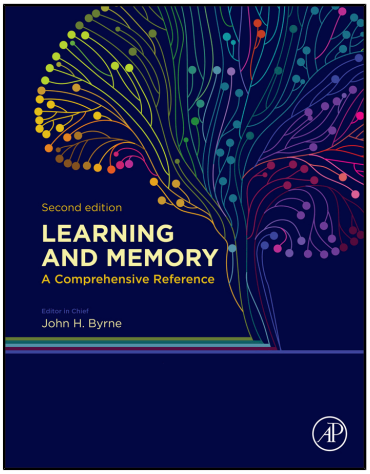

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1.02 A Typology of Memory Terms☆

Henry L Roediger, III, Franklin M Zaromb, and Wenbo Lin, Washington University in St. Louis, St. Louis, MO, United States

1.02.1 Introduction

The English language provides us with the term memory to denote several interrelated ideas, such as "the power of the mind to remember things" or "something remembered from the past; a recollection" (both quotes are from the Oxford American Dictionary). These definitions of memory are fine for everyday conversation and communication, but scientists interested in studying the biochemical, neural, or psychological underpinnings of this topic have found the need to describe many distinctions about memory that laypeople do not use. Such a need is further underscored by a growing interest in interdisciplinary approaches to the study of human memory and in adapting cognitive research paradigms to the study of nonhuman animal learning, an area that has developed largely in isolation of the human memory research tradition (e.g., Wright, 1998; Wright and Roediger, 2003). Most of Volumes 1 and 4 of this reference work are concerned with learning and memory via studies of nonhuman animals. This chapter is intended to explain the meaning of some of the most popular terms that have been contributed to the literature, although some apply more to memory in humans (reporting using language) than in animals (who demonstrate memory in behavior).

We aim to paint with a fairly broad brush and not to get involved in matters such as whether one term (say, implicit memory) is to be preferred to another term (indirect memory), although buckets of ink have been spilt on these matters. Rather, we intend to provide general definitions and meanings of terms without defending them as theoretically critical (or not). In this sense, the chapter is descriptive rather than theoretical, although we fully understand that by choosing one's terms and their definitions, one implicitly adopts a theory.

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How many types of memory are there? In the early 1970s, Tulving wrote: "In a recent collection of essays edited by Norman (1970) one can count references to some 25 or so categories of memory, if one is willing to assume that any unique combination of an adjectival modifier with the main term refers to something other than any of the references of other such unique combinations" (Tulving, 1972, p. 382). Tulving added two more terms (episodic memory and semantic memory) in that chapter. Yet more important for present purposes, Tulving continued to keep a list of memory terms as he encountered them. Thirty-five years later, Tulving (2007) wrote another chapter entitled "Are There 256 Different Kinds of Memory?" which was the number of combinations of the adjective + memory sort that he had collected by that time. The list goes from abnormal memory (at the beginning), through terms such as diencephalic memory and false memory, then on to rote memory and sensory memory, and finally, at the end of the list, to working memory. (There are 250 others.)

We hasten to add that we are not going to cover 256 kinds of memory in this chapter. We aim to provide a lexicon of some of the primary terms that readers will find in the four volumes of *Learning and Memory: A Comprehensive Reference*. We have tried to weave the terms together in a loose sort of story, so as not to provide just a glossary with a long list of terms and definitions. The story is one conception of the varieties of memory provided elsewhere (Roediger et al., 2002). We try to give a verbal definition of each type of memory we chose to include, as well as a practical example of how the type of memory might operate in a person or other animal, and we usually point to a paradigm by which this type of memory is studied, to provide kind of an operational definition.

The reader will notice that in some cases the same memory term (e.g., episodic memory) may refer to a process, entity (e.g., memory trace), system, mental state of awareness, or type of cognitive task, depending on the context. Such linguistic flexibility can easily lead to confusion, so we attempt to distinguish among different uses of each term where appropriate. The index of the book can be used to glean other uses of the term. In addition, semantic confusion can easily arise from the types of metaphors employed to describe a memory concept. Most cognitive psychologists use a spatial metaphor in which memories are conceived as physical entities stored in a mind space, and the act of remembering involves searching through the mind's space to retrieve the objects of memory (e.g., Roediger, 1980; Tulving, 2000). In contrast, others have proposed nonspatial metaphors that make analogies to concepts such as strength—memories are comparable to muscles whose strengths are directly related to performance on memory tasks (e.g., Hull, 1943); construction – the act of remembering involves constructing memories from available information (e.g., Bartlett, 1932); depth of processing – memory is a by-product of the level of perceptual analysis (Craik and Tulving, 1975); or auditory resonance – memories are like notes played on piano keys or individual tuning forks resonating (e.g., Wechsler, 1963; Ratcliff, 1978), to list but a few. To reiterate, we do not mean to provide exhaustive coverage, but rather to paint with broad strokes and to represent the way memory terms are used by cognitive psychologists and others.

We begin with consideration of some general distinctions made among types of memory. We then turn to the idea that it is useful to catalog memories by their time course in the system (from brief sensory memories, to short-term conscious memories, to various sorts of long-term memory). Most work has been devoted to the various types of long-term memory that have been described, so this is the focus of the next section of this chapter. Inevitably, given our organization, there is a bit of repetition because we needed to cover the same term (say, episodic memory) in more than one context.

1.02.2 Broad Distinctions

This section of the chapter is devoted to consideration of several broad distinctions among forms of memory. We consider the issue of explicit and implicit memory, conscious and unconscious forms of memory, voluntary and involuntary retention, intentional and incidental learning and retrieval, declarative and procedural memory, and retrospective and prospective memory. These distinctions apply more naturally to human memory than to the study of memory in infrahuman animals.

