A STUDY OF COGNITIVE SEX DIFFERENCES AS RELATED TO BRAIN LATERALITY

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A STUDY OF COGNITIVE SEX DIFFERENCES
AS RELATED TO BRAIN LATERALITY

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ABSTRACT

Subjects were given a short form of the WAIS plus two group tests, one verbal and one spatial. Hand preference was assessed by responses to the Annett Handedness questionnaire. Verbal and perceptual-spatial abilities were compared for firm right, firm left and mixed left males and females. It was predicted that left-handed females would be most impaired, relative to dextral males, on the spatial measures, while left-handed males and right-handed females would be intermediate in spatial competence between right-handed males and left-handed females, but not different from them in verbal competence. Mode of writing in sinistrals was also examined.

The group tests proved more sensitive to the phenomena under study. Predictions were confirmed on the verbal group test, and on the spatial test all differences were in the expected directions but were statistically significant only for firm left subjects. Firm left, mixed left and right-handed females were not different from their opposite-sex groups on either the verbal or spatial measure; thus on these tests handedness proved to be a better predictor of cognitive abilities than sex.

The WAIS measures found no significant differences, and several possible explanations for this are discussed.

Results for normal- and inverted-writing left handers were not different for males, but female inverted writers

were impaired both verbally and spatially relative to normal-writing females.

These results lend partial support to Levy's hypothesis that poorer spatial ability reflects weaker functional lateralization. However, a careful definition of handedness is needed, as well as a clear description of "spatial" and "verbal" abilities. It is also necessary to determine which tests can best detect various aspects of cognitive function.

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INTRODUCTION

It is now widely accepted that men and women do not differ on test of overall intellectual ability (reviewed in Garai and Sheinfeld, 1968, and in Maccoby and Jacklin, 1974). Admittedly, some tests, such as the Stanford Binet, have been standardized so as to minimize sex differences. Other tests, relying primarily on one or a few specific abilities, show female superiority or male superiority, depending on the items included in the test. However, the majority of studies of general ability with subjects over age six use well-balanced tests and find no sex differences (Maccoby and Jacklin, 1974).

When specific cognitive abilities are measured, however, significant differences between the sexes are regularly found. Moreover, the persistent manifestation of important sex differences as an incidental by-product in studies which did not set out to explore such differences (Garai and Sheinfeld, 1968) has forced researchers increasingly to realize the importance of such differences. Two of the most commonly-found differences are those in verbal and spatial skills, females showing superiority in the former and males in the latter.

Verbal-Spatial Sex Differences

Maccoby and Jacklin (1974) reviewed the more recent studies (1967 to 1973) comparing verbal abilities of the two sexes and found that, particularly during and after adolescence, females' verbal performance generally surpasses that of males. In those studies with the largest samples, the female advantage ranges from about .1 to nearly .5 SD, with the usual difference being about .25 SD. Earlier writers (Bennett et al, 1959; Miele, 1958, Terman and Tyler, 1954) had suggested that female superiority was confined to verbal fluency and the mastery of the mechanics of language (spelling, punctuation, grammar, etc.) while males excelled in verbal comprehension, verbal reasoning, and vocabulary. However, the large number of more recent studies reviewed by Maccoby and Jacklin (1974) and showing superior female verbal power tested higher-level skills as well, including "comprehension of complex written text, quick understanding of complex logical relations expressed in verbal terms, and in some instances verbal creativity of the sort measured by Guilford's tests of divergent thinking."*

Male superiority in spatial tasks, on the other hand, appears to be equally well established. Studies of both adults and children of various ages have found male superiority in various tasks requiring the perception, judgement and manipulation of spatial relationships (Broverman et al, 1968; Garai and Scheinfeld, 1968; MacFarlane Smith, 1964; Nash, 1970.) Using the Porteus Maze Test, Porteus (1965) tested dozens of cultures all over the world ranging from Australian aborigines to French school children, and found that girls

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*Maccoby, E.E. and Jacklin, C.N., The Psychology of Sex Differences. Stanford, Calif.: Stanford University Press, 1974, p. 84.

were significantly inferior to boys. Buffery and Gray (1972) point out that, since girls have a general maturational advantage over boys (Taylor and Ounsted, 1972), the male superiority in spatial ability even as children is particularly striking. In Maccoby and Jacklin's (1974) review of the literature in this area, however, findings in childhood appear to be inconsistent. A substantial number of studies find no sex differences, but when differences are found, they show higher scores for boys and men, particularly at the higher age levels. By adolescence the male advantage on spatial tests is clearly established, "increasing through the high school years up to a level of about .40 SD, and appearing equally on analytic and non-analytic spatial measures" (Maccoby and Jacklin, 1974.)

Such sex differences in cognitive abilities are of particular interest today in view of the movement toward more equal treatment of the two sexes. If men and women do differ in their capacities for particular kinds of mental (and hence occupational) performance, it becomes increasingly important to discover whether such differences are the result of innate (biological) factors, or of socialization, or both.

From a biological perspective, it has been suggested that the female language advantage is related to her historical preoccupation with domestic and interpersonal roles, whereas the male spatial superiority is related to his historical role as provider and protector, a role which would require him to cover a wider territory where spatial skill was imperative for survival (Garai and Sheinfeld, 1968; Gray and Buffery, 1971; Hutt, 1972; Levy, 1974a).

Lateralization of Function

It has further been proposed that the mechanism underlying such cognitive differences relates to functional differences in brain asymmetry in the two sexes. The proposal is intuitively appealing, for it has been recognized for some time that, while the brain operates in a unitary fashion, each cerebral hemisphere appears to be prepotent for certain kinds of cognitive operations; thus observed differences in cognitive abilities between the sexes may indeed relate to differences in lateralization of function between male and female brains.

Studies of brain-injured or neurosurgical patients first showed that damage to the left hemisphere produces relatively more deficits in language processing and the handling of analytical mathematical tasks, while damage to the right hemisphere produces more deficits in tasks involving spatial relationships and a Gestalt, holistic mode of perceiving (Bogen, 1969; Luria, 1966; Milner, 1965, 1971, 1974.) Sperry's (1964) dramatic findings with severe epileptics whose corpus callosum had been severed confirmed further the specialized functions of the two cerebral hemispheres: while the dominant (usually left) hemisphere in "split-brains" is superior for speech, writing and mathematical operations, it displays little ability to handle problems of a spatial, holistic or "intuitive" nature; conversely, while the right hemisphere is severely limited in speech and mathematics, it handles tasks with ease when these involve complex spatial relationships and musical patterns (Gazzaniga, 1970; Sperry, 1974; Sperry, Gazzaniga and Bogen, 1969.)*

Research with normally functioning people has shown that lateral specialization is not merely a function of pathology or surgery; the normal brain also appears to process information in the area most suited to the particular information type. The evidence here comes from research using reaction time tasks, dichotic listening tasks or tachistoscopic visual presentations: for example, Filbey and Gazzaniga (1969) presented information to the right hemisphere of normal subjects and measured reaction time. They found a greater delay when a verbal response was required than that for a nonverbal response. Kimura (1961) showed that, in dichotic listening tasks, verbal material is better recalled when heard through the right ear; melodies, however, are better recognized when presented to the left ear (Kimura, 1964). Other studies (Ehrlichman, 1971; Kimura, 1969) found superior recognition of tachistoscopically presented verbal stimuli in right visual field and nonverbal stimuli in left visual field.

It should be noted that these relationships are most clearly demonstrated for firm right handers. In many ambidextrals and left handers, and in some small fraction

*Sperry (1974) notes, however, that either hemisphere alone is less efficient than the intact brain.

of right handers, the language hemisphere is ipsilateral to the preferred hand (Lenneberg, 1967; Levy, 1974b; Roberts, 1969; Subirana, 1969; Wada et al, 1975.) However, this does not necessarily imply that the preferred hand is controlled by the nonlanguage hemisphere; there is evidence, in fact, tending to suggest just the opposite: Hecaen and colleagues (1971) have shown that a sinistral with left hemisphere lesion who displays aphasic disorders is also agraphic, suggesting control of both language and preferred hand by the left hemisphere. In addition, several histological studies have shown that some individuals have no pyramidal decussation, all pyramidal motor fibers running ipsilateral. Among such persons those who also have language ipsilateral to the preferred hand would of course have both language and control of preferred hand programmed by the same hemisphere.

There is no information on the prevalence of right cerebral speech dominance in the general population. However, recording of CNV slow potentials from the inferoposterior frontal scalp predicts a laterality of speech dominance, as verified by the carotid amytal test, in 10 out of 11 patients (Wada et al, 1975). In 11 normal "pure" right-handed subjects, Wada et al (1975) found CNV evidence of left speech dominance in 8, right speech dominance in 1 and equality in 2. In 11 normal "pure" left handers, left speech dominance was found in 3, right speech dominance in 6 and equality in 2. The same study also reported that the <u>right</u> temporal planum ranged in size from absent (10%) to larger than the left in about 10% of the brains examined, and females predominated ($p < .05$) in the latter group. These findings suggest that a higher percentage of persons may have right-sided cerebral speech dominance or bilateral representation for speech than has previously been assumed, and that more females than males fall into these categories.

Little is known about when and how functional lateralization develops in the human brain. Lenneberg (1967) suggested that 2 and 12 years are the lower and upper limits, respectively, for the process of lateralization of language function, implying that the two hemispheres are equipotential for the development of language during the first two years. However, Wada et al (1975) found the same anatomical asymmetry in infant brains as that earlier found in adult brains: i.e. the left temporal planum was always present and was usually larger than the right. EEG evidence also supports the notion that the infant's brain is lateralized: for example, syllables asymmetrically depress a 4 cps rhythm (the infant's homologue of alpha) in the infant's left hemisphere and music asymmetrically depresses it in the right (Levy, 1976). Behavioral evidence comes from a study by Kohn and Dennis (1974) which found that adult hemiplegics with infantile hemispherectomy displayed differing cognitive deficits depending on the hemisphere removed.

