MEMORY

Gabriel A. Radvansky
University of Notre Dame

Robert S. Wyer, Jr.
University of Illinois at Urbana-Champaign

Glossary

Category An organized set of conceptual entities (objects, events, concepts, etc.) that are similar to one another in some respect.

Episodic memory The memory system that contains knowledge concerning events from a person's life. Episodic memories are localized in time and place, and often include a representation of oneself as either a participant or observer of the events.

Explicit memory Memory processes that operate through a deliberate and conscious act of remembering (e.g., recognition and recall).

Implicit memory Memory processes that operate through unconscious mechanisms.

Long-term memory A large-capacity portion of the memory system where information is stored in a highly organized fashion for long periods of time, possibly lasting a lifetime.

Memory The mental systems, representations, and processes that are involved in the retention of information.

Procedural memory The memory system that contains memories of performance activities, including stimulus–response associations (e.g., knowledge of how to ride a bike or drive a car).

Schema General world knowledge structures of well-defined common human experiences used to organize new information and reconstruct information that may have been forgotten.

Semantic memory The memory system that contains encyclopedic general world knowledge which does not refer to a specific event in the individual's life.

Short-term memory A limited capacity portion of the memory system where information enters, but lasts for only a short period of time before being either transmitted to long-term memory or discarded. Sometimes referred to as working memory.

Spreading activation The notion that the activation or availability of one conceptual entity spreads to other related conceptual entities through a complex of associative pathways.

MEMORY refers to the mental systems, representations, and processes that are involved in the retention of information. The ability to remember the information one has accumulated plays an integral role in the comprehension of new experiences as well as in judgment and behavioral decision making. Indeed, the loss of memory (through amnesia, Alzheimer's disease, or other disabilities) is one of the most dehumanizing of experiences. This article provides a brief overview of some of the more important topics in current memory research, particularly from the area of cognitive psychology, with respect to how memory operates and has an influence in shaping our lives.

I. INTRODUCTION

Several characteristics of human memory are of interest to psychologists. The issues of concern include (a) the specification of different types of memory structures and processes, (b) whether memories are permanent or, alternatively, whether they eventually fade away and disappear entirely, and (c) how aspects of memory impact on people's daily lives. These issues are not mutually exclusive. For clarity of expression, however, they will be considered separately.

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II. TYPES OF MEMORY

A. Memory Models as Metaphors

Human memory is a repository for information as widely varied as images of people's faces, knowledge of how to drive a stick shift, phone numbers, how much money is in your checking account, the names of the countries of Europe, and the smells of good home cooking. A complete account of human memory must specify the structure of the mental representations formed for these types of information, their organization in relation to one another, and the processes that are involved in retrieving them. Because the structure of memory and the processes involved in its use cannot be directly observed, theoretical accounts of them make use of metaphors. In the earlier 20th century, models of memory used metaphors such as a filing cabinet or bin system. Later, with the expansion of telephone systems, memory was referred to as though it were a telephone operator's switch board. With the advent of the digital computer in the late mid-century, models of memory during the cognitive revolution adopted a computer metaphor, which relied on the way in which computers represent information, and the processes involved in encoding, storing, retrieving, and operating on information. This metaphor was especially important because of its separation of physical and mental states (the hardware versus the software). More recently, in an effort to consider how information might be represented neurally, some researchers have been calling for a brain metaphor, despite the oxymoron.

People exhibit different memory characteristics under different sorts of conditions. For instance, a person might forget the names of most of his high school classmates after 10 years, but might remember how to ride a bicycle throughout his life. Recognition of this fact has led to the postulation of different memory systems and different types of mental representations.

B. Short-Term and Long-Term Memory

Many metaphorical conceptualizations distinguish between long-term and short-term memory. Long-term memory contains a lasting record of the information one receives. In contrast, short-term memory, which is typically viewed as the place where information enters the information processing system, is assumed to last for only a short period of time before its contents are either transmitted to long-term memory or discarded. Whereas long-term memory contains information that has accumulated over a lifetime, short-term memory is of limited capacity, being able to retain only a small set of information chunks. However, this "physical" distinction between short-term and long-term memory is by no means universally assumed. In some theories, short-term memory is viewed merely as the portion of long-term memory that is currently active rather than as a separate memory system itself. In these theories, the limit on short-term memory capacity simply depends on the amount of information from long-term memory that can be called into consciousness at any one time.

