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RADICAL BEHAVIORISM AND EXCEPTIONAL MEMORY PHENOMENA

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ABSTRACT: The central claim of this paper is that radical behaviorism and cognitive psychology can both make important contributions to an experimental analysis of a cognitive skill such as memory performance. Though they currently differ in what constitutes an explanation of many phenomena, behaviorists and cognitive psychologists share interests in such human activities as problem solving and memory. We show how the behavioral approach may apply to one case that seems to epitomize cognition—the dramatic improvement in the memory span performance of one individual on a task often used by cognitive psychologists to assess short-term memory. After 230 hours of practice, ability to recall random digits improved from a span of 7 digits to a span of 80. Although a detailed account of the mechanisms that mediated such improvement has been given, we show that the acquisition of such exceptional memory skill can also be explained within the framework of behavior analysis.
Key words: exceptional memory, Radical Behaviorism, cognitive explanations, digit span.

A Behavioral Analysis of Exceptional Memory

Memory has generally been studied by cognitive psychologists and by scientists from some other disciplines, such as the neurosciences. The cognitive movement came about (or at least gained momentum) in the 1950s and 1960s because developments in the field of artificial intelligence, human factors, and psycholinguistics led to the widespread belief that radical behaviorism could not provide a satisfactory account of human behavior. Thus, the spatial metaphors were invented to account for human problem solving, and the structure models were invented to account for human memory phenomena. In contrast to radical behaviorists, cognitive psychologists are more concerned with ordinary-language categories, such as "memory," "reading comprehension," "problem solving," and with determining the limits of human capabilities (e.g., what is the span of immediate memory?).

Behavior analysts, on the other hand, are less interested in determining "limits" and more concerned with demonstrating functional relationships. Behaviorists also argue against the use of mediators, such as storage metaphors

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and retrieval mechanisms, mediators that are the essence of cognitive psychology. The widespread view among cognitive psychologists is that behavior analysis does not have any role, or not a significant one, to play in research on human memory. The belief that behavior analysis is excluded (or has excluded itself) from such areas was a major factor in precipitating the so-called cognitive revolution. Those seriously interested in human cognition believed that mediational constructs were indispensable to an understanding of "higher mental functions," such as human problem solving and memory.

However, some, such as Watkins (1990), argue that mediational constructs have impeded progress in memory research. He went so far as to write:

> Memory theorizing is going nowhere. The reason is that it is rooted in mediationism, the doctrine that memory is mediated by some sort of memory trace. (p. 328)

Watkins specifically disputed the usefulness of inferred stages of "encoding," "storage," and "retrieval," arguing that such a model far surpasses the conclusions that may be drawn from the data of experimental psychology. Excessive modeling has led to an overabundance of memory theories that employ terminology that is imprecise and assumptions that are difficult to disprove. Roediger (1985) agreed, claiming that there has been such a proliferation of analogical memory models that a huge array of hypothetical mental representations are tied loosely, if at all, to behavior. The proliferation of hypothetical mechanisms and mediators of memory had been noted earlier by many others, including Underwood (1972) and Tulving (1979).

We argue that not only can such "mental" phenomena as memory be the subject of behavior analysis, but also that the behavioral viewpoint may be profitably adopted by cognitive psychologists. We first briefly describe the cognitive and the behavioral approaches to memory. Then we describe a case study of an individual designated as "SF," who acquired exceptional memory through laboratory practice (Ericsson & Chase, 1982). Third, we provide a cognitive interpretation as well as a behavioral analysis of SF's performance, and we discuss ways in which behavior analysis can improve our understanding of memory. Finally, we compare and contrast the relative fruitfulness of the radical behaviorist and the cognitive positions, in explaining memory behavior.

The Cognitive Approach to Memory

Although there are many models of memory, most researchers argue in favor of two distinct memory systems, a short-term memory (STM) and a long-term memory system (LTM). The capacity of STM has been considered to be limited to about seven unrelated items (Miller, 1956) or "chunks," and to persist over about 30 seconds. After 30 seconds or so information in STM is either "lost" or forgotten unless it has been transferred to more durable storage in LTM. A person can use a number of devices to achieve storage in LTM, such as rehearsal or encoding the material in some meaningful manner, such as chunking. The capacity of LTM is assumed to be very large and information in LTM can last a lifetime. STM corresponds roughly with the current state of consciousness. Information that is stored in LTM cannot be retrieved directly from it—it must first be brought into STM before the "output" can be produced.

