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Analysis of Memory Codes and Cumulative Rehearsal in Observational Learning[1]

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The present study examined the influence of memory codes varying in meaningfulness and retrievability and cumulative rehearsal on retention of observationally learned responses over increasing temporal intervals. Symbolic codes combining meaningfulness with retrievability produced superior memory performances, but responses were poorly retained in symbolic representations containing only one of these properties. Individual response analysis further confirmed that the more meaningful the codes incorporating retrieval guides the better are modeled responses learned and retained. Cumulative rehearsal had differential effects on memory performances depending upon the serial input position of the responses and the form into which the modeled behavior was encoded. Code rehearsals facilitated retention of early and intermediate responses which were repeated more than later ones, but this was true mainly for codes vulnerable to loss. The overall findings provide further corroborative evidence that memory performances are governed more by information coding than by associative strengthening processes.

Observational learning has been analyzed from several theoretical perspectives. Associational theories conceptualize the process in terms of formation of stimulus-response linkages through the selective influence of reinforcement. Proponents of this view usually study instantaneous imitation, which does not require much in the way of cognitive functioning because reproduction is externally guided by the model's performance. Since observationally learned responses are rapidly lost without the benefit of symbolic memory aids (Bandura & Jeffery, 1973), theories that eschew cognitive or mediational processes have notable limitations.

A second line of theorizing depicts observational learning as essentially a template-matching process. In this view, observed behavior is stored

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as cognitive templates of actions. Many modeled activities are encoded as images or verbal facsimiles that serve as functional mediators in subsequent response reproduction. However, the changes that could be produced through modeling influences would be more limited than they have been shown to be if coded representations were confined to cognitive replicas of responses performed by others.

According to social learning theory, which advances an information processing interpretation of observational learning, transient modeling experiences are maintained in permanent memory through the medium of symbols (Bandura, 1971). In this approach, symbolic coding primarily involves a constructive rather than a direct copying process. Observers often abstract common features from otherwise varying modeled responses and construct higher-order codes that have wide generality (Bandura, 1971; Zimmerman & Rosenthal, 1974). They impose subjective organization upon modeled activities (Gerst, 1971). Modeled performances can be effectively learned and retained through reductive transformations that preserve vast amounts of response information in a few symbols (Bandura & Jeffery, 1973). In neither case are the coded representations necessarily structurally isomorphic to the observed activities.

Evidence is now accumulating that memory codes differing in characteristics (e.g., verbal, imaginal, reductive, elaborative) can all enhance retention of observationally learned responses. It is likely that a basic property—meaningfulness—underlies the mnemonic utility of diverse codes. Retention is improved by transforming the new into the familiar, which already exists in long-term memory. In a previous experiment (Bandura & Jeffery, 1973), modeled responses were learned and maintained much better through meaningful memory codes than with symbolic transformations devoid of meaning. The advantage of code meaningfulness became progressively greater over time.

Modeled performances can be encoded in ways that are meaningful but inadequately informative when responses must be retrieved from many alternatives. Meaningfulness itself may thus have limited mnemonic value unless it incorporates retrieval guides which delineate the correct responses. The present experiment investigated the effects on memory performance of code meaningfulness with and without response retrieval rules.

It has been previously shown that if modeling stimuli are not coded and symbolically rehearsed at the time of input they tend to be lost from memory (Bandura & Jeffery, 1973). Although immediate rehearsal substantially enhances retention of codes from which responses can be reconstructed, nevertheless some of the memory codes are lost over time. As a result, opportunities for delayed rehearsal do not improve memory performance. Ordinarily, modeled activities are symbolically reinstated from time to time rather than only at exposure or after a long period has elapsed. Encoded responses may thus be strengthened in memory through cumulative rehearsal.

In the present study, subjects observed a model perform complex movement configurations. One group constructed mnemonic sentences describing the essential features of the modeled patterns. This condition included meaningful linguistic codes but without generalizable retrieval rules. Because of the large number and similarity of constituent responses, the different patterns could not be easily conserved in changeable linguistic transformations. A second group assigned preselected letter associates to each component response as it was modeled and stored the patterns in memory as aggregate letter codes. Although this coding system provided precise retrieval rules, the letter aggregates corresponding to the modeled performances were meaningless. A third group of subjects, using meaningful codes with retrieval rules, first transformed constituent acts into corresponding letters, then constructed mnemonic sentences whose words began with the code letters. Immediately after a test for observational learning, subjects in each condition either cumulatively rehearsed the codes or had no opportunity to reinstate symbolically what they had seen. Response retention tests were conducted at the end of the experimental session and again one week later.

