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Hemispheric Asymmetry as Indexed by Differences in Direction of Initial Conjugate Lateral Eye-Movements (CLEMs) in Response to Verbal, Spatial, and Emotional Tasks

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Following previous research showing frequency and direction of conjugate lateral eye-movements (CLEMs) to be a valid indicator of hemispheric asymmetry (Schwartz, Davidson, & Maer, 1975), the purpose of the present experiment was to investigate frequency and direction of CLEMs in relation to verbal, spatial, and emotional tasks. The basic design was a 4 x 2 factorial with four types of questions presented under two levels of stress. Results showed a significantly higher frequency of right movements to verbal non-emotional questions, indicating left hemisphere dominance, and a higher frequency of left movements to spatial and emotional questions indicating right hemisphere dominance. No effect of the stress manipulation was found. The results support previous findings of a functional relationship between hemispheric functioning in the intact brain and direction of lateral eye-movements.

Following the pioneering work by Teitelbaum (1954), Day (1964), and Bakan (1969) on the relationship between the direction of conjugate lateral eye-movements (CLEMs) and hemispheric functioning, several later authors have reported distinct lateral gaze-shifts in response to tasks that presumably differentially activate the cerebral hemispheres (Galin & Ornstein, 1974; Gur, Gur, & Harris, 1975; Hiscock, 1977; Kinsbourne, 1972, 1974; Kocel, Galin, Ornstein, & Merrin, 1972; Schwartz, Davidson, & Maer, 1975).

Generally, the results show a predominant shift to the left of the eyes (i.e., indication of right hemisphere dominance) when subjects reflect upon tasks involving processing of spatial features, and a rightward shift (i.e., indication of left hemisphere dominance) to tasks demanding analysis of verbal features. These findings are in line with recent neuroanatomical and behavioral evidence indicating the right hemisphere subserves visuo-spatial functions, whereas the left hemisphere is dominant for verbal and language functions. This has been evidenced by such various techniques as, the sodium amytal test (Wada & Rasmussen,

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1960), studies on split-brain patients (Sperry, Gazzaniga, & Bogen, 1969), visual half-field and dichotic-listening experiments (Springer, 1977), and measures of scalp EEG from both the left and right hemispheres (Galin & Ornstein, 1972). Thus, the "gaze-shift-phenomenon" as an index of hemispheric functioning in the intact brain is well documented in empirical research (see also Gur & Gur, 1977).

In addition to being an index of hemispheric asymmetry in response to tasks demanding processing of spatial and verbal features of the stimulus, direction of lateral eye-movement has also been found to systematically vary as a function of emotional, or affective, tonus of the task. For instance, Schwartz, et al. (1975) and Harman and Ray (1977) found more left-movements accompanying subjects' answers to emotionally upsetting questions, whereas the reverse pattern was found to verbal non-emotional questions. The same pattern of left-right shifts of the eyes was also reported by Tucker, Roth, Arneson, and Buckingham, (1977) with predominantly left movements to stressing conditions, such as instructing the subject that the questions asked are part of an intelligence test. Thus, recent data suggest that asymmetrical hemispheric functioning, measured through CLEMs, may also be found in response to emotionally disturbing tasks (see also Dimond, Farrington, & Johnson 1976).

However, an important aspect of the use of CLEMs as a measure of hemispheric asymmetry is that the interaction between the experimenter facing the subject when asking the questions and the type of question asked may confound the results. Specifically, Gur (1975) found that, when the examiner sits behind the subject, verbal questions elicit rightward gaze deflections and spatial questions elicit leftward deflections. When confronted by the examiner, however, in a face-to-face situation, the subject usually breaks eye-contact with the examiner when reflecting upon the task, and moves his/her eyes in only one direction irrespective of the type of question asked (see also Gur, et al., 1975).