1.02.2.1 Explicit and Implicit Memory

Explicit memory refers to cases of conscious recollection. When we remember our trip to Paris or recognize that some words occurred in a recent list, these are instances of explicit memory. In cases of explicit retention, people respond to a direct request for information about their past, and such tests are called explicit memory tests. On the other hand, on tests of implicit memory, people are asked to perform some task, and the measure of interest is how some prior experience affects the task. For example, take the simple case of the word *elephant* appearing in a long list of words. If subjects are given a recognition test in which they are instructed to identify words studied in the list (and to reject nonstudied words), then their choice of *elephant* as a studied word would represent an instance of explicit retention. However, if a different group of subjects were given the same set of words to study and then were given a word stem completion test (with instructions to say the first word that comes to mind to the word stem ele_____), then this would constitute a test of implicit memory. The relevant measure on this test is priming, the greater probability of completing the stem with *elephant* rather than other plausible words (element, elegant, electricity, etc.) when the word has been studied than when it has not been studied. For example, the probability of producing *elephant* to the word stem might be 10% if the word had not been studied in the list and 40% when it had been studied, which would constitute a 30% priming effect. One reason for believing that these two measures represent different forms of memory is that they can be dissociated by many experimental (and subject) variables.

Graf and Schacter (1985) introduced the terms explicit and implicit memory to the field. Explicit retention refers to tests in which people are instructed to remember events from their past; most typical measures of retention that psychologists

have used over the years (recall, recognition, and their variations) are examples. On the other hand, implicit memory refers cases of past experience being deployed in the service of a task that seems unrelated to remembering. These implicit measures are usually types of transfer measures when people may not be aware of using memory at all (Jacoby, 1984). That is, past experience (memories) is used in the performance of some task and how much the past experience primes (or transfers to) the new task is the measure of interest. Various techniques are used to try to rule out subjects using conscious recollection (see Roediger and McDermott, 1993). Some writers prefer the terms direct and indirect memory for this contrast, because explicit tests measure memory directly, whereas implicit tests are indirect measures. Schacter (1987) offers a fine historical review of concepts related to implicit memory.

1.02.2.2 Conscious and Unconscious Forms of Memory

Conscious and unconscious forms of memory refer to the mental states of awareness associated with remembering the past. Attempts to describe human memory in relation to consciousness hearken back to the early introspective tradition of experimental psychology and the writings of Wilhelm Wundt, Edward Titchener, and William James (e.g., James, 1890/1950), as well as the psychoanalytical tradition and especially the well-known writings of Sigmund Freud (e.g., Freud, 1917/1982). Less well known is the fact that in the very first experiments on memory, Ebbinghaus (1885/1964) devised a relearning/savings technique for measuring memory that could detect unconscious knowledge. In Ebbinghaus's use of this technique, a subject (himself, in the original studies) learns a list of nonsense syllables such as JEK, BES, SUT, and so on. Ebbinghaus measured the number of repetitions (or the amount of time) required to learn the list to one perfect recitation. For example, a list of 15 syllables might take 20 trials to learn. In some experiments, Ebbinghaus varied the amount of time before relearning the list (the retention interval). He discovered that even when he had no conscious recognition of having learned the list previously, he still showed savings. For example, if it took him 10 trials to relearn the list, he showed 50% savings. Ebbinghaus preferred savings measures over the merely introspective techniques of recall and recognition, because these latter tests cannot, almost by definition, measure memories that are not conscious (Slamecka, 1985).

In contemporary studies of memory, conscious recollection refers to the subjective awareness of remembering information encountered in the past, a process that is likened to the experience of mentally traveling back in time (Tulving, 1985). Tulving has also termed this state of awareness autonoetic (self-knowing) consciousness. In contrast, a noetic (knowing) state of consciousness is the type of awareness associated with retrieving previously learned information, such as a geographical, historical, or personal fact, without recollecting details about the place and time in which that information was originally acquired. For example, noetic consciousness might characterize the experience of a person being asked to name the capital of Canada and who, after thinking for a bit, responds "Ottawa" without remembering when he or she last encountered or originally learned this fact. Autonoetic consciousness, on the other hand, is reflected by the person's ability to think back to and reexperience an episode, such as a visit to Ottawa.

Conscious recollection may be intentional and effortful, or it may occur without the intent to explicitly remember information relevant to a given memory task, as is the case with involuntary conscious recollection (e.g., Richardson-Klavehn et al., 1996). This term refers to the fact that one may suddenly be remembering some event from the past without ever having tried to do so. For example, a song comes on the radio and suddenly you are catapulted back in time and remember vividly an experience associated with the song. Conscious recollection does not have to be accurate; false memories (memory for events that did not occur) can arise and be associated with vivid conscious recollection, both in laboratory studies (e.g., Roediger and McDermott, 1995) and in remembering events from one's life (Talarico and Rubin, 2003).

Unconscious retention may be observed in performance on tests of implicit memory where individuals indirectly demonstrate their prior exposure to the test material under conditions in which they do not consciously recognize the material. Tulving has referred to the state of awareness associated with unconscious retention as anoetic (not knowing) consciousness. As noted previously, unconscious retention also occurs when subjects show savings in retention without being able to recollect the experience that gave rise to the savings (Ebbinghaus, 1885/1964).

1.02.2.3 Voluntary and Involuntary Retention

Voluntary retention refers to deliberate, willful recollection, whereas involuntary or incidental retention refers to recollection that occurs without conscious effort. Involuntary retention, as the name implies, refers to memories that arise in consciousness unbidden, with no conscious effort to recollect. For example, in studies of autobiographical memory (memory for events in one's life), voluntary recollections may be assessed by asking individuals to remember personal events in response to queries (e.g., recall a memory from your past that is associated with an automobile). The naturalistic study of involuntary memories can be achieved by asking individuals to keep a diary and jotting down memories that seem to come out of the blue, as it were, wherever and whenever they occur (e.g., Berntsen and Rubin, 2002; Rubin and Berntsen, 2003).

It should be noted, though, that acts of voluntary or involuntary recollection may not be entirely pure, and one may influence the other. For instance, a person's attempt to remember the details of a baseball game that occurred years ago might be influenced by his/her inadvertently remembering details of a more recent game. Or when engaging in a test of implicit memory, such as completing word fragments, a person might become aware of the fact that some of the target words were encountered during the study phase and, therefore, might intentionally think back to the study phase to help complete the test word fragments (Jacoby,

1991). In addition, as previously mentioned, one might experience involuntary conscious recollection whereby thoughts of a past event come to mind automatically, and it might take further reflection to realize how the memory came to mind (Richardson-Klavehn et al., 1996).

