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NOTE

SEX ROLE AND SPATIAL ABILITY: AN EEG STUDY

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Abstract—The purpose of this study was to examine the relationship between sex role and spatial ability using both performance and electrocortical (EEG) measures. Two hundred and fifty four subjects were given the Differential Aptitudes Space Relations Test and a short form of the Personal Attributes Questionnaire (PAQ) which gives an indication of sex role. From this initial group, 40 males and females were chosen based on sex role scores. These subjects were asked to solve additional visuo-spatial problems. Bilateral EEG measures were taken from the frontal and parietal areas. The results indicate that frontal EEG measures are related to the sex role orientation of the subjects whereas parietal EEG measures are associated with performance on the visuo-spatial task for males but not females. These results suggest that frontal and parietal EEG measures reflect different processes. Counter to the traditional hypothesis, performance on the visuo-spatial task was negatively related to masculine sex-role orientation suggesting that factors which influence spatial processing go beyond biological sex.

INTRODUCTION

RECENT RESEARCH indicates that men and women differ in the degree to which the cerebral hemispheres are specialized for processing different types of information. In general, visual spatial functions are represented in the right hemisphere, whereas verbal functions are typically represented in the left hemisphere. Such functional specialization of the hemispheres has been termed hemispheric lateralization and evidence suggests that men are more lateralized than women (see review by McGLONE [10]).

Recent EEG studies have shown that, at least among right-handed subjects, men tend to process visual spatial information in the right hemisphere more than do women. For example, WOGAN *et al.* [20] found that, for males, EEG activity in the alpha frequency range was greater in the left hemisphere (relative to the right) during performance of the Block Design subtest of the Wechsler Adult Intelligence Scale (WAIS). Since alpha activity has been interpreted as reflecting cortical deactivation, these results would indicate more right hemisphere involvement during the task. The reverse pattern of hemispheric involvement (i.e. more involvement of the left hemisphere) was evident during performance of a verbal task. Females showed no such consistent task-dependent patterns of EEG activity. RAY *et al.* [15] reported similar patterns of EEG activity in subjects presented with tasks more closely resembling those encountered in daily life (listening to music, mathematical addition and multiplication, visualizing a scene, etc.). Again, males were found to exhibit differential hemispheric involvement, dependent upon the type of task, whereas females showed no consistent pattern. Further, TROTMAN and HAMMOND [19] also found that males showed task-dependent differences.

It has been suggested (e.g. [6, 7]) that this sex difference in hemispheric lateralization serves as the neurophysiological basis underlying previously demonstrated sex differences in spatial abilities [8], which have shown men to perform better than women on tests of visual spatial ability. Research evidence has indicated a positive relationship between degree of hemispheric lateralization and performance on spatial tasks. McGLONE and DAVIDSON [11] found that men outperformed women on tests of spatial ability while at the same time evidencing more right hemispheric involvement in spatial processing. The same lateralization/performance relationship has been demonstrated by GUR and REIVICH [4], using direct blood flow measures of hemisphericity, and by FURST [2]

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and RAY *et al.* [16]). It snould be noted that the RAY *et al.* study also analysed for sex and found a relationship between EEG hemispheric activity and spatial ability for males but not females.

However, in a review of current methodological issues in this area, NEWCOMBE [14] points out the plausibility of other explanations implicating the influence of strategy and experiential factors. Sociocultural influences, such as sex role socialization, have been shown related to spatial ability. Several studies have found self-rated masculinity to be positively correlated with performance on spatial tasks [1, 5, 12, 13]. Further, when masculinity and femininity are assessed separately, it appears that masculinity is the dimension of greater influence [1]. Hence, it has been suggested that differences in socialization also contribute significantly to the development of sex diffferences in spatial ability (e.g. [17]).

With this in mind, it would seem inappropriate to conclude that sex differences in spatial ability are totally biologically determined via neurophysiological influences as LEVY [7] seems to suggest. This is especially unwarranted given that neurophysiological studies do not typically control the influence of sex role. In fact, sex role is likely to have a confounding influence in these studies, since the various sex role classifications are not equally distributed throughout the general population [9, 18]. In short, high-masculinity males are more likely to be selected as subjects in neurophysiological studies than low-masculinity males. Conversely, low-masculinity females may be represented more in these samples than are high-masculinity females.

The purpose of the present study was to examine three types of relationships: (1) the relationship of sex role to EEG (specifically, measures of hemispheric lateralization of spatial function); (2) the relationship of sex role variables to performance on a spatial ability test; and (3) the relationships of EEG laterality measures to spatial task performance when sex role is taken into account.

METHODS

Subjects

Subjects were undergraduate introductory psychology students at The Pennsylvania State University. Forty right-handed subjects (20 male; 20 female) were selected to participate in the experiment, on the basis of a sex role questionnaire, from an initial pool of 254 students (114 male; 140 female). Participation in the experiment was voluntary.