For this reason, it seems important to control for biases caused by the location of the questioner in studies on lateral eye-movements and hemispheric asymmetry. This will probably be even more important in experiments using emotionally disturbing questions. The interaction between the stress caused by the question and the influence of the examiner facing the subject may then further amplify the discomfort experienced. This in turn will then dissolve the relationship between direction of CLEMs and the type of question asked. This was also found by Tucker, et al. (1977) who demonstrated overall increased left eye-movements to stressing conditions.

In an attempt to replicate the results reported by Schwartz, et al. (1975) on differential left-right eye-movements to verbal, spatial, and

emotional questions we therefore decided in the present study to control for both the effect of having the examiner facing the subject, and the possible break-down of the typical pattern of responding due to a too-stressful experimental situation.

For these reasons a situation where questions were prerecorded on a tape-recorder was employed. Furthermore, to control for possible effects of performance-anxiety when reflecting upon the questions, one-half the subjects were deceived about the true nature of the experiment.

A third possible source of confounding seen in the Schwartz, et al. (1975) study is that eye-movements were scored directly as they occurred after each question. With this technique some movements may be missed due to experimenter inaccuracy at the moment of CLEM occurrence. However, if a video-technique is employed this source of error may be eliminated because such a device allows for replay of each sequence to recheck responses several times. Therefore, a concealed video-camera, not seen by the subject, was used in the present study.

To validate the content of the various questions used, subjects were required after the experiment to rate on a four-point scale various important features of the tasks (e.g., degree of difficulty, unpleasantness, and ease of visualizing the scenes depicted). This was done in order to make sure that, for instance, presumably emotionally upsetting questions were experienced as such by the subjects.

The type of questions used in the present study followed the grouping used by Schwartz, et al. (1975). Thus, there were four kinds of questions asked: Verbal Non-Emotional; Verbal Emotional; Spatial Non-Emotional; and Spatial Emotional. On the basis of previous results concerning the relationship between hemispheric functioning and cognitive mode (e.g., Kinsbourne, 1973) it was predicted that Verbal Non-Emotional questions would yield predominantly rightward movements, whereas Spatial Non-Emotional, and especially Spatial Emotional questions, would result in leftward movements. The Verbal Emotional questions were predicted to fall in between, with no difference in left versus right movements, since two opposing aspects of the information (i.e., the verbal and the emotional component) are combined in this category. It was further predicted that the effects of verbal questions would be reduced during the high stress condition as compared to the low stress condition, thus yielding more left movements to these questions than under the high stress condition.

In sum then, the purpose of the present experiment was to replicate previous results on the relationship between hemispheric asymmetry and cognitive and emotional functioning as indexed by measurement of conjugate lateral eye-movements. In order to better control for possible biasing factors in the original study, subjects in the present study were left

alone during the entire session, with questions presented through loudspeakers from a tape-recorder, and responses picked up by a closed videosystem.

Method

Subjects

Forty right-handed subjects participated in the experiment (20 males and 20 females). All subjects received 20 Swedish Kronor (approximately U.S.$4) for participation. The age range was between 18-35 years.

Questions

Subjects were exposed to 60 different questions read in successive order from a Tandberg tape-recorder. There were 15 questions of each category (i.e., Verbal Non-Emotional; Verbal Emotional; Spatial Non-Emotional; and Spatial Emotional). All questions were of the kind used by Schwartz, et al. (1975) with minor modifications adopted to Swedish standards. For example, a Verbal Non-Emotional type of question was: "Name a synonym to the word indifference"; a Verbal Emotional question was: "Say a sentence where the words razor and artery are included"; a Spatial Non-Emotional question was: "Visualize a Swedish Krona put in your palm with the face of the king up, in what direction is he looking?"; finally, a Spatial Emotional question was: "Visualize and report your immediate reactions when you enter an unfamiliar hotel-room, just closing the door and reaching for the light when an arm suddenly is twisted around your neck." All subjects heard all 15 questions within a category in succession, but the order of presentation between categories was counterbalanced between subjects.

