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EFFECT OF SEX OF SUBJECT AND EXPERIMENTER ON HEMISPHERIC BALANCE

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ABSTRACT

This study explores the relationship between social variables and hemispheric laterality. We examine the effect on the hemispheric distribution of alpha brain wave activity of sex of host experimenter and sex of subject over conditions varied by presence and absence of partner agreements and disagreements. Differences in subject's alpha balance are indeed detected when host and subject are of different sex, especially if the host is male. If sex is viewed as a status characteristic, we would expect that a setting with male hosts and female subjects would lead to different physiological outcomes when compared to settings with less obvious status-related differences. However, in most conditions within this experimental setting, men and women did not exhibit significantly different hemispheric balance.

Introduction

Sociologists have begun to look closely at the relationships between social and physiological phenomena. In this study we deal with the idea that there may be discernable relationships between social and central nervous system events and processes. Researchers from other disciplines have found that different task conditions produce differential activity in the hemispheres of the brain, and from this they have inferred differential informational processing. Previous research in our laboratory strongly suggested that the presence of certain types of social information occassion a shift in hemispheric activity. Our research was designed to pursue the question under modified conditions and with improved methodology.

Much speculation has been given to the phenomenon of hemispheric laterality, which encompasses the notion that the hemispheres of the human brain, while anatomically similar, are functionally different. Initially this idea came from work with brain-damaged patients or persons who had undergone surgical spearation of the hemispheres (Gazzaniga, 1970). From these reports emerged the notions that the left hemisphere is functionally specialized for algebraic, analytic, linear, mathematical and sequential processing; while the right hemisphere is oriented toward holistic, geometric, spatial and emotional processing. More recently work has been done with normal subjects using the electroencephalograph to record brain activity while tasks are performed. EEG readings are taken from homologous locations on the left and right sides of the scalp, and the measures of electrical impulses generated by the hemispheres are compared. Measurement of wave frequencies in the alpha band (8-13 Hz) have been taken to be a reflection of total brain activity (Galin and Ornstein, 1972). Since alpha waves occur more readily when a subject is in a resting state, a high level of alpha is taken to indicate a low level of brain activation.

Research using this method to measure differential processing of external stimuli by the human brain is still in its initial stages. Donchin (1977) in reviewing the literature has pointed out some of the difficulties involved, including the choice of electrode sites. In spite of several methodological difficulties, a look at bilateral alpha studies indicates that some type of differential processing is present and is detectable. The major focus of recent research with intact subjects has involved giving the subjects a specific type of task and correlating electrical activity with that task. Specific tasks that engage the left hemisphere differentially have included composing letters (Galin and Ornstein, 1972; Doyle *et al.*, 1974), word search tasks (McKee *et al.*, 1973), mental arithmetic (Morgan *et al.*, 1974; Osborne and Gale, 1976; Dumas and Morgan, 1975; Butler and Glass, 1974), and verbal listening (Dumas and Morgan, 1975). Tasks demonstrated to be associated with increased right hemispheric activity included drawing tasks (Galin and Ornstein, 1972; Doyle *et al.*, 1974) and musical tasks (McKee *et al.*, 1973; Osborne and Gale, 1976). The literature confirms that certain specific tasks do engage the hemispheres differentially. A word of caution is in order in this regard. Popular notions lead us to believe in the idea of cerebral "dominance". When measurements of electrical activity show, for example, increases in right-brain activity, it is not always the case that the right hemisphere "takes over" and is more actively engaged than the left, but simply that an increase in right activity is observed.

Our initial research strongly suggested that certain types of social information produced a shift in lateralization. Variables contributing to the observed shift were sex of subject, team orientation, manipulation into a high competence state,[1] and partner feedback prior to making a final choice. The present research was designed to clarify the contribution of these variables to the observed shift by focusing upon partner feedback (where we had observed significant differences), by using improved data collection methods, equipment and task stimulus, and by carefully randomizing variables such as seating, host experimenter, and order of presentation. We chose to eliminate competence manipulations, in order to focus upon partner feedback, and we chose to focus upon the nature of the feedback (agreements and disagreements). In addition, we included the variable of sex of host experimenter, as previous studies had suggested that this was a factor. We posited

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[1] Manipulation of a subject into a high competence state involved telling her/him how she/he has scored vis-a-vis a "national standard" which is fictitious, and in comparison with a partner. The scores were presented to each pair of partners at the same time; they were told they each scored "high" on the ability being measured.

that: 1) Females and males will differ with respect to hemispheric balance, and 2) Sex of host experimenter will affect the hemispheric balance of the subject. We treated the remaining variables in an exploratory fashion.