It was predicted that memory codes combining meaningfulness with retrievability would produce the superior memory performances. It was further hypothesized that cumulative rehearsal would improve retention of modeled responses, the effect being greatest for the items that were rehearsed most often.

METHOD

Subjects

The subjects were 30 males and 30 females drawn from an introductory psychology course and paid college volunteers. Equal numbers of men and women from these two sources were randomly assigned to each of the six experimental conditions.

Procedure

Subjects were told that they were participating in an experiment investigating visual perception. All experimental subjects were first shown a film of six component actions that were used in varying combinations to create complex modeled performances. Each component response consisted of a lateral movement covering either 1, 2, or 3 intervals followed by a downward and lateral movement of 1 interval; each of these three movement patterns could be made to the right or to the left, thus creating a total of six component moves.

For subjects in the coding conditions involving retrieval guides, each component move was assigned a distinctive letter associate. The letters N, B, C designated the three movements to the left of progressively longer length, while the letters S, T, P represented the corresponding movements to the right.

After subjects studied the component moves for a period of 1½ minutes, they were asked to reproduce them to ensure that all had learned the constituent responses, which they did. Subjects were then given three practice trials to familiarize them with the modeling and coding activities.

Modeling Stimuli

The modeling stimuli were identical to those used in a previous experiment (Bandura & Jeffery, 1973). Each modeled response configuration was formed by connecting sequentially six component moves of varying distances and directions. The responses were performed on a green panel containing a field of equidistant dots to clarify whether the model was moving one, two, or three intervals at any given time. All modeled performances were presented to subjects individually on color film.

Five novel modeled configurations were used to measure observational learning and response retention over time. These patterned movements constituted an exceedingly difficult memory task because they shared many common features. In the previous study (Bandura and Jeffery, 1973), subjects who observed the modeled performances without employing any memory aids were unable to reproduce any of the response patterns after a delay interval. This control condition, therefore, was not repeated in the present experiment.

Coding Operations

Subjects in the *sentence coding condition* were instructed to generate sentences that described the essential features of the modeled patterns. Those assigned to the *letter coding condition* were told to code the model's actions as they were being performed into the appropriate letters. They learned each modeled configuration by assigning letter associates to each constituent act, and storing the entire pattern in memory as an ensemble letter code. The modeled responses could later be reproduced by translating sequentially each of the code elements into its corresponding action.

Subjects in the dual coding condition, which involved a combination of reductive and elaborative mnemonics, first coded the constituent responses into letters, then constructed menemonic sentences of their own choosing using the aggregate code letters as the first syllables in the words. The reductive code TBSNSB corresponding to one of the modeled performances was, for example, elaborated by a subject into the linguistic mnemonic, "Tall boys stand near small boys." The modeled performances could subsequently be reproduced by decoding back from the linguistic elaborations, to the letter codes, and then to the constituent acts.

In three practice trials, which all subjects received, the modeled performances left a visible chalk trace to convey some idea of what a total response configuration might look like. For subjects in the conditions employing letter coding the appropriate letter associates appeared beside the response components as they were performed on the first item. In the remaining two practice trials, subjects in these conditions were asked to code aloud the component acts as they were performed rather than have the symbolic associates supplied for them on the film. Subjects using verbal elaboration as memory aids additionally received practice in constructing meaningful sentences.

Test for Observational Learning

Following the practice session, the model twice performed on the field of dots each of five response configurations, one at a time, with a metal stylus leaving no visible trace. Thus subjects were provided with no external response cues except those supplied by the transitory actions of the model. As they observed the modeled performance they silently transformed the sequence of actions into corresponding letter associates and sentences in accordance with their treatment condition.

