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Chapter 11

A Behavioral Interpretation of Memory

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The goal of this paper is to provide a behavioral interpretation — or at least the outline of an interpretation — of those phenomena for which the term memory is commonly invoked. Memory is typically studied as a discrete and unitary subject matter. Memory is seen as a capacity, and memories often serve as independent variables explaining subsequent behavior. "Memory" is not currently a technical term in behavior analysis, nor, I suggest, need it ever be one. I hope to show that the phenomena currently studied in academic programs in the "field of memory" are not theoretically coherent from a behavioral perspective. There are at least two broad classes of phenomena covered by the term, as it is commonly used, and the failure to distinguish them has seriously confused research in the field. Not only is memory not a coherent concept, it is not even a helpful one, as it usurps the role of explanation and impedes the search for controlling variables for current behavior.

Before discussing these points I want to make explicit some of the assumptions underlying my analysis and to clarify certain terms.

Interpretation Versus Experimental Analysis

The interpretation of complex phenomena in the light of empirically established principles lies hi the middle ground between experimental analysis and mere speculation. Speculation is unconstrained, while interpretation is constrained by experimental analyses. Interpretation is useful in circumstances too complex or too vast to control experimentally, but where informal or incomplete data are available. Interpretation has served, and continues to serve, an honorable role in science, so honorable that we often fail to distinguish between an interpretation and an experimental analysis. Newton's explanation of ocean tides is an interpretation based on his experimental analysis of phenomena such as the motion of pendulums and colliding balls of wool, glass and cork. No one, least of all, Newton, has attempted to establish experimental control over the tides. Yet Newton's principles (to a reasonable approximation) are so firmly established and the extrapolation to this phenomenon so plausible, that we accept his interpretation as if it were the direct outcome of an experimental analysis. Interpretation clearly serves an important purpose. We should not like to wait for an experimental analysis of the genesis of planets, the shifting of continental plates, the evolution of Homo sapiens, - or the behavior of solving a problem, writing a letter, or recalling an episode from our childhood. Interpretation is often the best we can do in an imperfectly known and exceedingly complex world. Indeed, when we consider the scope of experimental analysis and interpretation, we might regard the former as merely a procedure for giving us the tools to engage in effective interpretation.

Interpretation serves an especially important role in accounting for human behavior since contingencies are typically complex, reinforcement histories unknown, and effective experimentation seldom possible for ethical reasons. These limitations are not peculiar to a behavioristic approach but constrain any experimental analysis of human behavior. Indeed, behavioristic interpretations have the advantage of a foundation of well established principles developed from a vigorous basic science, and may thus be especially well suited to account for complex human behavior.

The interpretation of phenomena such as memory and verbal behavior can proceed well in advance of an experimental analysis. This serves the purpose of establishing the domain of the science, of identifying important experimental questions (the role usually assigned to theory), and of addressing popular interest in these areas. An appeal for interpretation is not an invitation to mentalistic analyses. The terms and principles adduced in a behavioral interpretation are derived from the experimental analysis of behavior and must be consistent with that analysis. I suspect that these principles are fully adequate, but, even if they are not, an interpretation is an inappropriate place to introduce new ones.

What is Behavior?

It is important to identify the unit of analysis in any scientific endeavor, but it is especially important in a domain with a rich prescientific vocabulary. I adhere to Skinner's position, first outlined in 1935, that the units of analysis in behavior are to be defined empirically, not a priori, or according to common usage. Specifically, environmental and behavioral units are to be defined according to the orderliness of the relationship between them. If the orderliness of our data is a function of the specificity of our definition of behavior and its controlling variables there is an inflection point, presumably falling short of complete specificity, at which our data are most orderly. It is this inflection point which determines the classes of responses and stimuli which serve as our units.

Behavior is any activity of an organism that can enter into these orderly relations. The subject matter of a behavioral analysis is not to be defined in terms of observability or locus but in terms of sensitivity to contingencies of reinforcement, generalization, discrimination and so on. Thus, a private event falls under the purview of a behavioral analysis provided that it is sensitive to reinforcement contingencies; it need not be peripheral or skeletal or motor. Of course, we cannot make reinforcement contingent on events that are unobservable to us, and we therefore cannot demonstrate the order necessary to establish units of private behavior, but this only reduces the scope of experimentation; it does not reduce the number of events that are in fact affected by temporal contiguity to an effective reinforcer.

Behavior lies on a continuum of observability, but where it lies on this continuum depends upon characteristics of the observer or of his tools of measurement; it is not an essential or intrinsic property of the response. Private behavior is simply unobserved behavior, not unobservable behavior. A private event, then, is one that lies below the threshold of observability for a particular observer using particular tools. To a myopic experimenter observing his subject through half- silvered glass certain behavior would be private that would be public for a second experimenter under more favorable conditions, and this second observer would be unable to detect responses monitored by an EMG device in the service of a third experimenter.

It is necessarily the case that under normal conditions a portion of the behavior of an organism will be private in this sense, but this private behavior raises no special theoretical or epistemological problems, however troublesome it may be from a practical or experimental point of view. However, when we appeal to private events we must be clear about their- status. Private events cannot serve as data; they cannot be used to generate principles or to buttress or refute theories. They serve no useful role in the **basic science** of behavior -- it is in the **interpretation** of the basic science that an appeal to private events becomes essential.

We often have indirect or incomplete evidence for private events, and we can often plausibly infer that they are being emitted. Since these events must obey behavioral principles, we are constrained in our inferences. For example, it is necessary that the private event be probable with respect to current controlling variables, and the control by these variables must in turn be plausible with respect to the ontogenic or phylogenic history of the organism. Thus an appeal to unobserved behavior is not equivalent to an appeal to internal processes or "representations." A private response that has been invoked to explain some anomaly, but that is itself anomalous, raises more questions than it answers.

The Problem of Memory

The Guinness Book of World Records is full of accounts of ordinary people who have accomplished extraordinary feats. Many of these feats can be understood, at least in principle, as results of special contingencies of reinforcement which shape ever more skillful or unusual behavior. Complex schedules of contingencies have been employed in the laboratory to shape unusual behavior in non-human organisms. Chimpanzees have been taught rudimentary sign language, pigeons to guide missiles and play ping-pong, and rats to execute long chains of odd responses such as wheeling themselves around in toy carts. In some cases, of course, unusual behavior can be attributed to great height or strength or other unusual physical characteristics that presumably reflect a special genetic endowment. We may marvel at behaviors of this sort, but we are not entirely at a loss to explain them.