Apparatus

Subjects were seated in an armchair in a Tegnér 2.0 x 1.8 x 1.5 m sound isolated cubicle within the laboratory. A microphone was placed in front of the subject through which he/she stated his/her answer to the questions. Questions were heard through two loudspeakers inside the cubicle, recorded on a tape-recorder outside of the cubicle. In order to make the environment within the cubicle as neutral as possible (i.e., not to encourage turning of head and looking around) white paper-walls were placed around the arm-chair. To avoid unwanted head movements during the session, subjects leaned the back of their heads into a specially designed neck-support attached to the armchair.

A small 10 x 5 cm one-way mirror was placed in the wall just in front of the subject, hiding a Sony video-camera, with a 135 mm telescopic lens. Finally two Beckman 1.5 mm electrodes were placed on the forehead (the electrodes were not connected to any recording equipment).

Design and procedure

The basic design was a 4 x 2 split-plot factorial (Kirk, 1968) with four different types of questions, and two levels of stress conditions. The first variable involved repeated measurement, and the second was randomized. In the statistical analysis, a third variable, direction of CLEMs (left versus right), also with repeated measurement, was added. In the low stress condition, subjects were told that the purpose of the experiment was to register (through the electrodes on the forehead) face muscles when people answer various questions. For this reason, subjects were told it was important that they state their answers with the kind of language they "usually used" when answering questions like these. They were finally encouraged not to try to be a good subject or answer "correctly" since the purpose of the study simply was to see what muscles in the face people normally use when speaking. In the high stress-condition subjects were told that the purpose was to register EEG-brain waves (through the electrodes) when people answer questions designed to measure intelligence and personality. They were encouraged to perform well and to do their best. After the experiment all subjects were informed of the true nature of the experiment.

Upon entry to the laboratory the subject was placed in the armchair, the purpose was explained, and electrodes fastened. They were then told that a number of questions would be played to them through the loudspeakers. After each question a tone was heard through the loudspeaker indicating that the subject should state his/her answer. He/she was told not to answer until the tone was heard. After the answer was completed there was a 10 second pause before the next question started.

Scoring of CLEMs

Following the suggestions by Ehrlichman and Weinberger (1978) CLEMs were scored from the videotape as the first identifiable lateral eye-movement immediately following the cessation of the question. This was done by assigning a number of 1 to 12, according to the clock-position, to the first movement. All movements within the clock positions 1 and 5 were considered left movements, and all movements within the positions 7 to 11 were considered right movements (cf. Galin & Ornstein, 1974). If the eyes were not visible on a trial or if no movements

were discernible, this was considered a blank (or a stare), and the trial was discarded. All videotapes were scored twice.

Results

Direction of CLEM

The mean number of left and right movements within each type of question was calculated for each subject. All scores were then subjected to an analysis of variance.

The means for frequency of left and right movements separated for the different kinds of questions are given in Figure 1.

The analysis of variance showed a significant effect of Direction of CLEMs, $F(1,36) = 8.28$, $p < .01$. An inspection of Figure 1 reveals that this is due to an over-all higher frequency of left-movements as compared to right-movements. Furthermore, a significant interaction, Direction x Type of question was found, $F(3,108) = 13.90$, $p < .01$. From Figure 1 it is obvious that while more right-movements occurred to the Verbal Non-Emotional questions, more left-movements occurred to the other three types of questions.

This was also confirmed by a priori t tests where left vs. right movements within each type of question were compared, $t(36) = -1.87$, $p < .05$, and $t(36) = 2.99$, $p < .01$ for the Verbal Non-Emotional and Verbal Emotional questions, respectively. For the left-right comparison within the other two types of questions the t values were $t(36) = 2.06$, $p < .05$ and $t(36) = 2.97$, $p < .01$, for the Spatial Non-Emotional and Spatial Emotional questions, respectively. No other sources reached significance.