Short-term memory is thought to be where information processing occurs. Because of this, it is sometimes referred to as working memory, and is even thought of by some researchers as the seat of consciousness in the memory system. On occasion researchers consider working memory itself as divided into subcomponents. These subcomponents include an articulatory loop, which handles linguistic information, a visual–spatial sketchpad for handling visual–spatial information, and a central executive which controls the processing of information. These subsystems are generally thought of as being semiautonomous. Thus, while one subsystem is actively processing information, another might be available for performing other tasks. For example, it is easier to read a paragraph (a linguistic task) if one is simultaneously trying to remember the location of a dot on a screen (using the visual–spatial sketchpad) than if one is trying to remember a set of words (using the articulatory loop).

In general, information remains in short-term memory until something comes to force it out. Because the capacity of short-term memory is limited, new information that enters the memory system is likely to push out the old, leaving only the most recently encountered information available. This property of short-term memory leads to what is referred to as the recency effect in which the recently acquired information is more available than earlier information. (For example, if a person is given a list of names and is then asked to recall them immediately afterward, the names at the end of the list will have a better chance of being remembered because they will still be in short-term memory.)

Most research and theory on memory, however, has focused on the structure and content of long-term memory, and the storage and retrieval processes associated with it. The remaining discussion will focus on these matters.

C. Analogue versus Propositional Representation

Memory theories often distinguish between information that is coded propositionally and information that is coded in an analogue fashion. In the propositional form, memory is thought to rely on a small set of very simple idea units. The structured complex of these idea units serves to represent more complex notions. In the analogue form, memory is thought to rely on representational structures that directly conform, in some way, to the outside world, such as a mental image.

These different types of memory representations predict different types of processing mechanisms and memory storage operations. For example, propositional representations convey information directly in terms of the idea units that are incorporated in the mental structure. Furthermore, propositions can be linked together to form a large associative network. Analogue representations convey not only the information that was originally directly encoded, but also any emergent properties that derive from the information (e.g., features and relations of the described information that are unmentioned). Several representations might contain similar sorts of information, organized in different ways.

Theories of memory often make different assumptions about the extent to which different representational formats are used. Some theories argue that all information is represented propositionally and that any apparent analogue aspects of human cognition, such as imagery, are merely epiphenominal. Others take the position that both types of representational formats are used, although at different levels of the memory system. Still others postulate two separate memory systems, one for handling propositional information and one for handing analogue information. According to this view, information is understood in terms of either one or both of these systems, depending on its nature.

III. ORGANIZATION OF LONG-TERM MEMORY

Information in memory is often assumed to be organized on the basis of both its content and the context in which the information was presented. However, not all types of information are represented in the same way. Theories of long-term memory often postulate different systems and subsystems, each of which is dedicated to the representation and processing of different types of information, and each of which exhibits properties that are not found in the others. Endel Tulving's monohierarchy of memory systems provides a particularly useful framework for conceptualizing how different types of information are organized and remembered. Other types of memory organization will be considered at the point in which they conform to the different levels of this hierarchy.

A. Tulving's Monohierarchy

Tulving's monohierarchy is a three-level organization, with one system occupying each level, and each of the higher systems being dependent on the lower ones. These systems are denoted procedural, semantic, and episodic and are each considered in turn.

1. Procedural Memory

The procedural memory system, which is at the most basic level of the monohierarchy, contains memories of performance activities, including stimulus–response associations. Examples of procedural memories include knowledge of how to ride a bike or drive a car, how to play the drums, how to solve a puzzle, and how to walk. The procedures contained in this memory system can potentially be activated without conscious awareness of their features. Thus, the procedural knowledge that governs driving a car is applied with minimal attention to the specific sequence of steps involved in this activity. As this observation implies, the information stored in procedural memory is often difficult to articulate, but typically lasts for quite a long time. In addition, procedural knowledge is relatively resistant to deliberate changes to add, modify, or rearrange various components of the memory. A person who needs to acquire some new form of procedural skill may gain some savings in learning from previous knowledge. Nevertheless, the person must go through an extensive learning process to acquire the new information.

2. Semantic Memory

The semantic memory system, which is at the second level of Tulving's monohierarchy, contains general knowledge of the world that does not refer to a specific event in the individual's life. As such it is an encyclopedia of facts about the world. The content of semantic memory, like that of procedural memory, is retained for quite a long time. Semantic memory differs from procedural memory, however, in that people can often effectively articulate the information that is stored. Semantic memory is typically conceptualized as a highly integrated system in which related concepts are stored together. This organizational structure of the memory can be seen in how general world knowledge is used. For example, semantic memory exhibits effects of relatedness. Information is identified faster if it is preceded by information that has similar content. Semantic memory also exhibits effects of ordered structure. For example, it takes longer to identify the order of two items in an ordered sequence (e.g., size) if they are close together than if they are far apart, because they are less discriminable in the former case.