Subjects were then given a response form containing a field of equidistant dots and instructed to reproduce the modeled performance as rapidly and accurately as possible. In addition they were asked to write the appropriate symbolic code (letter sequence or sentence) at the top of each response form before executing the responses. They were given no feedback concerning the accuracy of their coding or reproductions. One minute, which was previously established to be more than ample time, was allowed for the task. After completing a given item, subjects engaged in one of two rehearsal activities for 1.5 min, whereupon they were administered the next modeled item. This sequence of demonstration, encoding, test for observational learning, and rehearsal was repeated with each item until all five were completed.

Cumulative Rehearsal

Half of the subjects in each of the three conditions engaged in *cumulative symbolic rehearsal.* Following each modeled item they rehearsed aloud all of the memory codes they previously constructed and their verbalizations were tape-recorded. Letter coders reiterated the letter aggregates; sentence and dual coders repeated the mnemonic sentences. Early and intermediate items could thus be rehearsed more than later ones.

The remaining subjects, who were *prevented from rehearsing* what they had seen, performed an interpolated task for the same duration. They viewed a film in which a faint yellow dot flashed rapidly and unpredictably in different quadrants of a square, and they pressed one of two telegraph keys depending on the dot location. This signal location task was selected because it was sufficiently demanding to prevent symbolic rehearsal of the modeled performances, but it differed markedly in content so as not to interfere with either letter or sentence codes.

Delayed and Follow-Up Response Reproduction

At the conclusion of the entire series of modeled performances, all subjects performed the rehearsal-impeding task for approximately three minutes to extend further the retention interval. They were then asked to reproduce as accurately as possible all of the modeled configurations that they could still recall. This measure of long-term retention was supplemented with a further reproduction test conducted one week later. Subjects were mailed the response forms with instructions to record the memory codes and to reproduce the modeled patterns. They were not informed beforehand that they would be tested for retention either at the end of the experimental session or at a later time, in order to deter spontaneous rehearsal during the intervening periods. The latter measure was included to determine whether any of the behavior patterns could be enduringly retained in meaningful symbolic codes beyond the period of experiment.

Response Measures

Observational learning and retention were measured in two ways. The first was based upon the stringent criterion of perfect reproduction of the modeled response configurations. The performance records were scored by comparing subjects' responses against appropriate templates of the model's action patterns. The second measure, a partial reproduction score, was obtained by dividing each six element pattern into thirds and crediting one point for each third that was correctly reproduced. Interscorer agreement, based on independent ratings of two-thirds of the records, was virtually perfect ($r = .98$). In addition, measures were obtained of the accuracy with which subjects were able to produce the codes for the modeled configurations.

RESULTS

Figure 1 shows the percent of modeled items accurately reproduced as a function of coding, rehearsal, and retention interval. Analysis of variance of errorless reproductions revealed an equivalent level of observational learning in all groups when tested immediately after exposure to the modeled performances.

Delayed Response Reproduction

Analysis of covariance applied to the delayed reproduction scores reveals that coding substantially aided retention of observationally learned responses ($F = 9.30$; $p < .01$). In accord with prediction, subjects who

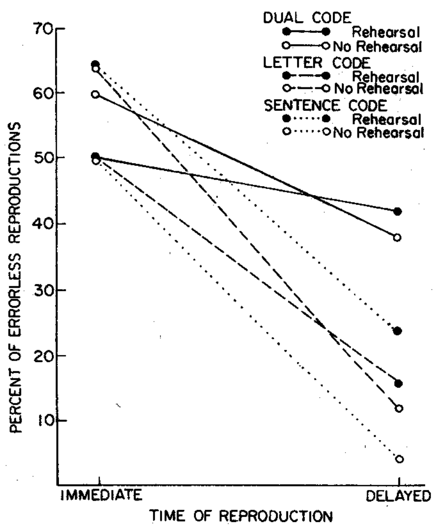

FIG. 1 Percent of modeled performances accurately reproduced as a function of symbolic coding, cumulative rehearsal, and retention interval.

transformed the modeled activities into reductive codes that were then meaningfully elaborated achieved the superior memory performances. Dual coders lost only 15% of what they had learned, whereas both the letter and the sentence coders displayed 43% response losses. In statistical evaluations of the differential retention levels, dual coders surpassed the letter ($F = 16.14$; $p < .01$) and sentence ($F = 10.34$; $p < .01$) coders, who did not differ from each other. Analyses of partial reproduction scores yielded the identical pattern of results.