Method

The subject pool consisted of sixty Stanford undergraduates, thirty men and thirty women. The subjects were all right-handed and ranged in age from eighteen to twenty-four. The dependent variables measured were: 1) alpha effects of feedback from the subject's partner, and 2) alpha effects of experimentally-manipulated disagreement and agreement trials. The independent variables were the sex of the subject and the sex of the host experimenter. In one phase of the study the subject was asked to work with his or her partner with no feedback. In the other phase he or she received the electronically-controlled opinion of his or her partner.

The behavioral setting was taken from the work of Berger, Cohen and Zelditch (1972). This setting provides a high degree of control over manipulations central to our hypotheses. An advantage of this setting is that subjects do not see or otherwise interact with each other directly, which allows the experimenter full control over interactive cues.

In our earlier research when information was exchanged with a partner, the rate of disagreements was standardized to 80%. This was done, as opposed to using veridical information, for purposes of having the behavioral setting as consistent as possible with prior non-physiological work in the setting. The shift in hemispheric balance we previously observed, however, could have been due to the disagreements, rather than the fact that subjects simply received information from their teammates; and there was no way to assess the differential effect of agreements and disagreements. In this study, in order to determine whether disagreements were more powerful social variables than agreements, each subject received disagreements (and agreements) from his or her partner 50% of the time. Subjects were run in pairs of the same sex by one of two host experimenters. Half of the subjects of each sex were hosted by the same-sex experimenter and half by the experimenter of the opposite sex.

Procedure

Each of two subjects was greeted separately by the experimenters and escorted to an interview room where the purpose of the study was explained and electrodes for recording EEG were attached. The subjects were told that they would participate in a study in which they would be working with a partner of the same sex in a team on certain tasks. They were further told that the purpose of the study was to see what types of brain activity occur while performing the tasks. Subject consent was obtained for monitoring the brain as well as for the behavioral components of the study.

The study took place in a soundproofed laboratory containing an electroencephalograph and slide screen. Each subject was seated at a table next to the other with a curtain between them which prevented each from seeing the other. The host experimenter sat directly in front of the subjects at a distance of about six feet. He or she then described the tasks to be performed.

Task

The task was presented to the subjects as measuring an ability called "Contrast Sensitivity". The stimuli were large rectangles made up of one hundred smaller black and white rectangles. Two of the large rectangles were presented on a slide which was shown on a screen located above the experimenter. The subjects were asked, "Does the top or the bottom slide contain the greater area of white?". The probability that a subject will pick either one of the slides had been established at the .50 level; this insures ambiguity of the stimulus. The experimenter stressed that Contrast Sensitivity ability is not related to other abilities about which the subject might have subjective biases.

In each of the two phases of the study, the task was to solve binary-choice decision-making problems. In each phase each of the two subjects performed sixteen similar trials. Each trial contained two components. The first required the subject to make an initial choice between two given alternatives. In one phase, after making an initial choice, the subject saw his/her partner's choice. After feedback of partner's initial choice, each subject made a final decision. In the other phase, the subject simply made an initial and a final choice, with no feedback from his or her partner. The sequence in which the experimental phases were presented was randomized to prevent a possible ordering or fatigue effect.

While the subjects performed the task, two ten-second bilateral alpha readings were taken on each trial, one as they first studied the slide and the other after they made their initial choice and were asked to restudy the slide before making a final decision. Observations of occipital EEG alpha amplitude (8-13 Hz) from each hemisphere were obtained in digital form. Grass gold-cup scalp electrodes were attached to the scalp with Grass EC-2 Electrode Cream at the central vertex (C_z) as reference, and at each occipital region (O_1 and O_2). A ground electrode was clipped to the earlobe. The EEG information was amplified by a Grass Model 7 amplifier and sent through a Med Associates EEG-500 alpha bandpass filter. The alpha components of the signal were then processed through an analog-to-digital converter (Med Associates ANL-940) and were displayed in digital form (Med Associates DIG-800) as well as being automatically printed on paper tape. The Med Associates equipment includes a holding register which allows the summation and readout of a representation of microvolts of alpha activity during the trial epoch (10 seconds). A second record of EEG information was processed through a Grass Model 5RDC Tape Reverter, Grass Model 5B Driver Amplifier and Grass Ink Writing Oscilloscope, for purposes of monitoring the occurrence of gross artifacts such as faulty electrode attachment, muscle movements, etc.