Several theories conceptualize semantic memory as an associative network of concepts. Each concept represents a separate entity that is associatively linked to other entities by pathways connecting them. Concepts that are more similar to one another are more closely associated in the network. So, when information from one concept is used, other concepts that are associated with it are also brought to mind. (This type of process will be discussed in more detail in the section on spreading activation and reminding.) Two types of mental representations contained in the semantic system, schemas and categories, are worth noting. [*See* SEMANTIC MEMORY.]

a. Schemas

Schemas are general world knowledge structures that help people to organize new information that they encounter and reconstruct information that they may have forgotten. Each schema is a structured representation of all the easily articulated information that a person has referring to a well-defined domain of common human experience, such as washing a car, getting a promotion, or reading a newspaper.

The way that schematic knowledge helps to encode information to make it more easy to remember was demonstrated by Bransford and Johnson. Subjects were given passages to read of the following form:

> The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to a lack of facilities, this is the next step; otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than to do too many. In the short run this may not seem important, but complications can easily arise. A mistake can be expensive as well. At first the whole procedure will seem complicated. Soon, however, it becomes another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one can never tell. After the procedure is completed, one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more, and the whole cycle will have to be repeated. However, this is part of life. (Bransford and Johnson, 1972, p. 722)

Although the individual sentences composing this paragraph are meaningful, the passage as a whole is very difficult to understand out of context. In the study, half of the subjects were given a title before reading each passage ("washing clothes" in the above example), whereas the remaining subjects were not. Subjects who were given a title had substantially better memory for what they had read than those that were not. This is because the former group of subjects were able to organize the incoming information with reference to a "clothes washing" schema that helped them to remember it later. In contrast, subjects who were not given a title could not identify a schema that would permit them to understand and organize the information, and so they had a more difficult time remembering it.

Schemas can also help people figure out things that they may have temporarily or permanently forgotten, or even missed entirely. Anyone who has begun watching a television show or movie from the middle of the story has had the experience of being able to figure out what has gone on previously without having actually seen it. People essentially fill in the gaps with what they know about similar situations. This reconstructive process can sometimes lead people astray. In James Bartlett's famous work on schemas, students in England were given an American Eskimo folktale to read. This folktale possessed a structure quite different from the stories of English culture. Bartlett found that as time passed, the students forgot more and more of the details and structure of the original story. The portions that they forgot were replaced with ideas that were Westernized transformations of the story. The students had filled in the gaps in their memory with schematic knowledge of what they knew about folktales and the topics covered in the folktale.

The organization of a schema's features may be spatial (as in a human face), temporal (as in a sequence of events), or logical (as in a syllogism). A special type of event schema, denoted a *script,* describes a temporally ordered sequence of events (or "frames") that frequently occur in the real world and can be used both to explain new events one encounters and to predict future consequences of the event. Moreover, they can be used as behavioral guides. For example, "Asking for a menu" is a frame in a "restaurant" script that precedes frames that pertain to ordering, eating, and paying the bill. Therefore, the determinants and consequences of a particular individual's request for a menu can be inferred on the basis of the additional frames of the script that are used to interpret it. Moreover, one's own decision to leave a tip at a restaurant may be based on the perception that this behavior is appropriate, as implied by the same script.

b. Categories

People can also organize information into mental categories. Each category is made up of a set of conceptual entities (objects, events, concepts, etc.) that are in some respects similar to one another. Categories help to organize the various entities that are encountered in the world.

There are several different classes of theories of how the categorization process is accomplished, and the representations of knowledge that result from it. A threefold classification of these theories was proposed by Douglas Medin. According to the classical view, categorization is accomplished by identifying a set of necessary and sufficient features or properties that correspond to the nature of the category. Entities either have these features or do not, and therefore either belong or do not belong to the category in question.

According to the probabilistic view, categorization is also accomplished with reference to a set of features or properties. However, these features are not all necessary and sufficient. Entities vary with respect to the number and pervasiveness of their features. Therefore, some entities are more well endowed than others, leading to a graded category structure. The defining features for each category are either contained in a representation of the prototypical member (real or not) or are derived from an average of all of the separate exemplars of the category.

The third class of theories is knowledge-based. In a lot of ways, this view is similar to schemia theories. According to this view, the organization of concepts into some categorical structure is based on knowledge of the world, and how the various members function or operate in the world. In other words, entities are organized into categories in the sense that they are used in similar ways to explain things about the world. This is in contrast to the other two classes of theories which regard the presence or absence of various features or properties as the basis for categorization. For example, the category "things to take out of the house in a fire" would be composed of things that are combustible, easily transportable, and difficult or impossible to replace. This would include such diverse things as family members, money, photos, and pets, which do not share features that would cause them to be classified together a priori except for the knowledge that they conform to a common goal. [*See* CATEGORIZATION.]