Instruments and measures

Handedness was assessed via an 18-item questionnaire in which the subject indicated with which hand he/she performed various tasks. The last item of the scale inquired about sinistrality in the subject's immediate family. Subjects were considered right-handed if they made no more than three non-right-handed responses and reported no sinistrality in their immediate family.

Sex role self-ratings were obtained using the short form of the Personal Attributes Questionnaire [18]. The PAQ requires the subject to rate him/herself along a series of bipolar continua (e.g., 'I am very competitive' vs 'I am not at all competitive'). Separate scales are derived to assess degree of masculinity and femininity, respectively. Subjects are then classified into four sex role groups: masculine (high masculinity, low femininity), feminine (low masculinity, high femininity), androgynous (high masculinity, high femininity) and undifferentiated (low masculinity, low femininity). Using this procedure, eight sex × sex role groups were defined, from each of which five subjects were chosen at random to participate in the study.

Fifty items from the Differential Aptitudes Space Relations Test were administered in the screening session to provide an index of spatial ability. This multiple-choice test required subjects to choose the correct three-dimensional figure that could be formed by folding together a given two-dimensional pattern. The number of correct responses given within a 35-min time limit served as a subject's score (these scores were not utilized for subject selection, however). Five items of similar difficulty from this test were not administered in the screening session and served as the spatial task in the experimental session.

Hemispheric laterality indices were calculated on EEG power figures in both the alpha frequency band (8–12 Hz) and the beta frequency band (20–24 Hz) for both frontal and parietal sites using the formula: (right − left)/(right + left).

Procedure

The experimental session occurred from 1–6 weeks following the screening session. Subjects were seated in a comfortable lounge chair while sponge-tipped EEG electrodes were attached, using an elasticized cap, over left and right frontal (F3 and F4) and parietal (P3 and P4) sites. These electrodes were referenced to linked ears. An impedence of 6000 Ohms resistance between electrodes and reference was used as a criterion. Visual inspection of ongoing EEG tracings was employed to detect potential muscle or eye movement artifact.

EEG signals were amplified by a Beckman R612 dynograph and then analysed by a FFT program (Fast Fourier) running on a PDP 11/34 computer, computer sampling was approximately 100/sec. Following initial tape-recorded instructions, one baseline sample of EEG was taken. Further instructions were then given concerning the experimental task. One task consisted of the five DAT items not used during the screening, while the other task was comprised of five short verbal paragraphs which subjects were asked to read in order to answer questions regarding the content. All tasks were presented, via a slide projector, for 30 sec, during which EEG was recorded. After EEG sampling was completed, each subject was asked to give a verbal answer. The order of tasks was counterbalanced across sex and sex role. Because the focus of the present investigation concerned the relationships of sex role and EEG to spatial ability, only data from the spatial task will be presented in this paper.

RESULTS

To examine the effect of sex role on hemispheric lateralization four factor analyses of variance (sex × masculinity × femininity × task) were performed using EEG data. Separate analyses were performed for alpha (8–12 Hz) and beta (20–24 Hz) activity using the ratio (R − L/R + L) for the frontal and parietal areas. The factor was comprised of data collected during baseline and task performance. Analysis of frontal EEG activity (8–12 Hz) revealed a significant sex × masculinity × femininity interaction [$F(1, 32) = 6.84$, $P < 0.05$]. Comparison of the individual cell means in this interaction was performed using the Tukey Wholly Significant Difference (WSD). The results of this comparison show that masculine men and feminine women differed significantly ($P < 0.05$) with regard to mean lateralization index (see Fig. 1). Masculine men showed more relative left hemisphere alpha activity. Feminine women, on the other hand, showed a more equal activity with a slight tendency toward more alpha in the right hemisphere. All other cell means fell in nonsignificant ranges between these two extremes. Beta activity was not