Cumulative rehearsal did not affect the overall level of faultless reproduction of modeled responses, but it did improve the accuracy of partial reproduction depending on the serial input position of the responses ($F = 32.67$; $p < .01$). Rehearsal enhanced memory performance of early and intermediate responses beyond the .01 level of significance; it did not aid retention of the last two items which were reinstated least often. A significant triple interaction ($F = 19.40$; $p < .01$), however, indicated that variations in repetitive code rehearsal had differential effects depending upon the types of memory code used. Intergroup comparisons revealed that, for subjects using the superior dual code, cumulative rehearsal significantly improved retention only when modeled responses were in the initial serial positions. Retention by letter coders was enhanced by rehearsing both the early and intermediate responses in the input sequence. Sentence coders also benefited from rehearsing codes for responses at initial and intermediate positions, but cumulative repetition of codes significantly decreased their ability to retain responses modeled in the last two serial positions.

Long-Term Retention

The follow-up measurement yielded approximately the same proportion of subjects (77%) in all experimental subgroups. Since substantial declines in memory performance in some conditions produced a highly skewed distribution, the enduring effects of the memory aids were analyzed by nonparametric techniques.

Results of the Kruskal–Wallis analysis of variance of errorless performances disclosed that long-term retention of modeled responses was significantly influenced by the manner in which the behavior was coded ($H = 7.24$; $p < .05$). Memory performances were 24%, 2%, and 14% correct respectively, for dual, letter, and sentence coders. Individual comparisons with the Mann–Whitney U test showed dual coding to be superior to letter ($z = 2.59$; $p < .01$) or sentence ($z = 1.64$; $p = .05$) coding. The latter two groups did not differ, however.

Subjects who previously rehearsed the memory codes achieved somewhat higher retention performances than those who were prevented from rehearsing ($z = 1.63$; $p = .05$). The same intergroup differences were obtained for partial reproduction of response patterns, except there the rehearsal effect achieved a higher level of significance ($z = 1.99$; $p < .025$).

Relationship between Code Retention and Response Reproduction

In analyzing the functional role of memory codes in retention of modeled responses, the letter and dual codes were used because they included predefined retrieval rules and could therefore be scored for accuracy. There was no objective way of rating the adequacy of idiosyncratic codes generated by subjects who constructed sentences of their own choosing without uniform retrieval guides.

The recorded letter aggregates and first letter in the words of the mnemonic sentences were scored for whether or not the response retrieval codes were accurate. The correspondence between code accuracy and errorless performances was then analyzed. The results show that response reproduction is dependent upon code availability. If subjects accurately encoded the modeled behavior and retained the codes the probability of correct performances was .95, .96, and 1.00 in immediate, delayed and follow-up tests, respectively. There was only one instance in which a modeled response was correctly reproduced when the subject did not generate the appropriate code in advance.

Although both the letter and dual codes, if retained, were equally effective in guiding behavioral enactment, the letter codes were much more vulnerable to loss. Dual coders retained 73% of their correct encodings after the delay interval, and 44% at the follow-up period. By contrast, letter coders retained only 25% and 4% of their correct encodings at the same temporal intervals. These retention differences were significant at both the delayed ($F = 16.20$; $p < .01$) and follow-up ($U = 58$; $p < .025$) phases of the experiment. Subjects who rehearsed cumulatively also achieved better partial retention of codes after the delay interval than did the nonrehearsers ($F = 4.82$; $p < .05$).

Effects of Linguistic Code Quality on Response Acquisition and Retention

Dual coders varied in the quality of sentences they were able to construct within the double constraints of time and first syllable requirements for the words. The linguistic codes produced for each modeled response were categorized into those that embodied the reductive codes in meaningful grammatical constructions versus those that involved either disconnected sequences of words or did not fully incorporate the reductive codes. The structural indices provide only approximate categorizations because incoherence to others does not preclude meaningfulness to the coder. Disjointed phrases can carry some meaning just as bizarre imagery may have mnemonic value.

The frequency of errorless reproduction corresponding to good and poor linguistic codes was evaluated by the t test for correlated means. Modeled responses were learned and retained much better when in meaningful linguistic codes as measured through the above criteria. The performances associated with meaningful representations exceeded those encoded in less meaningful or complete forms by 60%, 58%, and 40%, respectively, in the immediate, delayed and follow-up phases. These retention increments were significant beyond the .005 level at all three temporal intervals.

