Sex and coding strategy effects on reaction time to hemispheric probes

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Two experiments were conducted to investigate the influence of coding instructions on cerebral laterality differences. Experiment I required 20 subjects (10 female) to use either rehearsal or imagery coding strategies in a recognition task with word probes to the right and left hemispheres. No hemispheric differences were found, but sex of subject was found to be related to coding strategy. Ten subjects (5 female) in Experiment II performed a similar task, except picture probes were used. Subjects using rehearsal coding responded faster to left-hemisphere probes, but faster to right-hemisphere probes when imagery coding was employed. The differing laterality effects in these experiments were attributed to naming responses implicitly required in Experiment II.

The cerebral hemispheres appear to be asymmetric in the processing of verbal and nonverbal spatial information. Several authors have arrived at this conclusion after reviewing the research with both normal subjects (Buffery & Gray, 1972; White, 1969) and patients with cerebral disconnection or lateralized lesions (Gazzaniga, 1970; Milner, 1971; Nebes, 1974). For right-handed individuals, this asymmetry, referred to as the cerebral laterality effect, results in specialized processing of verbal material in the left hemisphere. Demonstrations of this processing have occurred using words (Gross, 1972; Isseroff, Carmon, & Nachson, 1974), mirror images of words (Isseroff et al., 1974), and digits (Geffen, Bradshaw, & Wallace, 1971). The right hemisphere deals more effectively with spatial, nonverbal material, for example, faces (Geffen et al., 1971; Rizzolatti, Umiltà, & Berlucchi, 1971), blackened matrix cells (Gross, 1972), lines of different directional orientation (Fontenot & Benton, 1972), and arrays of dots (McGlone & Davidson, 1973).

Cohen (1972) suggested that differential hemispheric processing should result in reaction time differences on a same-different letter classification task. The task, following the method introduced by Posner and Mitchell (1967), required subjects to recognize as the same physically identical stimuli (physical match) or stimuli with the same name (name match). The stimuli were rapidly flashed pairs of letters which were presented foveally, to the right visual field, or to the left visual field. Since the visual fields project directly to the contralateral cerebral hemisphere, the cerebral laterality effect could be investigated. Cohen predicted that physical matches would be made more rapidly in the right hemisphere

since the task did not require verbal coding. Name match reaction time, likewise, should be faster in the left hemisphere as a result of the verbal nature of the task. The results confirmed this Hemisphere by Task interaction, with name matches having shorter latency in the left hemisphere and physical matches made faster in the right hemisphere.

The physical match-name match paradigm has been extended to pictorial stimuli by Klatzky (1972). Right-handed females were presented with two consecutive pictures to either hemisphere for a same-different comparison. Physical matching pictures consisted of two identical stimuli. Pictures of two objects with the same name were presented on name matching trials. There was no evidence of hemispheric asymmetry for either physical or name matches.

Seamon and Gazzaniga (1973) demonstrated the importance of subjects' processing strategies in cerebral laterality research. They reasoned that instructions which stress the verbal nature of stimuli should enhance the left-hemisphere effect, while instructions which encourage a spatial representation would improve right-hemisphere performance. A same-different reaction time task was used with two words presented foveally followed by a picture probe to either the right or left visual field. The task was a name matching task, since the subject was required to decide if the probe depicted one of the immediately preceding stimulus words. In the verbal emphasis condition, subjects repeated the pair of stimulus words subvocally prior to the presentation of the probe. Relational imagery instructions required the subject to imagine a picture of the pair of stimuli in physical contact. Under the rehearsal instruction condition, subjects responded more rapidly to probes to the left hemisphere than to probes to the right hemisphere. The relational imagery instruction resulted in shorter reaction time to probes projected to the right hemisphere. Seamon and Gazzaniga

Portions of this research were reported at the 1975 Midwestern Psychological Association meeting. Requests for reprints should be addressed to James R. Antes, Department of Psychology, University of North Dakota, Grand Forks, North Dakota 58202.

interpreted the results as support for a dual hemispheric processing model based on verbal-spatial stimulus characteristics.

EXPERIMENT I

The present research investigated the effects of coding strategies on hemispheric differences in a physical matching task. The study of Seamon and Gazzaniga used a name match task to demonstrate the differential effectiveness of the cerebral hemispheres in coding in either image or verbal form. The physical match procedure requires subjects to match a probe to an initial stimulus on the basis of physical characteristics. It is possible that the presumably altered hemispheric processing, induced by coding instructions, could produce a laterality effect in this task as well. Experiment I was designed to test this possibility.

Method

Subjects. The subjects were 20 (10 female) University of North Dakota undergraduates who received extra course credit for volunteering. All subjects reported normal vision and all were right-handed.