Sex Differences in Laterality

Another growing body of evidence suggests that the assignment of functions to "left brain" or "right brain" may not be the same in men and women, and has led to the proposal that sex differences in cognition relate to differences in brain asymmetry in the two sexes.

Levy (1972) has argued that strong cerebral dominance facilitates performance on spatial tasks. Left-handed men, in whom cerebral lateralization is weak (Ettlinger et al, 1956; Luria, 1947; Zangwill, 1960) have been found to obtain lower scores in tests of perceptual-spatial ability (James et al, 1967; Silverman et al, 1966). Levy (1969) found that left-handed male graduate students at Caltech obtained considerably lower performance I.Q. scores than right-handed students, although their verbal I.Q.s were not significantly different.* Nebes (1971) also found left-handed university students to be significantly inferior to right-handed students, in a tactile test of perceptual ability. (Unfortunately, he did not give a verbal test as a control.) Miller (1971) gave both verbal and perceptual tests (not from the WAIS) to left- and right-handed university students and confirmed Levy's Caltech finding: the two groups did not differ on the verbal test, but left handers were inferior on the perceptual test.

Levy (1972) has suggested that females' poorer spatial ability also stems from weaker lateralization of verbal functions which impinge on the areas reserved for spatial functions in more specialized persons.

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*Factor analysis of subtest scores subsequently revealed that, on the purified factors, sinistrals were not only inferior to dextrals on the perceptual factor, but were also superior on the verbal factor (Levy, 1972).

A possible basis for the evolution of lateral specialization has been proposed by Levy (1969):

> There is evidence that the minor hemisphere possesses some minimal ability to express language, but this is difficult to observe because of competition from the major hemisphere for control of the motor mechanisms for the production of language. These interference effects support a rationale for the evolution of a unilateral control of language expression, namely that such lateralization was an adaptation permitting control of the unique vocal apparatus, uncomplicated by competitive antagonism between the hemispheres.

Levy has since proposed a hypothesis of mutual antagonism between the analytic left hemisphere and the Gestalt right hemisphere as a possible reason for functional asymmetry. She speculates that the left hemisphere became specialized for language in order to leave the right free for synthesis functions (Levy, 1972).

Levy (1969, 1974a) has further speculated that a selective advantage was conferred by genetically controlled cerebral and manual asymmetries: "Hominids with functionally asymmetric hemispheres had adequate depth perception, visual memory, Gestalk closure and directional discrimination of movement" required in the hunting society of early man. The smaller number of Hominids with functionally symmetric hemispheres (i.e. left handers) had in effect "two left brains" and survived because they were the best planners. Although Levy does not extend this speculation to include women, it is not inconceivable that the early female's pre-occupation with domestic and interpersonal roles was also best served by a more symmetric cerebral arrangement.

In support of her thesis concerning similar lateralization in females and left handers, Levy cites a report by Culver et al (1970) that "right- as well as left-handed females show a greater primary amplitude of evoked responses in the right hemisphere than in the left, an effect earlier found by Eason et al (1967) only in men who were left-handed." Moreover, in view of the data on girls with Turner's syndrome, Levy says "it is difficult to reject the notion that the spatial-perceptive deficit in women is a sex-linked, genetically determined incapacity, an incapacity which possible results from hemispheres less well laterally specialized than those of males." Certainly the suggestion that the sex chromosomes do participate in determining spatial ability is given strong support by the Turner's syndrome data, for girls with this XO chromosome condition have been shown to be profoundly defective in spatial perception (Alexander et al, 1966).

Lansdell's work with epileptics led him to conclude, like Levy, that the male brain is functionally more lateralized than the female's: in a study of linguistic skill (Lansdell, 1961) he found that scores on the Gorham's Proverbs Test following dominant (usually left) temporal lobectomy were lowered in men but unaffected in women, suggesting a greater overlap of cognitive function in females. Concerning aesthetic judgement of abstract designs as measured by the Graves design judgement test (Lansdell, 1962), he found that a non-dominant (usually right) temporal lobectomy lowered the scores only of male epileptics, and dominant (usually left) temporal lobectomy improved the scores only of males. (Effects for females were not significant.) This suggests that males rely on each hemisphere for specific tasks more than females do. Lansdell (1968) found similar sex differences in the verbal and nonverbal scores on the Wechsler-Bellevue after temporal lobectomy.

McGlone and Kertesz (1973) observed that, while spatial deficits in both males and females were worse after right hemisphere lesion, the impairment was greater for males, again suggesting that the right hemisphere in males is more specialized for such processes. These authors also found that women appeared to make more use of verbal mediation in nonverbal tasks than males, suggesting that in females the language function is present in both hemispheres to a greater extent than in males.

Kohn and Dennis (1974) investigated the spatial abilities of four adolescents who had undergone hemispherectomies when very young, two (one male, one female) of the left hemisphere and two (one male, one female) of the right. All of the subjects were competent in language. Left hemispherectomy impaired the female's spatial ability but not the male's. Right hemispherectomy impaired spatial ability in both the male and the female. Since both females suffered impaired spatial competence, this suggests that the females, but not the males, had spatial ability bilaterally.

Buffery and Gray (1972) have suggested that such findings may apply only to surgical cases. However, other data from normal subjects also appear to support the Levy hypothesis of weaker lateralization in females. For example, Kimura (1969) found a significant left-field (and hence right hemisphere) effect for males but not for females, in a dot-localization task. McGlone and Davidson (1973) found that dot enumeration (a nonverbal task) produced a left visual field superiority in a clear majority of right-handed males, but in only about 50% of right-handed females. In dichotic listening to nonverbal stimuli such as animal and environmental noises, Knox and Kimura (1970) also found greater localization among males than females, with the sex difference being apparent as young as age five. Lake and Bryden (1976) found 94% of right-handed males but only 67% of right-handed females were more accurate on the right ear, in a dichotic listening task; in left handers 73% of the men but only 59% of the women showed a right-ear advantage. Rudel et al (1974) tested the functional asymmetry of Braille letter learning in normal, sighted children age 7-13 and found that, while left-hand performance was superior for both boys and girls, the girls developed left-hand ability at a later age than the boys and also depended more on verbal mediation. Marcel et al (1974) presented words tachistoscopically to right and left visual fields and found that boys showed right over left field superiority to a greater degree than girls, thus implying greater hemispheric asymmetry for boys than girls.

Ehrlichman (1971) also used a techistoscopic task--recognition of verbal and nonverbal stimuli presented in left and right visual half-fields--and obtained a larger difference between visual fields for verbal stimuli for males than for females. He also found that relative superiority of one or the other visual field was more consistent across both kinds of stimuli for females than for males. Johnson and Kozma (1977) found that right-handed balancing of a dowel rod deteriorated with concurrent verbalization in males but not in females, again suggesting that the language function is more clearly lateralized in males.

Additional support for the hypothesis of greater male lateralization comes from studies of conjugate lateral eye movements, which several researchers (Bakan, 1969; Bakan and Svorad, 1969; Kinsbourne, 1974) have proposed as a useful index of lateralization of cognitive function. Given a cognitive task, a person's eyes tend to move in the direction contralateral to the hemisphere most involved in processing the information. However, Bakan (1971) found that males are much more consistent than females in making such eye movements. He also found that males with high basal alpha make more leftward lateral eye movements whereas females with high basal alpha do not. These findings led him to conclude that there may be more hemispheric integration in women than in men. More recently Bakan and Putnam (1974) found that lateral discrimination of body parts as right or left was poorer in right-handed females than in right-handed males.

Thus a sizeable body of evidence appears to lend credence to the notion that females may be hemispherically less specialized than men. Lesion data plus the several findings of sex differences in dichotic listening tasks, tactile learning, tachistoscopic tasks, hemispheric task-sharing, eye movements, and right-left discrimination all argue for a hypothesis of sex differences in brain laterality.

It should be noted, however, that even if male-female differences in cognitive abilities do result from different patterns of brain lateralization, this is not necessarily due to underdevelopment of the female spatial hemisphere or to over-reliance on the verbal hemisphere. Levy (1976) has commented that

> the cognitive and lateralization data are just as consistent with the hypothesis that, regardless of what the two hemispheres program, the female left hemisphere surpasses the right and the male right hemisphere surpasses the left. Since 95% of people have left hemisphere language, one sees a female spatial deficit and a male verbal deficit.

Unfortunately the available data do not provide a sufficient basis to choose between a cognitive hypothesis and a hemisphere hypothesis. While the cognitive hypothesis is assumed throughout the above discussion, it is recognized that cognitive sex differences could instead be a secondary consequence of asymmetry of left and right hemisphere development in males and females.

The Present Study

The present study was designed to test Levy's proposition that females have a pattern of verbal-performance abilities similar to that shown for left-handed males. It will be recalled that Levy's argument stems partly from her observation that left-handed males at Caltech had lower performance, but not verbal, scores than did their right-handed fellows. Noting the same pattern of verbal-spatial abilities in females, and considering that left-handed men are known to be less lateralized, Levy suggested that the female's poorer spatial ability may also stem from her lesser degree of lateralization.

If this thesis is correct, one would expect to find lower spatial ability among left-handed males and both right- and left-handed females, than among right-handed males. Moreover, since the handedness effect on spatial impairment is apparent for left-handed males, and the sex effect has been documented in studies showing poorer spatial competence in females, and since lesion data and other studies have suggested that both left handers and females are less clearly lateralized, it is not unreasonable to assume that the two effects--handedness and sex--are additive. If this is the case, then one would expect to find the poorest spatial performance among left-handed females, while right-handed females and left-handed males should be intermediate in spatial competence between right-handed males and left-handed females.

These predictions were tested by comparing verbal and nonverbal ability among right- and left-handed males and females. Assuming the additivity of the sex and handedness effects on laterality, the following hypotheses were proposed:

On tests of verbal and perceptual-spatial ability:

Left-handed females will be lower than right-handed males on perceptual-spatial, but not on verbal, measures;

Left-handed males and right-handed females will both be lower than right-handed males but higher than left-handed females on perceptual-spatial measures, but non on verbal measures.