The behavior of answering a simple question about one's past, however, seems to defy explanation in terms of these familiar principles. When asked, "What did you have for breakfast yesterday?" we reply with ease, "Scrambled eggs." So commonplace is the phenomenon that, at first, there seems to be no problem at all — memories are simply behavior under the control of particular discriminative stimuli, in this case, the question. It is only when we try to specify how the controlling stimuli acquired their control that we begin to appreciate the shallowness of this analysis. When we ask, "What are you eating?" the answer, "Scrambled eggs" can be understood in someone with an appropriate conditioning history as a response under the control of a constellation of current stimuli, namely, the eggs, the question, and the listener. We can reasonably assume that the speaker has learned to name eggs and that under suitable motivating conditions (the question), and in the presence of an audience, will do so. However, when we ask about yesterday's breakfast, a crucial controlling variable is missing: the eggs. Not only are the eggs not present, they no longer even exist. We cannot invoke a nonexistent stimulus as a current source of control. Unfortunately, the remaining environmental stimuli apparently do not control the response directly. We can demonstrate this by reproducing the external stimulus conditions in every detail on the following day and asking the question again. Perhaps our subject will then respond, "French toast." A second presentation of the discriminative stimuli has been followed by a completely different response.

Since we are apparently unable to appeal to environmental stimuli to account for the difference in the responses to our question we look to the person as a variable. In a sense we are different from who we were yesterday. Presumably yesterday's exposure to scrambled eggs changed us in such a way that we respond appropriately today when asked about yesterday's breakfast.

The Storage Metaphor

By far the commonest interpretation of these changes is that something about the experience has been stored inside us in our "memory banks," "memory storehouses," or, simply, our brains. When we are asked about the past we search through our storehouse of memories and retrieve the appropriate information. It is the information retrieved that serves as the missing variable that controls our response.

The storage metaphor is appealing. When we consult a grocery list or a memorandum we are responding to stimuli that can be said to be stored, and it is tempting to suppose that the nervous system records events in an analogous way.

Difficulties with the storage metaphor arise when we try to specify the actual events of which the metaphor is an abstraction. We can assume that an organism is changed by experience, presumably in some feature of its nervous system, but this brings us no closer to an explanation of recall. When we go to the supermarket we can store the words "tomato soup" in a grocery list, and no doubt changes in our nervous system are "stored" at the same time. At the supermarket we can retrieve the words from tie grocery list by looking at the list. Our history with respect to grocery stores, memoranda, and particular textual stimuli is sufficient to explain both looking at the list and taking appropriate action. We are in no such position with respect to our nervous system. The relevant physiological changes are not stimuli; we cannot respond to them as we can to items on a grocery list. Stored changes are of no use to us if they do not control behavior.

In the storage metaphor, physiological changes serve as copies, or more commonly, as representations, of the original stimuli. These representations usurp the role of stimuli in controlling behavior. This scheme appears to be adequate, but there is an unfortunate lacuna: No mechanism is specified for recruiting the correct representation. The question remains why the particular representation of "tomato soup" is invoked at the appropriate time rather than the representation of a day at the beach or of yesterday's breakfast. If surrogates or representations of events are stored, like books in a library, how are they indexed, and how does a particular volume get summoned? As in the case of yesterday's breakfast, identical stimuli appear to summon different volumes on different days. Thus the storage metaphor has not solved the problem of stimulus control; it has merely inserted some additional terms of dubious status into the analysis.

Memory Defined

The behaviorist has no tools, conceptual or physical, with which to study memory, he can only study behavior and its controlling variables. If he explains the behavior said to require memory he will have done all that can be done, given his assumptions. From this perspective there is no such thing as "memory" as a thing to be studied. He can study the behavior we engage in when we "try to remember" something, and the behavior said to show that we did in fact remember something, and he can study the behavior of subjects in memory experiments; but there appears to be no reason to distinguish such behavior from any other behavior of the individual. In short, the behaviorist can study, not a state or structure, but an activity, not memory, but remembering.

From a behavioral perspective, then, memories are not "things" and they are not "real" or "mistaken." When we recall that we used Cortland apples in the pie, we do not resurrect the original behavior of reading the label on the bag of apples. Current behavior is under the control of **current** variables, and while it may be similar in topography to behavior executed under control of other variables in the past, it is not the "same" behavior or somehow a "real" memory. We have not unearthed a trace or record of what happened in the past. Rather, we engage in behavior anew. If independent evidence proves that it was, in fact, Golden Russets in the pie, the response "Cortland" is not "wrong" or "mistaken" or the result of a faulty addressing mechanism. It is the "correct" response in the sense that current variables evoked it as ineluctably as earlier variables evoked "Golden Russets." It is perhaps all the more remarkable that there is so often a correspondence between behavior elicited in a recall task and behavior that would be elicited by reinstating the original conditions; that is, we say "Cortlands" when presented with a bag of apples, and we say "Cortlands" when asked about them the next day.

Memory Phenomena: A Fundamental Dichotomy

There are two classes of contingencies for which the term "memory" is commonly said to be required. Consider the following examples:

1) In a classroom demonstration, a pigeon's pecks to a key are reinforced on a variable ratio schedule when the key is colored by a red light. When the key is dark, extinction is scheduled. After a retention interval of one week, the pigeon is returned to the experimental chamber. When the keylight is turned on the pigeon immediately pecks it at a high rate. When the light is turned off pecking stops entirely.

2) In a symbolic matching-to-sample task a pigeon pecks the central key of a three key array, illuminating it for five seconds with either a red or a green light and illuminating the side keys with white light. A peck to the left key is reinforced if the sample is red; a peck to the right key is reinforced if the sample is green. In a later condition, the side keys are not made available until the center key has been off for five seconds.

In the first example behavior is brought under control of a stimulus at one time| and the stimulus is presented again at a later time. It may strike some as remarkable that a pigeon would "remember what to do" in a situation after the lapse of a week. However, it is not the memory of the earlier experience but the stimulus control of behavior that has endured. Since all conditioned behavior is under stimulus control as a result of certain prior experiences, memory in this sense is fundamental to all learning.

In the second example behavior is brought under control of a stimulus, and reinforcement is later made contingent on appropriate behavior in the absence of the stimulus. Appropriate behavior cannot be explained by appealing to the original training conditions; a more complex analysis is required.

In the first example the training stimulus is present at the time of the test; in the second example it is not. The first is an example of simple stimulus control established as the result of a three-term contingency. The second is an example of problem solving, and, while a behavioral analysis of this case will be different, the principles adduced will be the same. The remaining discussion will be divided between analyses of these two cases.

