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CHANGES IN MEMORY STRUCTURE AND RETRIEVAL OVER THE COURSE OF INSTRUCTION[1]

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Early research on retrieval of semantic information has provided a reasonably accurate description of retrieval of certain kinds of well-learned material. In the present study, 30 graduate students were asked to produce a type of semantic information; they named psychologists who satisfied certain restrictions. Not only was the speed of naming a psychologist influenced by the order in which restrictions were given, but the effect of order differed for advanced and beginning students. Advanced-student retrieval resembled the pattern observed for well-learned semantic material, while beginning-student retrieval did not. Retrieval was, thus, subtly related to how much instruction a student had completed. These data have implications for the use of reaction time to assess progress in the acquisition of new material.

One of the most fundamental problems confronting today's cognitive psychologist is how to (*a*) represent the knowledge that a person has and (*b*) determine the mechanisms by which a person uses this knowledge. This article addresses the question of how knowledge structures and retrieval mechanisms change during the course of learning new material.

In several recent experiments (Freedman & Loftus, 1971; Loftus, in press; Loftus & Suppes, 1972), a subject was shown a stimulus consisting of a noun category paired with either a letter or an adjective, and his job was to provide a word that satisfied these imposed restrictions. For example, a subject who was presented with the pair *animal–m* might have said mouse, moose, or monkey, among other possibilities. A correct response would have been any word beginning with *m* that named a kind of animal. For *fruit–yellow*, a correct response would have been any *fruit* to which the adjective *yellow* was applicable (e.g., banana, lemon, etc.). A model of semantic memory that accounts for the reaction time data in these experiments assumes that the memory store consists of a large number of interconnected and cross-referenced associative and category networks. According to the model, memory is organized into a complex network composed of categories (e.g., animals) with subsets of each (e.g., birds, dogs) and supersets (e.g., living things). Within each category a variety of subsets exist: Some of them are clusters of items that are highly associated because they have qualities in common (e.g., small animals). Retrieval from this hierarchical structure is assumed to consist of at least two major steps: (*a*) entering the appropriate category and (*b*) finding an appropriate member of that category.

In a newer version of this paradigm, the stimuli have become more complex; for example, in one experiment, subjects were presented with stimuli consisting of a noun category plus both an adjective and a letter (e.g., *animal–small–m*) and had to produce a member of the category that satisfied the two restrictions. That is to say, the response had to be a member of the category that began with the given letter and to which the adjective was applicable (e.g., mouse). Sub-

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jects were given the category first, but the order in which the adjective and letter restrictors were presented was varied. On half of the trials, subjects saw the adjective one-half second before the letter (e.g., *animal–small–m*), while on the remaining trials they saw the letter first (e.g., *animal–m–small*). Reaction time was measured from the onset of the last restrictor. The results indicated that a large advantage in reaction time exists when the adjective is presented before the letter. In other words, subjects are considerably faster at naming, for example, an *animal–small–m* than at naming an *animal–m–small*. A discussion of this finding in terms of the network model of semantic memory is as follows. When a subject must produce a category member that satisfies both an adjective and a letter restrictor (e.g., *animal–small–m*), he apparently first enters the category (animals), then restricts himself to the adjective-defined subclass (small animals), and finally he searches there for an item whose name begins with the particular letter requested (*m*). Thus, when the adjective is presented before the letter, the subject can begin the second step earlier.

Taken together, these experiments give us a reasonably good picture of retrieval from extremely well-learned categories. A question of interest is: What happens when categories are not so well learned or are in the process of being learned? One way to study the retrieval of information that is in the process of being learned is to find a situation in which natural learning of categories is taking place. Such a situation exists in all graduate schools of psychology where graduate students are learning, among other things, the names of psychologists. At an institution where one of the authors was teaching, students learn that there are roughly six areas of psychology (learning, perception, memory, personality, social, and developmental) and that various psychologists may be associated with one or more of these areas. Learning to associate psychologists with particular areas of research is tantamount to learning to categorize psychologists with respect to these areas. Different degrees of learning should be evident in people who are in different stages of graduate school.

For the moment let us assume that the number of credits a graduate student has completed is a rough index of the amount of psychology he knows, or the extent to which he has organized psychologists in semantic memory. The major question to which the present research is directed is: Does this objective measure of learning about psychology (number of credits) correlate with the extent to which retrieval (of psychologists) mirrors retrieval of well-learned information such as animals, fruits, etc.

How do we know when retrieval of psychologists mirrors retrieval of well-learned information? The present experiment allowed such a test. Graduate students were asked to produce the names of psychologists. On any given trial, the psychologist named had to satisfy two restrictions: Both (*a*) an area of psychology and (*b*) a letter were shown (e.g., *learning–b*), and the subject had to produce the name of a psychologist that began with the given letter and who was associated in the subject's mind with the given area. For example, a subject who was presented with the stimulus *learning–b* might say Bower, Bourne, or Blodgett, among other possibilities. On half of the trials, subjects saw the area first (e.g., *learning–b*), while on the remaining trials they saw the letter first (e.g., *b–learning*). Reaction time was taken from the onset of the last restrictor. As may be clear without further mention, this area-plus-letter experiment was extremely similar to the adjective-plus-letter experiment in which subjects had to name, for example, an animal that was small beginning with *m*. In the latter experiment, reaction time was much faster when the adjective preceded the letter. If memory for psychologists is as well organized, one might expect the same advantage in reaction time to obtain when the area precedes the letter. If memory for psychologists is not so well organized, no such advantage in reaction time would be expected.