3. Episodic Memory

Episodic memory, which is at the highest level of Tulving's monohierarchy, is like semantic memory in that the information that is stored in memory is easily articulated. However, episodic memory differs from semantic memory in that the subject matter which composes its content is concerned with events from a person's life rather than general world knowledge. Thus, episodic memories are localized in time and place, and often include a representation of oneself as either a participant or observer of the events that compose them. For example, general knowledge of police work is the domain of semantic memory, whereas knowledge of a particular incident in which one receives a speeding ticket is the domain of episodic memory. Episodic memories, unlike procedural and semantic memories, are more influenced by the passage of time. That is, they exhibit the classical exponential forgetting curve outlined by Hermann Ebbinghaus at the end of the 19th century. In the absence of maintenance procedures, such as the repeated recall and rehearsal of the features of an event, memory for the features of the event, if not the event itself, appears to decrease over time. Episodic memories also differ from procedural and semantic memories in the fact that the retrieval of one episodic memory is less likely to influence the retrieval of other episodes. Two specific theories that relate to Tulving's conception of an episodic memory system—mental models and autobiographical knowledge—are worth special attention. [*See* EPISODIC MEMORY.]

a. Mental Models

Whereas schemas, scripts, and categories refer to generalized knowledge structures, mental models are representations of specific situations in the world. A conception of these representations has been developed most fully by Philip Johnson-Laird. Mental models are organized representations of specific situations that directly model the functional relations of these situations. This construction often involves general world knowledge, possibly in the form of schemas. Consequently, the structure and organization of mental models are likely to resemble the structure and organization of one or more of the schemas used to construct them. The mental models that are formed could represent either simple mundane event descriptions or more complex life experiences. For example the statement "the book is on the table" may simulate the construction of a mental model based on a spatially organized schema concerning the physical location of objects on a table top. Alternatively, the model of a friend's story about the circumstances surrounding her divorce might be constructed on the basis of several different schemas or scripts, each of which is applied to a different sequence of events in the narrative.

Despite their similarity in structure to general world knowledge, mental models are distinguished from semantic knowledge in that they are stored and retrieved relatively independently of one another. For example, a set of related information (e.g., knowing about a group of people and the locations they are in) that refers to several different situations is stored in several mental models in memory and produces interference during retrieval. This is because the related mental models interfere with one another during retrieval. However, there is no interference for a similar set of information that refers to general knowledge (e.g., knowing about a group of people and the places they can be). In this case, there are no separate representations competing when someone is trying to remember something. Instead, everything is stored in a single, highly integrated representation, resulting in no interference at retrieval.

The mental models that are constructed in the course of processing information are likely to depend on the purpose for which the information is to be used. A person who receives information for the purpose of making a judgment or behavioral decision, for example, may form a different mental representation of the information than a person whose objective is to remember or comprehend it. The role of processing objectives in the construction of mental representations of information has been a particularly important consideration in research in social cognition. Social cognition research is concerned with the way people respond to information that they receive for the purpose of attaining objectives that do not necessarily require learning and remembering it (e.g., the goal of forming a general impression of a person or object, explaining the occurrence of social experience, or predicting a future event).

b. Autobiographical Memory

The information from which mental models are constructed can concern people, objects, and events that are not related to oneself except insofar as one is aware of receiving the information and comprehending its implications. Much of the information one receives, however, more directly involves oneself as an active participant in the experience that occurs. This self-knowledge, or autobiographical memory, composes a large share of the episodic information that people accumulate.

Autobiographical knowledge is presumably distributed throughout the episodic memory system. Representations of this knowledge, like other episodic representations, may initially be formed at different points in time and initially stored independently of one another. Nevertheless, these separate representations are often retrieved later and integrated into a single representation that describes the sequence of events that occurred over a period of days, weeks, or even years. Thus, a person might construct a representation of the events leading up to and following his marriage, based on pieces of episodic knowledge that were initially stored separately in memory at the time they first occurred. These constructive processes underlie the construction of mental models more generally. The reconstructive process also has some systematic effects on the memories for the event. For example, these memories tend to be remembered as closer in time to major events in a person's life, such as the start of a semester, losing a job, or the birth of a child. Once formed, these representations constitute "theories" about oneself and one's behavior in the situations in question. [*See* AUTOBIOGRAPHICAL REMEMBERING AND SELF-KNOWLEDGE.]

c. Temporal Dating

If episodic memories of events are stored independently of one another, how do people determine the temporal order in which these events occurred? It seems unlikely that people always store the day, month, and year of an event in the representation they form of it. How, then, might they determine whether John Lennon's death occurred before or after the eruption of Mt. Saint Helen's if these events have never been previously been considered in relation to one another? Sometimes this is done by relating each event to a "landmark" event relative to which the events being judged can be compared. Alternatively, people sometimes compute the recency of an event from the amount of knowledge they can retrieve about it, inferring that events they remember the best have occurred more recently. However, the computational process that underlie temporal dating, and when they are applied, have not been completely identified.