DISCUSSION

The present investigation sheds some light on the properties of cognitive aids that enhance observational learning and retention of modeled behavior. Memory codes combining meaningfulness with retrievability produced a threefold increase in retention compared to coded representations containing only one of these features. Results of the more refined analysis of linguistic codes lend further support to this finding. Responses that were transformed into reductive codes and then elaborated into a meaningful form were learned and retained better than if the elaborated representations were less well structured.

The findings regarding cumulative rehearsal indicated that memory performances are governed more by cognitive operations than by associative-strengthening processes. Retention of modeled behavior that is meaningfully encoded is not much improved by repetitive rehearsal. If, however, concise response codes are difficult to remember because they lack meaning, then memory performances can be enhanced to a somewhat greater extent by repetitive reinstatement of the codes. In the case of elaborative representations lacking dependable retrieval guides, cumulative rehearsal aided retention of past modeled behavior but, by creating a taxing memory load, it impeded memory for recently observed performances.

It would appear from the data of this study, combined with those reported earlier (Bandura & Jeffery, 1973), that symbolic rehearsal exerts its greatest effects on matching performances at the time of input or shortly thereafter. If modeled responses are coded but not symbolically rehearsed immediately after exposure they are rapidly lost from memory. Rehearsal at input helps to establish the responses in memory. Retention of modeled activities can be improved somewhat by further rehearsing the memory codes, especially if the symbols representing the modeled responses are vulnerable to loss. Delayed rehearsal, however, has no appreciable effects on memory performance. By then symbolic representations are either fixed in memory and sheer repetition is of little value, or they are lost and there is nothing to reinstate.

The important functional role of memory codes in delayed modeling is clearly revealed by analyses conducted at the individual response level regardless of coding conditions. Code availability was virtually a perfect predictor of accomplishments in response reproduction. Subjects were unable to enact performances in the absence of appropriate codes and, except for occasional errors in transforming representations into action, they reproduced only the behaviors that were coded accurately.

Some of the responses that subjects learned eventually faded from memory even with retention enhancing aids. This is not entirely surprising considering that the modeled performances were displayed on only one occasion. In observational learning in everyday life, the same conduct is usually performed repeatedly so that observers have ample opportunities to encode and rehearse whatever they may have forgotten. It would be of interest to study retention of observationally learned behavior as a function of repeated exposure to modeled activities.

Because remembering requires an active constructive process there is considerable selective forgetting which is not without benefit. If everything that people observed was automatically learned and completely retained they would be too overwhelmed with response information, most of it useless, for manageable retrieval of functional behaviors.

The manner in which modeling is tested deserves some comment because it bears importantly on the necessary and sufficient conditions for observational learning. In the standard procedure used in operant conditioning studies and in much of the animal experimentation, models exhibit discrete responses which observers copy as they are performed. Instantaneous matching can occur without much symbolic representation, or learning for that matter, just as individuals can successfully assemble a complicated apparatus by following step-by-step directions, yet be unable to produce the correct performance when the external guides are absent. The difference between instantly prompted and delayed modeling is analogous to the difference between drawing an object as it is displayed and from memory. In the latter situation, the hand does not automatically sketch the object; rather one must rely on memory guides. As a further illustration of how prompted mimicry cannot be equated with learning, let us consider research in paired-associate learning. If researchers simply asked subjects to repeat each associated pair of words when exhibited, the performances would be interpreted as reading exercises, requiring little in the way of cognitive mediation, rather than as evidence of associative learning.

In the present series of experiments, each of the modeled performances included a complex chain of six responses organized into novel patterns. Hence, even immediate reproduction required observers to retain in memory a great deal of response information before the behavior was first enacted. Delayed reproduction places even greater demands on memory mechanisms involving the storage and retrieval of modeled information. The data revealed that cognitive factors play an especially important role in modeling when retention over time is required. It is perhaps for this reason that young children whose cognitive functions are poorly developed, and lower species that have limited capacity to symbolize experiences, encounter difficulties in observational learning when there is an appreciable lapse of time between watching and performing (Bandura, 1973).

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