METHOD

Subjects

Subjects were 120 university undergraduates, 30 each of right-handed males, left-handed males, right-handed females, and left-handed females.[8] The mean age was 20.01; there were no significant differences in age among any of the groups.

Subjects were recruited on the basis of hand preferred for writing. No subject reported having switched preferred writing hand.

Following testing, handedness was more accurately assessed by responses on the Annett handedness questionnaire (Appendix A). Various criteria for determining handedness have been used by different investigators, but there is little consistency among authors and the choice of items appears to constitute a quite arbitrary, and not necessarily representative, sample of the subject's total set of habits. Moreover, most investigators have employed a simple dichotomous classification for handedness, excluding subjects with mixed right and left preferences. Annett (1970), however, has suggested that handedness is distributed continuously rather than discretely. Using an associational analysis of responses to a hand-preference questionnaire, Annett distinguished several patterns of hand preference, then evaluated these against an independent criterion: differences between the hands in manual skill. The classification achieved through the coordination of preference and skill shows that distinctions along the handedness continuum can be made at several levels:

1. writing and/or hammering;
2. consistency on the first six ("primary") items of the Annett questionnaire, which are highly associated with all other items;
3. consistency on the last six ("secondary") items of the questionnaire as well as on the first six.

(Inconsistency is a mixture of right and left usage, not facility with either hand.)

Forty-three dextrals were consistent on all 12 items of the handedness questionnaire and 17 were consistent on only the primary items. However, since there were no significant differences on any of the test measures between these two groups, all 60 right-handed subjects were counted as firm right handers.

Variability among left handers has been noted by several researchers (Annett, 1967; Herron, 1976; Zangwill, 1960). Both Annett (1967) and Miller (1971) have suggested that there are differences in lateralization between "pure" left handers and nominal left handers who use the right hand for other common activities. In the present study it was noted that left-handed males consistent on all 12 items of the handedness questionnaire were significantly poorer on the Flags test than those who were consistent on only the primary items ($t=1.86$, $p < .01$). While in females the difference did not reach significance, it was in the same direction as that for males. In order to look at differences between consistent left handers and those of mixed preference, left handers were subdivided according to consistency of response on the handedness questionnaire: Subjects consistently left on all 12 items of the questionnaire formed two "firm-left" groups, one of 17 males and the other of 14 females. The remaining left handers--i.e. those inconsistent in hand preference--included 13 males and 16 females, forming two groups of "mixed-left" subjects.

The greater incidence of undetected brain damage in left handers suggested by Levy could constitute a contaminating factor in left-handed groups. However, since all subjects in the present study were university students, it seems reasonable to assume that brain damage was not present to any significant degree.

Procedure

Subjects were individually administered the Doppelt short form of the WAIS (Doppelt, 1956), which has the advantage of being quicker to administer than the complete WAIS while testing approximately the same functions. The selection of tests in this short form was based on the data which Wechsler reported for his national standardization sample of the WAIS and reported in the WAIS Manual. The short form consists of four subtests, two Verbal tests (Vocabulary and Arithmetic) and two Performance tests (Block Design and Picture Arrangement). These correlate highly with total Verbal score, total Performance score, and Full-Scale I.Q.:

	Correlation
Between two Verbal tests and total Verbal score:	0.938
Between two Performance tests and total Performance score:	0.939
Between four subtests and Full-Scale score:	0.960

(Doppelt, 1956)

The above correlations are for age groups 18-19, the nearest of the age groups for which correlations are given, to those in the present study.

WAIS measures were selected for two reasons: First, since Levy used the WAIS in her assessment of left handers at Caltech, the same measure was chosen in order to facilitate comparison with her findings. Second, the Verbal scale of the WAIS has been shown to test "left hemisphere" abilities (e.g. language) while the Performance scale tests "right hemisphere" abilities (e.g. spatial) (Arrigoni and DeRenzi, 1964; Reitan, 1955).

In addition, two tests were administered in group sessions as separate measures of verbal and spatial ability. These were the synonyms section of the Mill Hill Vocabulary Scale (Appendix B), which was selected as a measure of verbal ability, and the Space Thinking (Flags) test (Appendix C), which was used as a measure of spatial ability. Spatial ability first emerged as a distinct factor in the early work of Thurstone. His Primary Mental Abilities test had a spatial measure involving the mental rotation of printed figures in order to identify them as the same as or opposite to the standard flag figures. This is the Flags test.

An additional aspect of interest was also studied in left handers. These subjects were examined to see whether they wrote with straight wrist (like right handers) or with wrist twisted and pen pointed down to the line. Levy and Reid (1976) in tachistoscopic tests of cerebral lateralization found that sinistrals who twisted their wrists when writing were those with language centers in left brain and ipsilateral motor control, with right-hemisphere dominance for perceptual functions. Normal writing reflected the typical contralateral control seen in right handers, but from a language-dominant right hemisphere, with spatial function ipsilateral to the preferred hand. Inverted writers and females of both writing-types had smaller field differences than normal writers and males, implying weaker lateralization (Levy and Reid, 1976).

Table 1

Mean centiles for four WAIS subtests and Mill Hill and Flags test

		WAIS Vocab.	WAIS Arith.	WAIS B.D.	WAIS P.A.	WAIS Verbal	WAIS Perf.	V-P Diff.	Mill Hill	Flags Test	V-S Diff.
RAW SCORE MEAN:		57.71	12.89	38.54	25.58	49.04	50.81		28.67	57.39	
S.D.:		9.86	2.54	6.64	4.98	24.95	24.05		4.13	22.10	
Males:											
RIGHT	(N=30)	45.55	53.47	58.75	49.80	49.56	54.28	-4.72	48.78	55.94	-7.16
FIRM LEFT	(N=17)	57.22	52.76	58.23	66.17	54.99	62.20	-7.21	61.58	47.39	14.19
MIXED LEFT	(N=13)	59.93	67.28	55.13	54.28	63.61	54.71	8.90	51.65	52.37	-.72
TOTAL LEFT	(N=30)	58.39	59.05	56.89	61.02	58.72	58.96	-.24	57.28	49.55	7.73
ALL MALES	(N=60)	51.97	56.31	57.82	55.41	54.14	56.65	-2.48	53.03	52.74	.29
Females:											
RIGHT	(N=30)	41.91	41.72	42.44	40.59	41.82	41.52	.30	45.89	51.22	-5.33
FIRM LEFT	(N=14)	55.19	39.54	45.96	49.93	47.37	47.95	-.58	57.40	35.11	22.29
MIXED LEFT	(N=16)	45.33	40.73	49.93	52.77	43.03	51.35	-8.32	37.16	54.91	-17.75
TOTAL LEFT	(N=30)	49.93	40.17	48.08	51.44	45.05	49.76	-4.71	46.61	45.67	.94
ALL FEMALES	(N=60)	45.92	40.95	45.26	46.02	43.44	45.64	-2.20	46.25	48.45	-2.20

RESULTS

All scores were converted to z-scores from which percentiles were derived, and these were used in the analysis for two reasons: First, there was some doubt about the applicability of the test norms to our Newfoundland population, and second, the use of centiles facilitated comparison of WAIS results with results from the two group tests. Table 1 lists the mean centile standing for each subject group on each of the test measures. For comparison with Levy's data, WAIS I.Q.s were also derived, and these are shown in Table 2.

Table 2

Mean Verbal and Performance I.Q.s (WAIS)

		Verbal I.Q.	Performance I.Q.
MALES:			
Right	(N=30)	115.70	112.48
Firm Left	(N=17)	116.71	114.29
Mixed Left	(N=13)	121.46	111.35
FEMALES:			
Right	(N=30)	112.37	104.98
Firm Left	(N=14)	115.64	108.86
Mixed Left	(N=16)	113.06	110.66