Memory as a Stimulus Control Phenomenon

Behavior in this category is "automatic," that is, it is directly under the control of environmental variables and does not require intermediate responses on the part of the organism. We experience memories of this sort as "spontaneous." A strain of music will often elicit emotional responses, and covert verbal and perceptual behavior appropriate to an earlier context, as it did so forcefully for Humphrey Bogart in the film, Casablanca. The taste of a madeleine will "summon up remembrance of things past." We name objects with ease, and with somewhat less ease recall the names of friends and acquaintances when we see them. We never forget how to ride a bicycle or how to swim.

In each case the behavior hi question is directly controlled by a particular stimulus or set of stimuli. We can produce analogous behavior in the laboratory by arranging contingencies of reinforcement (as we did with our demonstration pigeon in the first example above), and we can usually point to contingencies in our experience to explain the stimulus control of our behavior. Often the contingencies are explicit, as in educational practices. We are taught to say "twentyfive" in response to "five times five" or "5 X 5" or

$$\begin{array}{r} 5 \\ \underline{\times 5} \end{array}$$

We are taught to say "1492," "1066," and "1588" in response to particular classes of question. It is sometimes difficult to specify the dimensions of stimulus, response, and reinforcer in an arbitrary example from our past. The stream of behavior does not seem to divide into neat units as do educational contingencies, but the importance of these units in the laboratory suggests that interpretation in these terms is valid.

The acquisition of stimulus control. Conditioned stimulus control results from exposure to contingencies of reinforcement under appropriate motivational conditions. As Skinner (1938) has shown, one exposure is sufficient to effect at least some change in stimulus control. Behavior reinforced or elicited in a particular setting will have an increased probability of occurring again in that setting, other things being equal. That probability will be affected by familiar parameters such as reinforcement magnitude and frequency, temporal relationship with the response, motivational variables, etc. When these parameters have been specified, the future occurrence of the response in that setting requires no further explanation. One can provide plausible accounts at other levels of analysis. For example, one may propose that synapses have been modified or created, resulting in an organism that responds in a particular way in a particular setting, but accounts of this sort are not necessary if our criterion of explanation is to be the prediction and control of behavior. A physiological explanation supplements the behavioral one; it does not replace it.

Forgetting: The loss of stimulus control. The control of behavior by a stimulus changes as a function of variables such as the level of deprivation, schedule of reinforcement, and other stimuli present. A decline in stimulus control as a function of these variables is reversible and is not usefully considered a loss of stimulus control. The extinction procedure, in which discriminative stimuli are presented but responses are not reinforced, appears to reduce stimulus control, but as I will argue below, an extinction procedure is a special kind of discrimination procedure. It may, in fact, sharpen stimulus control, not reduce it. In any case, there is no known behavioral process by which stimulus control declines in **an orderly way** solely as a result of the lapse of time.

The possibility that stimulus control may spontaneously decay over tune has been considered for decades by students of memory. It is commonly our experience that responses recently conditioned are stronger than responses conditioned in the distant past. Having learned last week that Monrovia is the capital of Liberia, we are more likely to identify it correctly than the capital of North Dakota, which we learned ten years ago when driving across the continent. However, the decay hypothesis suggests more than that a stimulus will no longer control a response. It suggests that something has been permanently lost, something has deteriorated like crumbling parchment. Presumably, structural regularities hi the nervous system accompany regularities in stimulus control. The maintenance of these structural regularities is no doubt imperfect. Any deterioration may result in a loss of stimulus control. In this sense there is surely a "decay of stimulus control" but it is probably not a simple or orderly function of time. As for the obvious relationship between forgetting and the lapse of time, there are alternatives to the decay hypothesis that suggest more orderly processes.

1) Failure to reinstate all of the relevant stimulus conditions. Often the stimuli present when we have acquired an operant in the recent past are more similar to current stimuli than the stimuli that were present when we acquired an operant in the distant past. "Bismarck" may be controlled not simply by "capital of North Dakota" but by interstate highways, brown prairieland, eroded sandstone, diesel exhaust fumes, grit in our teeth, and the interoceptive

stimuli characteristically elicited by travel to new places, i.e. excitement, arousal, or fatigue. If contextual stimuli have changed, we will be less likely to respond to a stimulus. In effect, all stimulus control is conditioned stimulus control. The stimuli manipulated by experimenters are typically a small subset of the stimuli present in a conditioning preparation, and the nominal discriminative stimulus controlling a response is typically only one of many stimuli present when that response was reinforced. The importance of these contextual stimuli becomes apparent when we return to the home of our childhood and find ourselves recalling names, places, and episodes "long forgotten" in our daily lives.

2) Competing responses to the same stimuli. While it is unlikely that we have learned that anything other than Bismarck is the capital of North Dakota, competing responses may still interfere. The written or spoken words, "Capital of North Dakota," may be members of a unitary stimulus class with respect to the response "Bismarck," but each word is a stimulus, or is composed of stimulus elements that may be members of stimulus classes controlling other behavior. "North Dakota" may remind us strongly of Fargo, or fatal blizzards, or soybean production. "Capital" may control the response "Boston" or "Washington" if they have been in the news lately. "Capital of North --" might be sufficient to occasion "Raleigh" if that response had been thoroughly conditioned. In each case we are apt to "recognize that our response is inappropriate" and set to work to recall the "correct" response, a stratagem discussed below. The issue here is the failure of a response to occur in the presence of an appropriate discriminative stimulus. Given that we commonly have rich experience with elements of a complex stimulus, it is possible that a response does not occur simply because other responses to the same stimuli are prepotent. The more time that elapses after the acquisition of a response, the greater is the opportunity for competing responses to be conditioned.

3) Competing responses conditioned to other stimuli. If we have recently heard from a friend in Brisbane, the response "Brisbane" may be strong (i.e. under the control of many current contextual cues). We may have spoken of Brisbane, or located it on a map, or addressed a reply to our friend there. Incidental stimuli may control "Brisbane" when "Bismarck" would be reinforced. Because of the formal similarity of the two responses, "Brisbane" may be especially strong, since the form of the response will be, in part, supplemented by variables that control "Bismarck." The reverse is true as well; "Bismarck" may well be strengthened by the presence of stimuli that normally control "Brisbane."

Thus the failure of a discriminative stimulus to occasion a response may be due, not to a loss of control, but to competing responses and missing contextual support. However, demonstrating that decay is not at least partly responsible for a decrement in performance may be impossible, since it is not clear how to put the matter to experimental test.

