston, 1988) has been proposed to account for inconsistent findings. Peters (1988) also suggested that brain size, not sex of subjects, might be a critical variable, as sex differences in brain size are consistently reported. It thus appears that, even though the question of whether or not sex differences exist in the anatomy of the corpus callosum has not yet been answered, sex differences in functional asymmetries are small but significant. The small effect sizes observed for sex differences in functional lateralities can be conceived of as reflecting the inconsistencies in the findings of anatomical studies.

Inconsistencies in the findings concerning sex differences in brain anatomy suggest that asymmetries in brain anatomy and functional asymmetries are not necessarily related. Specifically, studies investigating the relation between the morphometry of the corpus callosum and laterality effects have obtained mixed results. Hines et al. (1992) reported a significant correlation between posterior callosal size and language lateralisation. However, these authors admitted that their finding did not provide strong evidence because the correlation between callosal size and laterality was significant only when based on a one-tailed test, and it was not consistent across the different analyses they conducted. In a similar study, Clarke, Lufkin, and Zaidel (1993) failed to obtain a significant correlation between the size of the corpus callosum and a measure of language lateralisation. The lack of strong evidence argues for the notion that there is not necessarily a link between anatomical measures of laterality and measures of functional asymmetries. This suggests the possibility that functional asymmetries and anatomical asymmetries are two unrelated phenomena. From this perspective, it is plausible to believe that functional asymmetries reflect physiological rather than anatomical asymmetries. It might prove fruitful to investigate the relation between functional lateralities and physiological asymmetries, as revealed in studies examining evoked response potential, cerebral blood flow, positron emission tomography, etc. Another possibility is that functional asymmetries may reflect processing or strategy differences between the hemispheres (Bryden, 1980). In this case, the absence of a relation between anatomical and functional asymmetries would be expected.

Unfortunately, in the context of a meta-analysis it is not possible to determine which of these speculations is the correct explanation for the lack of a relation between functional and anatomical asymmetries. This underlines the fact that meta-analysis does not allow causal statements, and emphasises the claim that a meta-analysis cannot replace a well designed empirical study in providing answers to theoretically guided questions (Sohn, 1995). This suggests that much empirical research remains to be done before a clear understanding of the relation between anatomical asymmetries and functional lateralities can be achieved.

The present analysis indicates that sex differences in laterality are significant. However, it is important to be cautious in interpreting tests of significance drawn from a sample of exclusively published studies. In fact, when the fail-safe values associated with the significant effects are examined, they fail to reach the criterion proposed by Rosenthal (1991). The fail-safe numbers associated with sex differences in the visual, auditory, and tactile modality are 1155, 207, and 136, respectively. In each of these clusters, the fail-safe is smaller than the criterion of $5k + 10$ (criterion: 1185 in the visual modality, 610 in the auditory modality, and 215 in the tactile modality). The criterion set by Rosenthal (1991) is admittedly arbitrary, and it could be argued that it is unlikely that 1155 studies of sex differences in visual laterality with null results are crammed in file drawers. Nevertheless, because it is difficult to determine what constitutes an unlikely fail-safe value, it is important to be aware that sex differences in laterality as reported in the present study are not resistant to the file drawer problem.

Another way to represent the file drawer problem is to use a plot of sample size (N) as a function of effect size (d). In this type of plot, when the overall effect size is significantly different from zero, unretrieved or unpublished significant effect sizes tend to truncate the distribution on one side. This plot can be found in Fig. 1 for laterality effects and in Fig. 2 for sex differences in laterality. A comparison of Figs. 1 and 2 clearly reflects the findings obtained with the fail-safe values. Specifically, effect sizes for the main effect of laterality, as seen in Fig. 1, are grouped above the zero point and the distribution is clearly truncated on the negative (left) side. This reflects the large fail-safe values associated with laterality effects. Concerning sex differences in laterality, the distribution found in Fig. 2 is not as clear-cut as the one in Fig. 1. Even though there are more effect sizes on the positive (right) side of the distribution, quite a few studies obtained negative effect sizes. The distribution of effect sizes for sex differences in laterality is therefore not as clearly truncated, reflecting the relatively small fail-safe values obtained in this analysis.

The magnitude of the estimates of effect sizes associated with sex differences in laterality suggests that a further distinction needs to be made between significance and meaningfulness. The largest significant effect size is found in the visual modality when nonverbal tasks are used, and it only represents a difference of 0.076 standard deviation units between the laterality effect of men and women. According to Cohen (1977) a d of 0.076 represents a small effect size. It is significant in the present study because meta-analytic procedures are

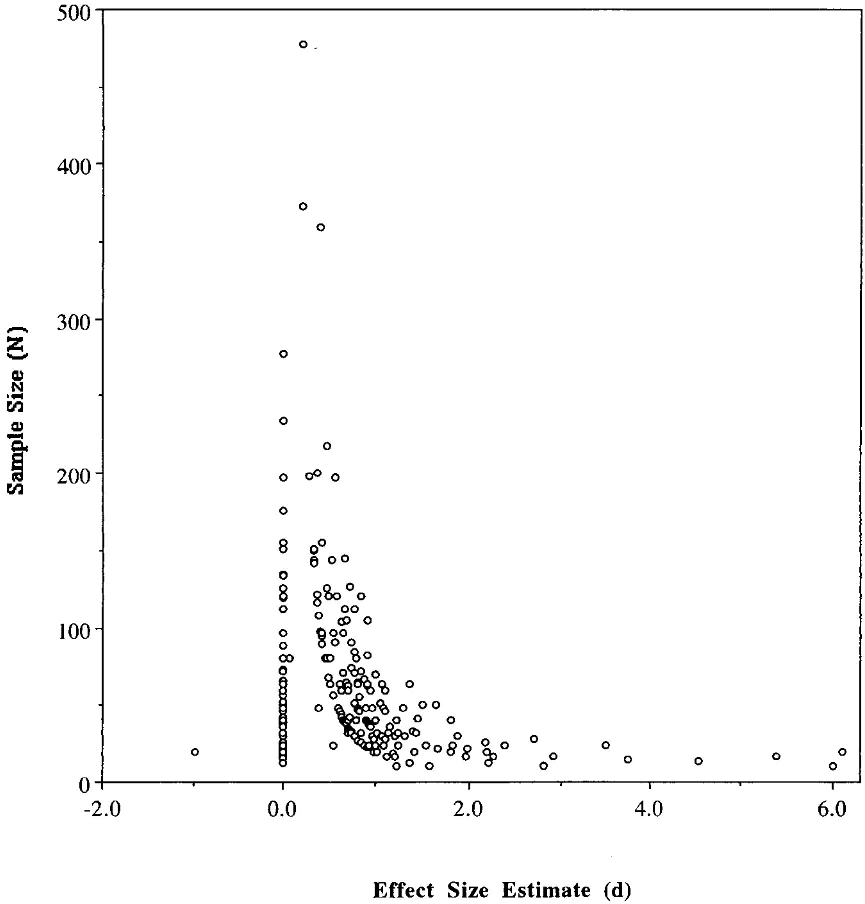

FIG. 1. Plot of sample size (N) as a function of effect size estimate (d) for laterality effects.

very sensitive and provide a powerful test of the null hypothesis, especially when a large number of studies is sampled. In fact if one was to obtain an effect size of 0.076 in a single study, a sample of about 2244 participants would be required to achieve significance at the 0.05 level with 95% power. None of the single studies sampled in the present analysis included such a large sample. For the purpose of comparison, 29 participants would be required to achieve significance at the 0.05 level with 95% power if the largest effect size obtained with laterality effects (0.674 in verbal tasks presented visually; see Table 1) was observed in a single study. It thus appears that the statistical significance of small effect sizes in a meta-analysis is due to the fact that it allows evaluation of the effects based on a procedure that virtually cumulates sample sizes as well as