Apparatus and Materials. The stimulus words were 90 three-letter concrete nouns selected from the Battig and Montague (1969) norms. The words were randomly paired, with the restriction that no words from the same categories could appear together. Half of the pairs were randomly selected to appear on "same" trials and one of the words was selected as the probe. The remaining pairs were used on "different" trials and were randomly assigned a third word as the probe, with category restriction. Thus, a 36-trial list with half same and half different items was formed, and this list was used in both coding strategy conditions, with half of the same and different word probes randomly assigned to each visual field of presentation.

Each pair of words was centered, one over the other, on a 4 x 6 in. card, each word subtending not more than 3° of visual angle horizontally or 1° vertically. The words were printed in black ink with a Pickett Futura template. The innermost letter of the probe word was offset 1.5° from the center in the assigned direction.

The stimuli were presented on a two-channel tachistoscope (Gerbrands, Model T-2B-1) with reaction times recorded by a Hunter Klockounter. Subjects made responses on two keys.

Procedure. The subjects were randomly assigned to either the rehearsal or imagery coding strategy condition. The instructions to subjects explained that they would see a pair of words for a short period of time, followed by a blank period and then another word. They were to respond by pressing the appropriate key to indicate if the word was one of the two they had seen before, a same response, or was not one they had seen before, a different response. Hand of responding was counterbalanced within and between instruction groups. The subjects in the rehearsal group were then told that "previous research has shown that the best way to remember the words is to say them over and over to yourself." The subjects in the image group were told that "previous research has shown that the best way to remember the words is to form a mental picture of the letters of the words and to concentrate on the picture." The instructions in both conditions encouraged both speed and accuracy. All subjects were instructed to focus on a centrally located fixation dot, which appeared whenever a stimulus or probe was not displayed.

A trial consisted of the presentation of the stimulus pair for 10 sec followed by a 2.5-sec blank period when the fixation dot was visible. The blank period was terminated by the 100-msec display of

Table 1
Means of the Median Reaction Times (in Milliseconds)
for Each Coding Strategy: Word Probes

Rehearsal			Coding Strategy Imagery			No Instructions*		
Hemisphere Right	Left	Mean	Hemisphere Right	Left	Mean	Hemisphere Right	Left	Mean
Female Subjects (n = 10)								
578	548	563	637	670	653	564	617	590
Male Subjects (n = 10)								
674	680	676	568	563	565	669	673	671
Mean								
626	614	620	602	616	610	616	645	630

*Data for the no instruction condition is described in Experiment 2 and had an $n = 5$ for each sex.

the probe. Thirty-six trials were conducted in a random order, with the first 12 discarded as practice.

Results

Responses on the same and different trials were pooled and the median reaction time to probes to the right and left hemispheres were computed for each subject. The means of these medians are shown in Table 1. The error rate was 3.5%, and these incorrect responses were deleted from the analysis. A Sex by Instruction by Visual Field analysis of variance was computed on the medians with none of the main effects found to be significant sources of variation. Only the Instruction by Sex interaction was significant, $F(1,16) = 4.537$, $p < .05$, $MS_e = 22306$, and this interaction is shown graphically in Figure 1. Males responded faster than females in the image condition, while the females responded faster in the rehearsal condition. Individual analyses were performed for males and females alone, and no significant main effects or interactions were obtained.

A separate analysis (Sex by Instruction by Visual Field by Same-Different) was performed using same trials/different trials as an independent variable.

Figure 1. Mean of the median response time for the coding instruction conditions of Experiment I and for the no-instruction condition of Experiment II.

There were no significant main effects or interactions, with the exception of the Instruction by Sex interaction. This was also the case when same trials and different trials were individually analyzed.

Similarly, a Sex by Instruction by Visual Field by Hand of Same Response unweighted means analysis was computed. This analysis was included to check for possible effects of hand-hemisphere connections. In addition to the Instruction by Sex interaction, the Hand of Same Response by Visual Field interaction was significant, $F(1,12) = 35.92$, $p < .01$, $MS_e = 680$. Stimuli presented to the right hemisphere were responded to more rapidly than were left hemisphere probes when the hand of same response was the right hand. The reverse was true when the left hand was used for same responses.

EXPERIMENT II

The failure to find hemispheric or instructional differences with the word probes on the physical matching task suggested a need to reproduce the laterality effect to picture probes of Seamon and Gazzaniga (1973). Furthermore, since sex of subject interacted with instructional condition in Experiment I, it was important to explore this possibility in a task using picture probes (Seamon and Gazzaniga did not report the sex of subjects).