Method

Subjects

The subjects were 24 students at the New School for Social Research, New York, New York. Each subject took part in one experimental session that lasted about 30 minutes.

Materials

Six areas of psychology were selected: learning, memory, perception, social, developmental, and personality. Each area was paired with eight different letters, creating 48 unique stimuli. Each stimulus was presented with the area shown first or second (e.g., *learning–b, b–learning*) and with an interval of .5 second between the area and letter. Stimuli were printed on 5 × 8 inch cards.

Each subject received a random permutation of 48 stimuli with the following restrictions: (*a*) A given stimulus (such as *learning–b*) occurred equally often in the area–letter and letter–area conditions; (*b*) half of the stimuli presented to any one subject were in the area–letter order, while the other half were in the opposite order.

Procedure

Each subject was told that the study concerned memory for psychologists and that he was to produce the name of one psychologist on each trial. He was told that he would see items consisting of an area of psychology and a letter and that he should respond with the name of a psychologist that began with the given letter and who was associated in his mind with the given area. He was given examples and told to respond as quickly as possible but to avoid errors.

The subject sat in front of a screen in which was a window covered by half-silvered glass. The index card containing the stimulus was placed in a dark enclosure behind the mirror and was presented by illuminating the enclosure. A microphone was placed in front of the subject, and he responded by speaking into it.

A trial consisted of the following. As a card with the item printed in large type was placed in the darkened enclosure behind the half-silvered mirror, the experimenter said, "Ready" and pressed a button that illuminated the first half of the stimulus. After a .5-second interval, the second half of the stimulus was automatically illuminated, and simultaneously an electric timer with a dc clutch was started. The subject's verbal response activated a voice key that stopped the clock and terminated the trial. A warm-up period of 15 trials preceded the experimental trials.

Results

Only correct responses (56%) to each of the 48 stimuli are included in the following analyses. The most important and interesting result obtained when we separated the subjects according to the number of graduate course credits they had completed. We operationally defined "beginning students" as those who had completed fewer than 40 credits (mean number of credits for these 12 subjects was 27) and "advanced students" as those who had completed more than 45 credits (mean number of credits for these 12 subjects was 54). Two median latencies were obtained for each subject's responses in the two conditions (area–letter and letter–area). For these two conditions, group mean latencies were obtained by averaging the medians separately for the advanced and the beginning students. The results of this analysis are shown in Figure 1. A two-way analysis of variance was performed on the median reaction times in terms of (*a*) order of presentation of the area and letter, and (*b*) type of student. Concerning the main effects: Order of presentation was not significant ($F < 1$), but advanced students responded more quickly than beginning students ($F = 5.60$, $df = 1/22$, $p < .05$). The interaction between these factors was highly significant ($F =$

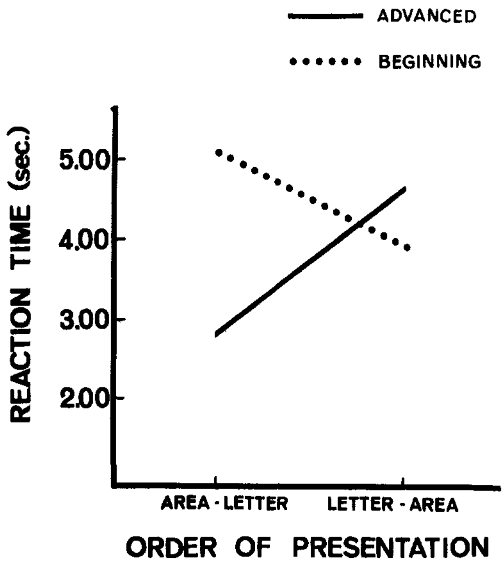

FIGURE 1. Reaction time as a function of order of presentation of area and letter for beginning and advanced students.

33.63, $df = 1/23$, $p < .001$), indicating that advanced students were faster when the area was presented first rather than second, while the beginning students favored the condition in which the letter occurred first.

Discussion

The retrieval pattern for advanced students is clearly different from the pattern for beginning students; advanced students responded more quickly when the area was presented first, while the beginners favored a letter–area presentation. This finding makes a great deal of sense when you stop and think about what a student of psychology knows. The advanced student is aware that the category of psychologists is subdivided into areas such as learning and perception, just as his category of animals is subdivided. When given the area before the letter, this student can restrict himself to the area-defined subclass and then search for a psychologist whose name begins with the particular letter requested. The beginning student, however, does not have psychology so well organized; the field is not yet neatly subdivided. This student knows a few important names; he probably knows Freud, Skinner, Piaget, and possibly some others. When the letter is given before the area, the beginning student probably begins scanning his list for a name beginning with the particular letter requested and then produces that name almost irrespective of which area is presented. If the student stretches it, Piaget and Skinner could both fit into quite a few different areas of psychology.

Regardless of the exact storage or the exact retrieval mechanisms that these two types of students are using, it is clear that the retrieval patterns observed in the present study are related to how much instruction a person has completed. Furthermore, the retrieval pattern for the advanced students resembles the pattern observed for well-learned material, that is, the more experience a student has had with the field of psychology, the more his retrieval of this information seems to mirror the retrieval of material that we know is well organized and learned. The implication here is that one of the consequences of instruction may be to change a student's retrieval pattern, such that it is more efficient, resembling the retrieval of well-learned material. It appears that we can use reaction time to assess the real impact of instruction in much more subtle ways than we now do. Instruction does more than teach content. In addition, as a person learns new material, his cognitive structure is organized and modified in some way. Reaction time measures such as the ones used in this study can give information about progress being made and ultimately about the process of acquiring new material.

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