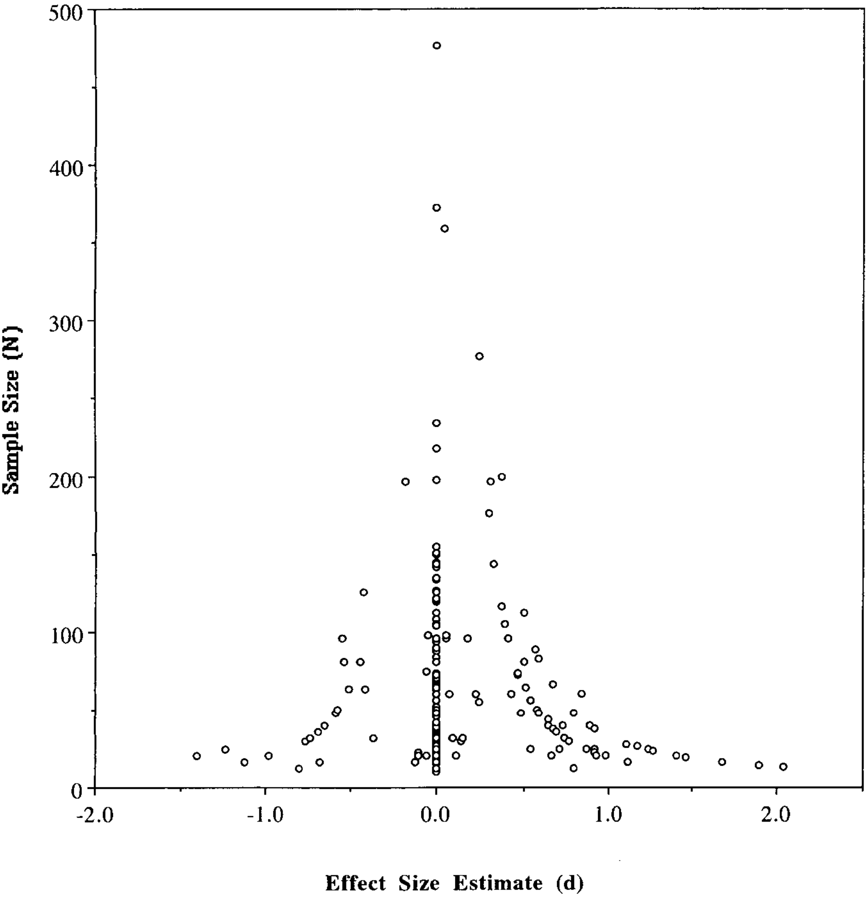

FIG. 2. Plot of sample size (N) as a function of effect size estimate (d) for sex differences in laterality.

significance levels. The importance of this factor is illustrated by the finding that an effect size of 0.076 represents an effect that accounts for approximately 0.1% of the total variance in a given sample (the effect size of 0.674 in the analysis of laterality effects accounts for about 10% of the total variance). Such a small percentage of variance accounted for requires a very large sample size to achieve significance. This effect reaches significance in the present analysis because it includes results obtained with a total of 21,197 participants (10,630 men, 10,567 women). This demonstrates that meta-analysis is a very powerful instrument. However, the fail-safe value can be considered its way of warning the meta-analyst against a Type I error. This suggests that sex differences might be significant in the context of a meta-analysis, but not meaningful at the level of an individual study.

The purpose of this discussion is to warn researchers to use caution in interpreting the present results. Even though the present analysis indicates that sex differences in laterality are significant, it does not mean that each individual study will produce a significant effect. Caution in interpreting meta-analytic results is particularly recommended when small fail-safe values are obtained.

It is interesting to note that the largest effect sizes for sex differences in laterality were found in the tactile modality, but they only achieved one-tailed statistical significance. Fortunately, the directionality of the hypothesis predicting the presence of sex differences in laterality makes the use of one-tailed significance legitimate. The significance of sex differences in the tactile modality is compatible with the results of the weighted regression analysis, which indicated that the magnitude of sex differences in laterality is not affected by testing modality and type of task. This suggests that sex differences in laterality in the tactile modality are comparable to those in the other modalities. However, the relatively small sample of studies in this grouping and the generally small number of subjects used in tactile studies did not provide enough power for two-tailed significance to be detected. This lack of power is especially important when one considers that only one of the partitions required to achieve homogeneity in the tactile modality achieved one-tailed significance (line orientation, see Table 4). This reflects the problems inherent in the need to partition effect sizes in small homogeneous groupings, because as groupings become smaller, power is reduced proportionally.

Another relevant problem concerns the apparently arbitrary decision to attribute a Z value of zero when authors reported the effects as nonsignificant and provided no further information. Even though this is the approach recommended by Rosenthal (1991), one may argue that this procedure is too conservative. However, the prevalence of this type of findings in the analysis of sex differences in laterality, where 271 (68.4%) of the Z values were equal to zero, reflects the conclusions reached in the present discussion. Given such a large number of studies with null results, it can be argued that this type of finding is typical. Therefore, it is legitimate to state that sex differences in laterality are significant but small in the context of meta-analysis, but that null results are prevalent at the level of individual studies. It is worth noting that the frequency of Z values of zero was much smaller in the analysis of laterality effects. Of the studies analysed, 118 (29.8%) produced this type of results. Null results are therefore not as frequent when laterality effects are concerned and this reflects the relatively large effect sizes and fail-safe values obtained when these effects were analysed.

CONCLUSIONS

The present meta-analysis indicates that laterality effects are clearly significant and relatively consistent. Specifically, the largest laterality effects are found in verbal tasks in the visual and auditory modality. Naming tasks produce the largest laterality effect in all the tasks sampled in the present analysis. However, it is important to remember that the conclusions of the present study concerning laterality effects apply only to studies that included sex of subjects as an independent variable in their design. It is probable that the results obtained in the present study in relation to the main effect of laterality can be extrapolated to studies that did not investigate the influence of sex of subjects on their results. Precise estimates of effect sizes for these studies remain to be determined.

Sex differences in functional asymmetries are also significant and they are relatively consistent, given the ease with which homogeneity of significance levels was obtained when they were partitioned in meaningful clusters. However, the present results indicate that sex differences in laterality are susceptible to the file drawer problem. This suggests that caution is recommended when attempting to use the present findings for the purpose of theory elaboration. Even though it is plausible to argue that a valid theory of lateralisation needs to account for sex differences in laterality, the limitations of the present analysis must be taken into account. When a sample of exclusively published studies is analysed, the small fail-safe numbers take on a very important meaning. It is quite probable that most researchers interested in laterality have a large number of unpublished studies showing non-significant sex differences gathering dust in their file drawers. Of course, this number would be very difficult to determine, but it would probably be much larger than the fail-safe values obtained in the present meta-analysis if all the laterality researchers across the world were considered. In view of this problem, it might be more fruitful to investigate why sex differences in laterality are found in some studies but not in others. A partial answer to this question may reside in the fact that many studies involve samples of participants that are too small to allow detection of sex differences. One can only wonder why such low sample sizes are used when the effects under study are so small. It is quite likely that, because most researchers are not interested primarily in the detection of sex differences, they use a sample size sufficient for the main effect of laterality to reach significance. Given that the magnitude of laterality effects is much larger than that of sex differences in laterality, this results in studies that are powerful enough to detect laterality effects but not sex differences. From this perspective, it might prove useful for future researchers to present power calculations for sex differences in laterality and to include the sample size required for this effect to be significant when it fails to reach conventional significance. Finally, the presence of sex differences in laterality argues for the plausibility of hypotheses stating that sex differences in cognitive abilities stem from sex differences in laterality. Specifically, the results of the present study argue for the plausibility of Levy's (1971) hypothesis, because they support the notion that men are more lateralised than women. Thus, sex differences in laterality might be responsible for cognitive sex differences. However, a meta-analysis does not allow definite causal claims to be made. For this reason, more empirical work is needed to test the hypothesis that there is a causal link between laterality and cognitive skills.

Manuscript received 12 April 1995
Revised manuscript received 31 July 1995

REFERENCES

Bleier, R., Houston, L., & Byne, W. (1986). Can the corpus callosum predict gender, age, handedness, or cognitive differences? *Trends in Neurosciences*, *9*, 391–394.

Bryden, M.P. (1979). Evidence for sex-related differences in cerebral organization. In M.A. Wittig, & A.C. Petersen (Eds.), *Sex-related differences in cognitive functioning* (pp. 121–143). New York: Academic Press.

Bryden, M.P. (1980). Sex differences in brain organization: Different brains or different strategies: *Behavioral and Brain Sciences*, *3*, 230–231.

Bryden, M.P. (1982). *Laterality: Functional asymmetry in the intact brain.* New York: Academic Press.

Buffery, A.W.H., & Gray, J.A. (1972). Sex differences in the development of spatial and linguistic skills. In C. Ounsted & D.C. Taylor (Eds.), *Gender differences: Their ontogeny and significance* (pp.123–157). Baltimore: Williams & Wilkins.

Butler, D.C., & Miller, L.K. (1979). Role of order of approximation to English and letter array length in the development of visual laterality. *Developmental Psychology*, *15*, 522–529.

Byne, W., Bleier, R., & Houston, L. (1988). Variations in human corpus callosum do not predict gender. A study using magnetic resonance imaging. *Behavioural Neuroscience*, *102*, 222–227.

Caplan, P.J., MacPherson, G.M., & Tobin, P. (1985). Do sex-related differences in spatial abilities exist? *American Psychologist*, *40*, 786–799.