There are, of course, many, many models for memory[1] and this sketch is an approximation only. Consider it a generic version. Anyone attempting even a brief summary of cognitive approaches to memory must pause and consider the opinion of Endel Tulving (1979, p. 27):

> After a hundred years of laboratory-based study of memory, we still do not seem to possess any concepts that the majority of workers would consider important or necessary. If one asked a dozen or so randomly selected active memory researchers to compile a list of concepts without which they could not function, one would find little agreement among them . . . if one compares different textbooks of memory, one discovers that there is little overlap among their subject indexes. It seems that important concepts of one author can apparently be dispensed with by another.

Radical behaviorists might argue that matters have not improved since 1979 and many cognitivists might agree!

The Behavioral Position on Memory

For behaviorists, or radical behaviorists at least, the construct of memory is not required in order to understanding remembering. This position was long expressed by Skinner, for example in C*ontingencies of Reinforcement* (1969), *About Behaviorism* (1974), and elsewhere. Specifically, Skinner (1969, p. 274) argued that the storage metaphor that cognitive psychology borrowed from computer science is inappropriate, since:

> . . . the organism does not need to make a copy of the environment in order to perceive it. When an organism that has been exposed to a set of contingencies of reinforcement is modified by them and so behaves differently, what is stored is a modified organism, not a record of the modifying variables . . . the conditions that determine the accessibility of stored memories really determine the accessibility of responses.

Cognitive psychologists disagree, but the fact is that the metaphor of *stored memories* is unnecessary to explain behavior. This is not a new nor even a recent view. James Angell (1907) promoted it a century ago, as did many others during the late 19th and early 20th centuries. Baum (1994) follows Skinner as a modern opponent of memory-as-storage and notes that we never say that we "remember" that we stubbed our toe 30 seconds ago. If we don't need to store-and-retrieve over a 30-second span, we need not do so over a 30-hour or 30-year span. Skinner

[1] The controversy about whether one needs to conceptualize memory in terms of one memory system or two (STM and LTM) is irrelevant to the present paper.

(1974, 1985) proposed that a storage battery was a better model of a behaving organism than is storage in a computer (or other) memory. We *store* electricity in a battery by changing its chemical composition and we remove electricity when we need it. But there is no electricity *in* the battery.

By the same token, organisms do not acquire various kinds of behavior as *possessions*; they simply come to act differently in different situations because of past experience. Many current cognitive psychologists would agree with Skinner—the storage metaphor has not proven useful in understanding memory and information is not passively stored (e.g., Ericsson, 1985; Ericsson, Weaver, Delaney, & Mahadevan, 1996). But many believe that the construct of *memory* is necessary, despite behaviorist objections.

One reason that cognitive psychologists see memory as necessary is to preserve the notion of a *problem space* to deal with cognitive activity such as problem solving, and the spatial metaphor has occupied a pivotal role in many cognitive theories. However, as Rubin (1988) has pointed out, the spatial metaphor predates the cognitive revolution because "Our spatial abilities are so strong and so pervasive that they do not allow for the development of complex process models" (p. 380). This "problem space" provides the static snapshot that seems so necessary to lay readers and to many psychologists. But it lacks a satisfactory description of what actually goes on when the movie begins.

A Case Study of Exceptional Memory

We turn now to the case study of subject SF. We describe his memory skill acquisition from the cognitive as well as from the behavioral perspectives. We propose that a behavioral account adds to our understanding of cognitive phenomena such as memory—which seem to be nonbehavioral by definition. The case that we describe is a modern classic in the literature of cognitive psychology and was first presented by Ericsson and Chase (1982). It involves an individual, identified as SF, who improved his memory performance dramatically under laboratory practice conditions. When this study commenced, SF was a junior at Carnegie Mellon University, with a very strong academic record. Academic record and junior standing were criteria used to ensure that the selected subject was likely to be available for the entire duration of the study. SF was paid an hourly stipend and was trained on the memory span task (Brener, 1940; Miller, 1956). Dempster (1981) provided a detailed review of the theoretical basis and the empirical findings associated with this task.