Since the direction variable does not contain independent scores because of interdependence between the left and right movements within a given set of questions, a separate analysis was performed for both right and left-movements. The results showed a significant effect for Type of Questions in both analyses, $F(3,108) = 13.57$, $p < .01$, and $F(3,108) = 13.59$, $p < .01$, for left-movements and right-movements respectively.

From Figure 1 it is easily seen that these results pertain to the greater frequency of right movements to Verbal Non-Emotional questions, versus right movements to the other types of questions. This was supported by follow-up tests, $t(36) = 2.78$, $p < .05$, $t(36) = 2.20$, $p < .01$, and $t(36) = 2.70$, $p < .01$ for the comparisons between Verbal Non-Emotional versus Verbal-Emotional, Verbal Non-Emotional versus Spatial Emotional, and Verbal Non-Emotional versus Spatial Emotional respectively. In the same vein, follow up tests on the separate analysis of left-movements showed significantly larger left responses to the Verbal-

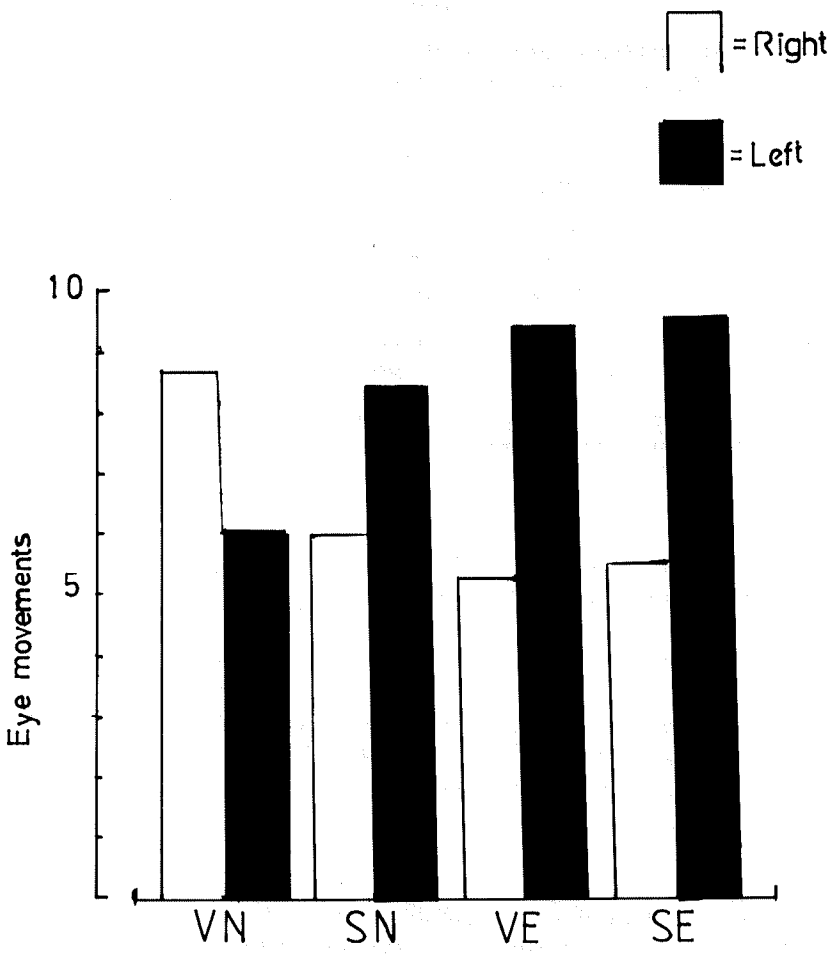

Figure 1. Mean number of right vs. left eye-movements to the different sets of questions. Note: VN = Verbal Non-Emotional questions, SN = Spatial Non-Emotional, VE = Verbal Emotional, SE = Spatial Emotional.