1.02.2.4 Intentional and Incidental Learning and Retrieval

1.02.2.4.1 Intentional and Incidental Learning

Intentional and incidental learning refer to whether or not people intend to learn material to which they are exposed. Of course, as we go about the world watching TV, driving, or reading the paper, we rarely say to ourselves: I need to remember this commercial on TV. Educational systems provide the main form of relentless intentional learning, although, of course, we all sometimes try to remember the name of a new acquaintance or the name of a book or movie someone recommended. In the laboratory, intentional or incidental learning is manipulated by instructions to subjects. In an intentional learning situation, an individual studies certain materials with the express purpose of remembering them at some later point in time. In an incidental learning task, the same materials might be provided but with an orienting task to induce some sort of processing of the material but without any instructions concerning a later memory test. For example, in a standard levels-of-processing manipulation (e.g., Craik and Tulving, 1975), a person might be shown a list of words and asked to judge whether each word (e.g., BEAR) is presented in capital letters (graphemic or structural processing), whether it rhymes with a certain word such as *chair* (phonemic processing), or whether it fits into a certain category such as animals (semantic processing). Subjects in incidental learning conditions would be told that the researchers are interested in studying the speed with which people can make such decisions. In the intentional learning conditions, they would be told the same rationale, but would also be told that their memory for the words will be tested later.

The natural expectation is that material studied under intentional learning conditions is better retained than under incidental learning conditions, and this outcome is sometimes obtained (Postman, 1964). However, at least when semantic orienting tasks are used, the differences between incidental and intentional learning conditions are surprisingly slight and often there is no difference at all (Craik and Tulving, 1975; Hyde and Jenkins, 1969).

1.02.2.4.2 Intentional and Incidental Retrieval

Just as intentionality can be manipulated during study of materials, so can it be manipulated during testing. In fact, the distinction already drawn between explicit and implicit memory tests can be cast in this light. Explicit tests require intentional retrieval, but implicit tests reveal incidental retrieval (Jacoby, 1984). Under intentional retrieval conditions, a person is asked to engage in conscious, deliberate recollection of a past event (e.g., recalling a word from a previously studied list that completes a word stem). By contrast, incidental retrieval involves giving people the same word stem with the instruction to write the first word that comes to mind. Incidental retrieval is indexed by priming, the better performance in completing the stem with the target word relative to a control condition in which the word had not been studied.

As noted, the comparison between intentional and incidental retrieval is not necessarily a pure one, because performance on explicit memory tests may be affected by incidental retrieval just as performance on implicit memory tests can be influenced by intentional retrieval (Jacoby, 1991). Several solutions exist for attempting to gain leverage on this issue. Schacter et al. (1989) proposed the retrieval intentionality criterion to test for the "contamination" of incidental retrieval measures by conscious recollection. The basic idea is to compare incidental and intentional recollection, holding all other study and test conditions constant. If performance differs markedly between the two tests when all conditions are held constant except for instructions just prior to the test, then one can have greater confidence that they measure intentional (conscious) and incidental (automatic or unconscious) retrieval. Roediger et al. (1992) crossed intentional and incidental study and test conditions with other variables and showed that incidental tests reflected quite different patterns of performance from the intentional tests. Jacoby (1991) proposed a different method, the process dissociation procedure, to separate conscious from unconscious influences during retrieval. Although providing the details of his ingenious method is outside the scope of this chapter, his method has proved extraordinarily useful in separating conscious from unconscious (or automatic) cognitive processes (see Yonelinas and Jacoby, 2012).

1.02.2.5 Declarative and Nondeclarative Memory

Declarative memory and nondeclarative memory (the latter sometimes referred to as procedural memory) are terms that have gained prominence following their use by Squire (1982), although the original distinction was proposed by Ryle (1949). Ryle distinguished between declarative knowledge (knowing that) and procedural knowledge (knowing how). For example, we know that Washington, DC, is the capital of the United States, but we know how to tie our shoes.

Squire has proposed declarative memory as an overarching category that includes episodic memory (remembering specific events of the past) as well as semantic memory (general knowledge). Declarative memory processes rely on the hippocampus and related structures in the medial-temporal lobe including the perirhinal, entorhinal, and parahippocampal cortices. As it has been extended, the term declarative memory has become a bit of a misnomer, because the concept is often applied to infrahuman species that are not prone to making declarations. (Ryle tied his distinction specifically to linguistic usage so that people would know that such and such occurred.)

Procedural memory was originally intended to cover motor skills, such as tying shoes, riding a bicycle, or typing (Ryle, 1949), but it was broadened to cover mental as well physical procedures. For example, the mental processes involved in multiplying

24×16 are examples of mental procedures that can be studied. As Squire (1992) developed his theory, the term procedural memory became broader and covered such topics as priming on implicit memory tests, classical conditioning of responses, and habituation. Because of these and other uses, the broader term nondeclarative memory came into use. It refers both to traditional procedural tasks and to others such as priming and skill learning. The distinction between declarative and nondeclarative types of memory rests partly on evidence that different brain structures are involved in various forms of memory. The evidence supporting the differences between the different forms of memory has come both from studies of human amnesic patients with damage to the medial-temporal lobes and in animals where such alterations can be achieved experimentally (e.g., Squire, 1992). Squire provides a recent account of the theory.

As noted, the term declarative memory originally referred to memories that could be verbally stated (Ryle, 1949). This term has also been broadened so that it now includes many other kinds of memory, including spatial memory, some types of long-term visual memory, and any other form of memory subserved by the hippocampus and its surrounding brain areas. Nondeclarative memories include all other types, whether they involve memories for physical movements and actions, priming, or skills.

Tulving (1985) proposed a somewhat different schematic arrangement of episodic, semantic, and procedural memory systems. In Tulving's scheme, procedural memory is phylogenetically oldest and is shared among all organisms. Semantic memory grows out of (and depends upon) procedural memory. Episodic memory is evolutionarily most recent and, according to Tulving, only humans have this form of memory (see Tulving, 2005, for further elaboration, although the contention that only humans have episodic memory is hotly contested). Different forms of consciousness are proposed for the three systems: anoetic (nonknowing) for procedural memory, noetic (knowing) for semantic memory, and autonoetic (self-knowing) for episodic memory. Tulving proposed that a critical function of autonoetic consciousness is planning for the future, which brings us to another critical distinction.