Verbal learning studies and stimulus control. Countless verbal learning studies, conducted over many decades, have attempted to evaluate the factors responsible for the loss of stimulus control. It is commonly thought that paired-associate learning studies arise from, or are congruent with, a radical behavioral approach to memory. A response is (presumably) brought under the control of a discriminative stimulus, and the retention of that stimulus control is tested. However, this is a superficial interpretation of what actually happens in a paired-associate study. It is a mistake to assume, without experimental verification, that the stimuli and responses as defined by the experimenter respect the "lines of fracture along which the environment and behavior actually break" (Skinner, 1935).

Consider, as an example, the pair ELBOW - QXV. The subject is shown the pair of items, perhaps on a memory drum, and will be reinforced if he replies "QXV" when the word "ELBOW" appears at a later time. Reinforcement usually consists of nothing more than seeing that the response is correct when the memory drum reveals the answer; more precisely, reinforcement consists of the formal similarity of the response to the word "ELBOW" with the textual operant controlled by the next stimulus ("QXV") presented by the drum. A casual interpretation of this sequence suggests that "QXV" is a discriminated operant under the control of the stimulus "ELBOW" analogous to the barpressing of a rat under the control of a 1000 Hz tone. The parallel is so obvious that researchers in verbal learning have assumed without further analysis that the models are analogous and that principles of equal generality can be derived from either approach. However, there are important differences that suggest that critical events in verbal learning studies are overlooked. A hungry rat will typically press a bar before the delivery of the first reinforcer, and if it does not, it can be shaped to bar-press by reinforcing successive approximations of the response. Thus the context controls relevant behavior prior to conditioning, but this baseline behavior is not orderly enough to be defined as an operant. In contrast, the baseline probability of a human subject uttering "QXV" in the presence of the written stimulus "ELBOW" is negligible. However, the experimenter in a verbal learning study does not emulate his colleagues in the animal learning laboratory; he does not shape the appropriate response from undifferentiated verbal behavior. Rather, he simply presents the textual stimulus "QXV" which controls the textual operants "Q," "X," and "V." These operants exist in strength because of prior training. The response "QXV" under the control of the stimulus "ELBOW" is one operant (the operant to be conditioned); the response (or responses) under the control of the printed letters "QXV" is a second operant (or set of operants) despite the fact that the responses have the same form. The operant to be conditioned is an intraverbal; the operant that is already conditioned is a textual operant. Therefore, performance in a paired-associate task is not a measure of retention but of transfer of stimulus control. The problem for the subject is to utter an operant of the same form but under different stimulus control. Certainly the textual operant "QXV" would survive the retention intervals typically studied in verbal learning experiments. Since letters are arbitrary symbols, the operant "QXV" under the control of "ELBOW," once conditioned, should last as long.

Unfortunately the events responsible for the transfer of stimulus control are not usually studied in typical verbal learning procedures. If barpressing (or saying "QXV") is under the control of a light (or the printed letters "QXV"), we do not transfer control to a tone (or "ELBOW") by presenting the tone and light together. To the contrary, that is the very condition under which we find blocking of stimulus control by the neutral stimulus (Kamin, 1969; Miles, 1970). Thus it is not surprising that subjects "forget" in verbal learning experiments; it is surprising that they ever remember. In the laboratory we transfer control from one stimulus to another using a fading procedure. The stimulus to be conditioned is made conspicuous while the controlling stimulus is gradually attenuated. Most of us have learned to use an informal fading procedure in rote memory tasks. We read carefully, then skim, then "peek," and so on, at every step reducing our exposure to the stimulus. It is quite likely that subjects in verbal learning tasks employ some of these techniques, often in conjunction with more elaborate acquisition strategies discussed below. In the absence of these strategies it is unlikely that stimulus control would transfer to the neutral stimulus. If this is the case, performance depends upon unanalyzed events during acquisition and in the history of the individual. It follows that paired-associate tasks, as typically studied, can tell us little about retention of the stimulus control of behavior.

In the extensive literature on memory for verbal material, it is clear that performance declines with time and that this decline is often regular. These findings are of interest since similar tasks are common in school and everyday life. Unfortunately, there is currently no understanding of **which** items in a list will be recalled and which forgotten. We can determine the probability of rolling double sixes in a game of craps, but we are unable to predict the outcome of a particular throw. Similarly, verbal learning experiments have generated "typical" forgetting curves under certain training conditions but are unable to determine which items will be recalled and which forgotten. Presumably, if we knew the precise starting position of the dice and the forces applied to them we could predict the outcome of a throw using the principles of Newtonian mechanics. A comparable analysis of memory performance is not possible with the conceptual apparatus of the students of verbal learning. A much more fine-grained analysis in terms of the stimulus control of verbal operants is necessary if we are to make predictions about specific responses.

Extinction. A final issue in the retention of stimulus control is that of extinction. As mentioned above, the only orderly procedure for decreasing or eliminating stimulus control is extinction. However, it maybe questioned whether extinction is a unique behavioral process at all. Extinction is clearly a **procedure**, but the effect of the procedure may be simply to establish a discrimination. As Skinner (1950) puts it, "The very conditions of extinction seem to presuppose a growing novelty in the experimental situation. Is this why the extinction curve is curved?" In other words, the environment of an extinction condition is different from that of an acquisition condition in that reinforcing stimuli and the stimuli arising from the consumption of the reinforcer are absent. This interpretation is supported by two lines of evidence. First, the more closely acquisition conditions resemble extinction conditions, the more the organism perseveres during extinction. If ratio schedules of reinforcement are gradually stretched, very high ratios can continue to maintain behavior. Subsequent extinction curves are enormous. Conversely, extinction following continuous reinforcement is relatively abrupt.

Secondly, reacquisition following extinction is typically rapid. If extinction were the opposite of acquisition, if it eliminated stimulus control that had been established during acquisition, we would not expect rapid reconditioning.

An implication of this interpretation of extinction is that the establishment of stimulus control may be unidirectional. We do not lose what we have learned, we simply bury it or dilute it with what we learn later, or we learn incompatible responses to the same stimulus. Thus, extinction procedures may not reduce stimulus control; like any discrimination procedure, they may actually sharpen it. The issue might not be testable. Skinner (1950) continues, "It would appear to be necessary to make the conditions prevailing during extinction identical with the conditions prevailing during conditioning. This maybe impossible, but hi that case the question is academic."

Parameters that affect the stimulus control of behavior. Parameters that affect stimulus control are central to many issues in the field of memory as it is usually studied, though the relevance of the literature of the experimental analysis of behavior is seldom noted. As a consequence, many experimental questions in the field have been poorly framed. I will briefly consider two such parameters.

