THE BASIC UNIT IN MEANINGFUL LEARNING—ASSOCIATION OR PRINCIPLE?

To provide a substantive base for their research, educational psychologists have frequently resorted to the languages, paradigms, and theories of the mother science of psychology. Mediational elaborations and ope rator conditioning paradigms of the S-R language and more general, but less well specified, cognitive theories have been popular.

Each approach has important limitations. From one point of view, parsimony suggests that the properties of overt S-R associations should also be attributed to mediational links. Yet, practice has shown that mediational interpretations become increasingly cumbersome and less further that the second is learned to occur more complex. Similar difficulties have plagued researchers who have used operant techniques to study meaningful verbal learning. A general limitation of cognitive theories is their relative imprecision. Typically, "cognitions" are either not clearly specified in observable terms or are only partially defined.

In short, the choice to date has been between a precise, but seemingly inappropriate S-R language, and presumably more relevant cognitive formulations which leave much to be desired insofar as scientific coherence and rigor are concerned.

The purpose of this paper is to introduce what I feel are the basic ingredients for a new scientific language for formulating research questions on meaningful learning. This so-called Set-Function Language (SFL) is precise and seems particularly well suited for dealing with mathematics, my own area of concern, and science, but it undoubtedly can be used with other subject matters as well. Rather than try to detail the SFL or to summarize the related research that we have completed or have under way, let me simply try to convey the general idea. In the process, SFL and S-R formulations of several meaningful learning tasks will be contrasted. The SFL is behavioristic, as is the S-R Language, but, unlike the S-R Language the SFL denies the primacy of the S-R association.

To illustrate some of the advantages of the SFL, consider an experimental situation where S is required to respond appropriately to learning stimuli (objects) which are large or small, black or white, circles or triangles. Suppose further that S is required to learn the particular S-R pairs: (a) A large black triangle > "black" (S1 > R1); (b) a large white circle > "large" (S2 > R2); (c) a small white triangle > "white" (S3 > R3); (d) a small black circle > "small" (S4 > R4). After the four S-R pairs are mastered so that S can reliably give the correct response to each stimulus, the question still remains as to just what was learned. Did the subject learn four distinct pairs—four discrete associations—and notice no relationships between them? Or, did he learn the two principles, "If triangle, then color," and "If circle, then size"?

This question first began to bother me during the summer of 1963. Greeno and I found, in a verbal concept learning situation, that essentially an S either gives the correct response the first time he sees a transfer stimulus or the transfer item is learned as its control.

The thought later occurred to me that if transfer obtains on the first trial, if at all, then responses to additional transfer items should be contingent on the response given to the first transfer stimulus. In effect, a first transfer stimulus could serve as a test to determine what had been learned during the original learning, and to make it possible to predict what response a subject would give to a second transfer stimulus. To obtain evidence on this point, I had 15 pre- and postdoctoral Ss overlearn the four S-R pairs listed above. The Ss were told to learn the pairs as efficiently as they could since this might make it possible for them to respond appropriately to transfer stimuli. After learning, two Test 1 stimuli (a small black triangle and a large black circle) were presented and the Ss were instructed to respond on the basis of what they had just learned. All answers were reinforced as correct. The Test 2 stimuli (a large white triangle and a small white circle) were presented in the same manner.

The results were clear-cut. All but three Ss gave the correct responses to Test 1 and Test 2 stimuli. It would appear that when a S thinks he is right and the new situation remains relevant, he will continue to respond in a similar manner.

On what basis could this happen? It was surely not a simple case of stimulus generalization; the responses were distinct and, in any case, did not depend solely on common stimulus properties. The first Test 1 stimulus (a small, black triangle), for example, is as much like the fourth learning stimulus (a small, black circle) as the first (a large, black triangle)—and, yet, "black" was invariably given as the response rather than "small." Perhaps the simplest interpretation of the obtained results is that most of the subjects discovered the two underlying principles while learning the original list and later applied them to the test stimuli. In effect, the relationships between the S-R pairs, themselves, combined with a response consistency hypothesis, provided a basis for assessing what was learned.

Before introducing the SFL let us ask how the S-R theorist might represent what was learned in the preceding exercise. In S-R psychology, the basic building block is the, association, a construct which was abstracted directly from observed connections between observable stimuli—light, nonsense syllables, or mathematical problems—and observable responses—salivation, other nonsense syllables, or solutions. A connection or association is said to have been formed if the corresponding response appears with a positive probability whenever the stimulus is presented. Learning a concept, presumably a more complex form of learning, involves the ability to give a common response to any one of a set of stimuli. To say that a subject has acquired the concept of red, for example, implies that the subject is able to give some common response when shown any red object, but will not give this response to any nonred stimulus. In short, whereas
an association pairs one stimulus with one response, a concept is a many–one relationship.