The measurement of the physiological dependent variable, the ratio of left to right hemispheric activity, was calculated from the amount of alpha. As stated, these measures were taken for ten seconds prior to each initial and final choice made by the subject.

From these measurements the following formula (Morgan et al., 1974) was used to calculate a ratio of hemispheric lateralization:

$$\frac{L-R}{L+R}(100)$$

with L = amount of alpha in left hemisphere and R = amount of alpha in the right hemisphere. Ratio measures were used instead of raw measurements in order to control for individual differences in alpha amplitude.

Between-subject communication was actually manipulated by the experimenter and was accomplished by use of an Interaction Control Machine (ICOM). This consists of a master control unit (located in another room) and a console which is placed on a table in front of each subject. Subjects registered their decisions by pushing buttons on the consoles. As a button is pushed, a light comes on reflecting the subject's choice. In the feedback condition, the partner's choice, which is electronically controlled, is also shown to the subject by a panel light. The machine was programmed to produce 50% disagreements between partners. The actual alpha measurements were taken while the subject presumably was engaged in the decision-making process. Subjects were instructed to remain as motionless as possible and to try not to blink. The time period of alpha measurement was completed before subjects pressed the buttons indicating their choices. Interviews with subjects concerning their strategies for making the decision revealed that ten seconds was not enough time for them to "solve the problem". We take this as an indication that a 10-second epoch is appropriate.

After the slide trials a brief post-experimental questionnaire was administered to determine whether or not the subject was serious about performing the task, as well as to determine certain physiological facts about the subject. Each subject was interviewed. The interview was designed to determine whether the subjects met all the conditions of the study. That is, if a subject was suspicious of the task, or decided not to pay attention to partner feedback, that subject's data was excluded from the analysis. Data from five subjects were thus excluded from analysis. After the interview a thorough explanation of the experiment was given to each subject, and it was strongly emphasized that no such ability as Contrast Sensitivity existed. Subjects were paid for their participation.

Results

A total of sixty non-suspicious subjects were run in the experiment. In each case the subject was involved in both a feedback and a non-feedback situation when undertaking the Contrast Sensitivity task. Further, within each feedback phase, each subject experienced both conditions of agreement and conditions of disagreement. The trials were grouped into two major sections of sixteen each, one designated the feedback section; the other, the no-feedback section.

One possible method of data analysis, analysis of variance, was not appropriate to this design because of the problem of repeated measures, which produces a situation of confounded variables, and therefore could result in misleading outcomes. The alpha laterality ratios were averaged for each subject over the sixteen trials. We chose to use a t-test procedure to distinguish between paired sets of readings under different conditions by sex. Assumptions of the t-test procedure (normal distribution and equal variances) were met.

We began our analysis by comparing overall scores for each case by sex, to see if any gross differences, independent of experimental condition, were evident. We tested this phenomenon in initial choice, final choice and overall decision situations, and in all possible combinations of sex of subject and sex of host experimenter. As a second level of analysis, we broke this gross analysis into sub-units within categories of condition, feedback and no-feedback, agreement and no-agreement, to determine whether the gross measures were obscuring less obvious effects within separate conditions. The results are reported below.

TABLE I HERE

The results shown in Table I indicate there is no significant difference between overall measures of hemispheric balance in any one of the comparison groups distinguished by sex. Overall effect of sex of host does not appear to provide sufficient impetus to affect the outcome, and similarly, sex of subject appears to be independent of changes in hemispheric lateralization. Although not presented in a table, no significant differences were found between the overall measures of the feedback and the no-feedback conditions.