1) The stimulus-response and interstimulus intervals. How long after the offset of a stimulus will it continue to control behavior? How long is it "available for conditioning?" Students of memory have asked the question in different terms: "What is the duration of short-term memory?" If we briefly present a subject with a number, prevent rehearsal by requiring the execution of a distractor task, and ask the subject to name the stimulus, over what intervals will the subject be able to do so? The answer to this question depends on many things such as the response system, stimulus intensity, competing behavior, and mediating responses. The concept of short-term memory does not map on to distinctions honored by a behavioral analysis, but the procedure is related to studies of conditional discriminations, symbolic delayed

matching to sample, and interstimulus intervals in classical conditioning procedures. Results from all of these procedures converge, under some conditions, on a common answer.

Peterson and Peterson (1959), among the first to use the short-term memory procedure, found a 60% decrement in control after 6 seconds and virtually complete loss of control after 18 seconds in humans. Blough (1959) found delayed matching-to- sample performance in pigeons to decline to the level of chance in 5 to 20 seconds unless the birds engaged in distinctive mediating behavior. Parametric studies of interstimulus intervals in classical conditioning indicate considerable variability between organisms and between response systems, but generally stimuli to be conditioned decline in effectiveness after a few seconds with little or no conditioning after 30 seconds (see Mackintosh, 1974, for a review). It appears that under most conditions a stimulus is effective for only a half minute or so, although it may be that in a featureless environment a conspicuous novel stimulus would be effective for a considerably longer period.

2) The role of discrepancy in stimulus control. The conditioning of a response can be blocked if the reinforcer has been "predicted" by antecedent stimuli. Technically speaking, reinforcement only occurs when there is a discrepancy between responses elicited by the putative reinforcing stimulus and responses elicited by other stimuli present (Donahoe, Crowley, Millard & Stickney, 1982). Anthropomorphizing, we say that reinforcement is effective only if it "surprises" the organism. As this has been shown to be relevant to the acquisition of stimulus control, we would expect it to be relevant to the retention of stimulus control. This conclusion has been directly confirmed by several studies in the animal laboratory, (e.g. Colwill & Dickinson, 1980; Grant, Brewster, & Stierhoff, 1983; Maki, 1979; Terry & Wagner, 1975) and indirectly in human studies (e.g. Atkinson & Wickens, 1971; Merryman & Merryman, 1971; Richardson & Stanton, 1972). Moreover, a wide range of phenomena in the memory literature can plausibly be interpreted in terms of behavioral discrepancy and blocking, for example, the Von Restorff effect (a novel element in an otherwise homogeneous array is remembered better than other elements), selective memory phenomena (we all know whose picture is on the dollar bill, but we can't report what else is on it), the serial position effect (elements at either end of an array are remembered better than central elements), the 'tip-of-the-tongue' phenomenon (often we can't recall a word but we know what it begins with), and the 'Kennedy assassination' phenomenon (we all know where we were on November 22,1963, but none of us know where we were on November 23). Needless to say, the usual interpretation of these phenomena is not distinguished by reference to blocking or behavioral discrepancy.

Memory as a Problem Solving Phenomenon

To refine the distinction between memory as a stimulus control phenomenon and memory as a problem solving phenomenon, let us consider two simple mathematical questions. For most of us the question, "What is the square root of 144?" is a discriminative stimulus for the response, "12," a discriminated operant acquired in grade school. When asked, "What is the square root of 1764?" however, few of us can reply immediately, though if given a few minutes, we will come up with the correct answer. It is not a matter of latency, with the second response being under weaker control of the question and hence having a longer latency, we simply never have encountered the three-term contingency necessary to condition the response as a discriminated operant to the question.

The relationship between the questions "What did you have for breakfast yesterday?" and "What is the square root of 1764?" is not merely one of analogy. From a behavioral perspective they require identical treatment. Both are examples of **problem solving** and require analysis as such.

"Problem" defined. In both cases a verbal stimulus is presented which, partly by its form, partly by the intonation with which it is spoken, signals an aversive consequence which we can avoid only by replying within a brief period of time. (When we are unable to make a prompt substantive reply, we employ a host of temporizing expressions that serve as well: "Ah," "Now, then," and "Let me see ..." Of course a positive contingency may be signaled also. "I don't know!" will not be reinforced, but the correct response may be.)

Generally speaking, a person is faced with a problem when reinforcement is contingent, in part, upon conditions that do not currently obtain. However, if we confine our discussion to potentially solvable problems, the following criteria define the domain:

1) A target response (or set of responses) is part of the organism's repertoire under one or more stimulus conditions.

2) Discriminative stimuli are present indicating that the response is scheduled for reinforcement.

3) The response is not under direct control of current discriminative stimuli. For example, for most of us the response "42" is an operant (or chain of operants) in our repertoire; in fact the response is a member of a number of response classes distinguished by their controlling variables, e.g. "6 X 7," "40 + 2," the printed numerals, "42," etc. In contrast, an Olympic gymnastic stunt is not in our repertoire under any discriminative stimuli whatever, nor is, say, uttering the Coptic word for "watermelon."

Secondly, the response "42" is scheduled for reinforcement when the square root of 1764 is requested. (The reinforcement in this case may be trifling: a nod of the head, a "Thank you," a check in the margin of a classroom assignment, and so on. However, there is no doubt that humans can be quite sensitive to reinforcers of this magnitude.) Finally, the response is not under the direct control of the question, "What is the square root of 1764?" or of the contextual stimuli, in contrast to the response, "12," to the question, "What is the square root of 144?" That is, it is not a member of an operant for which the question is a controlling variable.

Similarly, the response, "Scrambled eggs," is a response in my repertoire, under the control of, among other things, a plate of scrambled eggs. It also happens to be the correct answer to the question, "What did you have for breakfast yesterday?" and hence is scheduled for reinforcement. Moreover, it is clearly not related in an orderly way to the question. Thus, while the utterance is a response in laymen's terms, it is not, technically speaking, a response under the control of the question as a discriminative stimulus. That is not to say that the question exerts no discriminative control over my behavior, or that it does not contribute importantly to the response in question, but it does not have the same orderly relationship to the response as a red light has to pecking in our demonstration pigeon. The question initiates a sequence of problem solving responses, just as a mathematical question initiates a sequence of mathematical responses eventually leading to an answer, but it does not control the response directly.

If this analogy (or isomorphism) between remembering and problem solving is correct, a common formulation will suffice. We can begin by considering mathematical problem solving since that is often codified and hence more explicit and more nearly universal than the strategies used in recall tasks. If the required response is part of the repertoire of the individual but is not directly controlled by the nominal discriminative stimulus, the individual must engage in precurrent behavior providing himself with supplementary discriminative stimuli until the combined effect of the nominal and the supplementary stimuli are enough to occasion the target response. Finally, the response must be **recognized** as correct, as distinct from all of the other responses of the organism. That is, one must stop engaging in problem solving responses (those that generate supplementary discriminative stimuli) and emit the target response as such.