Clarke, S., Kraftsik, R., Van der Loos, H., & Innocenti, G.M. (1989). Forms and measures of adult and developing human corpus callosum: Is there sexual dimorphism? *Journal of Comparative Neurology*, *280*, 213–230.

Clarke, S., Lufkin, R.B., & Zaidel, E. (1993). Corpus callosum morphometry and dichotic listening performance: Individual differences in functional interhemispheric inhibition? *Neuropsychologia*, *31*, 547–557.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences.* (2nd edn.). New York: Academic Press.

Day, J. (1977). Right hemisphere language processing in normal right handers. *Journal of Experimental Psychology: Human Perception and Performance*, *3*, 518–528.

de Lacoste-Utamsing, C., & Holloway, R.L. (1982). Sexual dimorphism in the human corpus callosum. *Science*, *216*, 1431–1432.

Demeter, S., Ringo, J., & Doty, R.W. (1985). Sexual dimorphism in the human corpus callosum. *Society for Neuroscience Abstracts*, *11*, 868.

Ellis, R.S. (1928). *The psychology of individual differences.* New York: Appleton.

Eysenck, H.J. (1995). Meta-analysis squared—Does it make sense? *American Psychologist*, *50*, 110–111.

Fairweather, H. (1982). Sex differences: Little reasons for females to play midfield. In J.G. Beaumont (Ed.), *Divided visual field studies of cerebral organisation* (pp.147–194). London: Academic Press.

Feingold, A. (1988). Cognitive gender differences are disappearing. *American Psychologist*, *43*, 95–103.

Garai, J.E., & Scheinfeld, A. (1968). Sex differences in mental and behavioral traits. *Genetic Psychology Monographs*, *77*, 169–299.

Geschwind, N., & Galaburda, A.M. (1987). *Cerebral lateralization: Biological mechanisms, associations, and pathology*. Cambridge, MA: MIT Press.

Harris, L.J. (1978). Sex differences in spatial ability: Possible environmental, genetic, and neurological factors. In M. Kinsbourne (Ed.), *Asymmetrical functions of the brain*, (pp.405–522). Cambridge: Cambridge University Press.

Hedges, L.V., & Becker, B.J. (1986). Statistical methods in the meta-analysis of research on gender differences. In J. Hyde & M.C. Linn (Eds.), *The psychology of gender: Advance through meta-analysis*. Baltimore: John Hopkins University Press.

Hedges, L.V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. Orlando: Academic Press.

Hines, M., Chiu, L., McAdams, L.A., Bentler, P.M., & Lipcamon, P. (1992). Cognition and the corpus callosum: Verbal fluency, visuospatial ability, and language lateralization related to midsagittal surface areas of callosal subregions. *Behavioral Neuroscience*, *106*, 3–14.

Hiscock, M., Inch, R., Jacek, C., Hiscock-Kalil, C., & Kalil, K. (1994). Is there a sex difference in human laterality? An exhaustive survey of auditory laterality studies from six neuropsychology journals. *Journal of Clinical and Experimental Neuropsychology*, *16*, 423–435.

Hyde, J.S., & Linn, M.C. (1988). Gender differences in verbal ability: A meta-analysis. *Psychological Bulletin*, *104*, 53–69.

Iaccino, J.F. (1993). *Left brain–right brain differences.* Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Kertesz, A., Polk, M., Howell, J., & Black, S.E. (1987). Cerebral dominance, sex, and callosal size in MRI. *Neurology*, *37*, 1385–1388.

Levy, J. (1969). Possible basis for the evolution of lateral specialization in the human brain. *Nature*, *224*, 614–615.

Levy, J. (1971). Lateral specialization of the human brain: behavioral manifestations and possible evolutionary basis. In J.A. Kiger, Jr. (Ed.), *The biology of behavior* (pp.159–180). Corvallis: Oregon State University Press.

Linn, M.C., & Petersen, A.C. (1985). Emergence and characterisation of gender differences in spatial abilities: A meta-analysis. *Child Development*, *56*, 1479–1498.

Lipsey, M.W., & Wilson, D.B. (1995). Reply to comments on Lipsey and Wilson (1993). *American Psychologist*, *50*, 113–115.

Maccoby, E.E.,& Jacklin, C.N. (1974). *The psychology of sex differences.* Stanford, CA: Stanford University Press.

Martin, M. (1978). Hemispheric asymmetries for physical and semantic selection of visually presented words. *Neuropsychologia*, *15*, 751–756.

McGee, M.G. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin*, *86*, 889–918.

McGlone, J. (1980). Sex differences in human brain asymmetry: A critical survey. *The Behavioral and Brain Sciences*, *3*, 215–263.

Oppenheim, J.S., Lee, B.C.P., Nass, R., & Gazzaniga, M.S. (1987). No sex related differences in human corpus callosum based on magnetic resonance imagery. *Annals of Neurology*, *21*, 604–606.

Pedhazur, E.J. (1982). *Multiple regression in behavioral research* (2nd edn.) New York: Holt, Rinehart & Winston.

Peters, M. (1988). The size of the corpus callosum in males and females: Implications of a lack of allometry. *Canadian Journal of Psychology*, *42*, 313–324.

Reinarz, S.J., Coffman, C.E., Smoker, W.R.K., & Godersky, J.C. (1988). MR imaging of the corpus callosum: Normal and pathological findings and correlation with CT. *American Journal of Radiology*, *151*, 791–798.

Rosenthal, R. (1979). The ‘‘file drawer problem’’ and tolerance for null results. *Psychological Bulletin*, *86*, 638–641.

Rosenthal, R. (1980). Summarizing significance levels. In R. Rosenthal (Ed.), *Quantitative assessment of research domains.* San Francisco: Josey Bass.

Rosenthal, R. (1991). *Meta-analytic procedures for social research.* (Rev. edn.). Beverly Hills, CA: Sage.

Sohn, D. (1995). Meta-analysis as a means of discovery. *American Psychologist*, *50*, 108–110.

Voyer, D., Voyer, S., & Bryden, M.P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*, 250–270.

Witelson, S.F. (1985). The brain connection: The corpus callosum is larger in left-handers. *Science*, *229*, 665–668.

APPENDIX

Note: The following studies were included in the meta-analysis.

Allard, F., & Bryden, M.P. (1979). The effect of concurrent activity on hemispheric asymmetries. *Cortex*, *15*, 5–17.

Andrews, R.J. (1977). Aspects of language lateralisation correlated with family handedness. *Neuropsychologia*, *15*, 769–778.

Babkoff, H., Genser, S., & Hegge, F.W. (1985). Lexical decision, parafoveal eccentricity and visual hemifield. *Cortex*, *21*, 581–593.

Bagnara, S., Simion, F., Umilta, C., & Roncato, S. (1980). Sex-related differences in hemispheric asymmetries in processing simple geometrical figures. *Perceptual and Motor Skills*, *51*, 223–229.

Bakker, D.J., Hoefkens, M., & Van der Vlugt, H. (1979). Hemispheric specialization in children as reflected in the longitudinal development of ear asymmetry. *Cortex*, *15*, 619–625.

Barry, C. (1981). Hemispheric asymmetry in lexical access and phonological encoding. *Neuropsychologia*, *19*, 473–478.

Bashore, T.R., Nydegger, R.V., & Miller, H. (1982). Left visual field superiority in a letter-naming task for both left- and right-handers. *Cortex*, *18*, 245–256.

Bentin, S. (1981). On the representation of a second language in the cerebral hemispheres of right-handed people. *Neuropsychologia*, *19*, 599–603.

Benton, A.L., Varney, N.R., & Hamsher, S. (1978). Lateral differences in tactile directional perception. *Neuropsychologia*, *16*, 109–114.

Berlin, C.I., Hughes, L.F., Lowe-Bell, S.S., & Berlin, H.L. (1973). Dichotic right ear advantage in children 5 to 13. *Cortex*, *9*, 393–401.

Best, C.T., Hoffman, H., & Glanville, B.B. (1982). Development of infant ear asymmetries for speech and music. *Perception & Psychophysics*, *31*, 75–85.

Birkett, P. (1980). Predicting spatial ability from hemispheric ‘‘non-verbal’’ lateralization: Sex, handedness, and task differences implicate encoding strategy effects. *Acta Psychologica*, *46*, 1–14.

Birkett, P. (1981). Hemispheric asymmetry for classifying upright and inverted letter pairs: Handedness and sex differences. *Neuropsychologia*, *19*, 713–718.

Boles, D.B. (1983). Hemispheric interaction in visual field asymmetry. *Cortex*, *19*, 99–113.