1.02.2.6 Retrospective and Prospective Memory

The vast majority of memory research deals with the ability to remember past events when given specific cues (as in explicit memory tests of recall or recognition) or with the effects of past experience on current behavior (priming on implicit memory tests). All tests that fall into these categories assess retrospective memory: memory for the past or effects of past experience on current behavior. In the past three decades, researchers have examined memory for intentions to be performed in the future, or prospective memory. Strictly speaking, prospective memory is retrospective in nature: it involves remembering a past intention. A prospective memory task differs from a retrospective memory tasks in that there is usually no explicit cue to elicit recall of the intention. Instead, a prospective memory task requires that subjects must use an environmental cue or a temporal cue to know when to retrieve the intention, so it is a curious mix of incidental and intentional retrieval. We face prospective memory tasks all the time, whenever we need to remember to perform some act in the future. Prospective memory tasks can be classified as event-based (when some event should cue us to perform an action, such as passing along a message to a friend when we see him/her) or time-based (such as remembering to take an antibiotic four times a day). Both cue-based and time-based prospective memory tasks have been investigated in naturalistic settings and in the laboratory. Retrieval of prospective memories may sometimes involve monitoring and may sometimes be spontaneous and effortless (Einstein and McDaniel, 2005).

Another broader sort of "memory for the future" is what is called episodic future thought (Atance and O'Neill, 2001) and sometimes prospection or simulation of the future. The basic idea is that we are often using the past to help construct our future. We may think of an upcoming vacation and imagine the hotel, the pool, the beach, and so on, even if we are going to a new place. Of course, being able to construct the future event relies on memories from the past (Schacter et al., 2007). Topics surrounding episodic future thinking have been hotly investigated in the past 15 years. Szpunar (2010) and McDermott and Gilmore (2015) provide reviews.

We turn next to categorizations of memory based on (roughly) the time they persist, starting with varieties of short-term memory.

1.02.3 Types of Short-Term Memory

Information from the external world is believed to be represented in various storage systems that, roughly speaking, hold information for fractions of a second, seconds, or much longer. Atkinson and Shiffrin's (1969, 1971) influential theory, shown in **Fig. 1**, provides one conceptualization. Our treatment here provides some amendments to their original theory.

1.02.3.1 Sensory Memories

The border between perceiving and remembering is blurred. There is no good answer to the question: When does perception end and memory begin? Even the operations in the two types of experiments are similar. When stimuli are presented rapidly to the visual or auditory system and some report or judgment is made quickly afterward, the experiment is referred to as one of perception. If the report or judgment is delayed after presentation, the study is usually called a memory experiment. Sensory memories are the brief holding systems for information presented to the various sensory systems; the information is thought to be held briefly in each system as it undergoes further processing.

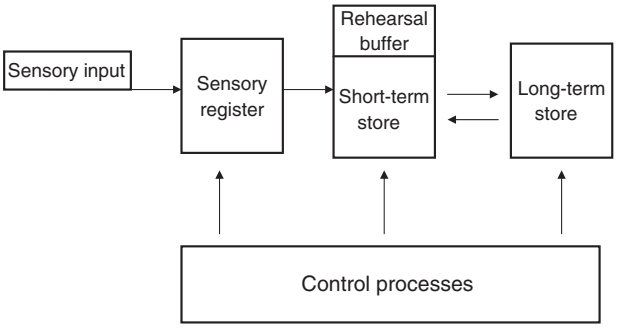

Figure 1 Simplified version of the original multistore memory model of Shiffrin and Atkinson. Information is conceived as being transmitted through various memory stores. Adapted from Shiffrin, R.M., Atkinson, R.C., 1969. Storage and retrieval processes in long-term memory. Psychol. Rev. 76, 179–193, used with permission of the American Psychological Association.

Sperling (1960) identified a rapidly fading store of visual information that he called precategorical visual storage. The term precategorical was in the title, because Sperling's evidence convinced him that the information was held in a relatively raw form, before linguistic categorizations had been applied. Somewhat later, other researchers proposed a system of precategorical acoustic storage, the auditory equivalent of Sperling's visual store (Crowder and Morton, 1969). These two sensory stores have been studied quite thoroughly by many researchers, but the names they are given in the literature today have been changed to iconic and echoic memory [following Neisser's (1967) suggested terminology]. Iconic memory refers to the visual store, whereas echoic memory is used for auditory storage. Echoic storage seems to persist longer than iconic storage, although the decay characteristics of both systems have been debated and depend on such factors as stimulus intensity and the technique used to measure loss of information over time.

Researchers assume that similar storage systems exist for the other senses, but touch is the only sense that has been studied in this regard (and rather sporadically). The close association between smell and taste makes such studies difficult, although longer-term olfactory memory, in particular, has been well studied (e.g., Herz and Engen, 1996).

1.02.3.2 Short-Term Storage

Short-term memory (or short-term storage; the two are often used interchangeably) refers to retention of information in a system after information has been categorized and reached consciousness. In fact, contents of short-term memory are sometimes equated with the information of which a person is consciously aware. Information can be continually processed in short-term storage (e.g., via rehearsal or subvocal repetition). If a person is distracted, information is rapidly lost from this store.

Many different techniques have been developed to study aspects of short-term memory, but all have in common that subjects are given relatively brief numbers of items (often digits or words) and are asked to recall or recognize them later (often after some brief interfering task).

Another term used for short-term memory is primary memory, owing to a distinction introduced by William James (1890/1950) between primary and secondary memory (reintroduced to the field much later by Waugh and Norman, 1965). Primary memory is what can be held in mind at once, whereas secondary memory referred to all other kinds of long-term memory. The terms short-term memory and long-term memory seem to have become accepted today.