Since the association is felt to be basic, the S–R theorist has felt obliged to represent the many–one concept relationship as a composite of one–one relationships. This has been made possible by the postulation of mediating links or associations. Thus, the many–one relationship may be represented,

\[ S_1 \rightarrow M_{rs} \rightarrow R, \]

where the stimuli \( S_1, S_2, \) and \( S_3 \) are connected to the mediating response, \( M_{rs} \), whose stimulus properties, in turn, elicit the observable response, \( R \). In the case of the concept red, \( M_{rs} \) might be an internalized representation of the label “red.”

But the original task we were confronted with involved principles, a construct more complex than either associations or concepts from the standpoint of S–R associationism. Probably because of this felt complexity, most psychologists, particularly experimental psychologists, have ignored this notion.

Nonetheless, an increasing number of pedagogically oriented psychologists have come to recognize the central role of the principle in meaningful learning and at least two association-based representations of the principle have been proposed. Rather than delve into the possible limitations of these formulations, I shall propose an S–R formulation of my own—and, then attack it.

First, consider the representation,

\[ S_1 \rightarrow \text{Triangle} \rightarrow \text{Color} \rightarrow R_1 \]

\[ S_2 \rightarrow \text{Triangle} \rightarrow \text{Color} \rightarrow R_3 \]

This representation has been chosen to reflect the principle, “If triangle, then color” as it relates to the situation described above. In this case, the overt stimuli, \( S_1 \) and \( S_2 \), are presumed to elicit the mediator “triangle” which, in turn, elicits the mediator “color.” “Color,” then, is presumed to elicit \( R_1 \) and \( R_3 \)—with equal probability. Of course, we know that this is not what happens from the study just described, \( S_1 \) elicits \( R_1 \) and \( S_3 \) elicits \( R_3 \).

To overcome this inadequacy we may postulate a second pair of connecting chains, between \( S_1 \) and \( R_1 \) and \( S_2 \) and \( R_3 \). According to this interpretation, \( S_1 \) elicits \( R_1 \) (black) and not \( R_3 \) (white) because \( S_1 \) elicits “black” as well as “triangle” and has no direct relationship to “white.” Of course, \( S_3 \) elicits “white” for the same (implied) reason. With this representation in hand, the S–R associationist is now able to predict the results of the experiment described. “Black” is given as the response to the first test stimulus, a small black triangle, because of the prelearned association between the stimulus and “black” and the learned mediating association, “triangle elicits color.” Actually this principle is rather a special case. It is easy to devise other principles which cannot be represented in this way. Transformations or combining operations are necessarily involved.

It is important to emphasize that this situation was not picked arbitrarily simply to embarrass S–R psychologists. Stimulus dimensions (e.g., color), which uniquely determine the responses and combining operations (e.g., name and color) by which the responses are derived from these stimulus properties appear to be crucial aspects of all principles.

Fortunately, these characteristics play a central role in the SFL. In fact, it is assumed that four elements, \( I, D, O, R \), are needed to specify a principle. The stimulus properties in the set \( I \) tell when the rule \( (D, O, R) \) is to be used, those in \( D \) tell which properties determine the response, and the combining operation \( O \) tells how the response properties \( R \) may be derived from those in \( D \). In the preceding task, \( I \) includes colored triangle, \( D \), color, \( O \), color naming, and \( R \) the color names.

The denotation of a principle is simply taken to be equivalent to the mathematical notion of the function, a notion which may be defined as a set of ordered stimulus-response pairs such that to each stimulus there is one corresponding response. The denotation of a concept is simply represented as a function in which there is one response common to all stimuli. To represent an ordinary association, the set is further restricted so as to include only one S–R pair.

The principle, itself, is characterized as an ordered four-tuple \( (I, D, O, R) \), where \( I, D, O \) and \( R \) are as previously defined. In the case of concepts and associations, there are certain restrictions placed on these elements but they need not concern us here. Finally, notice that the statements in the column on the right are constructed from those symbols, \( I', D', O', \) and \( R' \), representing the constructs \( I, D, O, \) and \( R \).

The SFL, in which the principle is taken to be basic, is therefore able to represent principles, concepts, and associations as did the S–R language. However, unlike the S–R language, explicit distinctions are made between: \( a \) the observable S–R instances of a principle—the denotation, \( b \) the principle itself, that which underlies behavior and whose presence can be inferred only indirectly, and \( c \) statements of the principle in symbolic form.

Space limitations demand that I not attempt to detail my reasons for preferring the SFL to the S–R language.