Boles, D.B., Rogers, S., & Wymer, W. (1982). Age of acquisition and visual field asymmetry in word recognition. *Perception & Psychophysics*, *32*, 486–490.

Borod, J., Ohler, L., Albert, M., & Stiefel, S. (1983). Lateralization for pure tone perception as a function of age and sex. *Cortex*, *19*, 281–285.

Borowy, T., & Goebel, R. (1976). Cerebral lateralization of speech: The effects of age, sex, and socioeconomic class. *Neuropsychologia*, *14*, 363–370.

Bradshaw, G.J., Hicks, R.E., & Rose, B. (1979). Lexical discrimination and letter-string identification in the two visual fields. *Brain and Language*, *8*, 10–18.

Bradshaw, J.L., Bradley, D., Gates, A., & Patterson, K. (1977). Serial, parallel or holistic identification of single words in the two visual fields? *Perception and Psychophysics*, *21*, 431–438.

Bradshaw, J.L., & Gates, E.A. (1978). Visual field differences in verbal tasks: Effects of task familiarity and sex of subject. *Brain and Language*, *5*, 166–187.

Bradshaw, J.L., Gates, A., & Nettleton, N.C. (1977). Bihemispheric involvement in lexical decisions: Handedness and a possible sex difference. *Neuropsychologia*, *15*, 277–286.

Bradshaw, J.L., Nettleton, N.C., & Taylor, M.J. (1981). Right hemispheric language and cognitive deficit in sinistrals? *Neuropsychologia*, *19*, 113–132.

Bradshaw, J.L., & Sherlock, D. (1982). Bugs and faces in the two visual fields: The analytic/holistic processing dichotomy and task sequencing. *Cortex*, *18*, 211–226.

Bradshaw, J.L., & Taylor, M.J. (1979). A word-naming deficit in nonfamilial sinistrals? Laterality effects of vocal responses to tachistoscopically presented letter strings. *Neuropsychologia*, *17*, 21–32.

Brand, N., Bekkum, I.V., Stumpel, M., & Kroeze, J.H.A. (1983). Word matching and lexical decisions: A visual half-field study. *Brain and Language*, *18*, 199–211.

Briggs, G.G., & Nebes, R.D. (1976). The effects of handedness, family history and sex on the performance of a dichotic listening task. *Neuropsychologia*, *14*, 129–133.

Bruyer, R., & Stroot, C. (1984). Laterality differences in face processing: Task and modality effects. *Cortex*, *20*, 377–390.

Bryden, M.P. (1965). Tachistoscopic recognition, handedness and cerebral dominance. *Neuropsychologia*, *3*, 1–8.

Bryden, M.P. (1970). Laterality effects in dichotic listening: Relations with handedness and reading ability in children. *Neuropsychologia*, *8*, 443–450.

Bryden, M.P. (1973). Perceptual asymmetry in vision: Relation to handedness, eyedness and speech lateralisation. *Cortex*, *9*, 419–435.

Bryden, M.P. (1975). Speech lateralization in families: A preliminary study using dichotic listening. *Brain and Language*, *2*, 201–211.

Bryden, M.P. (1976). Response bias and hemispheric differences in dot localization. *Perception and Psychophysics*, *19*, 23–28.

Bryden, M.P. (1986). Dichotic listening performance, cognitive ability, and cerebral organization. *Canadian Journal of Psychology*, *40*, 445–456.

Bryden, M.P., Free, T., Gagné, S., & Groff, P. (1991). Handedness effects in the detection of dichotically presented words and emotions. *Cortex*, *27*, 229–235.

Bryden, M.P., Ley, R.G., & Sugarman, J.H. (1982). A left-ear advantage for identifying the emotional quality of tonal sequences. *Neuropsychologia*, *20*, 83–88.

Bryson, S.E., McLenen, J., Wadden, N.P., & McLean, M. (1991). Differential asymmetries for positive and negative emotion: Hemisphere or stimulus effects? *Cortex*, *27*, 359–365.

Burton, L.A., & Levy, J. (1989). Sex differences in the lateralized processing of facial emotions. *Brain & Cognition*, *11*, 210–228.

Burton, L.A., Wagner, N., Lim, C., & Levy, J. (1992). Visual field differences for clockwise and counterclockwise mental rotation. *Brain and Cognition*, *18*, 192–207.

Caplan, B., & Kinsbourne, M. (1981). Cerebral lateralization, preferred cognitive mode, and reading ability in normal children. *Brain and Language*, *14*, 349–370.

Caplan, D., Holmes, J.M., & Marshall, J.C. (1974). Word classes and hemispheric specialization. *Neuropsychologia*, *12*, 331–338.

Carr, B. (1969). Ear effect variables and order of report in dichotic listening. *Cortex*, *5*, 63–68.

Chiarello, C., Dronkers, N.F., & Hardyck, C. (1984). Choosing sides: On the variability of language lateralization in normal subjects. *Neuropsychologia*, *22*, 363–373.

Chiarello, C., Nuding, S., & Pollock, A. (1988). Lexical decision and naming asymmetries: Influence of response selection and response bias. *Brain and Language*, *34*, 302–314.

Cohen, H., & Levy, J.J. (1986). Cerebral and sex differences in the categorization of haptic information. *Cortex*, *22*, 253–259.

Cohen, H., Levy, J.J., & McShane, D. (1989). Hemispheric specialization for speech and non-verbal stimuli in Chinese and French-Canadian subjects. *Neuropsychologia*, *27*, 241–245.

Corballis, M.C., & McNeill, M.J. (1987). The effect of head turn on auditory asymmetry. *Brain & Cognition*, *6*, 193–201.

Corballis, M.C., & Sergeant, J. (1989). Hemispheric specialization for mental rotation. *Cortex*, *25*, 15–25.

Cormier, P., & Stubbert, J.A. (1991). Instruction effects on gender differences in visual field advantages during lexical decision tasks. *Cortex*, *27*, 453–458.

Cranney, J., & Ashton, R. (1980). Witelson's dichhaptic task as a measure of hemispheric asymmetry in deaf and hearing populations. *Neuropsychologia*, *18*, 95–98.

Crossman, D., & Polich, J. (1988). Hemisphere differences for orthographic and phonological processing. *Brain and Language*, *35*, 301–312.

David, A.S., & Cutting, J.C. (1992). Categorical-semantic and spatial-imagery judgments of non-verbal stimuli in the cerebral hemispheres. *Cortex*, *28*, 39–52.

Davidoff, J.B. (1977). Hemispheric differences in dot detection. *Cortex*, *13*, 434–444.

Davidoff, J.B., & Done, D.J. (1984). A longitudinal study of the development of visual field advantage for letter matching. *Neuropsychologia*, *22*, 311–318.

Dawe, S., & Corballis, M.C. (1986). The influence of gender, handedness and head-turn on auditory asymmetries. *Neuropsychologia*, *24*, 857–862.

Denes, G., & Spinaci, M.P. (1981). Influence of association value in recognition of random shapes under dichhaptic presentation. *Cortex*, *17*, 597–605.

Diehl, J.A., & McKeever, W.F. (1987). Absence of exposure time influence or lateralized face recognition and object naming latency tasks. *Brain & Cognition*, *6*, 347–359.

Ditunno, P., & Mann, V.A. (1990). Right hemisphere specialization for mental rotation in normals and brain damaged subjects. *Cortex*, *26*, 177–188.

Dodds, A.G. (1978). Hemispheric differences in tactuo-spatial processing. *Neuropsychologia*, *16*, 247–250.

Dorman, M., & Porter, R. (1975). Hemispheric lateralization for speech perception in stutterers. *Cortex*, *11*, 181–185.

Duda, P.D., & Adams, J.O. (1987). Dichhaptic-visual form matching in adults. *Cortex*, *23*, 399–414.

Duda, P.D., & Brown, J. (1984). Lateral asymmetry of positive and negative emotions. *Cortex*, *20*, 253–261.

Efron, R., Yund, E.W., & Nichols, D.R. (1987). Scanning the visual field without eye movements—A sex difference. *Neuropsychologia*, *25*, 637–644.

Elias, J.W., Yandell, L., & Kavacos, N. (1982). Cerebral asymmetry in word–object matching by appearance and by function. *Neuropsychologia*, *20*, 215–218.

Eling, P., Marshall, J.C., & Van Galen, T. (1981). The development of language lateralization as measured by dichotic listening. *Neuropsychologia*, *19*, 767–774.

Eviatar, Z., & Zaidel, E. (1991). The effects of word length and emotionality on hemispheric contribution to lexical decision. *Neuropsychologia*, *29*, 415–428.

Finlay, D.C., & French, N. (1978). Visual field differences in a facial recognition task using signal detection theory. *Neuropsychologia*, *16*, 103–107.