The Digit-Span Task

On the digit-span task, digits (0-9) are presented at the rate of one per second. After a series of digits is presented, the subject is asked to repeat them in the correct order of their presentation. The sequence of events on a trial begins with the experimenter announcing list length (the number of items to be presented) to the subject. Next, the digits are presented; in this case, they were spoken by the experimenter, though visual presentation is sometimes done. Following presentation, a cue is given which signifies that the subject is to repeat the list in the correct order. Once the subject has finished this, the experimenter provides feedback—“You are correct,” or “You are incorrect.”

In the case we are describing, testing began with a list of three digits. With this method, correct recall of the list means that the list length for the next trial is increased by one digit, chosen from a list of random numbers. If the subject makes a mistake, another list of the same length is given. If a mistake is made on that list, testing is terminated. Across a wide variety of testing materials, such as digits, letters, and words, memory span is found to lie in the range from five to nine symbols, with an average around seven (e.g., Miller, 1956). Ericsson and Chase (1982) were interested in whether SF could *improve* his memory span, at least when digits were employed as the material-to-be-learned.

SF’s Performance on the Digit-Span Task

This subject’s digit span was seven when practice commenced. After 230 hours of practice, his digit span improved from seven to 80—a remarkable change. The practice was conducted in one-hour blocks, one per day, five days a week. SF was given no instructions on how he might be able to improve his performance.

A Cognitive Interpretation of SF’s Experience and Performance

How was SF able to increase in his performance by a factor of twelve? Ericsson and Chase (1982) explained SF’s improvement from a cognitive perspective. According to this view, there were two strategies that were primarily involved: *meaningful encoding* (or chunking) and the use of an *explicit retrieval structure*.

Meaningful encoding occurred as follows. During the first few sessions, SF’s memory span did not improve beyond 7 or 8 digits. But then he recognized some three-digit groups that reminded him of familiar numbers; he was a long-distance runner and possessed a good knowledge of the times of different people in different races. He used this knowledge, comprising 11 major categories and their subcategories, to aid him. Thus, a series such as 347 would be encoded as 3 minutes and 47 seconds—the official running time for some person for a mile run.

However, if a string of three or four digits did not remind him of a running time, his memory performance would drop below the previous trial because he could not employ this powerful mnemonic strategy. Occasions when this occurred were evident in his performance. He was able to subsequently increase his repertoire for the purpose of chunking digits by using, apart from running times, dates and ages of people. Hence, SF’s inability to “encode” digit strings as running times meant that this type of tacting[2] behavior was extinguished and replaced by a broader set of tacts, to use Skinner’s (1957) term for “naming.”

[2] This is Skinner’s (1957) term for “naming” things.

Explicit Retrieval Structure

Chunking enables a person to assign a single, familiar verbal label to a set of nominally independent items. For example, the “nominally independent” set of digits *1, 0, 6, 6* might be assigned the label “Battle of Hastings,” or “first sighting of what would later be called Halley’s Comet.” Chunking is a very efficient strategy because a single verbal label contains several individual units—the term “chunk size” refers to the number of such units encompassed. Thus, if one is learning a list of digits and if the size of each chunk is four digits, then four chunks will constitute 16 digits. Thus, the 16 digits *1066177619455280* could be represented by four chunks: “Hastings, Declaration of Independence, WWII,” and “mile.” These labels are all that need be rehearsed, since recall of the label means recall of the digits.