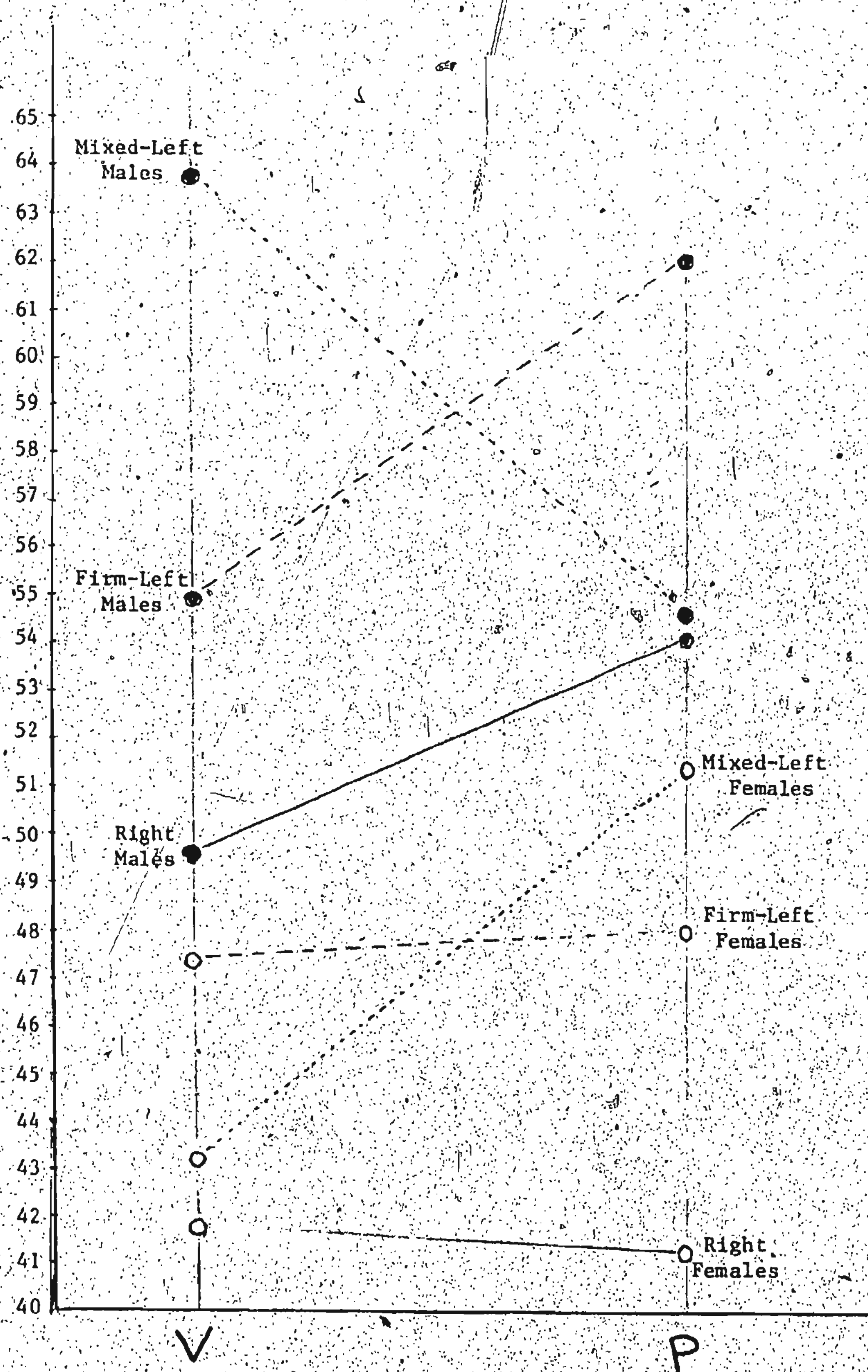

Figure 1.

WAIS Verbal and Performance means.
(Centiles)

WAIS Verbal-Performance Measures

Figure 1, graphically depicting WAIS Verbal and Performance means, shows that groups differed in overall I.Q. as well as in differences between Verbal and Performance scores. For this reason a two-factor (Sex, Handedness) analysis of variance on Verbal-Performance differences was performed. This analysis is summarized in Table 3. Neither the main effects nor the interaction of these was significant.

Table 3

Analysis of variance for WAIS Verbal-Performance differences

Source	SS	d.f.	MS	F
Sex	93.99	1	93.99	<1
Handedness	322.51	2	161.26	<1
Sex x Hand	3230.04	2	1615.02	2.69, n.s.
S/AB	68376.43	114	599.79	

The Six Individual Tests

A second analysis of variance was performed with Sex and Handedness as between-group factors and Tests as a within-group factor. Results of this analysis are summarized in Table 4. In this analysis two effects were significant: the main effect for Sex, $F(1,570)=5.84$, $p < .05$), showing that this population of females performed more poorly overall than the males, and the Handedness x Test interaction,

$F(10,570)=2.37$, $p < .05$). When posthoc comparisons (following Winer, pp. 208-209) were conducted to examine the locus of the interaction effect, it was found that firm-left subjects were significantly better than dextral and mixed-left subjects on the Mill Hill test, $F(1,570)=5.9$, $p < .05$). Firm-left groups were also significantly poorer than dextrals and mixed-left subjects on the Flags test, $F(1,570)=4.8$, $p < .05$. There were no other significant differences between the hand conditions on any other test. Figure 2 depicts graphically results on the Mill Hill and Flags tests.

Table 4

Analysis of variance for four WAIS subtests and two group tests

Source	SS	d.f.	MS	F
Sex	13136.00	1	13136.00	5.84*
Handedness	2565.97	2	2382.98	.57
Sex x Hand	72.74	2	36.37	.16
S	256522.00	114	2250.20	
Test	554.46	5	110.89	.20
Sex x Test	1891.92	5	378.38	.68
Hand x Test	13435.00	10	1343.50	2.37*
Sex x Hand x Test	4806.12	10	480.61	.85
T x S	323347.00	570	567.28	

*p < .05

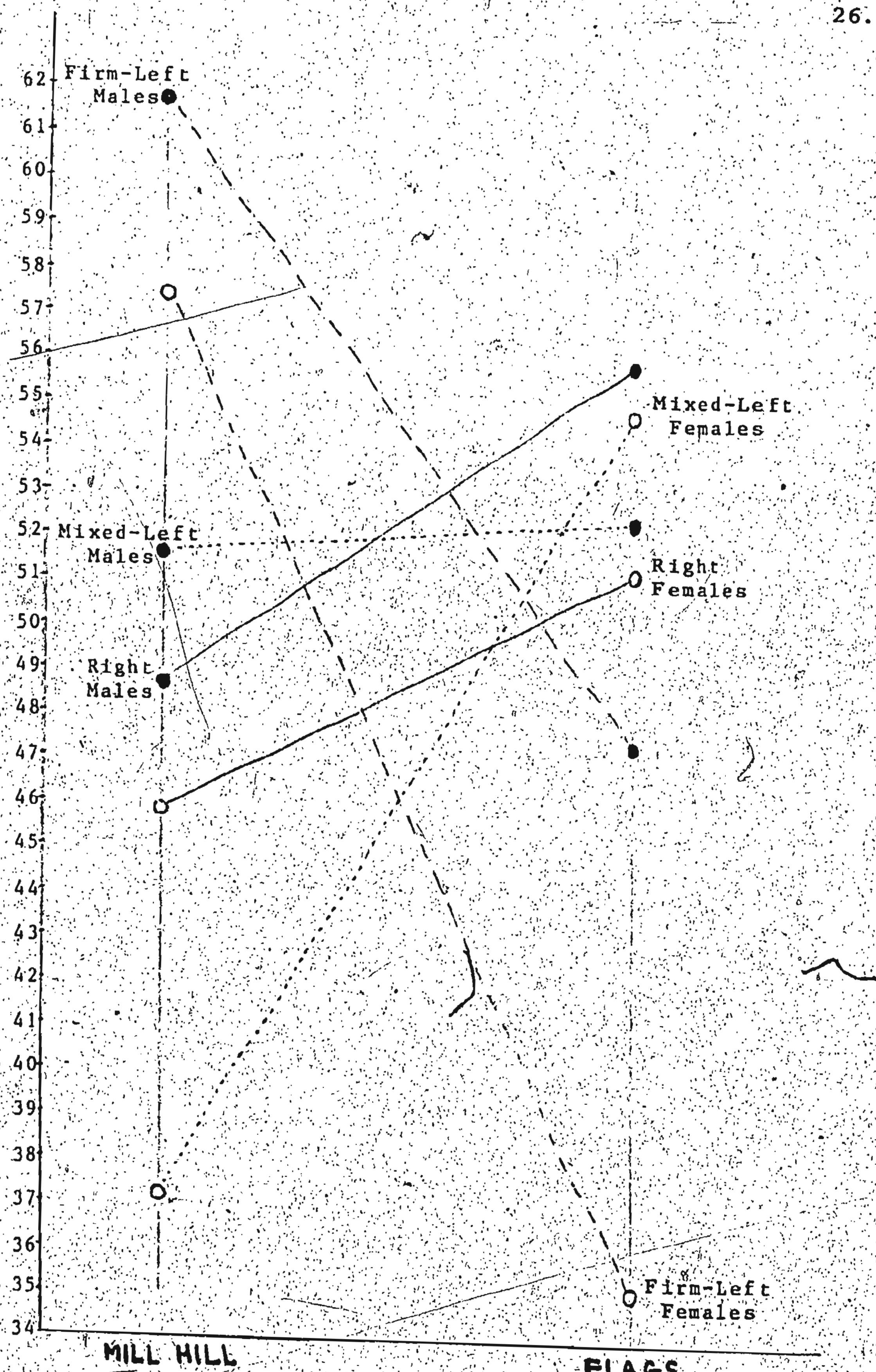

Figure 2.

Mean centiles - Mill Hill and Flags tests.

Vocabulary Measures

When the WAIS Vocabulary test was compared to the Mill Hill test, it was found that mixed-left females performed significantly worse on the Mill Hill ($t=2.20$, $p < .05$). There were no differences among the other groups on these two measures.

Mode of Writing in Left Handers

Thirteen sinistral males wrote with straight wrist and 17 with inverted hand. Among left-handed females, 18 wrote with straight wrist and 12 with inverted hand. These groups were unrelated to degree of consistency in hand perference: within both male and female groups were both firm-left and mixed-left subjects (see Table 5).

Table 5

Mode of writing in sinistral males and females

	Normal Writing		Inverted Hand	
	M	F	M	F
Firm Left	8	9	9	5
Mixed Left	5	9	8	7
TOTALS	13	18	17	12

Table 6 shows mean Verbal and Performance centiles on the WAIS for both males and females. There were no significant differences for males, but inverted-hand females proved to be significantly lower on Performance (t=2.45, p <.05) than females who wrote normally.

Table 6

Mean centiles of inverted and normal writers

	Normal Writing	Inverted Hand	Significance (t-test)
MALES:	(N=13)	(N=17)	
WAIS Verbal	56.51	58.81	n.s.
WAIS Performance	58.36	56.55	n.s.
Mill Hill	53.88	56.69	n.s.
Flags	42.23	54.88	3.47**
FEMALES:	(N=18)	(N=12)	
WAIS Verbal	49.23	43.73	n.s.
WAIS Performance	50.04	41.60	2.45*
Mill Hill	51.17	35.47	3.56**
Flags	50.91	34.97	3.82***

*p <.05
**p <.01
***p <.001

Mean centiles on the Mill Hill and Flags tests are also shown in Table 6. While males in the two groups were not different on the verbal measure, the spatial performance of inverted writers was significantly better than that of males who wrote normally (t=3.47, p <.01). Inverted-hand females were significantly poorer on both the verbal (t=3.56, p <.01) and the spatial (t=3.82, p <.001) test than were females with normal writing.