1.02.3.3 Working Memory

Working memory is a term for the type of memory used to hold information for short periods of time while it is being manipulated (Baddeley, 2001). Working memory encompasses short-term memory, which in Baddeley's theory refers only to the short-term passive storage of information. Working memory also adds the concept of a central executive that functions to manipulate information in working memory and three separate storage components: the phonological loop, visuospatial sketchpad, and episodic buffer (see Fig. 2). To test the short-term memory of humans, tasks that require short-term storage of information (such as digits in a serial recall task are used, as in remembering a phone number briefly) are used. On the other hand, working memory tests use tasks that require both short-term storage and manipulation of information (such as the operation span task, in which subjects solve simple arithmetic problems while also being given words to remember.

Three different storage systems are believed to constitute working memory. The phonological loop is involved in subvocal rehearsal and storage of auditory information (or written visual information) and is the most-studied component of working memory. The phonological loop is responsible for subvocal rehearsal and is used to account for many different empirical findings, such as the word length effect, or the finding that longer words are recalled less well than shorter words (because they take longer to rehearse).

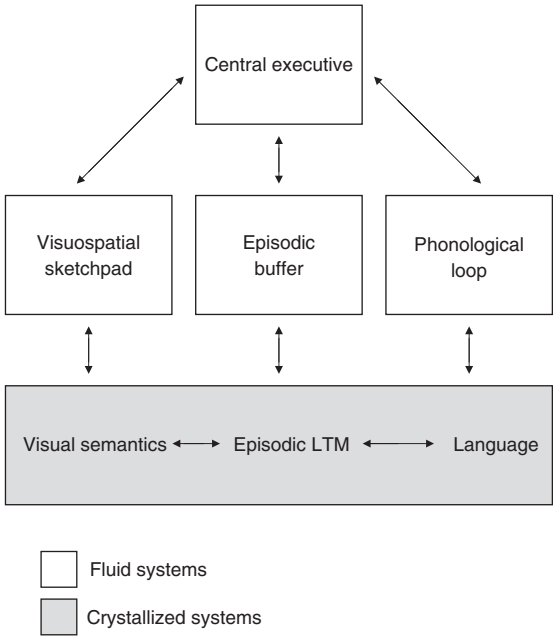

Figure 2 Baddeley's working memory model. Working memory is conceived as having separate storage components and a central executive process. *LTM*, long-term memory. Adapted from Baddeley, A., 2001. Is working memory still working? Am. Psychol. 56, 849–864, used with permission.

The visuospatial sketchpad is similar to the phonological loop, except it maintains visual and spatial information, rather than acoustic information. The visual and spatial components of the sketchpad are at least partially separable, because one can observe dissociations between performance on visual working memory tasks and spatial working memory tasks (Baddeley, 2001). Most of the work on the visuospatial sketchpad up to now has focused on dissociating it from the other components of working memory.

The episodic buffer is the newest component of working memory, proposed by Baddeley (2000) to explain several experimental findings. The episodic buffer is much like the phonological loop or the visuospatial sketchpad: it is a short-term store of information, although it is assumed to be able to store information of different modalities. Any information that is retrieved from long-term episodic memory (see section Episodic Memory) is temporarily stored and manipulated in the episodic buffer.

The central executive component of working memory controls the subsystems. Some critics have complained that the concept is underspecified and that it is used to explain findings not well handled by the basic model. However, the executive component has much in common with other proposals of a central executive attention system that is used to explain how people can divide attention to different sources of information, switch attention among sources or tasks, or focus attention exclusively on one task. The study of working memory has today developed in many ways that take the concept rather far afield from the original model. In particular, the definition now includes the ability to hold information in mind while under conditions of distraction: how well can you hold information while working with it. Much current research is aimed at elucidating the neural underpinnings of working memory.

1.02.3.4 Long-Term Working Memory

Long-term working memory extends the concept of working memory to account for a person's ability to readily access and utilize information stored in long-term memory. The concept of long-term working memory is particularly useful in explaining how skilled readers have the ability to easily read and comprehend texts. Indeed, the act of reading seems to require much more capacity and flexibility than the proposal for short-term or working memory can offer. A skilled reader must keep in mind words from previous sentences, paragraphs, or pages of text and readily access prior background knowledge to quickly and fluently process upcoming words and understand the text as a whole (e.g., Ericsson and Kintsch, 1995). In addition, readers can be reading several novels at once and pick up the story of each of them with hardly any loss (relative to reading one novel). The idea is that we can hold the information about several novels in a highly accessible state that can be called into action as we pick up one of the books to read.

The concept of long-term working memory is also used to describe the superior mnemonic skills of experts functioning within their domain of expertise. For instance, chess masters demonstrate a remarkable ability to quickly encode and accurately remember the positions of every piece on a chess board sampled from the middle of a game, or to readily call to mind moves played in

thousands of previous games to decide how to make the next move in a game. While researchers have attempted to explain the superior memory capacity of experts in their domain within the limits of short-term memory (Chase and Simon, 1973), evidence suggests that expert memory performance is mediated by long-term memory (e.g., Chase and Ericsson, 1982; Charness, 1991).

In contrast to the limited, fixed capacity of short-term working memory, the capacity of long-term working memory is assumed to be flexible and may even be expanded through training. Thus, according to Ericsson and Kintsch (1995), long-term working memory is not a general cognitive ability, but rather a specialized ability that is acquired through the development of expertise for specific domains of knowledge. On the other hand, long-term working memory still depends on the maintenance and utilization of a few retrieval cues in working memory that are, in turn, linked to retrieval structures stored in long-term memory.

1.02.4 Varieties of Long-Term Memory

Long-term memory is one of the most abused terms in psychology (and there is great competition for this honor). The reason is that the term is made to cover nearly every kind of memory not covered in the previous section. The term is used to refer to retention of words from the middle of a list presented 15 s previously to recollection of early childhood memories to many other situations.

Not surprisingly, there exist various ways of carving up this huge subject. One is by type of material and mode of presentation, with the primary distinctions being among verbal memory, visual/spatial memory, and olfactory memory. Relatedly, learning of motor skills (sometimes called procedural memory, as discussed in the section Declarative and Nondeclarative Memory) is another critical and somewhat separate topic, sometimes called kinesthetic or motor skills memory.