But there are limits to the number of verbal items (chunk labels) that can be rehearsed as a set. A number of investigators (e.g., Ericsson & Chase, 1982; Ericsson, Weaver, Delaney, & Mahadevan, 1996) have found this number to be four or five chunk labels. Any attempt to rehearse more than five or so labels would result in errors, such as omission of a chunk label or transposing of labels—perhaps as *17761066* in the above example. SF found that he could not rehearse more than three or four chunk labels in proper sequence. If he attempted to handle more, he committed errors in ordering the chunks during recall. For example, the sequence *347562138916425* might be presented during learning and these digits might be chunked as 347-562-138-916-425. However, if SF attempted to chain these five chunks as a *super group*, then his recall would fail and he might report 347-138-562-916-425. The inability to rehearse more than three or four chunk labels is not unique to SF but appears to be a limit in the processing capabilities of humans in general. This has been demonstrated in several other case studies of exceptional memory (e.g., Ericsson, Weaver, Delaney, & Mahadevan, 1996; Gordon, Valentine, & Wilding, 1984; Kleigel, Smith, Heckhausen, & Baltes, 1987).

In order to recall more than three or four chunks in proper sequence, SF (as well as others, such as Rajan,[3] as subsequent research demonstrated) developed what Ericsson and Chase (1982) called an *explicit retrieval structure* (Figure 1). According to the cognitive interpretation, this is developed during the encoding phase and begins with chunking the individual digits. Each chunk includes no more than three or four digits. A set of three or four of these chunks forms what could be called a *supergroup*. Then, two *supergroups* form a *higher-order group*. All of this is necessary to preserve the sequencing of a large number of chunks. During retrieval, the subject has first to recall the label of the first chunk of the first supergroup, which cues the recall of the second chunk label, which cues the label for the next, and so on. Such cuing will occur because the three or four chunk labels were rehearsed together during encoding. The same retrieval process occurs for each successive supergroup.

[3] Ericsson, *et al.*, 1996.

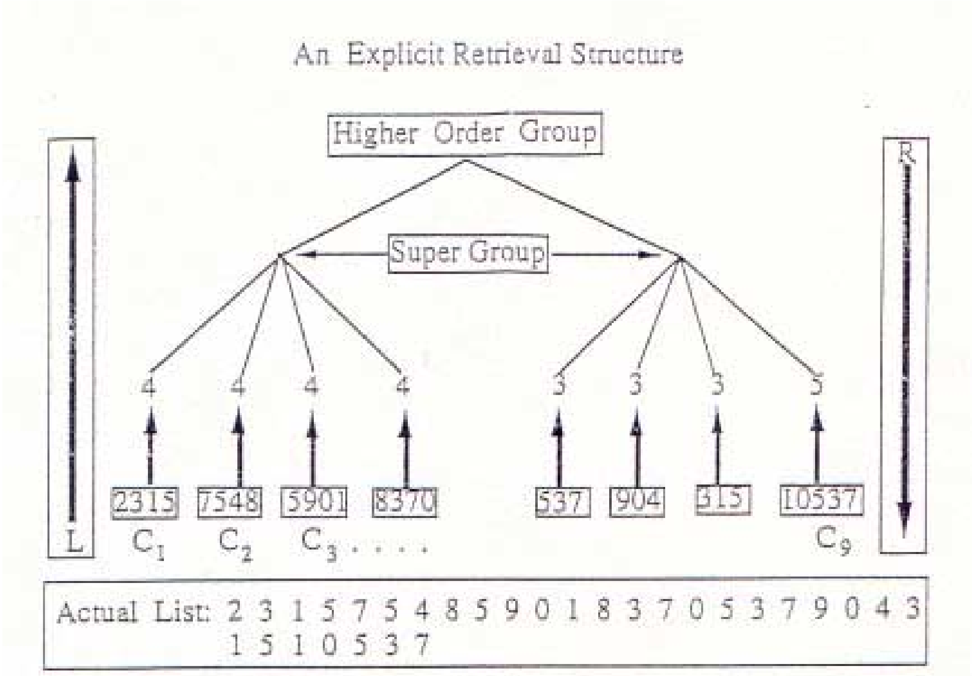

Figure 1: An illustration of the type of explicit retrieval structure that was used by SF, in his acquisition of a memory skill. C_n denotes the n^{th} chunk. In this particular illustration, four chunks make up a Super Group, and two Super Groups make up a Higher Order Group. On the left-hand side of the figure, L denotes "Learning." That is, individual elements → chunks → super groups → higher order group. On the right-hand side, "R" denotes recall. During recall, the sequence of events that take place during the learning phase is reversed. This type of a retrieval structure (that is composed of chunks, super groups, and higher order groups) enables one to overcome the limitations of the "bottleneck" that typically constrains the amount of information that can be transferred from STM to LTM.