DISCUSSION

It appears that the group tests (Mill Hill and Flags) are more sensitive to the phenomena examined in this study. The results of those tests lend partial support to the hypotheses. As predicted for the verbal test, neither sinistral males or females (i.e. firm left) nor dextral females were lower than right-handed males on the verbal measure. On the spatial test, all differences were in the predicted directions, but spatial impairment in females was statistically confirmed for sinistrals (i.e. firm left) only. Dextral females were not different from dextral males. Thus the predicted handedness effect in spatial ability was confirmed, while the sex effect was not. It appears then, that handedness is a better predictor of spatial ability than is sex.

Both groups of firm left handers showed the elevated verbal score on the Mill Hill which was found in a factor analysis of Levy's Caltech sample of left handers. In the present study firm-left males scored highest of all the groups on the verbal test, followed by firm-left females, and both of the firm-left groups were significantly higher than all other groups on this test.

The predicted impairment for left handers on the Flags test was apparent only for <u>firm</u> left handers; mixed-left males and females were not significantly different from dextrals on either the spatial or the verbal measure.

Results on the WAIS tests were not the same as those on the group tests. No significant differences were found in an analysis of Verbal-Performance difference scores, and although Figure 1 suggests a Sex x Task interaction for mixed-left subjects, this interaction did not prove significant in an analysis of the individual subtests.

There are several possible explanations for the failure of the WAIS measures to find the hypothesized differences. First, the WAIS may not be able to detect such differences in a sample of moderate intellectual ability. Levy's Caltech sample had a mean Verbal I.Q. of 142 for left handers and 138 for right handers--exceptionally high levels for both groups. These subjects were also high on the Performance scale, right handers having a mean of 130 and left handers (the "impaired" group) of 117. By comparison, in the present sample left handers had a mean Verbal I.Q. of 116.72 and right handers a mean of 114.04, while Performance I.Q.s for the two groups were 108.73 (left handers) and 111.29 (right handers). Thus it seems possible that a "floor" effect in our more average sample precluded the possibility of obtaining the significant Verbal-Performance discrepancy found in Levy's left handers. In order to observe the same 25-point Verbal-Performance difference in left handers which Levy found at Caltech, our left handers would have had to score in the retarded range on Performance I.Q. It is interesting to note that when our left-handed males were divided into an upper and a lower group according to I.Q., it was found that the 15 with I.Q.s in the 120-139 range had a Verbal-Performance discrepancy of 12.17, whereas the 15 with I.Q.s in the 94-118 range had a Verbal and Performance mean which were almost identical (Verbal=110.13, Performance=110.80). This suggests that a large Verbal-Performance discrepancy on the WAIS is much more likely to be found among higher-I.Q. subjects.

Another possible explanation for the failure of the WAIS measures to detect the effects found on the group tests is that the Flags test constituted a purer measure of spatial ability than did the two subtests used to measure Performance on the WAIS. While the verbal pattern was similar for all groups (except mixed-left females) on the two vocabulary measures, the perceptual-spatial pattern was not. It seems clear, therefore, that our two WAIS Performance subtests were not tapping the same cognitive function as that measured by the Flags test. Block Design has been shown to be influenced by rate of motor activity (Freeman, 1964; Wechsler, 1958). Moreover, both Block Design and Picture Arrangement have been shown to correlate rather highly with overall Verbal score on the WAIS: for Block Design the correlation is .69 and for Picture Arrangement, .64 (Wechsler, 1958). Factor analysis of the Flags test, on the other hand, found a slight negative (-.12) correlation with the verbal factor extracted from tests of verbal ability (Di Vesta et al, 1971). Freeman (1964) points out that the so-called "nonverbal" WAIS subtests can, in fact, involve the ability to verbalize the colour-and-form relationships of each block design before reproducing it, or to verbalize the story told by the Picture Arrangement cards before placing them in sequence. Thus certain subjects may have used verbal mediation in the Block Design and/or Picture Arrangement tests, whereas on the Flags test a verbal strategy would not be helpful.

It is also possible that the Flags test was able to detect spatial differences better than the WAIS because the former represents a more complex visuo-spatial task. The Block Design test requires only that the subject arrange blocks to form a copy of a printed design, and may thus be seen as a "matching" task, while the Flags test requires the subject to perform a genuine spatial shift--i.e. mentally rotating a figure in order to determine whether it is the same as or the opposite to another figure.

The results for normal- and inverted-writing left handers were different for males and females. While males with inverted writing were not different from normal-writing males on either of the verbal measures or on WAIS Performance, inverted writers were significantly better on the Flags test than were normal-writing males. Their performance on this spatial measure was, in fact, not different from that of right-handed males. This is consonant with Levy and Reid's (1976) finding that inverted writers, like right handers, had superior dot location in left visual field, implying a right hemisphere specialized for spatial functions. The poorer spatial performance of normal writers is understandable if, as Levy and Reid (1976) suggest, these persons have right hemisphere language dominance, since this would be expected to "crowd out" the spatial function which in most people is located in the right hemisphere.

Among left-handed females, however, inverted writers were significantly impaired on both of the right-hemisphere measures (WAIS Performance and Flags), relative to normal-writing females, as well as on the Mill Hill verbal measure. (They were also poorer on the WAIS Verbal measure, but this difference did not reach significance.) These results suggest lack of specialization for either verbal or spatial functions in such females, leading to impaired performance on both, which is consonant with Levy and Reid's (1976) finding of weaker lateralization in inverted writers, particularly females. However, a closer inspection of our data for inverted-hand females revealed that it was primarily the firm-left subjects who contributed to the poor spatial performance (17th centile), while on the verbal measure these subjects were close to average (42nd centile). Mixed-left subjects, on the other hand, were primarily responsible for the poor verbal performance of the group (31st centile), while on the spatial measure they were not impaired (48th centile). This pattern of firm-left and mixed-left subjects contributing differentially to verbal and spatial means was not true for inverted-hand males.

Since inverted-writing firm-left females exhibited the same spatial deficit as did normal-writing sinistral males, it is possible that these females have the same pattern of lateralization as that which Levy and Reid (1976) propose for normal-writing sinistrals--i.e. right hemisphere language dominance and left hemisphere spatial competence. The reverse pattern, which Levy and Reid (1976) describe for inverted writers, would apply then only to mixed-left females of this writing mode. These could be persons with both language and preferred hand controlled by the left hemisphere, a sharing of function which might explain the poor verbal competence demonstrated by this group.

CONCLUSIONS

These data support a hypothesis of cognitive differences reflecting differences in brain laterality, but with a stronger weighting for handedness than for sex. Poorer spatial ability was evidenced in sinistrals, for whom previous studies have inferred less clear lateralization, but not for females as a whole. A recent study (Waber, 1976) which used a dichotic listening task to determine lateralization confirmed the relationship between spatial ability and degree of lateralization found in the present study, those groups having better spatial ability relative to verbal ability also being most lateralized. However, these issues are apparently much more complex than some previous studies have suggested.

It is obviously not accurate to make inferences about brain laterality in females as a group, for right-handed females perform quite differently from left-handed females on certain tasks, and even among sinistral females are sub-groupings with different cognitive abilities. The same is true for males.

Nor can one confidently describe "left handers" without qualification concerning degree of firmness in hand preference, for sinistrals clearly are a far from homogeneous population. Persons whose hand preference is firmly left manifest a pattern of abilities quite different from those who call themselves left-handed because they write with the left hand but who use the right for other common activities. Even within a firm-left or mixed-left population there appear to be differences according to mode of writing and according to sex within the writing-mode parameter. Thus the simple dichotomous classification of handedness employed in many previous studies is clearly inadequate.

The Annett questionnaire proved to be an effective instrument for separating firm left handers from those of mixed preference, and seems preferable to other handedness questionnaires because the items have been shown to coordinate with manual skill. Future work on lateralization of functions should include a careful definition of handedness and allow for the separation of firm left handers from those of mixed preference.

There is also a need for a clearer definition of what constitutes "spatial" ability. Researchers may have been too general in claiming that left handers and/or females are poorer perceptually or spatially. In the present study the WAIS subtests designed to tap perceptual-spatial functions did not reveal the deficit detected by the Flags test. Moreover, none of the three "spatial" tests employed here detected the spatial deficit in right-handed females which other tests in previous studies have found. It seems important, therefore, that closer attention be paid to the particular tests which detect various aspects of cognitive function. There may be different kinds of spatial handicaps which have not yet been distinguished, and these may relate differentially to various sex and handedness groups.

The same may be true for tests of "verbal" ability. In the present study, for example, mixed-left females were significantly worse on the Mill Hill test than on the WAIS Vocabulary test. It is difficult to explain why two tests supposedly tapping an identical cognitive function should have different effects, and why such a difference should be manifested in only one subject group.

While the present study failed to confirm the cognitive sex differences found in previous studies, the issue of sex differences in cognition is obviously far from settled. There is an urgent need for researchers to treat sex as a separate variable in studies of cognitive function, and to report often-neglected aspects of handedness in studies which deal with that area. The all-too-common practice of grouping together males and females and thus obliterating sex differences, or using only male subjects and thus ignoring such differences, constitutes a serious handicap in this area. A recent example is Wada et al's (1975) fascinating report of right hemisphere language dominance and mixed language dominance in both "pure" right handers and "pure" left handers. Are these subjects male, female, or both? Do right handers with unusual dominance include a disproportionate number of females? What is the mode of writing in these left handers?

Clearly, the understanding of sex differences in cognition as related to brain laterality calls for a great deal of further research. A study conducted concurrently with the present study argues that apparent sex differences may instead reflect differences in maturation rate. Investigating the effects of early or late maturation on verbal and spatial abilities in adolescence, Waber (1976) found that sex accounted for only a small proportion of the variance in comparison to maturational rate. Those maturing late were more lateralized for speech and better spatially, while the opposite was true for those maturing early. Since maturational rate was shown to be related to spatial, but not verbal, ability, Waber (1976) suggests that sex differences in these two cognitive functions may have different etiologies and cannot be explained by a common set of causes. Some time ago Sherman (1967) also proposed that girls' earlier development of speech was related to their poorer spatial ability in adulthood, arguing that early language development inhibits the development of nonverbal, particularly spatial, thought. However, as noted earlier, a female language advantage in childhood has not been established; moreover, it is not known whether the rate of maturation observed in adolescents is a true measure of the earlier rate of maturation. What appears to be needed are longitudinal studies of maturation rate from infancy to adolescence, to observe the development of verbal and spatial ability and lateralization in males and females.