Franzon, M., & Hughdal, K. (1986). Visual half-field presentations of incongruent color: Effects of gender and handedness. *Cortex*, *22*, 433–445.

Gates, A., & Bradshaw, J.L. (1977). Music perception and cerebral asymmetries. *Cortex*, *13*, 390–401.

Geffen, G. (1978). The development of the right ear advantage in dichotic listening with focused attention. *Cortex*, *14*, 169–177.

Geffen, G., & Reynolds, N. (1982). Pure-tone perception and ear advantages in dichotic listening. *Perception & Psychophysics*, *31*, 68–74.

Geffen, G., & Traub, E. (1979). Preferred hand and familial sinistrality in dichotic monitoring. *Neuropsychologia*, *17*, 527–531.

Geffner, D.S., & Dorman, M.F. (1976). Hemispheric specialization for speech perception in four-year-old children from low and middle socio-economic class. *Cortex*, *12*, 71–73.

Geffner, D.S., & Hochberg, I. (1971). Ear laterality performance of children from low and middle socioeconomic levels on a verbal dichotic listening task. *Cortex*, *7*, 193–203.

Gibson, C., & Bryden, M.P. (1983). Dichhaptic recognition of shapes and letters in children. *Canadian Journal of Psychology*, *37*, 132–143.

Gibson, C.J., & Bryden, M.P. (1984). Cerebral laterality in deaf and hearing children. *Brain and Language*, *23*, 1–12.

Gordon, H.W. (1978). Left hemisphere dominance for rhythmic elements in dichotically-presented melodies. *Cortex*, *14*, 58–70.

Graves, R. (1983). Mouth asymmetry, diochotic ear advantage and tachistoscopic field advantage as measures of language lateralization. *Neuropsychologia*, *21*, 641–649.

Graves, R., Landis, T., & Goodglass, H. (1981). Laterality and sex differences for visual recognition of emotional and non-emotional words. *Neuropsychologia*, *19*, 95–102.

Hannay, H.J., & Boyer, C.L. (1978). Sex differences in hemispheric asymmetry revisited. *Perceptual and Motor Skills*, *47*, 315–321.

Hannay, H.J., & Malone, D.R. (1976). Visual field effects and short-term memory for verbal material. *Neuropsychologia*, *14*, 203–209.

Hannay, H.J., & Rogers, J.P. (1979). Individual differences and asymmetry effects in memory for unfamiliar faces. *Cortex*, *15*, 257–267.

Harter Kraft, R. (1983). The effect of sex, laterality, and familial handedness on intellectual abilities. *Neuropsychologia*, *21*, 79–90.

Harter Kraft, R. (1984). Lateral specialization and verbal/spatial ability in preschool children: Age, sex and familial handedness differences. *Neuropsychologia*, *22*, 319–335.

Hassler, M. (1990). Functional cerebral asymmetries and cognitive abilities in musician, painters, and controls. *Brain and Cognition*, *13*, 1–17.

Hatta, T. (1990). Development of visual field advantage for digit and random shape recognition: Comparison of cross-sectional and longitudinal studies. *Neuropsychologia*, *28*, 1053–1062.

Hatta, T., & Yamamoto, M. (1986). Hemispheric asymmetries in a tactile bisection task: Effects of hemispace of presentation. *Neuropsychologia*, *24*, 265–270.

Hatta, T., Yamamoto, M., Kaivabata, Y., & Tsutui, K. (1981). Development of hemisphere specialization for tactile recognition in normal children. *Cortex*, *17*, 611–616.

Healey, J.M., Waldstein, S., & Goodglass, H. (1985). Sex differences in the lateralization of language discrimination vs. language production. *Neuropsychologia*, *23*, 777–790.

Heister, G. (1984). Sex differences and cognitive/motor interference with visual half-field stimulation. *Neuropsychologia*, *22*, 205–214.

Hellige, J.B. (1976). Changes in same–different laterality patterns as a function of practice and stimulus quality. *Perception and Psychophysics*, *20*, 267–273.

Hellige, J.B. (1980). Effects of perceptual quality and visual field of probe stimulus presentation on memory search for letters. *Journal of Experimental Psychology: Human Perception and Performance*, *6*, 639–651.

Hellige, J.B., Bloch, M.I., & Taylor, A.K. (1988). Multitask investigation of individual differences in hemispheric asymmetry. *Journal of Experimental Psychology: Human Perception and Performance*, *14*, 176–187.

Hellige, J.B., Corwin, W.H., & Jensson, J.E. (1984). Effects of perceptual quality on the processing of human faces presented to the left and right cerebral hemispheres. *Journal of Experimental Psychology: Human Perception and Performance*, *10*, 90–107.

Hellige, J.B., & Webster, R. (1979). Right hemisphere superiority for initial stages of letter processing. *Neuropsychologia*, *17*, 653–660.

Hellige, J.B., & Wong, T.M. (1983). Hemisphere-specific interference in dichotic listening: Task variables and individual differences. *Journal of Experimental Psychology: General*, *112*, 218–239.

Hernandez, S., Nieto, A., & Barroso, J. (1992). Hemispheric specialization for word classes with visual presentation and lexical decision task. *Brain and Cognition*, *20*, 399–408.

Hirschman, R.S., & Safer, M.A. (1982). Hemisphere differences in perceiving positive and negative emotions. *Cortex*, *18*, 569–580.

Hiscock, M., & Hiscock, C.K. (1988). An anomalous sex difference in auditory laterality. *Cortex*, *24*, 595–599.

Hiscock, M., & MacKay, M. (1985). The sex difference in dichotic listening: Multiple negative findings. *Neuropsychologia*, *23*, 441–444.

Hiscock, M., & Stewart, C. (1984). The effect of asymmetrically focused attention upon subsequent ear differences in dichotic listening. *Neuropsychologia*, *22*, 337–351.

Hughdal, K., & Andersson, L. (1986). The ''forced-attention paradigm'' in dichotic listening to CV-syllables: A comparison between adults and children. *Cortex*, *22*, 417–432.

Hughdal, K., & Andersson, B. (1987). Dichotic listening and reading acquisition in children: A one-year follow-up. *Journal of Clinical and Experimental Neuropsychology*, *9*, 631–648.

Hughdal, K., & Andersson, B. (1989). Dichotic listening in 126 left-handed children: Ear advantages, familial sinistrality and sex differences. *Neuropsychologia*, *27*, 999–1006.

Hynd, G.W., Snow, J., & Willis, W.G. (1986). Visual-spatial orientation, gaze direction and dichotic listening asymmetries. *Cortex*, *22*, 313–317.

Ingram, D. (1975). Cerebral specialization in young children. *Neuropsychologia*, *13*, 103–105.

Jones, B. (1979). Sex and visual field effects on accuracy and decision making when subjects classify male and female faces. *Cortex*, *15*, 551–560.

Jones, B. (1980). Sex and handedness as factors in visual-field organization for a categorization task. *Journal of Experimental Psychology Human Perception and Performance*, *6*, 494–500.

Jones, B., & Anuza, T. (1982a). Effects of sex, handedness, stimulus and visual field on ''mental rotation''. *Cortex*, *18*, 501–514.

Jones, B., & Anuza, T. (1982b). Sex differences in cerebral lateralization in 3- and 4-year-old children. *Neuropsychologia*, *20*, 347–350.

Kail, R.V., & Siegel, A.W. (1978). Sex and hemispheric differences in the recall of verbal and spatial information. *Cortex*, *14*, 557–563.

Kamptner, L., Harter Kraft, R., & Harper, L.V. (1984). Lateral specialization and social-verbal development in preschool children. *Brain and Cognition*, *3*, 42–50.

Keenan, P.A., Whitman, P.D., & Pepe, J. (1989). Hemispheric asymmetry in the processing of high and low spatial frequencies: A facial recognition task. *Brain & Cognition*, *11*, 229–237.

Kelly, R.R., & Orton, K.D. (1979). Dichotic perception of word-pairs with mixed image value. *Neuropsychologia*, *17*, 363–371.

Kim, H., & Levine, S.C. (1991). Inferring patterns of hemispheric specialization of individual subjects from lateralization data: A two-task criterion. *Neuropsychologia*, *29*, 93–105.

Kim, H., & Levine, S.C. (1992). Variations in characteristic perceptual asymmetry: Modality specific and modality general components. *Brain and Cognition*, *19*, 21–47.

Kim, H., Levine, S.C., & Kertesz, S. (1990). Are variations among subjects in lateral asymmetry real individual differences or random error in measurement? Putting variability in its place. *Brain and Cognition*, *14*, 220–242.

Kimura, D. (1963). Speech lateralization in young children as determined by an auditory test. *Journal of Comparative and Physiological Psychology*, *56*, 899–902.