Emotional, Spatial Non-Emotional, and Spatial Emotional questions as compared to the Verbal Non-Emotional questions. The corresponding t values were $t(36) = 2.73$, $p < .01$, $t(36) = 1.88$, $p < .05$, and $t(36) = 2.71$, $p < .01$.

In order to control for eventual differences in number of stares in response to the various types of questions, which may have distorted the distribution of the frequency of left versus right movements within each

Table 1

Mean Number of Stares in Response to the Different Types of Questions Separated for the High and Low Stress Conditions[a]

	Type of question			
	VN	VE	SN	SE
Low stress	0.25	0.45	0.65	0.25
	(0.67)	(0.54)	(0.97)	(0.29)
High stress	0.10	0.40	0.80	0.30
	(0.10)	(0.89)	(2.24)	(0.29)

[a]Standard deviations within parentheses. Note: VN = Verbal Non-Emotional questions; VE = Verbal Emotional questions; SN = Spatial Non-Emotional questions; SE = Spatial Emotional questions.

set of questions, a separate analysis was performed on the stares (i.e., frequency of non-scorable trials within each stress condition and type of question).

The mean number of stares for the various sets of questions are given in Table 1.

As can be seen in Table 1, the number of non-scorable trials is small, and equally so within each set of questions. This was supported by the lack of any significant differences between the cells.

Subjective ratings

The first column of scores in Table 2 shows the means and standard deviations for ratings of subjects' perceptions of the question difficulty. Note that no ratings were required for the Spatial-Emotional questions. The middle column shows how well subjects rated their degree of visualizing the situations depicted in the two types of spatial questions. The third column shows ratings of how unpleasant they experienced the two types of emotional questions to be.

As can be seen in Table 2, no differences emerged between the low and high-stress conditions—indicating that this may not have been a valid manipulation. Furthermore, it is quite obvious that subjects, on the average, easily visualized the spatial items with no differences between non-emotional and emotional questions. It is also obvious from an inspection of Table 2 that the Spatial-Emotional questions were considered as more unpleasant than the corresponding Verbal questions. This dif-

Table 2
Mean Subjective Ratings of Difficulty, Visualizing and Unpleasantness Associated With the Different Sets of Questions Under Both the High and Low Stress Conditions

	Degree of Difficulty	Ease of Visualizing	Degree of Unpleasantness
High Stress			
VN	2.52 (0.26)	–	–
VE	2.14 (0.18)	–	1.59 (0.31)
SN	2.60 (0.11)	3.02 (0.13)	–
SE	–	3.01 (0.29)	2.42 (0.35)
Low Stress			
VN	2.54 (0.27)	–	–
VE	2.11 (0.21)	–	1.31 (0.15)
SN	2.27 (0.15)	2.90 (0.42)	–
SE	–	3.05 (0.39)	2.24 (0.45)

ference was also statistically confirmed, $t(18) = 3.39$, $p < .01$. Finally no differences were observed concerning degree of question difficulty.

Discussion

In summary, significantly more initial right-movements were found in response to Verbal Non-Emotional questions as compared to the number found to the three other types of questions. Conversely, a higher number of left-movements was found to Spatial and Emotional questions when compared to Verbal Non-Emotional questions. No difference in either left or right-movements were found between the other three sets. No effects due to stress conditions were obtained. Thus, the present results fit well with the data reported by Schwartz, et al. (1975) and are consistent with the main predictions made.

It is interesting to note that the present results are almost identical to the data reported by Schwartz, et al. (1975) except for the Verbal-Emotional questions. It may therefore be argued that these kinds of questions do have enough power to differently affect the hemispheres when being processed on a cortical level (see also Tucker, et al., 1977).

