COGNITIVE PSYCHOLOGY 5, 249–256 (1973)

Coding Strategies and Cerebral Laterality Effects[1]

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In a short-term recognition memory task, Ss were given relational imagery and rehearsal coding strategies in different sessions, with probes presented to the left or right cerebral hemisphere. Consistent with a model of separate processing systems for verbally and visually coded information, Ss yielded significantly faster response latencies for probes to the left hemisphere than the right when employing the rehearsal strategy, and significantly faster latencies for probes to the right hemisphere than the left when using the imagery code. This suggests that cerebral laterality effects are functionally related to coding strategies, and argues for the inclusion of imagery, or generated visual information, as part of the visual processing system. As such, generated visual information may be viewed as a coding alternative to verbal mediation.

It is well-known that information can be represented or coded in different forms in memory. Conrad (1964) noted that Ss made acoustic confusions in a recall task, even though the original stimulus presentation was visual. The acoustic confusions suggest that the Ss recoded the stimuli from a visual to a verbal base prior to recall. Posner, Boies, Eichelman, and Taylor (1969) present data which are consistent with the hypothesis that Ss can generate a visual representation of an auditorily presented letter. Further, Bahrick and Boucher (1968) have demonstrated that object drawings may be visually or verbally coded in memory independently. Additional research has shown that stimulus (Tversky, 1969) and task (Frost, 1972) expectancy can influence the

[1] This research was conducted while the first author served on a fellowship at New York University. It was aided by USPHS Grant 17883 awarded to the second author. The authors thank Gordon H. Bower for reviewing an earlier draft of this paper.

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form of the information code, regardless of the manner of presentation.

Verbal and visual information codes can be conceptualized as different modes of thought (Bower, 1970, 1972; Paivio, 1969). Bower (1970) views these modes as different processing systems, and he suggests that the systems might be functionally discriminated along hemispheric lines. A verbal processing system, which is specialized for speech and abstract information, may be primarily a left hemisphere function, while a visual processing system, which is more adept with spatial and concrete information, might be predominantly associated with the right hemisphere. There is some behavioral and neurological evidence to support this view for information held in memory (Milner, 1970; Milner & Teuber, 1968).

The purpose of this experiment is to determine if varying coding strategies can produce hemispheric differences which are consistent with the model of separate processing systems, in particular, to observe if the left hemisphere will be faster than the right in a same–different recognition memory task when the information is verbally coded, but the right hemisphere faster than the left when the same information is visually coded by the use of imagery. Past research with a same–different recognition memory task has shown that facial stimuli are recognized significantly faster when the probes are presented to the right hemisphere than the left (Geffen, Bradshaw, & Wallace, 1971; Rizzolatti, Umilta, & Berlucchi, 1971), while letter stimuli are recognized significantly faster when the probes are presented to the left hemisphere (Rizzolatti *et al.*, 1971). Since the left and right visual fields project exclusively to the contralateral hemisphere, a probe may be initially presented to the left or right hemisphere in normal Ss by spatially displaying it briefly to the right or left of a visual fixation point. If imagery, or generated visual information (Posner *et al.*, 1969), can be viewed as part of the visual processing system, then a hemispheric difference in accord with the above data would be predicted when the Ss employ a visual code, while the difference should be reversed when the Ss use a verbal code.

METHOD

Subjects. Six right-handed, native English-speaking students from New York University served as Ss in a Repeated Measures design with each S exposed to both coding strategies and memory probes to each hemisphere. All Ss had previous practice in recognition memory tasks employing reaction time (RT), although none had participated in studies involving visual imagery.

Procedure. The experiment was run in two sessions, with a 1-wk separation. Half of the Ss were given relational imagery instructions in the first session followed by rehearsal instructions in the second, and half were given the reverse arrangement. The relational imagery and rehearsal strategies were the same as those used previously to study retrieval processes (Seamon, 1972).

On a given trial the Ss were simultaneously presented with two simple English nouns arranged horizontally on a rear-projection screen for 7.5 sec. The stimuli were followed by a 2.5-sec blank period, a short auditory warning signal, and a recognition memory probe to a single hemisphere. The Ss were required to indicate if the probe was a picture of one of the items in the study set by manually depressing a YES button with their right index finger, or a NO button with their right middle finger as quickly and as accurately as possible at all times. Instructions emphasizing speed and accuracy were given before each session. A total of 36 trials was presented in each session, with a 3-sec intertrial interval. The first 12 trials for each session were considered practice. New 3- or 4-letter concrete nouns (e.g., HAT, DUCK, etc.) were used on every trial, with half of the responses positive and half negative. All Ss viewed the stimuli in the same order within and between sessions.