TABLE II HERE

Table II shows that when the data is broken down into its constituent parts, a different pattern emerges. In a comparison of male host/female subject with female host/female subject, significant differences emerge in three of the four experimental conditions. These are in the initial portion of the no feedback condition, and in both parts of the agreement and disagreement trials. Similarly, in the comparison between female host/male subject and male host/female subject, two of the four conditions give rise to significant differences between the two groups. This is true when compared with aggregated measures as well, as seen in Table III.

TABLE III HERE

TABLE IV HERE

Table IV is a summary of means of the actual alpha laterality ratios of pairs of experimental groupings. Only those means whose differences (shown by t-test) are significant at the .05 level are presented. It appears that female subjects process information more actively with the right hemisphere when hosted by males, and with the left hemisphere when hosted by females. Male subjects, when hosted by males, tend to use the left hemisphere more than the right. There were no significant results in the other conditions. The same-sex situation produces relative left-brain activity and the cross-sex situation for females is associated with relative right-brain activity. The cross-sex situation produced no statistically significant differences for male subjects. The direction of hemispheric activity in non-significant cases is the same as that shown in Table IV.

Discussion

We have hypothesized that the sex of experimenter and the sex of subject are major influences in determining the hemispheric balance of alpha activity. Neither the sex of host nor the sex of subject, independent of one another, appears to provide support for this idea. But while we are unable to distinguish overall effects, effects are evident within condition, and within the more complex comparisons we made between subgroups by sex. The primary source of interest lies in that comparison which was made between the male-hosted female subjects and the female-hosted male and female subjects, both on individual breakdowns and aggregated measures. In all these sets of comparisons statistically significant differences appeared in both the agree and disagree trials in the feedback condition. In the case of female-hosted women, the no-feedback condition provided a significant difference in alpha activity when compared with male-hosted male subjects in the same condition.

We consider these results to be important for several reasons. To begin with, the study represents a rigorous experimental study which relates hemispheric lateralization to sex differences. The suggestions in the popular literature that the hemispheres function differentially in women and in men has no support from this study--in fact, no overall sex differences were evident. Nor do gross differences appear with sex-of-host changes. While these status differences related to sex of experimenter are not evident universally, they are evident in the extreme comparison (male host/male subjects vs. female host with both male and female subjects). We should emphasize that these differences can readily be exaggerated, but they do suggest that status differences may be at work with regard to sex of host in situations of extreme status differentiation.

The consequences of this finding are, of course, important, but we must emphasize the overall pattern before any wider generalizations can be suggested. The overall pattern shows that sex differences are minimal. We have to take the extreme form of the status relationship to show any effect, and that effect is small even at this point. A further point is that we are studying a population of students whose intellectual ability is within a narrow range; that is, a population which well may not exhibit the full range of physiological responses in cognitive situations. Thus, the effect of intellectual socialization may be a more powerful influence towards uniformity between the sexes than any differences resulting from biological sex-related status pressures. As a consequence, when confronted with such a task as the Contrast Sensitivity task, we may be seeing a physiological outcome which results from extensive socialization in a relatively familiar setting: the task may be new, but the procedures which people used for its solution were surprisingly uniform, from individual to individual, and between the sexes. Had lateralization differences been found, we would have anticipated these to have arisen from differential socialization. Since our subject pool has been similarly socialized for a long period of time, such potential differences may be obscured. To further test this idea would require that differentially socialized groups be compared. Any lateralization differences may then be linked to sex. However, we suggest they would more likely relate directly to other factors, in particular, educational experience and social class. In addition, it is possible that in this study individual characteristics of the experimenters, apart from sex, were confounding variables.

It would seem therefore that sex-related status differences appear to have little impact on hemispheric lateralization, within the limitations of our study. The notion that men and women are distinguished in any concrete way by the manner in which they specialize use of their cerebral hemispheres has little scientific support.

Conclusion

In summary, the cross-sex host-subject situations produce positive alpha scores, while same sex- host-subject situations produce negative alpha scores. By convention we can interpret these results as suggesting that the cross-sex situation produces a shift toward increased right-brain activity, while the same-sex situation favors a relative shift toward left-brain activity. To determine whether this is an effect specific to sex, or whether sex represents a class of variables by which persons are distinguished (age, rank, education, ethnicity) would require further experimentation. Further, this data suggests that it is the discrepant sex (and by inference, status or role) situation which produces differences in lateralization, rather than sex as a property of the subject or of the experimenter. If it is true that the hemispheres of the brain can be differentiated in terms of analytic or holistic functions, it is possible to make a global assignment of hemispheric cognitive specialization. In our study, it appears that the sex discrepant situations evoke more holistic processing, while the non-discrepant situations produce more analytic processing. We suggest that in the same-sex situation subjects are focusing upon the task itself as the salient element, while in the discrepant, cross-sex, situation the social element elicits an increased right-brain activity. This is particularly evident for female subjects although the males show the same trend.