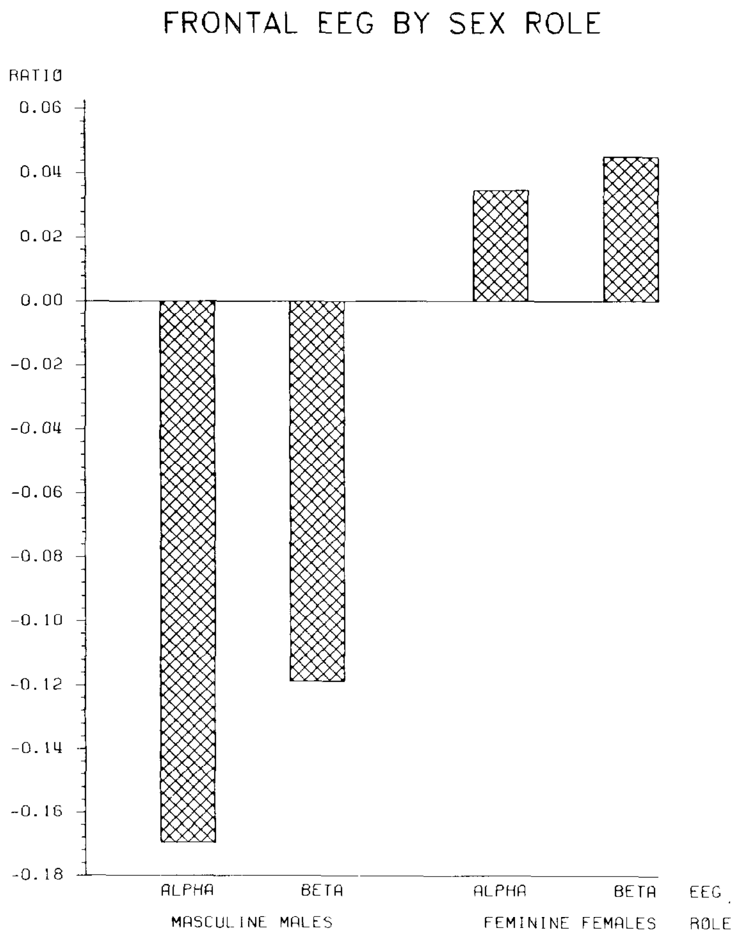

FIG. 1. EEG frontal ratio data of alpha activity for masculine men and feminine females. Follow-up statistics differences for alpha activity.

significantly different between groups although it is interesting to note the similarity of alpha and beta activity presented in Fig. 1. The only significant analysis involving task was a sex × masculinity × task interaction found in frontal alpha activity [$F(1, 32) = 4.51$, $P < 0.05$]. No significant main or interaction effects were found in the parietal EEG data for the sex role variable.

A three-factor analysis of variance (sex × femininity × masculinity) was performed on responses to the 50 DAT items to assess the influence of sex role upon spatial performance. A significant main effect for masculinity was found [$F(1, 32) = 7.06$, $P < 0.05$]. Subjects low in masculinity answered more DAT items correctly than did subjects high in masculinity, with mean number of correct responses for the two groups being 36.95 and 28.45, respectively.

Finally, males showed a significant correlation ($r = 0.47$, $P < 0.05$) between baseline parietal EEG power ratios in the beta range (20–24 Hz) and spatial performance scores. Examining this correlation in specific sex role groups revealed a fairly strong, though nonsignificant, correlation for androgynous males ($r = 0.85$, $P < 0.067$). Females showed no correlation between EEG measures and spatial performance scores.

DISCUSSION

The results of the present study are noteworthy on a number of counts. First, the present findings indicate that there exist distinct patterns of lateralization for sex role stereotyped men and women (i.e. masculine men and feminine women), as evidenced by the significant sex × masculinity × femininity interaction. These findings indicate that masculine men tend to evidence more relative right hemispheric activation (via left hemisphere deactivation), whereas feminine women evidence a more bilateral pattern of activation. This finding is significant in that it conforms to previous generalizations about sex differences in hemispheric lateralization. This would suggest the possibility that sex differences in hemispheric lateralization may reflect difference due to sex role stereotypy more than differences due to biological sex *per se*.

The second point to be made regards the relationship between masculinity and spatial performance. Previous research (e.g. [1, 13]) has reported a positive relationship between performance on spatial tasks and masculinity. However, the present study found the opposite relationship. Masculinity was found negatively related to spatial performance. This suggests that a positive relationship between these variables may not be as universal as thought and subject to other influences.

Finally, consistent with previous research [2, 16], the present study also found a significant correlation between parietal EEG activity and spatial performance for males . This finding raises the possibility of certain neurological 'sets' or patterns better preparing a person for spatial performance. Future research should be directed in this area. Also these parietal EEG/performance correlations are dependent upon sex, but not clearly related to sex role. Since sex role differences were found in EEG data recorded frontally, it would appear, then, that in terms of EEG activity, the electrocortical processes associated with sex role characteristics are different from those involved in visuo-spatial processing. Hence, this research suggests the intriguing hypothesis that sex role characteristics exert an indirect influence on the neurophysiological processes underlying spatial ability by mediating correlations between ability and brain activity. The nature and extent of this influence awaits future research.

In summary, significant differences in hemispheric lateralization were found in frontal areas only between men and women reporting stereotyped sex role self-ratings. These differences were found in frontal areas. This lends support to the proposition offered by SHERMAN [17] that certain aspects of hemispheric lateralization may be mediated by various experiential factors (e.g. sex role socialization). Parietal areas on the other hand figure more prominently in EEG/performance relationships, suggesting that the relationship of sex role to visuo-spatial ability, via neurophysiological mechanisms, is indirect at most. How sex role influences spatial performance as well as why the positive relationship between masculinity and visuo-spatial ability which has previously been reported in the literature was not found in the present study remains an open question. Finally, the results of the present study do not support the suggestion that hemispheric lateralization is purely a function of biological sex and not experientially mediated.

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