Kimura, D. (1966). Dual functional asymmetry of the brain in visual perception. *Neuropsychologia*, *4*, 275–285.

Kimura, D. (1967). Functional asymmetry of the brain in dichotic listening. *Cortex*, *3*, 163–178.

Kimura, D. (1969). Spatial localization in left and right visual fields. *Canadian Journal of Psychology*, *23*, 445–448.

Kimura, D., & D'Amico, C. (1989). Evidence for subgroups of adextrals based on speech lateralization and cognitive patterns. *Neuropsychologia*, *27*, 977–986.

King, F.L., & Kimura, D. (1972). Left-ear superiority in dichotic perception of vocal nonverbal sounds. *Canadian Journal of Psychology*, *26*, 111–116.

Kirsner, K. (1980). Hemisphere specific processes in letter matching. *Journal of Experimental Psychology: Human Perception and Performance*, *6*, 167–179.

Klein, R., & MacInnes, J. (1988). Visual field differences in the processing of numerical stimuli. *Brain and Cognition*, *7*, 247–256.

Klein, S.P., & Rosenfield, W.D. (1980). The hemispheric specialization for linguistic and non-linguistic tactile stimuli in third grade children. *Cortex*, *16*, 205–212.

Klisz, D. (1980). Visual field differences between a fricative and stop consonant. *Cortex*, *16*, 169–173.

Knox, C., & Kimura, D. (1970). Cerebral processing of nonverbal sounds in boys and girls. *Neuropsychologia*, *8*, 227–238.

Krutsch, A., & McKeever, W.F. (1990). Cross-modal correlation of dichotic and tachistoscopic laterality tasks: The importance of familial sinistrality. *Brain and Language*, *38*, 384–397.

Ladavas, E., & Umilta, C. (1983). Do laterality measures relate to speed of response in central vision. *Brain & Cognition*, *2*, 119–128.

Ladavas, E., Umilta, C., & Ricci-Bitti, P.E. (1980). Evidence for sex differences in right-hemisphere dominance for emotions. *Neuropsychologia*, *18*, 361–366.

Lake, D.A., & Bryden, M.P. (1976). Handedness and sex differences in hemispheric asymmetry. *Brain and Language*, *3*, 266–282.

Lambert, A.J., & Beaumont, J.G. (1981). Comparative processing of imageable nouns in the left and right visual fields. *Cortex*, *17*, 411–418.

Lambert, A.J., & Beaumont, J.G. (1983). Imageability does not interact with visual field in lateral word recognition with oral report. *Brain and Language*, *20*, 115–142.

Landis, T., Assal, G., Perret, E. (1979). Opposite cerebral hemispheric superiorities for visual associative processing of emotional facial expressions and objects. *Nature*, *278*, 739–740.

Leehey, S.C., & Cahn, A. (1979). Lateral asymmetries in the recognition of words, familiar faces and unfamiliar faces. *Neuropsychologia*, *17*, 619–635.

Leehey, S.C., Carey, S., Diamond, R., & Cahn, A. (1978). Upright and inverted faces: The right hemisphere knows the differences. *Cortex*, *14*, 411–419.

Leksa, B.J., & Jackson, T.L. (1983). Language lateralization as measured by dichotic VRT and recognition tasks. *Brain and Language*, *18*, 86–97.

Lenhart, R.E., & Schwartz, S.M. (1983). Tactile perception and the right hemisphere: A masculine superiority for imagery coding. *Brain & Cognition*, *2*, 224–232.

Leong, C.K., Wong, S., Wong, A., & Hiscock, M. (1985). Differential cerebral involvement in perceiving Chinese characters: Levels of processing approach. *Brain and Language*, *26*, 131–145.

Levine, S.C., Banich, M.T., & Koch-Weser, M. (1984). Variations in pattern of cerebral asymmetry among dextrals. *Brain and Cognition*, *3*, 317–350.

Levine, S.C., & Koch-Weser, M.P. (1982). Right hemisphere superiority in the recognition of famous faces. *Brain & Cognition*, *1*, 10–22.

Levy, J., & Kueck, L. (1986). A right hemisphere advantage on a verbal free vision task. *Brain and Language*, *27*, 24–37.

Levy, J., & Reid, M. (1978). Variations in cerebral organization as a function of handedness, hand posture in writing, and sex. *Journal of Experimental Psychology: General*, *107*, 119–144.

Ley, R.G., & Bryden, M.P. (1982). A dissociation of right and left hemispheric effects for recognizing emotional tone and verbal content. *Brain & Cognition*, *1*, 3–9.

Liederman, J. (1986). Determinants of the enhancement of the right visual field advantage by bilateral vs. unilateral stimuli. *Cortex*, *22*, 553–565.

Lishman, W.A., & McMeekan, E.R.L. (1977). Handedness in relation to direction and degree of cerebral dominance for language. *Cortex*, *13*, 30–43.

Lokker, R., & Morais, J. (1985). Ear differences in children at two years of age. *Neuropsychologia*, *23*, 127–129.

Lukatela, G., Carello, C., Savic, M., & Turvey, M.T. (1986). Hemispheric asymmetries in phonological processing. *Neuropsychologia*, *24*, 341–350.

Magnani, G., Mazzuchi, A., & Parma, M. (1984). Interhemispheric differences in same versus different judgment upon presentation of complex visual stimuli. *Neuropsychologia*, *22*, 527–530.

Mahoney, A.M., & Sainsbury, R.S. (1987). Hemispheric asymmetry in the perception of emotional sounds. *Brain & Cognition*, *6*, 216–233.

Marcel, T., Katz, L., & Smith, M. (1974). Laterality and reading proficiency. *Neuropsychologia*, *12*, 131–140.

Marcel, T., & Rajan, P. (1975). Lateral specialization for recognition of words and faces in good and poor readers. *Neuropsychologia*, *13*, 489–497.

Marino, M.F., & McKeever, W.F. (1989). Spatial processing laterality and spatial visualization ability: Relations to sex and familial sinistrality variables. *Bulletin of the Psychonomic Society*, *27*, 135–137.

Martin, C.M. (1978). Verbal and spatial encoding of visual stimuli: The effect of sex, hemisphere and yes–no judgments. *Cortex*, *14*, 227–233.

Mathieson, C.M., Sainsbury, R.S., & Fitzgerald, L.K. (1990). Attentional set in pure- versus mixed-lists in a dichotic listening paradigm. *Brain and Cognition*, *13*, 30–45.

Mayes, J.T. (1982). Hemisphere function and spatial ability: An exploratory study of sex and cultural differences. *International Journal of Psychology*, *17*, 65–80.

Mazzuchi, A., Parma, M., & Cattelani, R. (1981). Hemispheric dominance in the perception of tonal sequences in relation to sex, musical competence and handedness. *Cortex*, *17*, 291–302.

McGlone, J., & Davidson, W. (1973). The relation between cerebral speech laterality and spatial ability with special reference to sex and hand preference. *Neuropsychologia*, *11*, 105–113.

McGuinness, D., & Bartell, T.E. (1982). Lateral asymmetry: Hard or simple-minded? *Neuropsychologia*, *20*, 629–639.

McKeever, W.F. (1981). Evidence against the hypothesis of right hemisphere language dominance in the Native American Navajo. *Neuropsychologia*, *19*, 595–598.

McKeever, W.F. (1986). The influence of handedness, sex, familial sinistrality, and androgyny on language laterality, verbal ability, and spatial ability. *Cortex*, *22*, 521–537.

McKeever, W.F., & Dixon, M.S. (1981). Right hemisphere superiority for discriminating memorized from nonmemorized faces: Affective imagery, sex, and perceived emotionality. *Brain and Language*, *12*, 246–260.

McKeever, W.F., Gill, K.M., & Van Deventer, A.D. (1975). Letter versus dot stimuli as tools for ''splitting the normal brain with reaction time''. *Quarterly Journal of Experimental Psychology*, *27*, 363–373.

McKeever, W.F., & Hoff, A.L. (1982). Familial sinistrality, sex, and laterality differences in naming and lexical decision latencies in right handers. *Brain and Language*, *17*, 225–239.

McKeever, W.F., & Hunt, L.J. (1984). Failure to replicate the Scott et al. finding of reversed dominance in Native American Navajo. *Neuropsychologia*, *22*, 539–542.

McKeever, W.F., Hunt, L.J., Wells, S., & Yazzie, C. (1989). Language laterality in Navajo reservation children: Dichotic test results depend on the language context of the testing. *Brain and Language*, *36*, 148–158.