As there was no difference in lateralization between agreement and disagreement trials, which might also be considered a class of discrepant and nondiscrepant information, we infer that the right shifts are elicited by the more global discrepancies reflected in the larger culture rather than in purely informational and task-specific incongruities. We take this as further support that differences in cognitive processing reflected in alpha-measured laterality scores are better understood as a cultural product rather than as sex-linked biologically determined.

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TABLE I

	Condition 1 Combined Initial/Final Scores		Condition 2 Separate Initial/Final Scores	
	HOST: Female vs. Male	SUBJECT: Female vs. Male	HOST: Female vs. Male	SUBJECT: Female vs. Male
Feedback	1.23	0.77	I: 0.84 F: 1.49	0.80 0.68
No Feedback	0.54	1.58	I: 0.54 F: 0.50	1.34 1.73
Agree	1.25	0.93	I: 0.92 F: 1.50	0.63 1.18
Disagree	1.31	1.41	I: 1.08 F: 1.44	1.33 1.37
Total			0.87	1.12
		df = 59		df = 59

t-test results across all conditions for male- and female-hosted subject groups, and male and female subjects both overall and broken down by initial and final choices.

TABLE II

		Male H/Male S vs. Fem H/Fem S	Male H/Male S vs. Fem H/Male S	Male H/Fem S vs. Fem H/Fem S	Male H/Male S vs. Male H/Fem S	Fem H/Male S vs. Male H/Fem S	Fem H/Male S vs. Fem H/Fem S
Feedback	I	0.03	0.68	1.85	1.16	1.76	0.70
	F	0.53	0.24	1.07	1.59	1.71	0.35
No Feedback	I	0.55	1.22	2.08*	1.34	1.57	0.76
	F	0.90	0.57	1.82	1.49	0.93	0.33
Agree	I	0.19	0.82	2.12*	1.19	2.01	0.73
	F	0.22	0.29	2.17*	1.93	2.09*	0.09
Disagree	I	0.16	0.09	2.05*	1.81	1.68	0.28
	F	0.05	0.35	2.39*	1.94	2.15*	0.35

*$p < .05$ df = 59

Breakdown of t-test results across all conditions varying sex of host and sex of subject.

TABLE III

	Male H/Male S vs. Fem H/Fem S	Male H/Male S vs. Fem H/Male S	Male H/Fem S vs. Fem H/Fem S	Male H/Male S vs. Male H/Fem S	Fem H/Male S vs. Male H/Fem S	Fem H/Male S vs. Fem H/Fem S
Feedback	0.31	0.48	1.51	1.82	1.44	0.16
No Feedback	0.74	0.17	2.01	1.27	1.47	0.58
Agreement	0.21	0.59	2.25*	2.13*	1.62	0.45
Disagree	0.07	0.22	2.33*	2.01	1.97	0.32

*$p < .05$ df = 59

t-test results across all conditions (overall) varying sex of host and sex of subject.

TABLE IV

	Host Sex	Subject Sex		Host Sex	Subject Sex	
Overall Disagree	M	F	+1.9288	M	F	+1.9288
	F	F	-0.2992	M	M	-0.7093
Overall Agree	M	F	+1.4487			
	F	F	-0.4938			
Initial Agree	M	F	+0.6943			
	F	F	-0.2695			
Final Agree.	M	F	+0.7543	M	F	+0.7543
	M	M	-0.3335	F	F	-0.2243
Final Disagree	M	F	+0.9898	M	F	+0.9898
	M	M	-0.2110	F	F	-0.1870

Means of hemispheric balance across all conditions shown to be significant by t-test, varying sex of host and sex of subject. Positive values indicate left hemispheric dominance of alpha and therefore a higher level of brain activation in the right hemisphere. Negative values indicate the reverse, i.e., a higher level of brain activation in the left hemisphere.