B. Relations among Memory Systems

Although episodic and semantic memory systems are assumed to function independently, it is clear that episodic and semantic memories can play similar roles in cognitive functioning. Moreover, semantic representations may be formed on the basis of episodic ones and vice versa. A man who is asked directions to a restaurant might respond on the basis of an episodic memory of how he drove there the previous day, or on the basis of more general knowledge that is not temporally localized and is not based on personal experience at all. In some instances, semantic memories may simply be episodic representations (e.g., mental models) in which situation-specific features denoting the time and place of occurrences (and of oneself as the experiencing agent) have somehow been forgotten. Consequently, the distinction between episodic and semantic memory is not quite as clear as Tulving's monohierarchical system might suggest.

C. Reminding

One intriguing aspect of memory is the fact that when people think of one thing, they are often reminded of some other similar thing. These remindings are often of either information of similar content that the person may know or earlier experiences that are in some way similar to the current situation. The use of free association to bring otherwise unaccessible memories into consciousness is based on the notion that the information currently being processed not only draws on the most direct sources in memory to understand the information, but can also remind the person of related pieces of knowledge that are more remotely associated with it.

1. Spreading Activation and Priming

The most popular mechanism that memory researchers use to describe the reminding process is spreading activation. The notion of spreading activation assumes that memory has the form of a network with concepts being connected through a complex of associative links. When information from the network is used in some way, those concepts that are used are energized or activated. This activation spreads along the associative pathways emanating from each of the activated concepts to other concepts, and when the activation building up at these concepts exceeds some threshold value, they are activated as well. The activation from the original concepts is theoretically distributed over the pathways connected to it. This means that the greater the number of concepts that are independently associated with an originally activated concept, the less likely it is that a related concept is activated as a result of thinking about it.

This activation process is generally thought to be able to occur for both general world knowledge and event-specific knowledge. For example, if you were in a conversation and someone brought up the topic of fire trucks, your concepts for fire trucks would become activated in long-term memory. The activation would also spread to related general world knowledge concepts that are related to fire trucks, such as red, emergency, and dalmatians. This activation could also spread to event-specific knowledge, such as a memory that the last time you saw a speeding fire truck, you were in your neighbor's Volvo and the engine conked out in the middle of a busy intersection.

This spreading activation process is generally thought of as largely automatic. That is, it proceeds without any deliberate intention to do so. However, spreading activation can be controlled to some extent. When related information is deemed to be irrelevant, or the activation has been spreading for some time with no benefit to the current processing goals, it can be dampened, so that activation resources can be directed elsewhere. This serves to help people pursue their current processing goals, and keep them from constantly rattling through an endless series of irrelevant associative meanderings.

The effects of spreading activation have been investigated in many experiments. In a typical study, people are asked to decide whether each of several letter strings are words or nonwords. People can identify "nurse" more quickly after seeing the word "doctor" than after seeing the work "bread." Presumably, encountering the word "doctor" and accessing its meaning in memory caused activation to spread to the concepts related to it, including "nurse," thus making "nurse" easier to identify. In other words, "nurse" was primed by the word "doctor."

D. Explicit and Implicit Memory

Recently, much interest in memory research has been focused on the distinction between explicit and implicit memory. Explicit memory processes operate through the conscious action of remembering. These processes are used deliberately and, therefore, generally involve conscious awareness. Recognition and recall memory tasks, in which a person deliberately tries to remember something, are salient examples of tasks that rely heavily on explicit memory. In contrast, implicit memory processes operate through unconscious mechanisms. Typical tests of implicit memory involve the assessment of the unconscious influence of previous encountered information on an ostensibly unrelated task. For example, subjects in a test of implicit memory might read a list of words, one of which is "memoirs." Later, they might perform a task that does not involve conscious recollection, such as a word stem completion task in which the subject is asked to complete a word stem such as MEM___ with the first word that comes to mind. People are more likely to complete the word stems with words that they had seen earlier than are people who were not exposed to the original list.