With the presentation of the auditory warning signal, S focused on the fixation marker in the center of the screen to await the probe 0.5 sec later. A memory probe consisted of a picture of a single object which varied in size from 1.5 to 3.5 degrees of visual angle. All probes were presented from 100 msec on either the left or right side of the fixation marker with the innermost edge of each probe 1 degree from the fixation point. Probes in the left or right visual fields occurred equally often for positive and negative responses, with their order randomly determined on each trial. A positive probe consisted of a line drawing of a pictorial representation of one of the two study words in the memory set, while a negative probe was a drawing of an unrelated object whose name was given by a 3- or 4-letter word. No picture probes were used more than once.

The Ss were instructed in a particular coding strategy at the start of each session. For the rehearsal strategy, Ss were told to rehearse the two study words subvocally and continually during their presentation and the blank period preceding the probe. When the picture probe was presented they were told to indicate if the picture represented one of the words in the study set. For the relational imagery strategy, the Ss were instructed to generate an imaginal representation of each of the study words, and to put the two images together into a single interactive scene so that one image was always touching the other image. The Ss were told to hold the imaginary scene by concentrating on it until the probe was presented, and to respond YES only if the probe represented one of the objects imagined in the scene. If the Ss were unable to comply with the imagery instructions on any trial, they were asked to verbally respond "Can't do it" instead of making a recognition response. Thus using the two word set of BEAR—BOOK as an example, when using the rehearsal strategy, the Ss simply recited the two words to themselves, whereas, when using the relational imagery strategy, the Ss might have imagined a book with a picture of a bear on the cover, a bear reading a book, or some other idiosyncratic relation.

Appropriate instructional examples were provided for each strategy to ensure that all Ss understood their task during each session. In addition, before each session, the Ss were told to follow the coding instructions explicitly. The Ss were specifically told not to subvocally rehearse the stimuli when using relational imagery, and not to form images when using rehearsal. The necessity of complying with the instructions on each trial was duly emphasized for each S.

RESULTS

Errors for picture probes for the relational imagery and rehearsal conditions occurred on 1.74 and 2.43% of their trials, respectively, and were excluded from analysis. No responses of "Can't do it" were reported when the Ss were using relational imagery.

Mean latencies for correct responses were obtained from the individual S means of pooled YES and NO responses and are shown in Table 1. Coding strategy clearly produced differential effects on RT and hemisphere in agreement with the predictions. RTs were faster for probes to the right hemisphere than the left when the Ss were using relational imagery, and faster for probes to the left hemisphere than the right when

TABLE 1
Reaction Time as a Function of Coding Strategy and Hemisphere of Memory Probe

Coding strategy	Relational imagery		Rehearsal	
Hemisphere	Lf H	Rt H	Lf H	Rt H
*S*1	428	385	637	676
*S*2	497	503	563	585
*S*3	646	608	684	708
*S*4	600	588	637	645
*S*5	568	554	549	552
*S*6	571	528	540	605
Means	552	528	602	629
Mean difference	24		−27	

they were using rehearsal. This is supported by the results of an analysis of variance which showed a significant interaction of coding strategy and hemisphere, $F(1,5) = 10.10$, $p < .025$, with the right hemisphere significantly faster than the left for the relational imagery code, $F(1,5) = 7.48$, $p < .05$, and the left hemisphere significantly faster than the right for the rehearsal strategy, $F(1,5) = 9.35$, $p < .05$. A significant main effect for hemisphere was not observed, $F < 1.0$, and the overall effect of coding strategy produced only a weak effect, $F(1,5) = 4.12$, $p < .10$. A separate analysis of YES and NO response RTs was not attempted as only six observations per S were obtained for each response, coding strategy, and hemisphere combination.