Another set of distinctions, which cut across those mentioned earlier, are among types of declarative (or perhaps explicit) memory: episodic memory, autobiographical memory, semantic memory, and collective memory. We begin discussing specific codes thought to underlie long-term memory and then turn to the various types of explicit, declarative memory that have been proposed.

1.02.4.1 Code-Specific Forms of Retention

As humans possess multiple senses, there are multiple ways to sense new information and to encode that information. Raw sensory information comes in as visual, auditory, or olfactory information, as well as in other modalities. However, memories for tastes have not been much studied and because smell so greatly affects taste, separating these modalities would be difficult. Haptic memory, referring to memory for skin sensations, is also not much studied, although kinesthetic memory (for muscular movements) is a well-studied area. Studying memory for information presented in different sensory modalities has revealed both similarities and remarkable differences in how modality affects memory performance.

1.02.4.1.1 Visual–Spatial Memory

Memory for scenes and spatial relationships is often referred to as visual–spatial memory or just spatial memory. This type of memory is responsible for humans navigating around town in a car and for squirrels finding buried caches of acorns. Although spatial memory and episodic memory both rely on the hippocampus and surrounding areas, some theorists have argued that spatial memory is different from episodic memory and other relational (semantic) memory systems because it requires the formation of mental maps (O'Keefe and Nadel, 1978). On the other hand, Mackintosh (2002) argued that spatial learning is no different than other types of associative learning.

1.02.4.1.2 Imagery

Information presented in events or pictures or words may be represented in the spatial system in imaginal form. One may see a butterfly and remember its appearance using this imaginal coding, or one may hear the word butterfly and be asked to form an image of the named insect. Converting verbal memories to images aids their memorability, either because the image is a deeply meaningful form (Nelson, 1979) or because coding information in verbal and imaginal codes provides additional retrieval routes to the information (Paivio, 1986).

1.02.4.1.3 Olfactory Memory

Olfactory memory is more difficult to study than visual or auditory memory. Due to limitations of human olfaction, memory for odors has generally been tested with recognition tests, not with recall tests (see Herz and Engen, 1996; for a review). Olfactory memories seem to differ in some ways from other forms of memory, such as a tendency of smells to be particularly evocative of emotional memories. Indeed, the olfactory nerve is only two synapses away from the amygdala (responsible for certain types of emotions) and three synapses away from the hippocampus (which is critical for long-term memory). Olfactory memory is similar to auditory and visual memory in that performance on recognition tests decreases as the distracter set increases and as distracter similarity to targets increases. However, olfactory memory does differ from other kinds of memory in two respects. First, olfactory memory is highly resistant to forgetting: multiple studies have shown that recognition performance for odors in a laboratory preparation is only about 5% less after 1 year than after a 30-s delay. Related to this remarkably flat forgetting curve is the finding that olfactory memory is highly resistant to retroactive interference (interference from events occurring after the experienced smell). Proactive interference (events before the to-be-remembered smell) reduces olfactory memory performance greatly.

1.02.4.1.4 Skill Learning

Perhaps the largest subset among different kinds of memory is the broad class of memories classified kinesthetic memory or skill learning or procedural memory (the last of which was described earlier). Kinesthetic (sometimes called motor) memories are those involved in motor skills: the swing of a baseball bat, how to keep a hula hoop going, and so on through hundreds of other examples. These are motor skills, the classic type of procedural memory. However, many other types of skill learning exist. There is verbal skill learning, such as learning to read distorted or inverted text (Kolers and Roediger, 1984)—learning of grammars, both real ones and artificial ones—and even the skillful learning of what items belong to what categories. Although a review of the various kinds of skill learning is beyond the scope of this chapter (see Gupta and Cohen, 2002), we can briefly point out one of the most consistent findings across the procedural learning literature: skill learning is highly specific and transfer is often quite narrow, for example, learning to read inverted (upside down) text does not aid in learning to read backward text (Kolers and Roediger, 1984; Healy, 2007).

1.02.4.1.5 Verbal Memory

Doubtless the greatest form of memory recoding and storage for human beings is based on language. People can remember events as verbal information even if they were originally presented in a different form (visual, auditory, or even olfactory or kinesthetic). Psychologists have long believed in the primacy of verbal coding, and Glanzer and Clark (1964) even proposed a verbal loop hypothesis, which theorized that all human experience is recoded into language. Subsequent research indicates that this hypothesis was a bit overstated and other forms of coding exist, but nonetheless verbal coding and verbal memories are critically important in human cognition. Verbal recoding can be impaired by instructing subjects to perform some irrelevant verbalization such as repeating nonsense words while being exposed to nonverbal information, a technique known as articulatory suppression. Memory for text and discourse represents an active area of research, with obvious educational implications.

1.02.4.2 Forms of Explicit Memory

We have covered these earlier in the section Broad Distinctions but review them again here in more detail and provide more detailed examples of tasks used to study these forms of memory.

1.02.4.2.1 Episodic Memory

Episodic memory refers to memory for particular events situated in space and time, as well as the underlying cognitive processes and neural mechanisms involved in remembering those events. A key ingredient of episodic memory that distinguishes it from other forms of memory is the retrieval of information regarding the spatial and/or temporal context in which the remembered event occurred. As previously mentioned, episodic memory is also associated with autonoetic consciousness, considered by some researchers to be an evolutionarily advanced, unique human capacity (e.g., Wheeler, 2000; Tulving, 2002, 2005). On the other hand, research with infrahuman animals has pointed to "episodic-like" behavior, and so some researchers dispute the claim that only humans have episodic memory.