McKeever, W.F., & Jackson, T.L. (1979). Cerebral dominance assessed by object- and colour-naming latencies: Sex and familial sinistrality. *Brain and Language*, *7*, 175–190.

McKeever, W.F., Seitz, K.S., Hoff, A.L., Marino, M.F., & Diehl, J.A. (1983). Interacting sex and familial sinistrality characteristics influence both language lateralization and spatial ability in right handers. *Neuropsychologia*, *21*, 661–668.

McKeever, W.F., & Van Deventer, A.D. (1977). Visual and auditory language processing asymmetries: Influence of handedness, familial sinistrality and sex. *Cortex*, *13*, 225–241.

McKeever, W.F., & Van Deventer, A.D. (1980). Inverted handwriting position, language laterality and the Levy-Nagylaki genetic model of handedness and cerebral organization. *Neuropsychologia*, *18*, 99–102.

McKeever, W.F., & Van Eys, P. (1986). Evidence that fixation digits can contribute to visual field asymmetries in lateralized tachistoscopic tasks. *Brain and Cognition*, *5*, 443–451.

McLaren, J., & Bryson, S.E. (1987). Hemispheric asymmetries in the perception of emotional and neutral faces. *Cortex*, *23*, 645–654.

McRoberts, G.W., & Sanders, B. (1992). Sex differences in performance and hemispheric organization for a nonverbal auditory task. *Perception & Psychophysics*, *51*, 118–122.

Measso, G., & Zaidel, E. (1990). Effect of response programming on hemispheric differences in lexical decision. *Neuropsychologia*, *28*, 635–646.

Metzger, R.L., & Antes, J.R. (1976). Sex and coding strategy effects on reaction time to hemisphere probes. *Memory and Cognition*, *4*, 167–171.

Miller, L.K., & Butler, D. (1980). The effect of set size on hemifield asymmetries in letter recognition. *Brain and Language*, *9*, 307–314.

Milstein, V., Small, I.F., Malloy, F.W., & Small, J.G. (1979). Influence of sex and handedness on hemispheric functioning. *Cortex*, *15*, 439–449.

Mohr, E. (1987). Cognitive style and order of recall effects in dichotic listening. *Cortex*, *23*, 223–236.

Mondor, T.A., & Bryden, M.P. (1991). The influence of attention on the dichotic REA. *Neuropsychologia*, *29*, 1179–1190.

Murray, J. (1986). The role of spatial complexity in the perception of speech and pure tones in dichotic listening. *Brain and Cognition*, *5*, 452–464.

Murray, J., Allard, F., & Bryden, M.P. (1988). Expectancy effects: Cost-benefit analysis of monaurally and dichotically presented speech. *Brain and Language*, *35*, 105–118.

Nagafuchi, M. (1970). Development of dichotic and monaural hearing abilities in young children. *Acta Otolaryngologica*, *69*, 409–415.

Natale, M. (1977). Perception of nonlinguistic auditory rhythms by the speech hemisphere. *Brain and Language*, *4*, 32–44.

Natale, M., Gur, R.E., & Gur, R.C. (1983). Hemispheric asymmetries in processing emotional expressions. *Neuropsychologia*, *21*, 555–565.

Nettleton, N.C., & Bradshaw, J.L. (1983). An unexpected interactive pattern of visual field asymmetries revealed by faster/slower response partitioning. *Cortex*, *19*, 273–280.

Nguy, T.V.H., Allard, F.A., & Bryden, M.P. (1980). Laterality effects for Chinese characters: Differences between pictorial and nonpictorial characters. *Canadian Journal of Psychology*, *34*, 270–273.

Nichelli, P., Manni, A., & Faglioni, P. (1983). Relationship between speed, accuracy of performance and hemispheric superiorities for visuo-spatial pattern processing in the two sexes. *Neuropsychologia*, *21*, 625–632.

Nilsson, J., & Geffen, G. (1987). Perception of similarity and laterality effects in tactile shape recognition. *Cortex*, *23*, 599–614.

Norman, W.D., Jeeves, M.A., Milne, A., & Ludwig, T. (1992). Hemispheric interactions: The bilateral advantage and task difficulty. *Cortex*, *28*, 623–642.

O'Boyle, M.W., & Benbow, C.P. (1990). Enhanced right hemisphere involvement during cognitive processing may relate to intellectual precocity. *Neuropsychologia*, *28*, 211–216.

Oscar-Berman, M., Rehbein, L., Porfert, A., & Goodglass, H. (1978). Dichhaptic hand-order effects with verbal and nonverbal tactile stimulation. *Brain and Language*, *6*, 323–333.

Patterson, K., & Bradshaw, J.L. (1975). Differential hemispheric mediation of nonverbal stimuli. *Journal of Experimental Psychology: Human Perception and Performance*, *1*, 246–252.

Pennal, B.E. (1977). Human cerebral asymmetry in color discrimination. *Neuropsychologia*, *15*, 563–568.

Peretz, I., & Morais, J. (1983). Task determinants of ear differences in melody processing. *Brain & Cognition*, *2*, 313–330.

Peretz, I., Morais, J., & Bertelson, P. (1987). Shifting ear differences in melody recognition through strategy inducement. *Brain & Cognition*, *6*, 202–215.

Peters, M., & McGrory, J. (1987). Dichotic listening performance and writing posture in right-and left-handers. *Brain and Language*, *32*, 253–264.

Piazza, D.M. (1980). The influence of sex and handedness in the hemispheric specialization of verbal and nonverbal tasks. *Neuropsychologia*, *18*, 163–176.

Pitbaldo, C. (1979a). Cerebral asymmetries in random dot stereopsis: Reversal of direction with changes in dot size. *Perception*, *8*, 683–690.

Pitbaldo, C. (1979b). Visual field differences in perception of the vertical with and without a visible frame of reference. *Neuropsychologia*, *17*, 215–226.

Pizzamiglio, L., & Zoccolotti, P. (1981). Sex and cognitive influence on visual hemifield superiority for face and letter recognition. *Cortex*, *17*, 215–226.

Poizner, H., & Lane, H. (1979). Cerebral symmetry in the perception of American Sign Language. *Brain and Language*, *7*, 210–226.

Pring, T.R. (1981). The effect of stimulus size and exposure duration on visual field asymmetries. *Cortex*, *17*, 227–240.

Prior, M.R., Cumming, G., & Hendy, J. (1983). Recognition of abstract and concrete words in a dichotic listening paradigm. *Cortex*, *20*, 149–157.

Rastatter, M.P., & Gallaher, A.J. (1982). Reaction-times of normal subjects to monaurally presented verbal and tonal stimuli. *Neuropsychologia*, *20*, 465–473.

Rizzolatti, G., & Buchtel, H.A. (1977). Hemispheric superiority in reaction time to faces: A sex difference. *Cortex*, *13*, 300–305.

Ross, P., & Turkewitz, G. (1981). Individual differences in cerebral asymmetries for facial recognition. *Cortex*, *17*, 199–214.

Rudel, R.G., Denckla, M.B., & Spalten, E. (1974). The functional asymmetry of Braille letter learning in normal sighted children. *Neurology*, *24*, 733–738.

Safer, M.A. (1981). Sex and hemisphere differences in access to codes for processing emotional expressions and faces. *Journal of Experimental Psychology: General*, *110*, 86–100.

Salis, D.L. (1980). Laterality effects with visual perception of musical chords and dot patterns. *Perception & Psychophysics*, *28*, 284–292.

Samar, V.J. (1983). Multidimensional influences of cerebral asymmetries on visual half-field asymmetries and cognitive skills. *Brain & Cognition*, *2*, 355–382.

Sananuma, S., Itoh, M., Mori, K., & Kobayashi, Y. (1977). Tachistoscopic recognition of Kana and Kanji words. *Neuropsychologia*, *15*, 547–553.

Sananuma, S., & Kobayashi, Y. (1978). Tachistoscopic recognition of line orientation. *Neuropsychologia*, *16*, 239–242.

Sanders, G., Wright, H.V., & Ellis, C. (1989). Cerebral lateralization of language in deaf and hearing people. *Brain and Language*, *36*, 555–579.

Satz, P., Bakker, D.J., Teunissen, J., Goebel, R., & Van der Vlugt, H. (1975). Developmental parameters of the ear asymmetry: A multivariate approach. *Brain and Language*, *2*, 171–185.

Schaller, M.J., & Dziadosz, G.M. (1975). Individual differences in adult foveal asymmetries. *Journal of Experimental Psychology: Human Perception and Performance*, *1*, 353–365.

Schaller, M.J., & Dziadosz, G.M. (1976). Developmental changes in foveal tachistoscopic recognition between prereading and reading children. *Developmental Psychology*, *12*, 321–327.