Behavioral Interpretation of SF's Performance

Behavior analysis is concerned with variables of which behavior is a function and does not rely on metaphors to "explain" remembering. Thus, the "encoding," "retrieval" and other storage metaphors of cognitive theory are superfluous, if not misleading. A radical behaviorist would ask what exactly occurred during SF's training and how that may account for his improvement in recall of strings of digits. Cognitive mediators are replaced by terms describing what SF actually *did*.

On each testing trial, the experimenter presented SF with digits at the rate of one per second. After the entire string of digits was presented, the experimenter gave the verbal cue, "Recall," at which time SF would attempt to report the string of digits. When he was successful, the experimenter reinforced his reporting with the words "That was correct." A second consequence of a correct response was an increase in the list length by one digit on the following trial. When SF was unsuccessful, the experimenter said, “That is incorrect,” and he presented another series of the same length. The subject’s reporting of the list is the response to the stimulus word “Recall” and is dependent upon previous conditioning history—that is, “recalling behavior” is prompted by the experimenter’s command and the subject’s reinforcement history.

For the first few testing sessions, SF’s performance was typical of that of most people—about seven or eight digits. Then his performance began to improve, so that he was able to repeatedly report 10 to 12 digits by session five. He accomplished this by using tacts and intraverbals[4] to chain a set of about four tacts to form what Ericsson and Chase called a “supergroup” (1982). In SF’s case, an intraverbal would be a set of four tacts.

As noted above, SF was a long-distance runner and he had learned the times of many different runners in different races. So, when presented with a sequence of digits such as *9-4-6*, the appropriate tact might be “John Doe,” since SF had learned that Doe had run a race in nine minutes and 46 seconds.[5] When SF, or any other digit-memory expert (such as Rajan), was given a series of digits, they relied on intraverbals and tacting intraverbals as essential intermediary steps preceding the response. This was evident based on analysis of extensive verbal protocols from SF. The feedback from the experimenter, “That is correct,” served as a reinforcer. The tact involved is a special type of tact, just as the names of people are special kinds of tacts (Skinner, 1957, p. 208).

SF’s knowledge of running times meant that he could, if required, produce a sequence of digits by first tacting a sequence of three or four digits and then chaining about three or four tacts to form an intraverbal. The importance of forming such intraverbals in order to enhance remembering behavior was pointed out by Skinner (1957, p. 104), who discussed the mnemonic advantages that can result from mnemonic elaboration. As he explained, “A favorite device of the memory expert is to convert [the to-be-remembered information] to a description . . . no matter how fanciful or implausible the description may be.”

Reinforcers in the form of feedback and approval from the observer or observers perhaps led to an increase in the probability that he would make the same response to the same digits when presented with them on a different occasion. These were the contingencies that mediated SF’s acquisition of a repertoire of running times. However, SF’s store of running times was not sufficiently large to enable him to rely on the tact function for any given series of digits. When his performance dropped, he had to change his behavior, which he did by using a wider range of tacts than simply running times. For example, he

[4] An intraverbal is a verbal response that has no direct correspondence with the stimulus that served as the antecedent. A tact is a verbal response that is evoked in the presence of a nonverbal stimulus—that is, tacting is naming things. See Skinner, 1969, p. 25.
[5] When SF, or any other digit-memory expert, was given a series of digits, they relied on intraverbals and tacting intraverbals as essential intermediary steps preceding the response. This was evident based on analysis of extensive verbal protocols from SF. This complex chain of behaviors occurred during every memory span trial, but such behaviors are not easy for others to observe.

found that he could use memorable dates and ages of people. He thus was able to develop an increasingly sophisticated repertoire of responses with continued training. Thus, SF's inability to tact digit strings as running times meant that this type of tacting was extinguished and replaced by a broader set of tacts.

SF found that he could produce a string of two intraverbals (i.e., two chains of tacts), but any attempt to string more than four tacts within an intraverbal led to errors of transposition in the response. This meant a nonreinforced trial. A lengthy set of digits might be composed of two or three such strings. Within each string of intraverbals, the first serves as a discriminative stimulus (S^D) for other intraverbals in that string.