Explicit memory and implicit memory respond to different sorts of influences. For example, performance on explicit memory tasks tends to be affected by conceptually driven strategies, imposed by the individual, that help to organize the information. Conversely, implicit memory performance is affected by factors that govern more data-driven strategies that rely on the physical properties of the stimulus and are likely to be invariant over stimulus situations. Some theories argue that explicit and implicit memory are two distinct systems containing different representations and different processes. Advocates of these theories point to evidence that people can sometimes show deficits in explicit memory but not implicit memory. However, other theories assume that explicit memory and implicit memory reflect two different types of processing mechanisms that operate independently on a common memory representation. Proponents of these theories point to studies in which the two processes have been put in competition. For example, suppose some subjects in a word-stem completion task are asked to try to complete the stems with words that they saw earlier, whereas others are asked to complete the stems with words they did not see. The differential rate of completing the stems with earlier seen items provides an index of the use of explicit and implicit memory processes. This rate varies with the sort of tasks and the conditions in which they are performed, suggesting that different processing strategies are at work rather than different memory systems. [*See* IMPLICIT MEMORY.]

E. Evidence from Amnesia

A great deal of knowledge about how information in memory is organized, and the possible existence of different memory systems, has come from studies working with anterograde amnesics. These individuals have suffered some brain injury, typically due to head trauma, surgical mishaps, or chronic alcohol abuse. Such individuals usually have difficulty remembering information they have received after the time that the injury occurred. (Some of the more severe cases need to be reintroduced to their doctors if they leave the room for a few minutes because they have no memory of them.) Although amnesics are unable to recollect some types of information, they retain other types quite well. For example, severe amnesics who show a deficit in semantic and episodic memories appear to have intact procedural memories. Amnesics, who knew how to play the piano before their injury, could be taught to play a new song. When asked if they know how to play the song they would report no memory of it, yet they would be able to play it successfully if coaxed into trying. Amnesics also show deficits in explicit memory tasks, such as recognition and recall, which require active remembering, but show memory performance similar to that of normal people in implicit memory tasks, such as word-stem completion. [*See* AMNESIA.]

F. Alternative Types of Memory Models

Associative network models of the sort described in the section on spreading activation provide only one of the several possible theoretical accounts of how information is represented in memory. Two other types are noteworthy.

Multiple trace memory models assume that information is stored in memory as a series of distinct traces. Each trace is theoretically composed of a set of features and properties that, in combination, represent a different episode, concept, or some other coherent mental structure. These traces are relatively independent of one another. There is generally little or no structure which organizes these traces. When information needs to be retrieved from long-term memory, a probe composed of the desired set of features and properties is compared with all of the traces in memory. Traces that are more similar to the probe will "resonate" with it more than traces that have little to do with the memory probe. These related memory traces are then made available for further processing. For example, if one were trying to remember what was eaten on his last birthday, all of the memory traces relating to eating, possibly cake, birthday, and the previous year would be activated. Those traces containing more features would be activated more, and the trace that contains the desired information would receive the most activation. This information would be what was actually retrieved from memory.

Unlike multiple trace memory models, distributive memory models assume that large amounts of information are stored using a rather limited set of structures. This limited structure might take the form of vectors of features in some holographic memory system. An alternative representation is assumed by connectionist models of memory, which are currently an area of great interest. In these models, information is represented in a massive assemblage of simple units and connections in which all of the units are connected to most if not all of the other units at a series of computational levels. Information is represented as a pattern of activation across a series of these units and connections. An attractive feature of distributive memory models is that information does not need to be represented in a single location in memory. So, if one portion of the memory network is damaged, the information may be available at other areas, since it is distributed throughout the memory system.

IV. PERMANENCE OF MEMORIES

People encounter a great deal of information in their lifetime. They see lots of things, meet many people, read many things, and have lots of experiences. What happens to all of this information? Is all of it remembered forever, such that a person needs only to figure out how to bring the information to consciousness? Or is it the case that once information has been lost from memory it is lost forever, and will never again be recovered and play a role in influencing behavior?

A. Evidence for the Permanence of Memory

One position is that everything that is ever encountered and stored in long-term memory remains there permanently. This permanent store of information either can be actively retrieved into consciousness and/or exerts an unconscious influence on behaviors and ideas through the lifespan. Stronger positions of this view claim that absolutely anything ever encountered in life is permanently stored in long-term memory, although one may have difficulty activating the information at any given point in time. Less strong positions claim that only certain things actually have an opportunity to be stored in long-term memory; however, once there, they remain permanently.

