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Retrieval of pictorial and verbal stimulus codes*

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An experiment that required same-different comparisons of successive pairs of geometric figures represented pictorially or verbally demonstrated that Ss could, even after 8 sec, recode to or retrieve the alternative code of a stimulus in memory such that it was as effective for judgment reaction times as the original representation. Thus, where both pictorial and verbal codes are available, either can be accessed as is needed for the task. There was no tendency to revert to verbal codes; in fact, comparisons to pictures were faster than comparisons to words.

That pictorial as well as verbal codes of stimuli are effective in memory, of both the short-term and more permanent varieties, has been established by numerous experiments (for example, Bower, 1972, Paivio, 1971, Posner, 1969, Shepard & Chipman, 1970, Tversky, 1969). Nevertheless, there is still some disagreement as to the status of pictorial codes, with several theoretical positions contending that pictorial codes are rapidly replaced by verbal codes except in unusual circumstances (see Craik & Lockhart, 1972, Clark & Chase, 1972). Verbal encoding is viewed as temporally subsequent to and cognitively more advanced than pictorial encoding, and pictorial codes are considered more difficult to retain than verbal. An alternative position regards verbal and pictorial codes as alternative modalities for representing stimuli, either one of which may be more efficacious for storage of particular types of information or for utilization in particular tasks. While naming may be an essential or at least typical step in comparison of letters, it does not seem to be an essential step in visual scanning or in reading.

In line with the latter position, the present experiment is another attempt to demonstrate selection of encoding modality in accordance with task demands, despite a relatively long retention interval (10 sec). A stimulus, either a picture or a word, is presented to the S to remember in order to perform a delayed match for meaning to a comparison stimulus (i.e., name identity, e.g., "0" and "circle" are same) which may also be either pictorial or verbal. On half the trials, the S is informed of the comparison modality, and therefore has the opportunity to code the first (memory) stimulus appropriately in order to facilitate the match. This should yield faster matches, either verbal or pictorial, on trials where information is provided. Yet, if either code reverts to a verbal one rapidly, then the comparison modality information should not help reduce pictorial match reaction times. Moreover, on half the trials, the information as to comparison modality is delivered 8 sec *after* the memory stimulus, so that in order to utilize the comparison modality information, the S must, on many occasions, recode a stimulus which is already encoded in memory. If Ss are able to utilize comparison modality information for encoding the memory stimulus, but if the original code then is dominant, and recoding is difficult, then there should be a marked improvement in reaction time only when comparison modality information precedes the memory stimulus. If, on the other hand, the S is able to utilize the comparison modality information in order to recode one representation to another or to retrieve an alternative one, then there should simply be a reliable improvement in match times attributable to information, with no effect of the time of information.

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METHOD

Subjects

The Ss were eight right-handed Stanford University undergraduates paid for their participation and run individually.

Stimuli and Apparatus

The stimuli were the words (verbal modality) and the outline figures (pictorial modality) *square, rectangle, circle,* and *ellipse* drawn individually in black ink on white cards that were presented in a three-field Iconix tachistoscope.

Procedure

The S initiated each trial by pressing a footlever. This allowed viewing of the first stimulus (termed memory stimulus) in the tachistoscope for 1 sec. Then a blank field was illuminated for 10 sec, followed by the second stimulus (termed comparison stimulus) which was illuminated until S responded. S responded by pressing one of two keys with his index finger, "same" if the two stimuli had the same name, and "different" otherwise.

Design

All of the Ss participated in all conditions of the experiment. Each S had two blocks of 48 trials each per session for four sessions run on separate days. Half of the stimulus pairs were same and half different; this was randomized within blocks with runs constrained to four trials of either type. On half the trials, the S was informed of the comparison stimulus modality, and on half the trials he was not informed; this variable was also randomized within each block, also with runs restricted to four trials. On half the trials, the comparison stimulus modality was pictorial and on the other half, verbal, again randomized within blocks with runs constrained to four. Each of the four stimuli appeared equally often as memory and as comparison stimuli within each block. For one block of each session, the memory stimulus modality was pictorial; for the other block it was verbal. For two sessions, information concerning comparison stimulus modality was given, when it was given, prior to presentation of the first stimulus. For the other two sessions, this information was given, when given, 8 sec after presentation of the first stimulus, that is, 2 sec before onset of the comparison stimulus. Information was given verbally by the E, who said out loud "picture" or "word" as appropriate. On all those trials were information was not given, the E said "stimulus" 2 sec prior to comparison stimulus onset. Block and session types were spread out evenly within Ss to counterbalance practice effects, and were counterbalanced across Ss. For half the Ss, the left key signified "same," and for the other half, the left key signified "different." To summarize, the factors comparison modality, information vs no information, and same vs different were randomized within blocks, while the factors memory stimulus modality and time of information were blocked.

Instructions and Training

The task and design of the experiment were carefully explained to each S before the start of the experiment, and the particular conditions of each block explained before each block of trials. Ss were instructed to respond as quickly as possible without making errors. Ss had eight practice trials before each block, in which the conditions were representative of the conditions of the block.