Fairweather (1976) recently surveyed the literature on sex differences in cognitive skills and concluded there is suggestive evidence that verbal and spatial abilities are more symmetrically represented across the cerebral hemispheres in the female brain than in the male brain, but that much more research is needed to identify the role played by age, birth order, culture, sex of experimenter, and sex role pressure in the development and measurement of different cognitive skills in males and females. While the present study has not touched upon the influence of socialization on the expression of sex differences, its contribution is undoubtedly an important one, and the interaction of environmental influences with the phenomena which are the subject of this study should not be overlooked.

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APPENDIX A

ANNETT HANDEDNESS QUESTIONNAIRE

Please indicate which hand you use or would use for each of the following activities. Put a circle around R (for right)
or L (for left)
or E (for either).

1.	To write a letter legibly?	R L E
2.	To throw a ball to hit a target?	R L E
3.	To hold a racket to hit a ball?	R L E
4.	To hold a match whilst striking it?	R L E
5.	To hammer a nail into wood?	R L E
6.	To hold a toothbrush while cleaning your teeth?	R L E
7.	To cut with scissors?	R L E
8.	To guide a thread through the eye of a needle (or guide a needle onto thread)?	R L E
9.	At the top of a broom while sweeping?	R L E
10.	At the top of a shovel when moving sand?	R L E
11.	To deal playing cards?	R L E
12.	To unscrew the lid of a jar?	R L E

APPENDIX B

MILL HILL VOCABULARY SCALE (SYNONYMS SUBTEST)

In each group of six words below, underline the word which means the same as the word in heavy type above the group, as has been done in the first example:

1 TOMATO

fly	crack
wood	dunce
fruit	step

2 REST

lie down	sing
go away	taste
run up	cry

3 PATCH

switch	watch
hand	bang
mend	cook

4 AFRAID

pleased	warm
goodness	horse
tired	frightened

5 CRUEL

clean	green
pretty	found
water	unkind

6 BLAZE

kitchen	flare
grass	roof
coat	side

7 ACHE

screen	tree
prize	pain
boom	land

8 SQUABBLE

quarrel	lift
babble	photo
mould	saw

9 RAGE

crease	love
invite	anger
rain	hoist

10 SHRIVEL

linger	heed
volunteer	haunt
wither	shiver

11 CONNECT

accident	join
lace	bean
flint	field

12 PROVIDE

harmonize	commit
hurt	supply
annoy	divide

13 STUBBORN

obstinate	steady
hopeful	hollow
orderly	slack

14 SCHOONER

building	man
ship	singer
plant	scholar

15 LIBERTY

worry	freedom
rich	serviette
forest	cheerful

16 COURTEOUS

dreadful	proud
truthful	short
curtsey	polite

17 RESEMBLANCE

attendance	fondness
assemble	repose
likeness	memory

18 THRIVE

flourish	try
thrash	reap
think	blame

19 PRECISE

natural	stupid
faulty	grand
small	exact

20 ELEVATE

revolve	move
raise	work
waver	disperse

21 DWINDLE

swindle	pander
diminish	wheeze
linger	compare

22 LAVISH

unaccountable	selfish
romantic	lawful
extravagant	praise

23 WHIM

complain	noise
tonic	fancy
wind	rush

24 SURMOUNT

mountain	descend
overcome	concede
appease	snub

MILL HILL SYNONYMS - continued

25 BOMBASTIC

democratic	pompous
bickering	cautious
destructive	anxious

26 RECUMBENT

fugitive	cumbersome
unwieldy	repelling
reclining	penitent

27 ENVISAGE

contemplate	activate
surround	estrange
enfeeble	regress

28 TRUMPERY

worthless	heraldry
etiquette	highest
amusement	final

29 GLOWER

extinguish	shine
disguise	gloat
aerate	scowl

30 PERPETRATE

appropriate	commit
propitiate	deface
control	pierce

31 LEVITY

parsimony	velleity
salutary	frivolity
alacrity	tariff

32 LIBERTINE

missionary	rescuer
profligate	canard
regicide	farrago

33 AMULET

savoury	jacket
flirtation	crest
cameo	charm

34 QUERULOUS

astringent	fearful
petulant	curious
inquiring	spurious

35 TEMERITY

impermanence	rashness
nervousness	stability
punctuality	submissiveness

36 RECUND

esculent	optative
profound	prolific
sublime	salic

37 ABNEGATE

contradict	decry
renounce	execute
belie	assemble

38 TRADUCE

challenge	attenuate
suspend	establish
misrepresent	conclude

39 VACARY

vagabond	caprice
obscurity	vulgarity
evasion	fallacy

40 SPECIOUS

fallacious	coeval
palatial	typical
nutritious	flexible

41 SEDULOUS

rebellious	dilatory
complaisant	diligent
seductive	credulous

42 NUGATORY

inimitable	adamant
sublime	contrary
numismatic	trifling

43 ADUMBRATE

foreshadow	protect
detect	eradicate
elaborate	approach

44 MINATORY

implacable	diminutive
belittling	quiescent
depository	threatening

FLAGS

A Test of Space Thinking

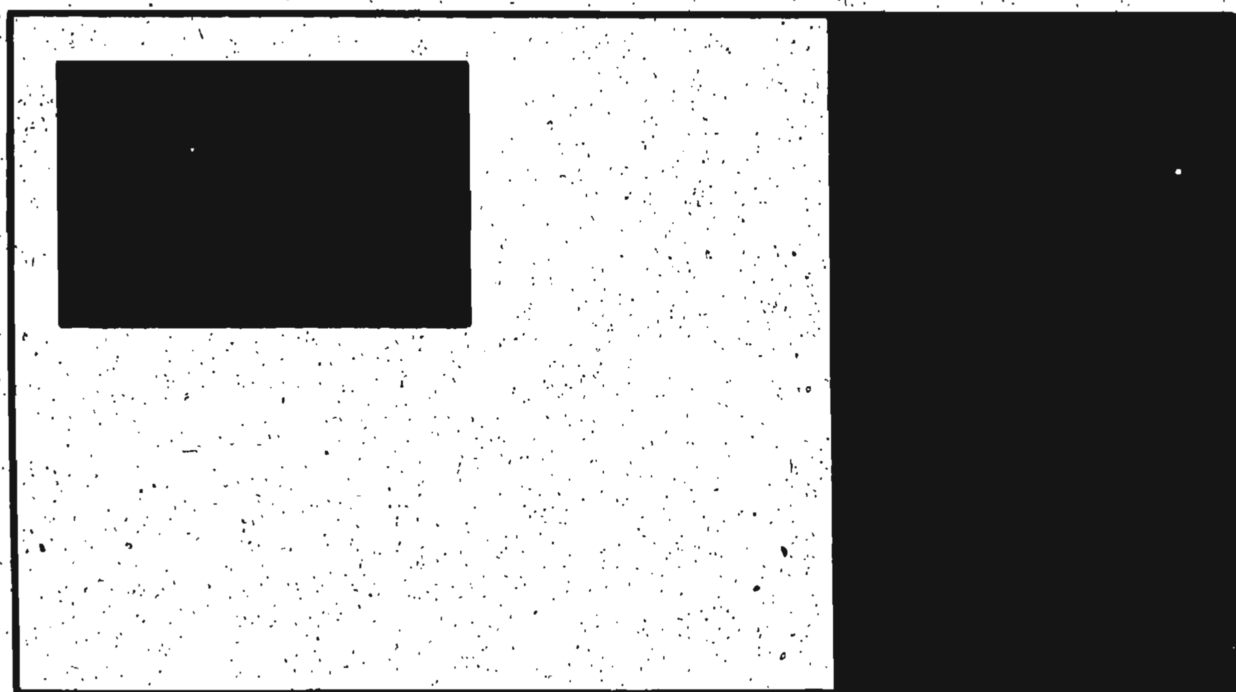
Please fill in:

Name ______________________

Age ________ Sex ________ Date ________

Occupation ______________________

Prepared by: L. L. Thurstone and T. E. Jeffrey
The Psychometric Laboratory
The University of North Carolina



Here is a picture of a flag. Notice the position of the black portions of the flag. The black stripe is along the right-hand edge, and the black rectangle is in the upper left corner of the flag.

The opposite side of this flag is shown on the next page.

GO TO THE NEXT PAGE. DO NOT WAIT FOR ANY SIGNAL.