1. Penfield

A well-known and seemingly powerful source of evidence for the permanence of memory comes from the work of the neurosurgeon Wilder Penfield. During the 1950s, he performed operations that involved cutting away part of a patient's brain in the treatment of some ailment. Before actually removing part of the cortex, Penfield stimulated various areas with a mild electrical charge to determine what functions the areas were in charge of so as not to remove any vital functions. Sometimes the patient reported having vivid experiences, such as: "Yes, sir, I think I heard a mother calling her little boy somewhere" (Penfield, 1955, p. 54). These experiences, because of their mundane nature, led Penfield to suggest that the electrical stimulations caused a re-emergence of previously forgotten memories from the person's distant past. Such evidence seemed to suggest that everything that a person had ever experienced was stored somewhere in long-term memory, and that all that is needed is for some way to get the information out; electrical stimulation of the cortex in this case.

However, despite how convincing this finding seems, there are some serious considerations against it. First of all, only about 25% of Penfield's patients actually reported having some experience, and only

3–7% of these reports were sufficiently clear to suggest that the patients were actually re-experiencing a previous life event. Finally, there is no independent source of evidence that these experiences actually happened to the patients providing the reports.

2. Permastore

While Penfield's account of long-term memory as being a repository for the continuous stream of consciousness, other positions have been put forward in support of some version of permanent long-term memory storage. In this section, we consider Harry Bahrick's permastore idea. According to this position, when information is first encoded into long-term memory, initially there is some forgetting over time. However, at some point, the amount of forgetting ceases and the amount of information retained from the original time period remains constant over long periods of time. The information that remains is said to be in a permastore where it does not decay.

In one study, Bahrick has been able to show this with people's memory of Spanish after college. For the first 3 years after college, there is a drop in the amount of information remembered by the students. However, the amount of information stored remains relatively constant for the next 40 years or so, regardless of the student's initial level of performance and other factors. The drop off did appear to resume again in later years, possibly reflecting more global changes in memory that occur at that time.

3. Reasons for Forgetting in a Permanent Memory System

Under some theories, memories are thought to be permanently stored in the long-term memory system. If this is the case, then there must be some account of why forgetting would occur in such a system. Two of the more prominent reasons considered here are the lack of sufficient retrieval cues and retrieval interference.

a. Retrieval Cues

Although information may be stored in memory, it may be destined for some dark and dusty corner of the system if the person cannot get at it. One often cited reason for this inability is the idea that the person does not have the proper retrieval cues for accessing the information. Retrieval cues are the set of features or properties that allow for the appropriate selection and retrieval of the memory. If these cues are not available, the memory cannot be retrieved. A common metaphor that is used to describe this process is that of a library. A book may be stored somewhere on the library shelves, and if it can be gotten, all of the information in it would be available. However, if its entry in the card catalog is missing, it becomes very difficult to retrieve, and might even be said not to exist in the library at all.

i. Depth of Processing One of the factors that can influence the ability to remember information at a later point in time is the amount of processing that the information had received when it was first encountered. Basically, the more time and effort that a person expends processing newly encountered information through elaboration or association with previously known information, the more likely that the person will be able to remember that information at a later point in time. This is referred to as the level of processing hypothesis. According to this position, information that is processed at a deeper level is remembered better because there are more cues that can be used to retrieve the information. For example, is a person were to scan a newspaper article for certain letters, it is unlikely that much would be remembered. Whereas, if a person were to read the article in detail, thinking of related stories that have been reported earlier, or to other related topics, much of the information in the newspaper article would be remembered.

Recently, there has also been a lot of investigation on the related topic of the generation effect. Basically, information that was generated by a person is remembered better than information that is presented to the person. This presumably occurs because all of the processing involved in the generation of the information is somehow associated with it in memory, thus allowing for a richer set of retrieval cues to access the information.

ii. Flashbulb Memories An extreme example of a depth of processing effect is what are referred to as "flashbulb" memory. Flashbulb memories are typically thought to occur in situations of extreme surprise, shock, or other events that have a strong emotional impact. Common examples of flashbulb memories are highly detailed memories of what a person was doing, who they were with, what they were wearing, etc., when some surprising and important news was heard, such as the assassination of President Kennedy, or the explosion of the space shuttle Challenger. It is as though a picture of the situation had been taken, hence the name flashbulb memory. The high degree of detail encoded in them would make them highly accessible because there would be many cues to retrieve them. However, other possible explanations for flashbulb memories, besides being highly detailed permanent memories is that the facts that are associated with flashbulb memories are retrieved over and over again. This constant usage of information is what allows it to be easily retrieved. This is basically a use-it or lose-it theory of memory. There is also some evidence that the information stored in flashbulb memories is often incomplete and inaccurate.