Supplementary stimulus control techniques. In some cases, we physically manipulate environmental variables. We organize materials or underline important words. We improve the lighting or fetch the right wrench. We shuffle Scrabble tiles or arrange cards by suit. The effect of these manipulations is to improve the stimulus control exerted by relevant variables and, just as importantly, to reduce the control by irrelevant variables. Clearly these are acquired strategies, and judgments of irrelevance and relevance will vary considerably with one's experience.

In some cases we supplement controlling variables. We consult a road map or a dictionary. In other cases we solve problems by supplementing environmental variables with stimuli provided by our own responses. In arithmetic problems, there are formal procedures, codified response chains, which, in conjunction with the nominal discriminative stimulus (the problem), are sufficient to both generate the appropriate response and identify it as the "answer." For example, while we have no response conditioned to the arithmetic problem, 263 X 28 as a complex stimulus, we have many responses conditioned to elements of the stimulus. First we rearrange the stimuli:

$$\begin{array}{r} 263 \\ \underline{28} \end{array}$$

We then execute a series of discriminated operants in an order determined by the physical arrangement of the numbers:

$$\begin{array}{r} 263 \\ \underline{\quad 28} \\ 2104 \\ \underline{\ 5260} \end{array}$$

By emitting these responses we alter the problem. The question, at some point, is no longer, "What is 263 X 28?" but "What is 2104 + 5260?" an arrangement that occasions further-responses. After the leftmost column has been summed we can read the answer as a simple textual response to the stimuli below the lower line. It is only the stimuli arising from our having executed a chain of responses in a particular order that enable us to emit the answer, or target response, as such. It typically has no distinctive properties that indicate that it is indeed the target response. If we have made an error, we will not know it, unless we employ further strategies to confirm the accuracy of our response.

In this case we have turned a multiplication problem into an addition problem and an addition problem into a textual stimulus. We have used a codified strategy, a chain of operants each of which was an important controlling variable for subsequent ones. The responses may be overt, but as I have argued earlier, they may be covert, i.e. below the threshold of observability. We may generalize the solution as follows: The subject has emitted discriminated operants to the nominal discriminative stimulus. These responses, in conjunction with the nominal stimulus have controlled further responses. There is an accumulation of discriminative stimuli, some proximal, some distal, as the solution progresses. The accumulated stimuli eventually are sufficient to occasion the emission of the target response, in this case, the "answer." The target response, once emitted, is a discriminative stimulus halting further mathematical behavior.

Typically, problems do not have codified solutions, but the behavior of the problem-solver is analogous. We solve problems by generating supplementary stimuli which, in conjunction with the context of the problem are sufficient to occasion the "solution." I have posed the following problem to a dozen people: "The square root of 1764 is an integer. What is it?" A typical reply takes several minutes and includes long pauses and a number of overt intermediate responses. One subject pondered and said, "Well, it's more than 40... It's less than 50... It's closer to 40... It can't be 41 because it has to end in '4'... It can't be 42... Wait! Yes it can. ... No. No, it isn't 42. Oh, I give up! I can't work that kind of thing in my head!"

In this case the correct response was emitted but for irrelevant reasons was rejected. It failed a corroboratory test and was not "recognized as correct." However, this subject's overt responses provide a good illustration of the strategy of providing oneself with supplementary discriminative stimuli (SDs). Each response is itself a stimulus exerting some control over subsequent behavior. Initially, the only relevant stimulus was the question. After a few minutes the relevant stimuli comprised a sequential array of verbal responses, some covert, some overt. We can suppose that an outline of such an array looks something like this:

What is the square root of 1764?
100 tunes 100 is zero, zero, zero, zero -- too many zeroes.
20 times 20 is 400.
50 times 50 is 2500.
It's less than 50.
40 times 40 is 1600.
It's more than 40.
40-something.
41 times 41 is something-one.
1764.
It ends in 4.
2 times 2 is 4.
It could be 42.
8 tunes 8 is 64.
It could be 48.
1600 - 1764 – 2500 ... It's closer to 40 than 50.
It's a number between 40 and 50 that ends in either 2 or 8, and it's closer to 40 than 50.

In the presence of this array (or sequence) of stimuli, the response "42" is highly probable. Of course the response has never been conditioned to this constellation of stimuli, but each of the SDs increases the probability of a number of response classes including, in each case, 42. The pooled effect of the SDs is to make the response more probable than competing responses. That is, at some point "42" becomes the prepotent response.

Problem solving, then, is an acquired strategy of manipulating or supplementing discriminative stimuli until a particular response in the repertoire of the organism becomes prepotent over the myriad other responses that are changing in probability. These manipulations are terminated when the original contingency (the problem) is fulfilled, i.e. when reinforcement is delivered, either by an external agent or natural consequence, or by a corroboratory test by the subject confirming that the target response has been emitted.

The behavior of a person asked to recall an incident in the past is the same, except in content, as the behavior of a person asked to solve a problem in his head. When asked, "What did you have for breakfast yesterday?" the "correct" response is in our repertoire in the sense that if the meal were still in front of us we could name it. However, the response does not exist as a discriminated operant under the control of the question. There is no alternative to generating supplementary SDs, and this is exactly what we do, just as we did with the square root problem. We have no codified solutions and therefore performance varies considerably from individual to individual. We evidently learn to use key responses as indices to other responses. As one example, in our culture, many people have schedules that are distinctive. We recite the days of the week forward and backward as intraverbal responses. We can tick off the invariant elements of our schedules for a given day, again as intraverbal responses. As we do so, we provide ourselves with important supplementary stimuli.

Let us consider responses to the question, "What did you have for breakfast three days ago?" One subject replied, "Let's see... today's Monday.. .Sunday.. .Saturday... Friday. That was the day I went to Springfield. Hmm ... Oh yeah -1 just had a glass of orange juice before I left." From this subject's overt responses we can see processes at work similar to those in the subject solving the square root problem. As the response was clearly not directly under the control of the question, it was necessary to provide supplementary discriminative stimuli. The subject in this case emitted an intraverbal chain to determine the appropriate day of the week. This is presumably an acquired strategy useful for a broad class of questions about recent experience, and can reasonably be assumed to be under direct control of elements of the question (What happened X days ago?)