Schmuller, J., & Goodman, R. (1979). Bilateral tachistoscopic perception, handedness and laterality. *Brain and Language*, *8*, 81–91.

Schmuller, J., & Goodman, R. (1980). Bilateral tachistoscopic perception, handedness and laterality. II. Nonverbal stimuli. *Brain and Language*, *11*, 12–18.

Scott, J., Hynd, G., Hunt, L., Weed, W. (1979). Cerebral speech lateralization in the Native American Navajo. *Neuropsychologia*, *17*, 89–92.

Searleman, H. (1980). Subject variables and cerebral organization for language. *Cortex*, *16*, 239–254.

Segalowitz, S.J., & Stewart, C. (1979). Left and right lateralization for letter matching: Strategy and sex differences. *Neuropsychologia*, *17*, 521–525.

Seitz, K.S., & McKeever, W.F. (1984). Unilateral versus bilateral presentation methods in the reaction time paradigm. *Brain and Cognition*, *3*, 413–425.

Sewell, D.F., & Panou, L. (1983). Visual field asymmetries for verbal and dot localization tasks in monolingual and bilingual subjects. *Brain and Language*, *18*, 28–34.

Shannon, B. (1980). Lateralization effects in musical decision tasks. *Neuropsychologia*, *18*, 21–32.

Shipley-Brown, F., Dingwall, W.O., Berlin, C.I., Yeni-Komoshian, G., & Gordon-Salant, G. (1988). Hemispheric processing of affective and linguistic intonation contours in normal subjects. *Brain and Language*, *33*, 16–26.

Silverberg, R., Gordon, H.W., Pollack, S., & Bentin, S. (1980). Shift of visual field preference for Hebrew words in native speakers learning to read. *Brain and Language*, *11*, 99–105.

Smith, L.C., & Moscovitch, M. (1979). Writing posture, hemispheric control of movement and cerebral dominance in individuals with inverted and noninverted posture during writing. *Neuropsychologia*, *17*, 637–644.

Springer, S., & Searleman, A. (1978). The ontogeny of hemispheric specialization: Evidence for dichotic listening in twins. *Neuropsychologia*, *16*, 269–281.

St. John, R.C. (1981). Lateral asymmetry in face perception. *Canadian Journal of Psychology*, *35*, 213–223.

Strauss, E. (1983). Perception of emotional words. *Neuropsychologia*, *21*, 99–104.

Strauss, E., & Moscovitch, M. (1981). Perception of facial expression. *Brain and Language*, *13*, 308–332.

Szelag, E., & Wasilewski, R. (1992). The effect of congenital deafness on cerebral asymmetry in the perception of emotional and non-emotional faces. *Acta Psychologica*, *79*, 45–57.

Tapley, S.M., & Bryden, M.P. (1983). Handwriting position and hemispheric asymmetry in right-handers. *Neuropsychologia*, *21*, 129–138.

Thompson, J.K. (1983). Visual field, exposure duration, and sex as factors in the perception of emotional facial expressions. *Cortex*, *19*, 293–308.

Tinkcom, M., Obrzut, J.E., & Poston, C.S.L. (1983). Spatial lateralization: The relationship among sex, handedness and familial sinistrality. *Neuropsychologia*, *21*, 683–686.

Tomlinson-Keasly, C., & Kelly, R.R. (1979). Is hemispheric specialization important to scholastic achievement? *Cortex*, *15*, 97–107.

Turner, S., & Miller, L.K. (1975). Some boundary conditions for laterality effects in children. *Developmental Psychology*, *11*, 342–352.

Uecher, A., & Obrzut, J.E. (1993). Hemisphere and gender differences in mental rotation. *Brain and Cognition*, *22*, 42–50.

Umilta, C., Brizzolara, D., Tabossi, P., & Fairweather, H. (1978). Factors affecting face recognition in the cerebral hemispheres: Familiarity and naming. In J. Requin (Ed.), *Attention and performance VII.* Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Vaid, J. (1987). Visual field asymmetries for rhyme and syntactic category judgments in monolingual and fluent early and late bilinguals. *Brain and Language*, *30*, 263–277.

Van Duyne, H.J., & Sass, E. (1979). Verbal logic and ear-asymmetry in third and fifth grade males and females. *Cortex*, *15*, 173–182.

Van Eys, P.P., & McKeever, W.F. (1988). Subject knowledge of the experimenter's interest in handedness and familial sinistrality variables and laterality test outcomes. *Brain & Cognition*, *7*, 324–334.

Van Strien, J.W., & Bouma, A. (1990). Mental rotation of laterally presented random shapes in males and females. *Brain and Cognition*, *12*, 297–303.

Vargha-Khadem, F., & Corballis, M.C. (1979). Cerebral symmetry in infants. *Brain and Language*, *8*, 1–9.

Voyer, D., & Bryden, M.P. (1990). Gender, level of spatial ability, and lateralization of mental rotation. *Brain and Cognition*, *13*, 18–29.

Voyer, D., & Bryden, M.P. (1993). Masking and laterality effects in a lateralized rod-and-frame task. *Canadian Journal of Experimental Psychology*, *47*, 26–37.

Waber, D.P., & Merola, J.L. (1985). Motor correlates of dichotic listening asymmetries in children. *Neuropsychologia*, *23*, 403–410.

Walch, J.P., & Blanc-Garin, J. (1987). Tactual laterality effects and the processing of spatial characteristics: Dichhaptic exploration of forms by first and second grade children. *Cortex*, *23*, 189–205.

Ward, T.B., & Ross, L.E. (1977). Laterality differences and practice effects under central backward masking conditions. *Memory and Cognition*, *5*, 221–226.

Weener, P., & Van Blerkom, M. (1982). Dichhaptic laterality and field dependence. *Brain & Cognition*, *1*, 323–330.

Wellman, M.M., & Allen, M. (1983). Variations in hand position, cerebral lateralization, and reading ability among right-handed children. *Brain and Language*, *18*, 277–292.

Wexler, B., Schwartz, G., Warrenburg, S., Servis, M., & Tarlatzio, I. (1986). Effects of emotion on perceptual asymmetry: Interactions with personality. *Neuropsychologia*, *24*, 699–710.

Wilkinson, J.M., & Carr, T.H. (1987). Strategic hand use preferences and hemispheric specialization in tactual reading: Impact of the demands of perceptual encoding. *Brain and Language*, *32*, 97–123.

Witelson, S.F. (1976). Sex and the single hemisphere: Specialization of the right hemisphere for spatial processing. *Science*, *193*, 425–427.

Yeni-Komshian, G.H., Isenberg, D., & Goldberg, H. (1975). Cerebral dominance and reading disability: Left visual field deficit in poor readers. *Neuropsychologia*, *13*, 83–94.

Young, A.W., & Bion, P.J. (1979). Hemispheric laterality effects in the enumeration of visually presented collections of dots by children. *Neuropsychologia*, *17*, 99–102.

Young, A.W., & Bion, P.J. (1980). Absence of developmental trend in right hemisphere superiority for face recognition. *Cortex*, *16*, 213–221.

Young, A.W., & Bion, P.J. (1981). Accuracy of naming laterally presented known faces by children and adults. *Cortex*, *17*, 97–106.

Young, A.W., Bion, P.J., & Ellis, A.W. (1980). Studies toward a model of laterality effects for picture and word naming. *Brain and Language*, *11*, 54–65.

Young, A.W., Bion, P.J., & Ellis, A.W. (1982). Age of reading acquisition does not affect visual hemifield asymmetries for naming imageable nouns. *Cortex*, *18*, 477–482.

Young, A.W., & Ellis, A.W. (1985). Different methods of lexical access for words presented in the left and right visual hemifields. *Brain and Language*, *24*, 326–358.

Young, A.W., Ellis, A.W., & Bion, P.J. (1984). Left hemisphere superiority for pronounceable nonwords, but not for unpronounceable letter strings. *Brain and Language*, *22*, 14–25.

Young, A.W., & Ellis, H.D. (1976). An experimental investigation of developmental differences in ability to recognize faces presented to the left and right cerebral hemispheres. *Neuropsychologia*, *14*, 495–498.

Young, A.W., & Ellis, H.D. (1980). Ear asymmetry for the perception of monaurally presented words accompanied by binaural white noise. *Neuropsychologia*, *18*, 107–110.

Young, A.W., Hay, D.C., & McWeeny, K.H. (1985). Right cerebral hemisphere superiority for constructing spatial representations. *Neuropsychologia*, *23*, 195–202.

Young, A.W., Hay, D.C., McWeeny, K.H., & Ellis, A.W. (1985). Familiarity decisions for faces presented to the left and right cerebral hemispheres. *Brain and Cognition*, *4*, 439–450.