One can point to a wide variety of examples of episodic memory, ranging from remembering what a friend wore at a party the night before to individual words studied in a list moments ago. In most contexts, episodic memory is synonymous with explicit memory, although the former term is usually used to represent a memory system and the latter term to designate types of tests that are used. Many tests have been designed to measure certain aspects of episodic memory in the lab, including free recall (recall of a set of material in any order), serial recall (recall of events in order), cued recall (recall of events given specific cues), recognition judgments (recognizing studied material intermixed with nonstudied material), source judgments (recognizing the source of presented material, such as whether it was presented auditorily or visually). Subjects may also be asked to make judgments of the recency of an event, its frequency of occurrence, or of some other quality. In addition, subjects can be asked to make metamemory judgments, or judgments about their memories. For example, a student might be asked to rate how confident he/she is in the accuracy of his/her recollections. Similarly, individuals might be asked to judge whether they can remember the moment an event occurred or the context in which it occurred or whether they only just know that they were previously encountered but cannot remember the context (Tulving, 1985). These remember/know judgments (with remember judgments reflecting episodic recollection) have been much studied. Episodic memory (as well as working memory) tends to decline with age.

1.02.4.2.2 Autobiographical Memory

Autobiographical memory refers to memory for one's personal history (Robinson, 1976). Examples might include memories for experiences that occurred in childhood, the first time learning to drive a car, and even such memories as where we were born. Brewer (1986) divided autobiographical memories into categories of personal memories, autobiographical facts, and generic personal memories. Personal memories are memories for specific events in one's life that are accompanied by imagery. As such, personal autobiographical memories are thought by some to be the real-world analogue to episodic memories as studied in the lab, because they are the episodes of one's life as dated in space and time. On the other hand, autobiographical facts are facts about the person that are devoid of personally experienced temporal or spatial context information. For example, you know when and where you were born, but you cannot remember the event. Finally, generic personal memory refers to more abstract knowledge about oneself (what you are like) or to acquired procedural knowledge such as knowledge of how to ride a bicycle, ski, or play a musical instrument. Despite the conceptual overlap across classification schemes, a unique feature of autobiographical memory is that it must directly relate to oneself or one's sense of personal history.

A variety of techniques have been used to examine autobiographical memory. One approach is to simply ask people to report the most important personal events of their life (e.g., Fitzgerald, 1988; Berntsen and Rubin, 2002; Rubin and Berntsen, 2003) or to report self-defining memories (e.g., Conway et al., 2004). Another frequently used method is to ask people to describe for each of a given set of cue words the first personal memory that comes to mind, e.g., being given the word window and asked to retrieve a discrete event from your past involving a window. This task is known as the Galton–Crovitz cueing technique after its inventor (Galton, 1879) and its first modern proponent (Crovitz and Schiffman, 1974).

Many studies have plotted the temporal distribution of autobiographical memories across the life span, as described more fully by Conway. Briefly, such distributions usually exhibit three striking features (Rubin et al., 1986; Janssen et al., 2005). The first is that people tend to recall very little from the first few years of their life. This is referred to as childhood amnesia. Second, people tend to recall quite a few events from early adulthood, roughly the ages 15–25. The effect is called the reminiscence bump, because when the number of memories retrieved from various periods of life is graphed over the life span, there is a bump in the era of 15–25 years. More memories are reported from this period than from any other. The reminiscence bump may reflect the fact that the cultural life script in Western cultures has many events during this critical time period (finishing high school, often going to college, getting married, obtaining a job). Bohn and Berntsen (2011) showed that when children are asked to predict events that would happen in their lives, they also showed a reminiscence bump. Finally, most reported events are recalled from the last few years, which (like many other examples of good recall of recent information) is known as the recency effect.

Due to the personal nature of autobiographical memory, researchers have difficulty comparing what a person remembers to what actually occurred. Researchers overcome this challenge in one of several ways. One approach is to have subjects keep a diary for a length of time (e.g., days, months, years) and to record events that occurred to them at regular intervals or in response to specific cues. In addition to providing descriptions of the events that occurred, subjects might also record other accompanying details such as the exact time or location of the event and its emotional valence, salience, or distinctiveness. In turn, the diary entries are treated as the to-be-remembered stimuli in subsequent tests of memory. Moreover, as previously mentioned, the diary method is also used to capture involuntary recollections of personal events that are extremely difficult to elicit in laboratory settings. Such involuntary recollections tend to come out of the blue in response to environmental cues such as specific smells, words, or objects (e.g., Berntsen, 1996).

Another method is to assess individuals' recollections for specific historical events (e.g., the German occupation and liberation of Denmark during World War II) and then to compare the recollections with objective records of what occurred at the time, such as weather reports, newspapers, or radio broadcasts (Berntsen and Thomsen, 2005). Numerous studies of flashbulb memories (vivid recollections that surround a salient personal experience) focus on personal recollections surrounding unexpected, momentous, or emotionally charged events of public or personal significance, such as (depending on one's age) the assassination of President John F. Kennedy, the explosion of the space shuttle Challenger, or the terrorist attacks on New York's World Trade Center (Brown and Kulik, 1977; Neisser and Harsh, 1993; Talarico and Rubin, 2003). However, it still remains unclear how reliable such memories are, what types of events induce flashbulb memories, and whether they really differ from memories for emotionally charged stimuli or circumstances.

One interesting discovery in recent years is that some individuals have "highly superior autobiographical memory." These individuals can recall all the days of their lives in the distant past much like readers of this chapter can recall what they did yesterday. The condition is relatively rare, but over 50 individuals have been identified as having this condition.

1.02.4.2.3 Semantic Memory

Semantic memory broadly refers to a person's general knowledge of the world. Of course, this is a vast store of information. Examples of semantic memory range from knowledge of words and their meanings, all kinds of concepts, general schemas, or scripts that organize knowledge, and also specific facts about the world, such as the capital of France or famous battles in World War II.

It is reasonable to assume that when information is first learned, it is accompanied by information regarding the time and place of the learning episode. Over time and with repeated presentations of the same information, the accompanying episodic information may be lost or detached, and what remains is semantic memory. Still the distinction between episodic and semantic memory can easily blur. If someone asks about what you learned during a recent lecture, your response will likely reflect the influence of both episodic and semantic memory: your reliance on temporal or contextual cues to remember particular points made during the lecture would reflect episodic memory. In contrast, how you choose to reconstruct, organize, interpret, or paraphrase knowledge garnered from the lecture would reflect the influence of semantic memory.