A later response was what we might call an exploratory response: "On Fridays I go to Springfield." When we learn our weekly schedules, responses are conditioned to the names of days of the week as stimuli. Presumably this was a strong response to the stimulus "Friday." Such a response may be of no use in controlling the target response, and in that sense is exploratory. It provides supplementary stimuli that may or may not be effective.

Finally the target response was emitted. There is a considerable gap in our account here, as the SDs provided by the question and the subsequent overt responses of the subject do not appear to be sufficient to control the target response directly. We may speculate that "trip to Springfield" controlled conditioned perceptual behavior (discussed below) that provided additional control. Further exploratory responses might have been necessary before the target response was emitted. Like the game of 20 Questions, each response confined the domain of subsequent responses, yet strengthened responses within that domain.

The details of the process are out of our reach, but it is clear that the target response, the "memory" in question, was controlled, not only by the original question, but by a host of intermediate responses as well. The cumulative effect of the question and the intermediate responses was to make the target response prepotent over other responses in the same domain, just as in the square root problem. No new principles are invoked in this account.

The role of conditioned perceptions. If asked our whereabouts last Wednesday, it helps to be able to say, "Wednesday... 9:00 — lab; 1:00 ~ learning seminar; selectmen's meeting in the evening." With such an intraverbal framework we could provide a plausible account of our day without further ado. However, such an account smacks more of inference than of memory. That is, the subjective impression that we are "reliving" the experience is missing if we merely recount what we must have been doing according to our invariant schedule. Key responses such as "Selectmen's meeting" are directly controlled by the question, but they in turn control other responses. "Selectmen's meeting" may control conditioned perceptions of a particular room in a particular town hall. These perceptual responses in turn control other responses. Similarly, the taste of a madeleine at tea time may directly control perceptual responses that were paired with that taste long ago, perhaps in one's childhood. That perceptual response controls other behavior which in turn alters the probability of still other behavior. In this way a reminiscence or a daydream, or in Proust's case, a book, may be born.

Conditioned perceptual behavior is commonly weak; competing perceptual behavior under the control of exteroceptive stimuli, behavior which we may tentatively regard as unconditioned, may be incompatible with it, and if so, is apt to be prepotent. In order for conditioned perception to be prepotent, it is often necessary to disrupt the stimulus control of incompatible responses. We do this with such devices as closing or unfocusing our eyes, turning away from the television, looking at the ceiling, or stopping other activity.

Implicit in this account is that perceptual behavior is continually being conditioned. If when asked, "What was on the kitchen table when you came downstairs this morning?" I engage in various recall strategies and find myself seeing a pipe wrench on the table, it must be the case that the perceptual response was conditioned to the constellation of stimuli that preceded it, including, presumably, stimuli generated by my own behavior. Seeing the wrench in the morning was conditioned to the context. Recalling the context as a result of a recall strategy occasioned the conditioned perception.

Perceptual responses are presumably conditioned in accordance with the same principles as other responses. Thus perceptual responses are more apt to be conditioned when, loosely speaking, we are "surprised" than otherwise. When questioned about John F. Kennedy's assassination not only can we report our whereabouts, we behave perceptually as we did then. We see again, as if in response to the original setting. Similarly, when asked about this morning's events, I might be able to see a pipe wrench on a table, but I might not see the salt shaker or the pattern of the tablecloth, since only the pipe wrench is an oddity in that context. Thus, we can visualize a painting we have seen but are unable to visualize the color of the painted wall on which it hangs.

The subjective impression that we are "reliving" an experience, then, is due to the conditioning of perceptual behavior. Not all examples of remembering require an appeal to conditioned perceptual responses, but they are clearly important in many cases.

Note that conditioned perceptual responses are responses to current stimuli. We are not responding to a copy or representation of a stimulus we have experienced in the past. That is, stimuli are not stored; past events have changed us in such a way that we now behave perceptually in the absence of the thing seen, under the control of stimuli in the present environment.

Conditioned perceptual behavior is a formidable problem for an experimental analysis. Determining response units empirically and, worse, measuring them objectively, are intractable obstacles at present. Yet the importance of such behavior is undeniable, and invoking it in an interpretation of human behavior is justified, so long as its use is consistent with established behavioral principles.

Recognizing the target response. I have argued that answering a question about the past is problem solving, that we do so by providing ourselves with supplementary stimuli that control necessary intermediate responses. However, a problem still remains: The target response must be "recognized" as such; that is, it must be emitted overtly "as the answer" and intermediate responses under the control of the question must stop. In written mathematics problems, with codified strategies, the answer stands in a particular ordinal and physical relationship to other responses. For example, in long division the answer is available when the remainder or a certain number of decimal places has been calculated, and it can be read as a textual response under the control of the digits above the division symbol. We emit that response as our answer to the problem, but we do not "know that it is right" unless we conduct corroboratory tests such as multiplying the quotient by the divisor to get the dividend.

What are the analogous properties of the "correct answer" in recall? If our first response to a question about a past breakfast is, "Today's Monday," why do we not announce "Monday" as our answer (i.e. with the same emphasis, tone of voice, and evident satisfaction as we announce "Juice")? What are the distinguishing properties of a target response as opposed to an intermediate response? There are several possibilities. First, the strength of a response to its controlling variables is often discriminable. (The usefulness of the concept of the descriptive autoclitic depends upon this fact.) The "correct" answer to a question will typically be strong with respect to all or most of the intermediate responses and, in addition, will be strong with respect to the question. Intermediate responses will typically be strongly controlled by the preceding intermediate response but may not be strongly controlled by the question. Thus the strength of the relationship between the target response and its controlling variables may be distinctive.

Second, the response will itself have stimulus properties. It may occasion a conditioned perceptual response or perhaps a chain or cascade of conditioned perceptual responses -- a reminiscence. In their relationship to the question these additional responses may serve to certify that a particular response is appropriate. A reminiscence of drinking orange juice while preparing lunch in one's kitchen could be a strong response to "Friday's breakfast," but a reminiscence of drinking orange juice in a dimly lit restaurant would probably not be. Thus the "answer" may be distinguished by its strength and the strength of responses that it controls with respect to the original contingency and the constellation of intermediate responses.

Recall strategies and acquisition strategies. In certain circumstances, reciting one's schedule is a useful strategy. In other circumstances, as in recalling a name, reciting the alphabet is helpful. The formal prompt provided by the initial letter of a word supplements other discriminative stimuli. Often recalling related material or answering related questions is helpful. Mnemonic devices of every variety invariably provide supplementary stimuli.