TMNF 114
7-8-1000

FORM A

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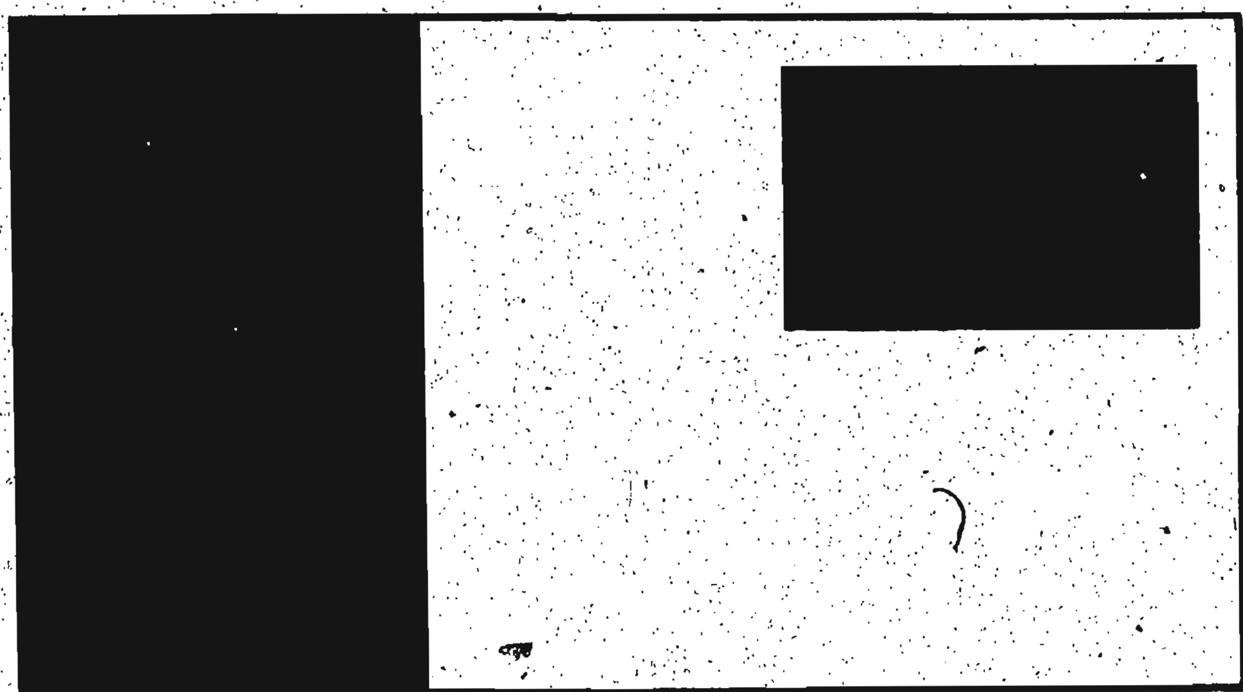
THE CHARLES STEWART MOTT BUILDING

Here is the opposite side of the flag shown on the first page. Notice that the location of the black portions of the flag is different. The black stripe is along the left-hand edge and the black rectangle is in the upper right corner of the flag.



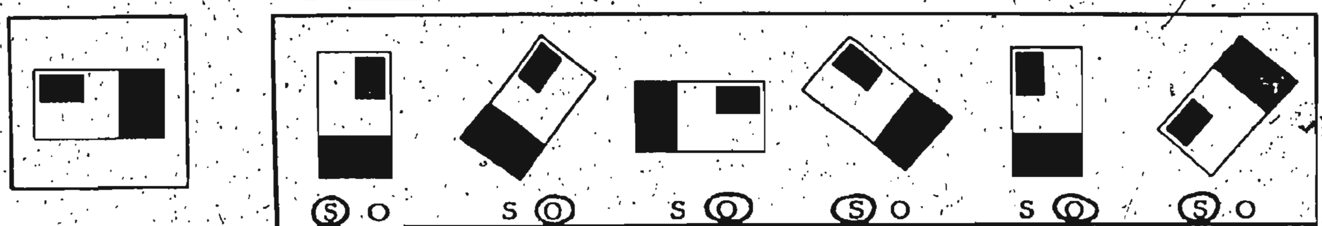
GO TO THE NEXT PAGE. DO NOT WAIT FOR ANY SIGNAL.

The two sides of the large flag previously shown appear below. Notice that you can not slide one around on the page to look exactly like the other one. Each picture is the opposite side of the other. One must be picked up and turned over in order to make it look exactly like the other one. This was demonstrated with the large flag.

The next two pictures are of the same side of the flag. You can slide one of the pictures around on the page so that it looks exactly like the other one.

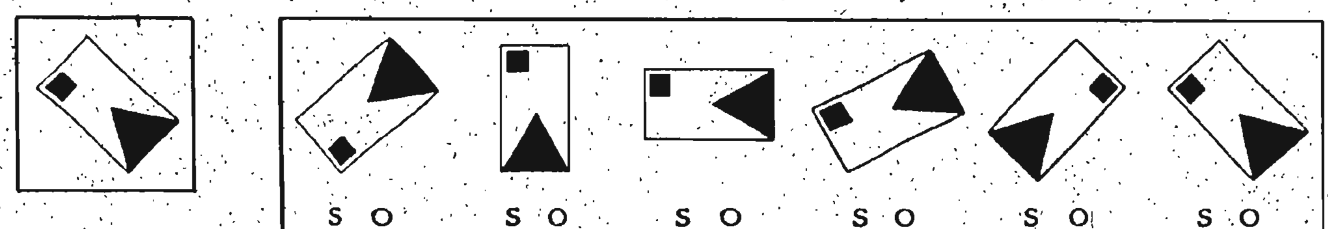
Below are more flags. For each of the six flags in the right-hand box, circle the letter S if the flag shows the same side as the single flag in the box at the left; circle the letter O if the flag shows the opposite side of the single flag at the left. This row has been marked.

a

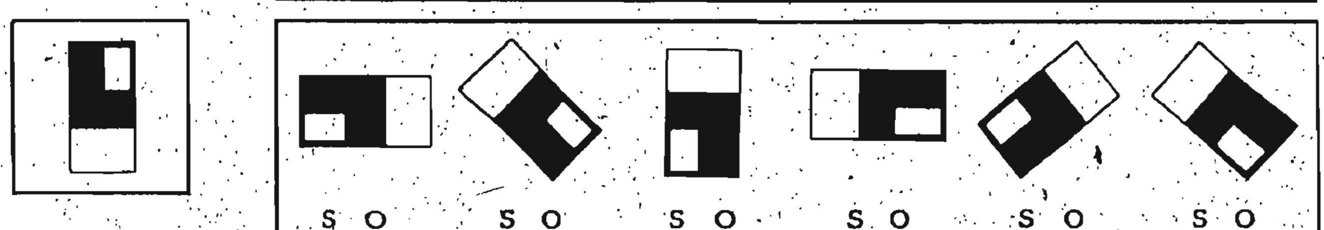


Here are two more rows of flags for practice. Mark all flags. REMEMBER: Circle the letter S if the flag shows the same side as the single flag in the box at the left; circle the letter O if the flag shows the opposite side of the single flag at the left. GO RIGHT AHEAD.

b



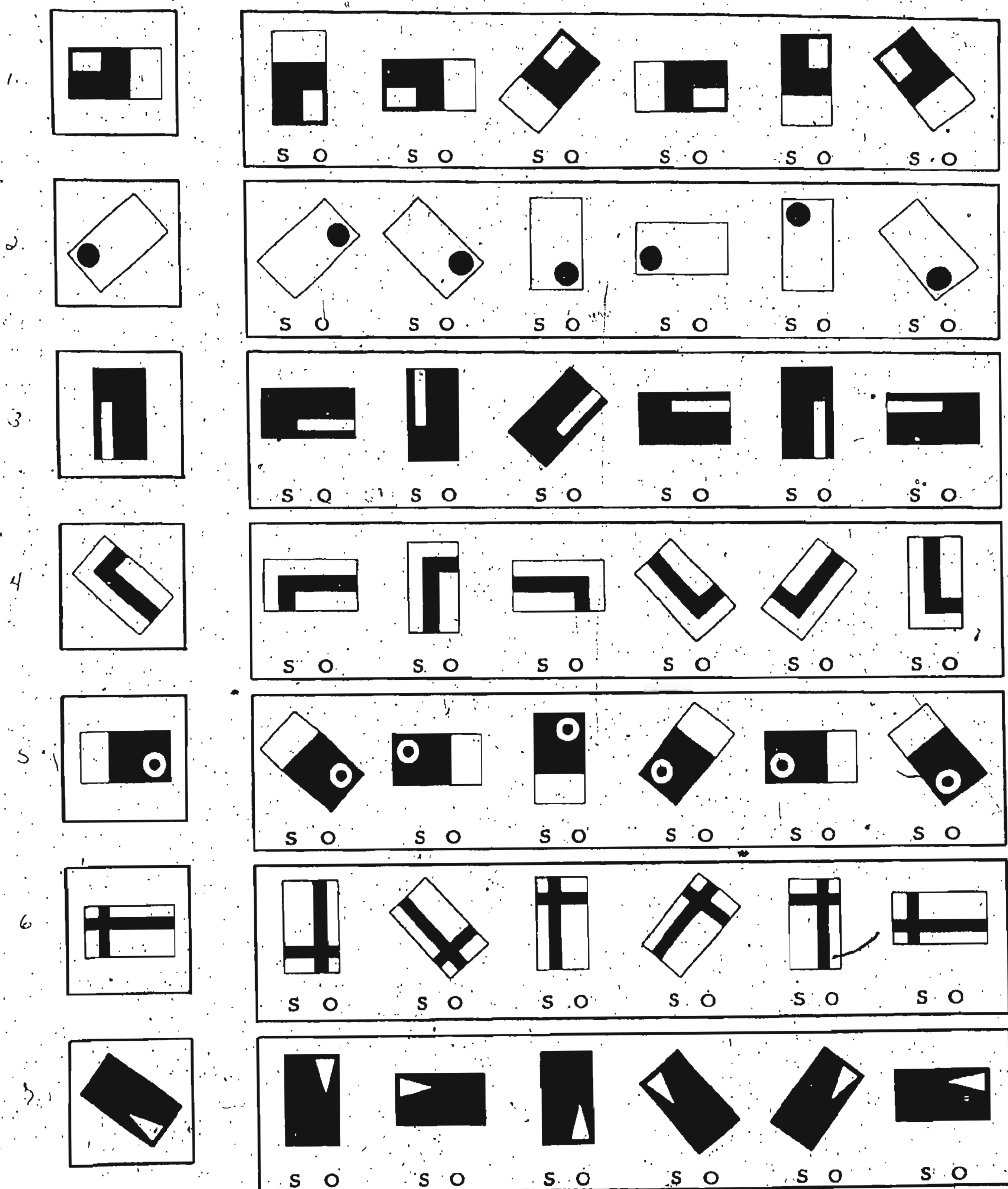
c



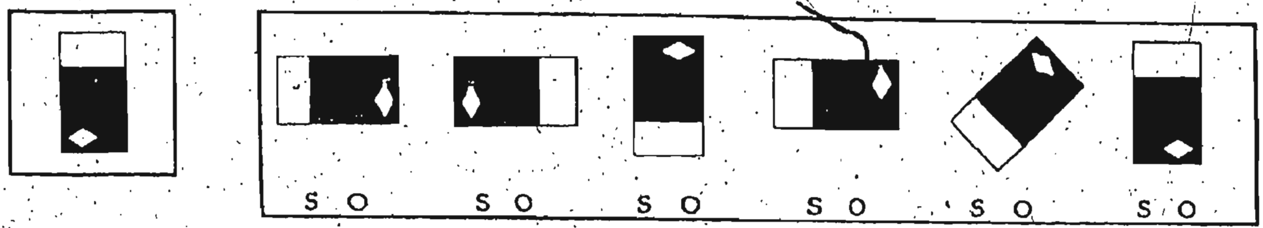
The answers for the first row from left to right are S S O O O S. The answers for the second row from left to right are O O S S S S.