In addition to tests of explicit and implicit memory, a variety of cognitive tasks are designed to measure the contents and organization of semantic memory. These tasks might involve naming as many members of a category or words that start with a given letter that come to mind, providing word definitions, or answering general knowledge questions. Other measures are designed to capture the psychological representations of word meanings by having individuals provide quantitative ratings of individual words along a variety of semantic dimensions (e.g., Osgood et al., 1957).

One of the most powerful tools for studying semantic memory is the word-priming technique in which individuals are asked to make lexical decisions (word–nonword decisions) for pairs of stimuli that might be semantically related or unrelated. For example, individuals are faster and more accurate at judging that *doctor* is a word if it is was preceded by a related word (*nurse*) relative to an unrelated word (*shoe*). Indeed, comparisons in the response times for items that are semantically related versus unrelated to current or previously encountered stimuli have inspired and helped to distinguish among competing theories of how knowledge is mentally represented and accessed (e.g., Collins and Quillian, 1969; Meyer and Schvaneveldt, 1971; Collins and Loftus, 1975; Neely, 1977).

1.02.4.2.4 Collective Memory

Collective memory is conceptualized in a variety of ways. In a literal sense, collective memory refers to remembering that occurs within any social context. When employees at a company meeting attempt to recall what was discussed during a previous meeting, they are engaging in a collaborative recall effort. In general, social situations can influence what individuals remember or choose to report of the past. A given social setting can dictate what sorts of recollections are most appropriate or commensurate with individual goals of communication. For instance, it is very tempting to highlight or embellish certain details of a remembered event to tell a more entertaining story. And in turn, an individual can influence what other individuals of a group remember of the past. Studies of collaborative recall typically involve having a group of people study lists of words, pictures, or prose passages and then asking them to recall the previously studied materials either individually or in collaboration with the rest of the group (Weldon, 2000).

Work in this area has shown that collaborative recall can increase the amount of previously studied information recalled as compared to individual recall performance, but that collaborative recall tends to reduce or inhibit the amount of information recalled per individual within a group (e.g., Weldon and Bellinger, 1997). Furthermore, collaborative recall can induce recall errors, as erroneous information supplied by one member of a group is accepted and later remembered by other members of the group (e.g., Roediger et al., 2001; Meade and Roediger, 2002).

Collective memory also refers to a representation of the past that is shared by members of broader social groups defined by nationality, religion, ethnicity, or age cohort. Such a conception of collective memory is shared across the fields of psychology, anthropology, and sociology, as may be seen in the writings of Wilhelm Wundt (1910/1916), Sir Frederic Bartlett (1932), and the French sociologists Maurice Halbwachs (1950/1980) and Emile Durkheim (1915). One commonly held assumption is that remembering is shaped by active participation within the life of a particular group. Thus, group characteristics may bias the recollections of individual group members. For instance, Russian and American high school students are likely to tell strikingly different versions of the history of World War II, with each group recalling and weaving together a different set of key events in their narratives (Wertsch, 2002). Despite the widespread use of the term collective memory, both in public discussions of how groups remember historical events such as the Vietnam War or the Holocaust and across academic disciplines, there is still little agreement as to its definition or methods of study.

In contemporary memory research, studies of collective memory bear resemblance to those of autobiographical memory in the sense that remembering one's personal history may be heavily influenced by one's cultural background. For instance, numerous studies of flashbulb memories have examined individual recollections for major historical events such as the assassinations of President John F. Kennedy, Martin Luther King, Jr., and the fall of the Berlin Wall in 1989. Some of these studies have shown striking differences in recollections across groups. Berntsen and Thomsen (2005) examined Danes' memories for the German invasion of Denmark in 1940 and their liberation in 1945. Interestingly, they found that individuals who had ties to the Danish resistance had more vivid and accurate memories than those who did not. A key difference between autobiographical and collective memory might, therefore, lie in the impact of group identification on memory and the extent to which remembering in general is socially framed. Collective memory is a burgeoning interdisciplinary study that spans the fields of history, sociology, and psychology, among others (see Corning and Schuman, 2005).

1.02.5 Conclusions

This chapter has surveyed some of the most common terms and distinctions among types of memory, especially as that pertains to the study of human memory. Of course, the various approaches to learning and memory use hundreds of other technical terms that are beyond the scope of this chapter. Although we have considered only a fraction of the 256 types that Tulving (2007) identified in his (semiserious) essay, we believe we have hit upon the great majority in contemporary use. Most of the terms used in this chapter were not used by researchers 50 years ago. We hazard the guess that someone examining the field in 50 more years might have an even greater variety of items to review, even if the serious contenders do not quite approach 256.

See also: 1.15 Memory for Space, Time, and Episodes. 1.16 Spatial Memory in Food-Hoarding Animals. 2.02 Encoding–Retrieval Interactions. 2.04 Collaborative Memory: A Selective Review of Data and Theory. 2.05 Implicit Versus Explicit Memory. 2.07 Autobiographical Memory. 2.09 Working Memory: The Information You are Now Thinking of. 2.10 Working Memory and Intelligence. 2.14 Exemplar-Model Accounts of Dissociations Between Categorization and Old–New Recognition. 2.17 How Emotional Arousal Enhances Episodic Memory. 2.18 Trauma and Disorders of Memory. 2.19 Spatial Memory and Navigation. 2.23 Metamemory: An Update of Critical Findings. 2.24 Tip-of-the-Tongue States. 2.25 Remembering to Remember: An Examination of the Cognitive Processes Underlying Prospective Memory. 2.28 Mnemonic Techniques: Underlying Processes and Practical Applications. 3.02 Interactions Among Multiple Parallel Learning and Memory Systems in the Mammalian Brain. 3.03 Anatomy of the Hippocampus and the Declarative Memory System. 3.09 Structural Basis of Semantic Memory. 3.13 Spatial Memory. 3.17 Procedural Learning in Humans. 3.18 Neurobiology of Procedural Learning in Animals. 3.19 Eyeblink Conditioning - A Behavioral Model of Procedural and Declarative Learning. 3.20 Procedural Learning: VOR. 3.21 Cerebral Cortex: Motor Learning. 3.22 Emotional Learning: Animals. 4.25 Neurobiology of Fear Memory.

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