These strategies are all responses, or sequences of responses that we employ at the time of recall to solve the problem that has been posed. Some strategies, however, are employed before recall is required. Let us call them acquisition strategies. Thus we orient, "attend," rehearse, elaborate, classify, and organize. If we expect to introduce a speaker at 6:00, and we learn relevant details of his life at 5:00, we will perhaps rehearse our speech and elaborate on what we have learned. If we must learn a number of unrelated things, we may employ a codified strategy, such as the method of loci, that will facilitate later recall. Acquisition strategies do not provide supplementary stimuli; rather, they strengthen behavior with respect to stimuli that are likely to be provided by recall strategies or properties of a typical recall task. Thus acquisition strategies and recall strategies work together. The first strengthens behavior to key stimuli, the second produces these key stimuli at the time of recall, thereby controlling the target behavior.

In many cases we do not explicitly employ strategies. However, when the current setting is insufficient to directly control the response scheduled for reinforcement, we must provide supplementary stimuli, whether we do so "automatically" or "deliberately." The term, "strategy," though it regrettably connotes awareness, is used here to encompass all supplementary stimulus control procedures whether we can describe them or not.

Implications of a behavioral analysis. The foregoing interpretation suggests the following:

1) Once a strategy is employed and a response to a question is reinforced, that question may control the response directly at a later time. Thus, in the future the response "42" may be directly under the control of the question, "What is the square root of 1764?" and "Scrambled eggs" may, perhaps inappropriately, be under the control of the question, "What did you have for breakfast yesterday?"

Adults are thoroughly practiced at answering questions about the past. Consequently, responses generating supplementary stimuli will often be under direct control of classes of questions, and the appropriate response may occur swiftly, effortlessly, and without awareness of any supplementary responding.

2) Effective supplementary stimuli may be idiosyncratic. An effective strategy for one person may be ineffective for another. Moreover, if one strategy fails in a given circumstance, another may succeed. There is no invariant property of recall behavior.

3) Strategies are acquired. Children must learn to recall events, just as they learn to solve other problems. A child asked about the past will simply be unable to respond appropriately unless he has learned to do so or unless supplementary stimuli are provided by adults. Of course, in the presence of appropriate stimuli there is no reason why children's recall should be inferior to that of adults. Thus, it is not helpful to speak of "memory as a capacity that undergoes developmental changes." Changes in recall behavior surely occur as a child matures, but it is unnecessary to appeal to anything other than the normal evolution of a behavioral repertoire in a complex and increasingly demanding world.

4) There are no qualitative differences between "correct" and "mistaken" recall responses. Both are under the control of the current constellation of discriminative stimuli. That is, there is no difference between a "memory that never happened" and one that "did happen."

5) If recall strategies are sequences of responses, then performance should be disrupted when incompatible responses are strong. For example, if "April" is a key intermediate response for the intraverbal response, "March," performance may be disrupted if "April is the cruelest month" is a strong response.

6) Responses controlled in part by a complex of supplementary stimuli are not operants. That is, they are not yet orderly units with respect to that complex of stimuli, as the stimuli have come together for the first time. Each strengthens a common response but may be insufficient alone to occasion the response. For example, the word, "harbor," does not commonly control the response, "Boston," but "harbor, baked beans, university, Bunker Hill" as a complex of stimuli might do so. In many problems a response of a particular topography will serve as a solution regardless of its orderliness as a unit. Recall strategies and problem solving strategies exploit this fact.

The origin of strategies. We learn to remember. More precisely, effective intermediate behavior, behavior which provides supplementary stimulus control in appropriate contexts, is differentially reinforced. The adult community implicitly shapes such behavior in children by providing and then fading prompts which facilitate the target response:

> Tell your father who came to visit today... Remember? She sat on the couch
> and read you a story... Was it Aunt R~?

More and more explicit prompts are provided until the target response occurs. Later, as the child begins to supply some of the intermediate responses himself, fewer prompts are provided.

Adults often model strategies in their own attempts to recall something:

> Who made this long distance call to New York?... Let's see... It was
> October 11. That was a week ago Monday... I drove the kids to the
> dentist that day... Oh, I remember! I called the insurance company.

The overt intermediate behavior of the adult is controlling the behavior not only of himself but of everyone around him, including the children. A child might find himself making an appropriate response in such circumstances. In any case, he may imitate the adult for other reasons and find himself recalling things adventitiously, as it were.

Some strategies are acquired by accident. A child who needs a flashlight may go to the family room to get one. By the time he arrives, he has forgotten what he came for. As he turns to go, he sees the flashlight on the shelf and recalls his errand. As a consequence he may learn to scan his environment for visual prompts when similar problems occur in the future.

Many codified strategies are explicitly taught. "Every good boy does fine" is a mnemonic we acquire in second grade, and in college we are not above murmuring in the middle of an exam, "Please eat old mashed potatoes politely," to help recall geologic epochs. Self improvement courses are widely offered to teach mnemonic strategies that are unlikely to be acquired under everyday contingencies.

There are many ways, then, in which individuals can acquire supplementary stimulus control techniques. While it seems unnatural that, until we have done so, we should be unable to answer simple questions about our past, we must remember that there are skilled mnemonists who can recall 50 digit numbers after a moment's study. Most of us would be staggered by such a task. The child is in just such a circumstance when required to recall past events.

Conclusion

The present analysis has attempted to provide a framework for a behavioral interpretation of phenomena studied in the field of memory. I have suggested that principles derived from the experimental analysis of three-term contingencies of reinforcement are sufficient to explain such phenomena. Moreover, I have argued that distinctions arising from a consideration of these principles have not arisen in traditional approaches to the subject, that what is usually considered a unitary field embraces phenomena that require quite different behavioral interpretations.

In contrast to the inductive science on which it rests, the present account has been deductive. We have begun by accepting general principles and asking what must be the case if certain conditions obtain. For example, if a person reports that he ate scrambled eggs yesterday it must be the case that that response was prepotent, that it had been reinforced in that setting in the past, or that the constellation of stimuli preceding it controlled the response. Similarly, since responses have stimulus properties, it must be the case that one response alters the probability of other responses, and that some of these responses may be covert. By examining a few examples of overt problem solving it has been suggested that no new principles are necessary, that supplementary stimulus control procedures are sufficient to explain conditioned behavior in the absence of a demonstrable controlling stimulus.

It maybe argued that by considering covert responses in its analysis radical behaviorism has compromised its status as an empirical enterprise. To argue so is to confuse the science of behavior with the interpretation of that science. Interpretation is reserved for phenomena in circumstances that, with our present methodology, are too complex for experimental analysis. The methodological problems do not vanish if one abandons radical behaviorism for another approach. Other approaches are faced with the same complexity but lack the broad empirical foundation and the coherent set of principles from which behavioral interpretations spring.

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