RESULTS

An analysis of variance was performed on correct reaction times with the following factors: Ss, memory stimulus modality, comparison stimulus modality, same vs different, information vs no information, time of information (before or after). Table 1 reports the data broken down by first (memory) and second (comparison) stimulus modality, same vs different, and information vs no information as to comparison stimulus modality. Eliminated erroneous responses constituted about 3% of the data. Responses to second pictures with a mean reaction time of 458 msec were significantly ($F = 8.22$, $df = 1,7$, $p < .05$) faster than responses to second words, with a mean reaction time of 471 msec. Six out of eight Ss responded faster to second pictures, one S responded equally quickly to second pictures and second words, and one S responded 4 msec faster to second words. All eight Ss were faster to respond "same" (449 msec) than to respond "different" (480 msec), a result significant at the .01 level ($F = 22.08$, $df = 1,7$). Likewise, all eight Ss were faster on trials where they were informed of the comparison modality (439 msec) than on trials were no information was given (490 msec), a result significant at the .001 level ($F = 43.57$, $df = 1.7$). Neither the effects of memory stimulus modality, with responses to pictures 7 msec faster than responses to words, nor the effect of time of information, with a 15-msec advantage to information before the first stimulus, were significant. Half the Ss responded faster when information was given before the first stimulus, and the other half responded faster when information was given after the first stimulus. The triple interactions, Memory Stimulus Modality-Comparison Stimulus Modality-Same-Different, Memory Stimulus Modality-Comparison Stimulus Modality-Information vs No Information, and Memory Stimulus Modality-Comparison Stimulus Modality-Time of Information were each significant at at least the .05 level, but the patterns of interactions were irregular and uninterpretable (for instance, mixed modalities, that is, picture-word and word-picture pairs, were fastest for "same responses while pictures second were faster for "different" responses). No other interactions were significant.

Table 1
Mean Correct Reaction Times (msec) for Pictorial and Verbal First and Second Stimuli Which Were Same (S) or Different (D) on Trials Where Comparison Modality Information Was or Was Not Given

			Comparison Stimulus Modality			
			Information		No Information	
			Picture	Word	Picture	Word
Memory Stimulus Modality	Picture	S	417	415	479	470
		D	432	471	497	507
	Word	S	421	416	463	510
		D	472	466	483	510

DISCUSSION

It is evident from the results that information as to the modality, pictorial or verbal, of the comparison stimulus reduces reaction times considerably, indicating that Ss encoded the first stimulus in the expected modality of the second. Time of information, either prior to viewing the memory stimulus or considerably after display of the memory stimulus, had no effect on reaction times for "same"-"different" judgments. In other words, the comparison stimulus is matched as quickly to a memory stimulus encoded appropriately at viewing as to the trace of the memory stimulus recoded after viewing. Furthermore, there was no effect of presented modality of the memory stimulus, nor was there a tendency to revert to verbal codes over time, even when the comparison stimulus modality was not known; on the contrary, responses to second pictures were faster than those to second words. These data are not consistent with theories which propose that verbal codes predominate pictorial or visual codes. Apparently, both pictorial and verbal codes of these simple geometric figures are available, and either code can be accessed, or the stimulus encoded and recoded, in accordance with the modality demanded by the task.

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Reinforcement probability and concurrent operants

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When reinforcements for concurrent operants are programmed by independent variable-interval schedules of reinforcement, the relative response rate obtained for each operant is found to approximate the relative reinforcement rate for that operant. This relationship, called matching, is a necessary consequence of a maximizing principle which states that the operant emitted is the one having the momentarily greater reinforcement probability. Matching, however, can come about in other ways as well. To test the maximizing principle rats were trained to respond on either one of two levers. Whether a leverpress was reinforced was governed by a random process having a constant reinforcement probability which was not necessarily the same for the two levers. It was found that, after a few sessions' exposure, responding occurred nearly exclusively to the lever having the greater reinforcement probability as predicted by the maximizing principle.

Switching between concurrent operants is sometimes attributed to local changes in reinforcement probability (Catania, 1966; Shimp, 1966, 1969). It is held that the operant having the momentarily greater reinforcement probability will be emitted. This "momentary maximizing" principle (Shimp, 1966) is offered to account for various properties of the response distributions, such as relative response rate and changeover rate, obtained under concurrent schedules of reinforcement.

The relevance of the momentary maximizing principle to free operant behavior is supported by an examination of concurrent variable interval-variable interval schedules. These schedules arrange average reinforcement rates for the concurrent operants. The probability of a response being reinforced is not explicitly programmed. Instead, reinforcement probability is determined by the programmed rate and distribution of reinforcements interacting with the obtained rate and distribution of responses. This dependence of reinforcement probability on properties of responding makes the momentary reinforcement probabilities unpredictable and poses an obstacle to empirical validation of the momentary maximizing principle. Instead, the principle has become an assumption which has been combined in formal analysis with characteristics of the reinforcement scheduling procedures. The most important consequence of such an analysis is the prediction of the matching law (Shimp, 1969) which states that the relative rate of responding and the relative rate of reinforcement are approximately equal in each component of a concurrent schedule of reinforcement. Since this matching law is already well established for concurrent variable interval-variable interval schedules (Herrnstein, 1961, 1970) the momentary maximizing principle is supported.

The experiment reported here sought to test the momentary maximizing principle directly by explicitly arranging reinforcement probabilities for two concurrent operants. The reinforcement probability associated with each operant did not change during an experimental session. Hence, when the two probabilities were unequal the momentary maximizing principle predicted exclusive emission of the operant having the greater reinforcement probability. In the terminology of Schoenfeld and Cole (1972) the procedure used was a concurrent random ratio-random ratio schedule of reinforcement.

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METHOD

Subjects

The Ss were four experimentally naive male Albino rats 120