From Figure 1 it is obvious that Verbal Emotional questions elicit more left-movements than right-movements—a finding which is statis-

tically confirmed. This is contrary to the prediction that no difference in left versus right movements would occur because the verbal and emotional components in these questions should be antagonistic to each other in hemispheric activation. In other words, because both hemispheres would be equally activated by these questions, the net result would favor *neither* left nor right movements of the eyes. In a similar vein, it was predicted that the spatial and emotional components in the Spatial-Emotional questions would act in an additive way to enhance leftward responding (i.e., increased right hemisphere activation) as compared to the Spatial Non-Emotional questions. As can be seen in Figure 1, neither of these predictions were confirmed. Instead, number of relative left movements is about equal in the Spatial Non-Emotional, Verbal Emotional, and Spatial Emotional conditions.

It is quite obvious that the emotional component overrides the verbal component in the Verbal Emotional questions, thus yielding predominantly leftward movements. It is also clear that the relative difference between the right and left movements to the Verbal-Emotional and the Spatial-Emotional questions is about the same. These results are surprising in view of the reported data on subjective ratings of degree of unpleasantness associated with these two kinds of questions. In Table 2 it can be seen that the Spatial-Emotional questions are experienced as more unpleasant than the Verbal-Emotional ones. A possible explanation for this discrepancy between the subjective and the autonomic (CLEM) recordings could be that the two measures differ in resolving capacity. Thus, whereas subjective feelings are more easily quantified in terms of intensity by the subject, frequency of eye-movements may reach an optimum at a lower level of emotionality—further increases require more "traumatic" experiences than the present ones. This conclusion is further substantiated by the lack of any difference in the eye-movement recordings between the two stress conditions. It may very well be the case that the presumed increase in emotionality and stress in the high stress condition is too small to yield a difference in eye-movements. In any case the present finding is in contrast to the data reported by Tucker, et al. (1977) showing an increase in left movements to emotional questions under high stress conditions. However, subjects in Tucker's study were told that their answers to the questions would directly indicate their *personal* intellectual ability and personality stability, as compared to the more generally stated relationship between intellectual capacity and mode of answer in the present study.

In conclusion then, the present results are in agreement with previous research on the relationship between direction of initial eye-movements (CLEMs) and differences in emotional, spatial, and verbal features of the tasks presented to the subjects. Seen in this perspective, lateral eye-

movements seem to be a reliable index of hemispheric functioning. This conclusion is based on the empirical fact that similar kinds of tasks (i.e., exposing subjects to stimuli varying in emotional, spatial, and verbal salience) systematically have been found to reflect differences in hemispheric dominance when other more direct techniques, such as the monitoring of EEG from both the left and right hemisphere, (Galin & Ornstein, 1972; Harman & Ray, 1977), as well as recordings of evoked potentials across each hemisphere (Buchsbaum & Fedio, 1969), have been employed.

Furthermore, in an attempt at explaining the functional relationship between the cerebral hemispheres and lateral eye-movements, Kinsbourne (1973) has suggested that the direction of orientation of the eyes and head is controlled by the hemisphere contralateral to the direction of movement. In other words, when one hemisphere is more activated (caused by the nature of the stimulus fed into the brain) relative to the other, the cognitive activity in that hemisphere will "overflow" into the orienting-controls of that hemisphere, causing contralateral eye-movements. Whether this model will turn out to be a valid description of the relationship between conjugate lateral eye-movements and the asymmetrical functioning of the hemispheres will have to await further research. However, the empirical phenomenon of differences in direction of lateral eye-movements in response to tasks differing in requirements of cognitive processing is well-established and is further supported in the present investigation. Thus, the use of conjugate lateral eye-movements in studies of hemispheric asymmetry seems to be a reliable and easy technique, not requiring advanced equipment for its application.

References

Bakan, P. Hypnotizability, laterality of eye-movement and functional brain asymmetry. *Perceptual and Motor Skills,* 1969, *28,* 927-932.

Buchsbaum, M., & Fedio, P. Visual information and evoked responses from the left and right hemispheres. *Electroencephalography and Clinical Neurophysiology,* 1969, *26,* 266-272.