For example, using the illustration depicted in Figure 1, "2315" serves as a cue to produce 7548-5901-8370 and not 904-315-10537. Over 230 hours of training, SF was able to construct a complex pattern of sequences of responses by which he was able to improve his "memory span" from seven to 80 digits.

Motivational Influences

One might think that memorizing random strings of digits is an uninteresting task for most people and that there must be some special source of motivation to sustain SF at this task, which lasted over an entire year. SF was a very good long-distance runner, so it is plausible that he could put up with other repetitive tasks better than could others. It is possible that SF succeeded where others failed, in the digit span task and also in distance running because of SF's unique past history. This raises the issue of individual differences in memory performance. While some individuals such as SF (and Rajan) have persisted with tasks involving digit-memorization, others have not. Indeed one of Ericsson and Chase's subjects did not get beyond 18 digits on the digit span task, and another subject found digit-matrix memorization so aversive, that she could not be persuaded to do that task (Thompson et. al., 1993).

Cognitive and Behavioral Explanations of SF's Memory Skill

Ericsson and Chase (1982) used metaphors such as "encoding" and "storage" in describing SF's performance. And they provided clear evidence that SF made extensive use of tacts ("chunking") and intraverbals, though they did not use those terms. Where a behavioral position differs is with regard to whether it is necessary to resort to mediational constructs in order to explain SF's performance—a "chunk" really corresponds to a "tact," and a "supergroup" is what Skinner called an "intraverbal." Tacts and intraverbals both refer to functional units of verbal behavior, not to mediators.

When SF was presented with a group of digits that he "recognized as a chunk," he was reinstating a familiar tact, rather than "retrieving information from memory." From the behavioral standpoint, even an explicit retrieval structure can be seen as rules governing the relationships among different intraverbals, that is, how to remember a long string of digits. These relationships can be assessed by the speed and accuracy of emission of a given sequence of digits, rather than construed as the rules that govern "retrievability of information from memory."

One striking feature of SF's performance was the number of tacts that he had "developed." An extensive repertoire of tacts was by no means unique to SF. Rajan too had several thousands of number-related tacts that he could use when learning new digit strings (Ericsson, Weaver, Delaney, & Mahadevan, 1996). In contrast, the novice memorizer of digits has only a handful of tacts. This is acknowledged implicitly in the "memory" chapters of most introductory psychology text books, in which the principle of chunking is demonstrated by using a digit series such as 17761941—dates with which most people are familiar.

Why have two different types of explanation when one might suffice? Does the difference between radical behaviorism and cognitive psychology amount to nothing more than saying the same thing in two different languages? We argue not. One answer to this question lies in the difference in the philosophy of experimentation and explanation in cognitive psychology and in behavior analysis. Radical behaviorists are interested in the interaction between the organism and the environment, as a sort of an ongoing continual process. In that sense, radical behaviorism developed process models best exemplified in schedules of reinforcement. Stated differently, radical behaviorists were interested in an *online* analysis of the organism-environment interaction. This must be cast in terms of the organisms' *activity*.

In contrast, cognitive psychologists are interested in reflective behavior. That is, cognitive psychologists are interested in *frozen snapshots* of behavior; these representations or structures are *always* intervening variables or hypothetical constructs. In terms of an analogy, behaviorism can be likened to a movie, whereas cognitive psychology can be likened to *a photograph*.

Skinner commented on the study of memory (1957, p. 207), arguing that the real value of classical studies of memory interference

> . . . is not so much in permitting us to draw the curve according to which intraverbal connections are weakened with the passage of time, but in showing how various intraverbal operants interact with each other to facilitate or interfere with stimulus control.

This is particularly relevant to gaining a better understanding of how forgetting occurs. Further, Skinner (1957, p. 207) remarked that the loss of verbal behavior over time has focused almost entirely on intraverbal behavior, in part because it can be lost rapidly, compared with echoic and textual operants. It is intraverbal behavior that is studied in research on exceptional memory.