Method

Subjects. The subjects were 10 (5 female) undergraduates, from the University of North Dakota, who received course credit for volunteering. All subjects were right-handed and reported normal vision.

Apparatus and Materials. The same apparatus described in Experiment I was used in the present study. Sixty-four three- and four-letter concrete nouns were obtained from the Battig and Montague (1969) and Paivio, Yuille, and Madigan (1968) norms and randomly divided into two lists of stimulus words. Within each 32-item list, half of the words were randomly assigned to appear on same trials and half on different trials. Thirty-two new three- and four-letter nouns were selected and randomly paired with the different trial stimulus words. Simple line drawings were made representing the 32 same trial stimulus words and the 32 words paired with the different trial stimuli. Half of the probes, for both same and different trials, were randomly assigned to each visual field of presentation. Thus, two lists of 32 word-probe pairs were constructed, one for each instruction condition, with an equal number of same and different trials to each visual field.

The words were printed in black ink using a Pickett Futura template and centered on 4 x 6 in. cards, and subtended not more than 3° of visual angle horizontally or 1° vertically. The probe drawings were in black ink on 4 x 6 in. cards with the innermost edge offset 1.5° from the center in the assigned direction. The drawings subtended not more than 3° of visual angle in any direction.

Procedure. All subjects were given 36 trials of the same-different word recognition task described in Experiment I. They received no instructions regarding coding strategy, and the task was introduced as an opportunity to practice with the reaction time apparatus.

In two additional sessions, subjects performed the picture probe task using rehearsal and imagery instructions in a predetermined counterbalanced order, with each coding strategy condition separated by a minimum of 24 h. The instructions for the rehearsal condition were the same as in Experiment I. The imagery instructions told the subject to "form a mental picture of the item the word represents and concentrate on that picture." The

remainder of the instructions were the same as in Experiment I, and the same controls were used for hand of responding.

There were 32 trials in each condition, with the first 12 discarded as warm-up. The same stimulus and probe intervals were used as in Experiment I.

Results

The stimuli for the practice trials were the items described in Experiment I, and the data provided a no-instruction control group for that experiment. The means of the median reaction times for the pooled same-different probes to each hemisphere are shown in Table 1. In addition, these values for each sex are shown in Figure 1.

Table 2 presents the means of the pooled same-different medians for picture probes to the right and left hemispheres of Experiment II. Incorrect trials constituted 4.1% of the trials and were eliminated from the analysis. An analysis of variance (Sex by Instruction by Visual Field) yielded an Instruction by Visual Field interaction, $F(1,8) = 6.79$, $p < .05$, $MS_e = 4390$, as the only significant effect. As can be seen in Table 2, probes to the left hemisphere were responded to more rapidly than those to the right hemisphere in the rehearsal condition. The reverse was true in the image condition, and both findings are consistent with the results of Seamon and Gazzaniga (1973).

As in Experiment I, separate analyses were computed for same-different trials and hand of same response. Both analyses yielded only the significant Instruction by Visual Field interaction.

Additional analyses (Sex by Instruction by Visual Field) were performed using the medians for same trials and for different trials as the dependent measures. No significant effects were found on the different trials, not even the Instruction by Visual Field interaction, $F(1,8) = 2.66$, $p > .05$, $MS_e = 8076$. However, when the same trials were analyzed, the Instruction by Visual Field interaction was highly significant, $F(1,8) = 21.65$, $p < .01$, $MS_e = 3178$.

DISCUSSION

Taken together, these two experiments have shown that rehearsal vs. image instructions produce a

Table 2
Means of the Median Reaction Time (in Milliseconds)
for Each Coding Strategy: Picture Probes

Coding Strategy					
Rehearsal			Imagery		
Hemisphere			Hemisphere		
Right	Left	Mean	Right	Left	Mean
Female Subjects (n = 5)					
632	555	594	542	641	591
Male Subjects (n = 5)					
541	520	530	503	525	514
Mean					
586	538	562	522	583	553

cerebral laterality effect in a task requiring the matching of stimuli on nonphysical characteristics but not when matches are made using physical features of the stimuli. It is possible that this difference is due to the specific matching demands of Experiments I and II. Experiment I required subjects to indicate whether or not a probe word was identical to one of two previously presented words. In neither instructional condition was it necessary for subjects to name the stimulus words. In the rehearsal condition, the word could have been coded according to acoustic properties; in the image condition, a visual code representing physical characteristics of the letters could have been used. Probes could be coded with a similar type of representation and used as a comparison to determine match or mismatch. Clearly, Experiment II required subjects to name the stimuli before a matching comparison could be made. In the rehearsal condition, both coding on the basis of acoustic properties and naming (semantic processing) were required and the left hemisphere was more effective than the right. A visual representation of the object represented by the word, obviously requiring semantic processing, was required under image instructions. In this situation, responses to probes to the right hemisphere were faster than those to probes to the left hemisphere. Possibly, then, the process of naming, or converting to a semantic representation from some other code, is a major factor contributing to the laterality effect here.