WHEN YOU GET THE SIGNAL TO BEGIN, turn the page and mark more problems of the same kind. Work as fast and as accurately as you can, but do not guess. Wrong answers will count against you. You are not expected to finish in the time allowed. You will have exactly five minutes to do as much as you can.

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.



GO TO THE NEXT PAGE. DO NOT WAIT FOR ANY SIGNAL.

8.


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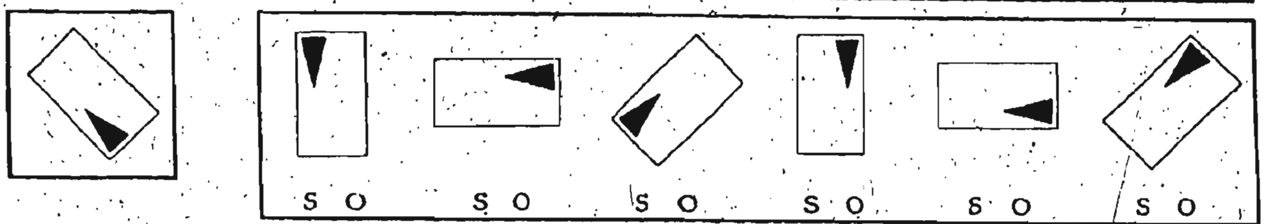

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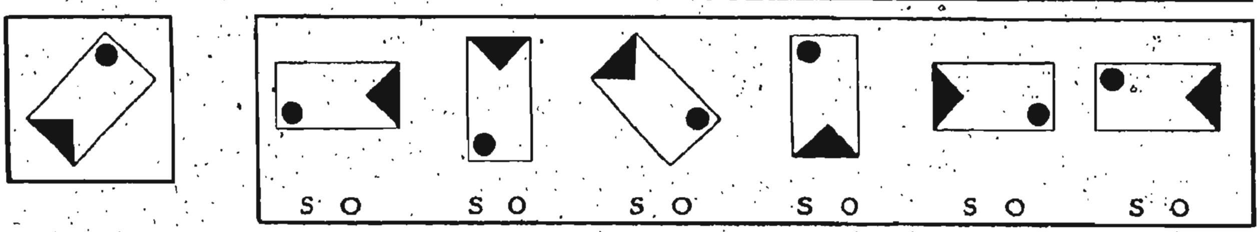

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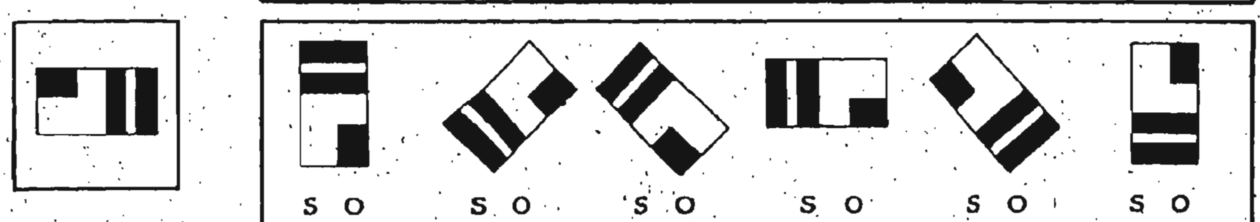

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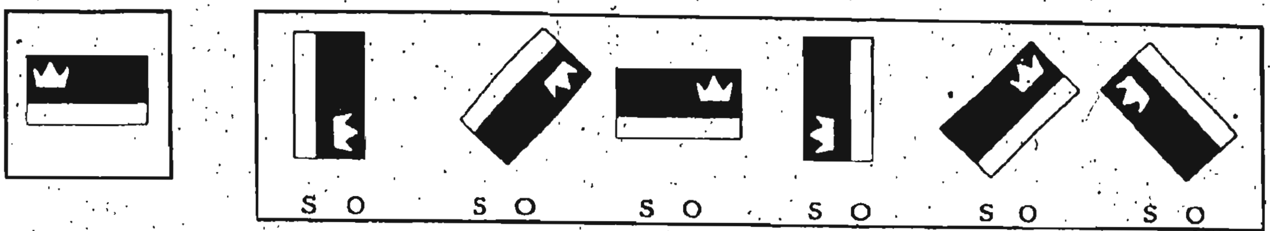
GO TO THE NEXT PAGE. DO NOT WAIT FOR ANY SIGNAL.

15



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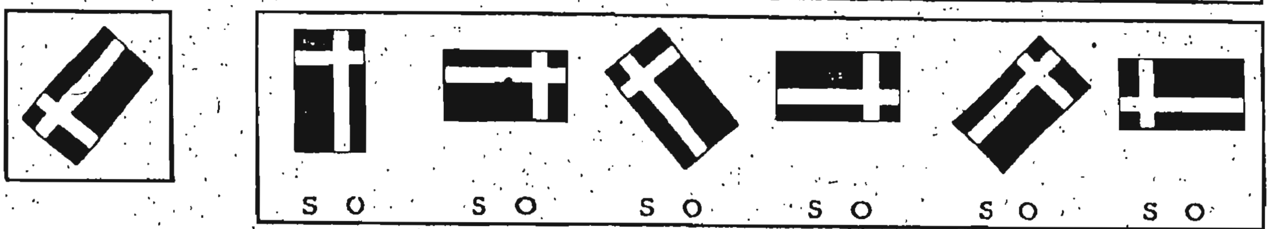

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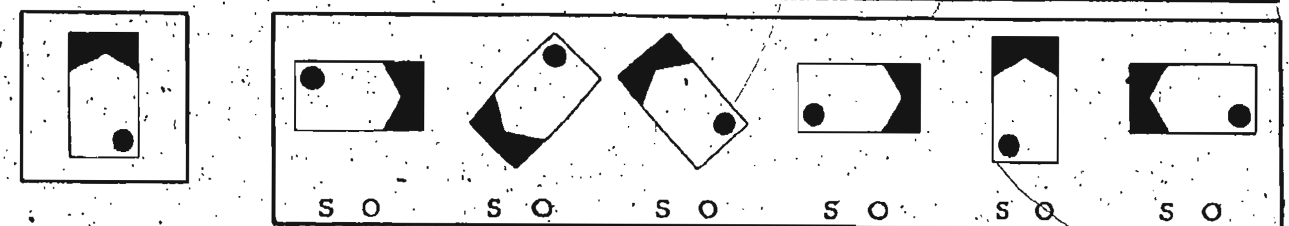

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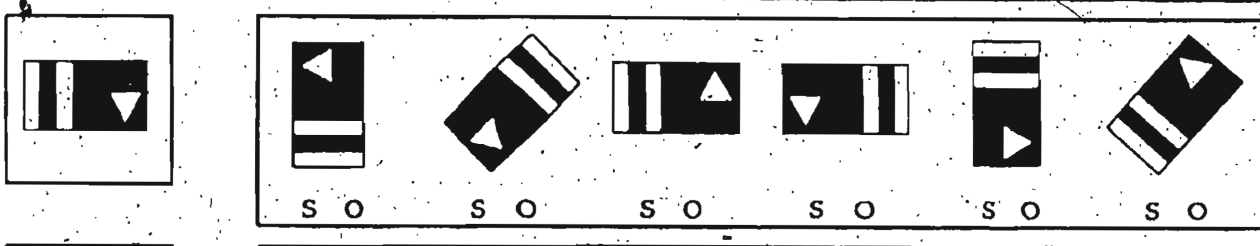

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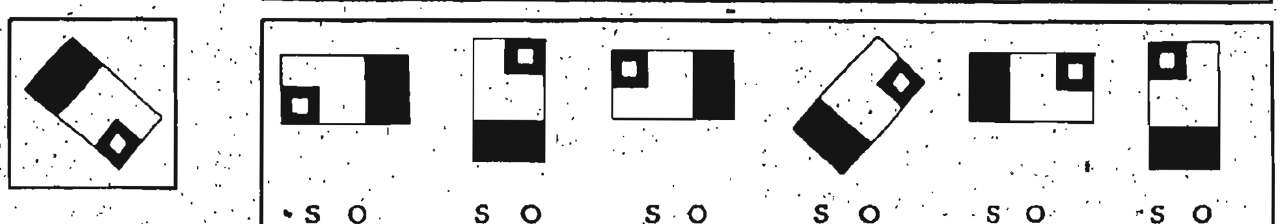
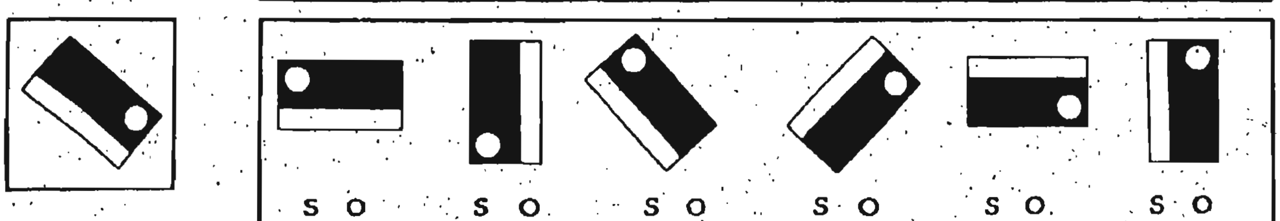


20



21

STOP HERE.