Day, M.E. An eye-movement phenomenon relating to attention, thought and anxiety. *Perceptual and Motor Skills,* 1964, *19,* 443-446.

Dimond, S.J., Farrington, L., & Johnson, P. Differing emotional response from right and left hemispheres. *Nature,* 1976, *261,* 690-692.

Ehrlichman, H., & Weinberger, A. Lateral eye movements and hemispheric asymmetry: A critical review. *Psychological Bulletin,* 1978, *85,* 1080-1101.

Galin, D., & Ornstein, R. Lateral specialization of cognitive mode: An EEG-study. *Psychophysiology,* 1972, *9,* 412-418.

Galin, D., & Ornstein, R. Individual difference in cognitive style-I: Reflective eye movements. *Neuropsychologia,* 1974, *12,* 367-376.

Gur, R.E. Conjugate lateral eye movements as an index of hemispheric activation. *Journal of Personality and Social Psychology,* 1975, *31,* 751-757.

Gur, R.E., Gur, R.C., & Harris, L.J. Cerebral activation, as measured by subjects lateral eye movements, is influenced by experimenter location. *Neuropsychologia,* 1975, *13,* 35-44.

Gur, R.E., & Gur, R.C. Correlates of lateral eye movements in man. In S. Harnad, R.W. Doty, L. Goldstein, J. Jaynes, and G. Krauthamer (Eds.), *Lateralization in the nervous system.* New York: Academic Press, 1977.

Harman, D.W., & Ray, W.J. Hemispheric activity during affective verbal stimuli: An EEG study. *Neuropsychologia,* 1977, *15,* 457-460.

Hiscock, M. Effects of examiner's location and subjects anxiety on gaze laterality. *Neuropsychologia,* 1977, *15,* 409-416.

Kinsbourne, M. Eye and head turning indicates cerebral lateralization. *Science,* 1972, *176,* 539-541.

Kinsbourne, M. The control of attention by interaction between the cerebral hemispheres. In S. Kornblum (Ed.), *Attention and human performance, Vol IV.* N.Y.: Academic Press, 1973.

Kinsbourne, M. Direction of gaze and distribution of cerebral thought processes. *Neuropsychologia,* 1974, *12,* 279-281.

Kirk, R.E. *Experimental design: Procedures for the behavioral sciences.* Belmont, California: Brooks-Cole, 1968.

Kocel, K., Galin, D., Ornstein, R., & Merrin, E.L. Lateral eye movement and cognitive mode. *Psychonomic Science,* 1972, *27,* 223-224.

Schwartz, G.E., Davidson, R.J., & Maer, F. Right hemisphere lateralization for emotion in the human brain: Interactions with cognition. *Science,* 1975, *190,* 286-288.

Sperry, R.W., Gazzaniga, M.S., & Bogen, J.E. Interhemispheric relationships; the neocortical commisures; syndromes of hemispheric disconnection. In P.S. Vilden & G.W. Bryn (Eds.), *Handbook of clinical neurology, Vol. 4.* Amsterdam: North Holland Publishing Company, 1969.

Springer, S.P. Tachistoscopic and dichotic listening investigations of laterality in normal human subjects. In S. Harnad, R.W. Doty, L. Goldstein, J. Jaynes, & G. Krauthamer (Eds.), *Lateralization in the nervous system.* New York: Academic Press, 1977.

Teitelbaum, H.A. Spontaneous rhytmic ocular movement. Their possible relationship to mental activity. *Neurology,* 1954, 350-354.

Tucker, D.M., Roth, R.S., Arneson, B.A., & Buckingham, V. Right hemisphere activation during stress. *Neuropsychologia,* 1977, *15,* 691-700.

Wada, J., & Rasmussen, J. Intracarotid injection of sodium amytal for the lateralization of cerebral speech dominance: Experimental and clinical observations. *Journal of Neurosurgery,* 1960, *17,* 266-282.