iii. Encoding Specificity In a more mundane vein, more accurate information retrieval has been shown to occur by providing the same sorts of contextual cues that were available when the information was first learned. This effect is known as encoding specificity. Contextual factors that can influence memory can be just about anything, including the person's mood, the room that the information was learned in, the person from whom the information was originally learned from, and so on. The effects of encoding specificity can be seen in daily life. How often have you thought of doing something when you were in one room of your home, and walked into another room to act on it and then you can't remember why you went in there. So, you return to the room in which you started and, all of a sudden, you remember why you went to the other room in the first place. This remembering presumably occurs because the room in which the original idea occurred presumably provides a sufficient number of retrieval cues to access the information.

b. Retrieval Interference

Another reason for forgetting things that are actually stored in memory is retrieval interference. When a large number of pieces of information about an object are acquired at different points in time, they are stored independently of one another. In some cases, the more recent information appears to "bury" the earlier information, making it more difficult to recall. This referred to as retroactive interference. In other cases, the earlier information makes it difficult to remember subsequent information. This is referred to as proactive interference. Both types of interference are more pronounced when the memories contain content information that is similar and possibly conflicting. Then, the stronger memories are typically recalled instead of the weaker ones. Thus, the weaker memories appear to have been forgotten despite the fact they still exist in memory. For example, when people move, it may be difficult after a period of time to remember some of the streets in the town they lived in previously. This is because the names of the streets in the new town interfere with the retrieval of the street names in the old town.

B. Evidence for the Nonpermanence of Memory

The arguments for permanent memories can be quite convincing. However, there is good reason to consider the possibility that, while some information may be retained throughout a person's lifetime, due to frequent use or strong encoding, most information is removed from long-term memory after a period of disuse. Two sources of evidence for the nonpermanence of memory considered here are reconstructive processing and misleading postevent information.

1. Reconstructive Processing

Reconstructive processing refers to situations where people have been presented with a set of information that they do not know that they will need to remember. When the people actually do recall the information, they have often forgotten various details of the original set of information and substituted other pieces of information. Much of the research on schema and script usage has shown that these gaps in memory are filled in with information that is consistent with the original source of information in terms of the gist of the originally presented facts, but nevertheless, is inaccurate. Even though gaps in one's knowledge have been filled in with unoriginal information, people express high confidence that the reported information was actually presented to them.

However, it could also be argued that although the schema-enhanced report did contain some reconstructed inaccuracies, the original information was retained. In such a case the general world knowledge was used as a crutch to avoid an extensive and effortful memory search. Some memory research has shown that if people are encouraged to adopt a perspective that is different from the one they originally adopted during encoding, their ability to recall the original information accurately improves. At first, this seems to run counter to the encoding specificity effects described earlier. However, in this case, people are able to access the information in memory. Rather than expending all the effort needed to retrieve that information, they choose to reconstruct the more detailed aspects of the memory by assuming various defaults for the type of situation that is being remembered. In the case of encoding specificity, the nature of the information is unavailable to the person, not the details.

2. Misleading Postevent Information

Other evidence that the information stored in memory is not permanent comes from research on misleading postevent information. In studies investigating this topic, people often watch a series of events, such as a scenario of a car accident, in a slide-show or videotape. After seeing the situation, people are presented with some description that provides misleading information. In the case of the car accident, for example, people might be asked whether one of the cars stopped before the yield sign, when in fact the sign in the scenario was a stop sign. Later, people are likely to report that the features of the postevent information were actually part of the original event they observed. This could occur because the more recent information contains features that were never observed, but were added to the original representation after it had been formed. Or, it could occur because the more recently described features actually replaced the original features in the representation, thus modifying it forever. This second possibility suggests that information in long-term memory will be discarded if it is superceded by other relevant and more recent information.

The question of how postevent information can affect memory is especially important outside the laboratory, for example, in trial cases involving eyewitness testimony. One problem is that over time, the information in the memory of an event may decay, be difficult to retrieve, be interfered with, and perhaps be reconstructed. The additional possibility that the information a person may encounter subsequent to an event can actually change the eyewitness's memory has enormous legal ramifications. Eyewitness testimony is often thought of as one of the most valuable sources of evidence. However, the fragility of memory contents questions this assumption, as demonstrated by the fact that leading statements or questions by other people could cause the eyewitness to incorporate additional and extraneous information into their memory representation, thus corrupting their memory of the event. [*See* EYEWITNESS TESTIMONY.]

V. SUMMARY

Human memory is a complex storage system. Information entering it is subject to different types of processing depending on whether it is in short-term or long-term storage. The question of how long information that is successfully stored in long-term memory will remain there is uncertain: it could remain throughout one's lifetime, or fade away permanently if it does not get used. Information is stored in different ways in memory depending on the type of information it is (whether it is knowledge of skilled action, general world knowledge, or knowledge of one's own life events). Information stored in memory has different effects on current processing goals depending on whether it was explicitly retrieved or whether it has an influence on behavior through some unconscious process.

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