In the physical matching task, women had lower reaction times than men when using the rehearsal strategy and men made more rapid responses using the imagery strategy. It is generally acknowledged that women are more fluent than men in their use of language while men are more proficient at tasks requiring visual and spatial manipulation (Buffery & Gray, 1972; Maccoby & Jacklin, 1974; Tyler, 1965). These conclusions seem to be related to the type of measurement involved. Women have been found to have higher verbal scores on the American College Test (Monday, Hout, & Lutz, 1966-67), the American College Entrance Examination (Rosenberg & Sutton-Smith, 1964, 1969), and the WISC vocabulary subtest (Achenbach, 1969), but are not different from men on anagram tasks (Feather, 1968, 1969; Mendelsohn & Griswald, 1967; Lipton & Overton, 1971) or the Scholastic Aptitude Test verbal subscale (Bieri, Bradburn, & Galinsky, 1958; Marks, 1968). Similarly, males have superior scores on the Embedded Figures Test (Bieri et al., 1958; Goldstein & Chance, 1965; Witkin, Goodenough, & Karp, 1967), the Rod and Frame Test (Kato, 1965; Silverman, Buchsbaum, & Stierlin, 1973; Vaught, 1965), and maze performance (Davies, 1965), but there is no difference in performance on identification of shapes (Connors, Schuette, & Goldman, 1967; Kaess, 1971; Shipman, Note 1), localization of a spatial target (Smothergill, 1973), or assembling

puzzles (Ruble & Nakamura, 1972). In general, when a verbal difference is found, it supports female superiority and when a spatial difference is found it favors males. The high incidence of no difference being found between sexes on both verbal and spatial tasks, however, cannot be disregarded. Thus, in Experiment I, the rehearsal instructions emphasized the verbal nature of the stimuli and the imagery instructions encouraged the use of the stimuli in a spatial manner. These findings are consistent with the sex difference literature.

The failure to find a similar instructional interaction with sex in Experiment II is likely due to the spatial characteristics of that task. All probe stimuli were drawings, which may not have provided an opportunity for female subjects to adequately utilize their verbal fluency in the rehearsal condition. Such a conclusion is supported by the finding that males responded faster than females in all conditions regardless of the field of probe presentation or instructional conditions (see Table 2).

Analyses of the same vs. different trials in the physical matching task of Experiment I yielded no differences for trial type, but identical analyses in Experiment II revealed that the Visual Field by Instruction interaction occurred only on the same trials. Thus, hemispheric differences were obtained only on same trials in the name match task. These results fail to support the findings of Egeth and Epstein (1972). They found that the left hemisphere was more efficient on same trials and the right was better on different trials. The Visual Field by Instruction interaction should not occur if the left hemisphere is functioning more efficiently on determinations of sameness. The interaction is consistent, however, with the contention of Davis and Schmit (1973) that the cerebral laterality effect is valid only for same judgments.

The Hand of Same Response by Visual Field interaction in Experiment I is difficult to interpret. Klatzky (1972) reported a strong relationship between hand of same response and the visual field of the stimulus. Right same-responders were faster for stimuli to the right visual field, and left same-responders were faster with left visual field stimuli. Klatzky explains this difference as resulting from the compatibility of responses. A compatible response is the reaction to stimuli presented to the visual field of the hand of same responding. Thus, the stimulus would project directly to the hemisphere which controls the motor movement. In the present study, the interaction showed the opposite finding, that is, stimuli to the left visual field were responded to most rapidly by right-hand same responders. However, the fact that this task involved word stimuli and Klatzky's task used picture stimuli suggests that this inconsistency warrants further investigation.

Finally, the practice session of Experiment II provided a no-instruction control for Experiment I.

When no coding instructions were given, subjects responded as did subjects in the rehearsal condition of Experiment I; females responded faster than males to both left- and right-hemisphere probes. This was true despite the indication that this may not be the most efficient strategy for males. Perhaps this is evidence that subjects normally employ a rehearsal strategy in such tasks. Adult subjects have certainly had considerable experience with verbal material and thus have probably had a much greater opportunity for learning and using a rehearsal rather than an imagery coding strategy.

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(Received for publication March 18, 1975;
revision accepted June 26, 1975.)