The interaction of coding strategy and hemisphere suggests that the Ss treated the information in a verbally coded fashion when instructed to rehearse, while permitting the information to be handled in a visually coded form when the Ss used relational imagery. Of interest is the finding that the RT reversal was obtained on an individual S basis. As shown in Table 1, all six Ss yielded faster RTs for probes to the left hemisphere when using rehearsal, and five of the six Ss produced faster RTs for probes to the right hemisphere when employing relational imagery. The demonstration that the RT reversal can be obtained within Ss might suggest that coding strategies are flexible and easily manipulated.[3]

DISCUSSION

The results of this experiment show that cerebral laterality effects are functionally related to coding strategies. This extends previous observations relating retrieval processes to coding strategies (Seamon, 1972, 1973). The relational imagery data are consistent with the behavioral and neurological evidence which show a right hemisphere superiority for visually coded information. This suggests that verbal mediation was not used as the underlying information code in this condition. Moreover, manipulation of the instructions to produce a verbal coding yielded a left hemisphere superiority consistent with the data for laterality effects and verbal information. Together, these data indicate that Ss instructed

[3] It was not possible to do an ANOVA on the available individual S data, as cell frequencies in the repeated measures design were not equal due to the nonreplacement of discarded trials. However, a program was devised which eliminated the entire row of data in which one RT observation was missing, and replaced the missing observation in its particular location by a normally distributed value for that cell, thus preserving the variability within each condition of the 2×2 matrix. ANOVAs on both of these sets of data failed to show a significant interaction, ($p > .05$), for any S. Because of the inherent variability in this RT task, it is suggested that more than 12 trials are necessary to observe the interaction on an individual S basis.

to use relational imagery did, in fact, employ a visual code. It is not known if the visual code is equivalent to the subjective experience of imagery, as Posner *et al.* (1969) point out. The data are not, however, inconsistent with this interpretation.

Comparison processes. It is assumed that a comparison between the recognition probe and the information in memory must precede each response decision. Use of a verbal code for the study set and a pictorial memory probe would appear to require a translation or recording on at least one of the items before a comparison could be made. It may be that the probe is first named, with the verbal referent of that name then brought into memory to compare with the verbal referents of the study words.

A fundamentally different comparison process may be present when the study set is visually coded and the probe in picture form. A direct, template comparison of the picture probe with the internal visual representation of the memory set is unlikely, due to the virtually unlimited number of imaginal representations permitted. One possibility is that the *S*s are able to make a feature comparison between the internal visual representation and the memory probe on a nonverbal basis. This would be similar to Posner *et al.*'s (1969) view of generated visual information as a program for analyzing visual features.

RT models. The finding of significant RT differences between the hemispheres might be explained by several different models. It may be that, in the present task, verbally and visually coded information was processed exclusively in the left and right hemisphere, respectively. As such, probes presented to the inappropriate hemisphere would yield longer RTs because of the time necessary for interhemispheric transfer. The RT differences of 24 and 27 msec would provide estimates of the interhemispheric transfer time, and would suggest that the transfer was temporally symmetrical.

A second model might hold that each hemisphere could process both information codes. The RT differences would be interpreted as a reflection of efficiency differences between the hemispheres for verbal and visual information. This would suggest that verbal comparisons are performed faster in the left hemisphere, and visual comparisons are performed faster in the right. Research by Gazzaniga (1970) which showed that both hemispheres in brain-bisected patients can recognize and respond appropriately to verbal and pictorial referents of simple objects, would seem to support this interpretation. However, additional research has shown that the right hemisphere is severely limited in its linguistic competence (Gazzaniga & Hillyard, 1971), hence the neurological data do not provide broad support for this model.

Alternatively, the interpretation of the RT differences may vary with the coding strategy employed. Only a verbal code may result from rehearsal instructions, while a verbal and a visual code may result from relational imagery instructions, as the stimuli were originally presented as words. If verbally and visually coded information is associated exclusively with the left and right hemispheres, respectively, the RT difference found when the Ss used rehearsal might reflect interhemispheric transfer. Dual coding under the relational imagery instructions might suggest that the RT difference be explained in terms of the ease of the comparison process involved. The pictorial memory probe may be more readily compared to the visually coded information in the right hemisphere than the verbally coded information in the left. Several theorists have suggested dual coding (Bower, 1970, 1972; Paivio, 1969) to account for the higher memorability of concrete information over abstract, but direct evidence of dual coding of specific items has been lacking.

In summary, these data support the original hypothesis that varying coding strategies can produce cerebral laterality effects consistent with the model of separate processing systems, and argue for the inclusion of imagery, or generated visual information, as part of the visual processing system. As such, generated visual information may be viewed as a coding alternative to verbal mediation.

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(Accepted February 6. 1973)