Re-evaluating the Role of Metaphors as Explanatory Constructs

Memory is a metaphor, not an explanation. The many metaphors used by cognitive psychologists, such as "encoding," "storing," "retrieving," and "chunking" could conceivably be subjected to rigorous analyses in terms of the contingencies/operations that define them. But that won't happen. Radical behaviorists believe that all cognitive phenomena can be accounted for with behavioral principles and that the chief problem with cognitive psychology is its reliance on metaphors.

However, some researchers such as Ericsson and Simon (1993) have developed techniques such as protocol analyses, where verbal reports are obtained from a subject after performance on every trial of a given task (say, a memory task) in an attempt to uncover what they interpret as the cognitive mechanisms that mediated a subject's performance on that trial. The goal of collecting such verbal reports is to tightly integrate hypothetical constructs (e.g., short-term memory) with experimental data. Despite the well-known limits on our ability to verbalize cognitive activity (e.g., Nisbitt & Wilson, 1977), some of it *is* open to introspection and may provide useful additional data.

In the case of subject SF, Ericsson and Chase (1982) proposed mechanisms that mediated his performance through analysis of verbal reports (concurrent and retrospective reports) that they collected after every trial on the digit span task. These reports then served as a basis for generating and testing new hypotheses. For example, based on SF's claims that he used to encode digits as running times, Ericsson and Chase (1982) found that his digit span dropped substantially when he was given a series of digits which he could not encode into running times.

A radical behaviorist would ask what has *this* to do with underlying mediating mechanisms and with generating new hypotheses? It was found that SF could deal with one kind of material—that which could be translated to running times—but not with another. There is no profit in referring to cognitive mediators here. Perhaps this reveals the tacit assumption of cognitive psychology: there are *always* mediators, and they are things to be "discovered." That's what the behaviorist questions.

Just as meteorologists do not believe that tornadoes and hurricanes are the result of "angry gods," neither should scientists believe that a delayed response to a stimulus is the result of short- or long-term memory. The proper question concerns what mediates the delayed response.

A Process Model for the Memory Skill That SF Acquired

In the case of SF, it is easy to explain the notion of an explicit retrieval structure—see Figure 1—in terms of a process model, compatible with radical behaviorism. Although Ericsson and Chase used the word *structure,* to describe the organization of information in LTM, in fact, one could also argue that what we have in Figure 1 can well be interpreted as a process model. All that one needs to do is to have a time-line on the X-axis. This substitution can be justified on the basis that the digits (and also other information such as the pauses between chunks and also the pauses between super groups) that are recalled are responses that are emitted over time. To that extent we have a process model. Also, it was the analyses of SF's verbal protocols during his skill acquisition that enabled Ericsson and Chase to come up with a good process model (their "explicit retrieval structure") for SF.

It therefore appears that at least in the case of SF, the two-dimensional spatial representation of his retrieval structure (in Ericsson and Chase's terminology) is really a means for communicating the process model. The Ericsson-Chase account of SF is especially appealing because as David Rubin[6] has pointed out—they kept close to the observable tacts.

Concluding Remarks

Radical behaviorism and cognitive psychology may be using different terminology and to an extent, perhaps they are different ways of expressing much the same thing. However, the movie-photograph metaphor is a good one because it shows that both cognitive psychology and radical behaviorism have a role to play in understanding complex human behavior. After all, well-taken photographs have their uses as well as do movies. But the behavioral approach may be closer to the facts. The factors that determine one's ability to recall digits, or to recall anything else, are complex. But they all lie in the interaction of organism and environment, as it occurs over long periods of time.

Finally, verbal protocol analysis may help bridge differences between radical behaviorism and cognitive psychology by providing as tight a fit as possible between cognitive theorizing and observable performance. In that regard, verbal protocol analysis has given us a good process model to account for SF's performance without some of the traditional disadvantages of cognitive accounts.

The real issue is not whether the cognitive account can provide insights that a radical behavioral account cannot. When it comes to explaining a specific behavior, both perspectives (radical behaviorism as well as cognitive psychology) can be considered as being speculative at best. The difference being that radical behaviorists speculate about prior history, whereas cognitive psychologists speculate about hypothetical constructs.

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