

Chapter 7: Long-term memory systems

We have an amazing variety of information stored away in long-term memory. For example, long-term memory can contain details of our last summer holiday, the fact that Paris is the capital of France, information about how to ride a bicycle or play the piano and so on. In view of this variety, Atkinson and Shiffrin's (1968) notion that there is only a single long-term memory store seems improbable.

Schacter and Tulving (1994), basing themselves on the work of many other theorists, argued for a more convincing view of memory in general and long-term memory in particular. In essence, they argued that there are five major memory systems: working memory; semantic memory; episodic memory; the perceptual representation system; and procedural memory. Working memory is of crucial importance to short-term memory. In contrast, the four other memory systems are concerned with long-term memory and are all discussed in detail in this chapter.

Amnesic patients have problems with long-term memory. HM was the most-studied amnesic patient of all time. The amnesic syndrome comprises an impairment in the ability to remember new information after the event (*anterograde amnesia*), difficulty in remembering events prior to amnesia (*retrograde amnesia*) and only slightly impaired short-term memory. The study of amnesia provides a good test-bed for theories of healthy memory, for example the distinction between declarative and non-declarative memory.

WEBLINK: [Video about HM](#)

WEBLINK: [Amnesia](#)

Memory can be divided into several subcomponents. *Declarative memory* involves conscious recollection of events and facts. It is also referred to as *explicit memory*. *Non-declarative memory* does not involve conscious recollection. It is also known as *implicit memory*, which involves enhanced performance in the absence of conscious recollection.

It is generally accepted that there are several major long-term memory systems. For example, a distinction has been drawn between declarative and non-declarative memory systems. Evidence for this distinction comes from brain-damaged patients and neuroimaging studies. Further divisions have been proposed within these major systems. For example, episodic and semantic memory relate to different types of information in declarative memory. Similarly, two non-declarative memory systems have been proposed: the perceptual representation system and procedural memory (skill learning).

- **Declarative memory**

Tulving (1972) argued for a distinction between episodic and semantic memory:

- *Episodic memory* involves storage and retrieval of specific events and episodes occurring in a given place at a given time.
- *Semantic memory* is the aspect of human memory that corresponds to general knowledge of objects, word meanings, facts and people, without connection to any particular time or place.

There are similarities between episodic and semantic memory – both are concerned with personal experiences from the past. However, information in episodic memory is relatively trivial and remembered only for a short period of time. Autobiographical memory stores important information for long periods of time.

Spiers et al. (2001) reviewed cases of amnesia involving damage to the hippocampus or fornix. All patients were impaired in episodic memory but had only modest problems with semantic memory. Vargha-Khadem et al. (2002) studied patients with bilateral hippocampal damage. They had very poor episodic memory but fairly normal semantic memory. Patient KC showed retrograde amnesia for episodic memory, but had intact semantic memory (Tulving, 2002). In retrograde amnesia, there appears to be a temporal gradient whereby older

memories are more spared than more recent ones (Kopelman & Bright, 2012). Patients with semantic dementia exist, whereby they have poor semantic memory but intact episodic memory (Mayberry et al., 2011). These dissociations suggest different types of memory.

WEBLINK: [Semantic dementia](#)

Kan et al. (2009) suggests there may be some interdependence between these types of memory. Semantic knowledge provides a framework for understanding and coding episodic information. Finally, there is a process of semanticisation in which episodic memories become more like semantic memories over time (Harand et al., 2012). This process fixes them in long-term memory but makes them less emotional.

There is strong evidence for separate episodic and semantic memory systems. This evidence comes from studies on retrograde and anterograde amnesia, and from functional neuroimaging. However, it should be noted that episodic and semantic memory systems typically combine in their functioning, and similar brain regions may be associated with both types of memory.

- **Episodic memory**

Most episodic memories exhibit substantial forgetting over time. However, there are exceptions, for example recognising a classmate's photograph from 25 years earlier (Bahrick et al., 1975). Bahrick (1984) used the term "permastore" to describe these very long-term stable memories. Episodic memory can be assessed using tests for recognition and recall.

- *Recognition memory test:* Participants view a series of items. They later decide if test items were presented previously.
- *Recall test:* Participants recall items either in the form of free recall (no order), serial recall (ordered) or cued recall.

Recognition memory

Recognition memory can involve recollection or familiarity. In the remember/know task (Gardiner, 1988), participants indicate whether their recognition decisions were based on recollection of contextual information (remember) or solely on familiarity (know). However, it is possible that strong memory traces give rise to recollection judgements and weak traces give rise to familiarity judgements. Indeed, remember and know responses give rise to different ERPs (Addante et al., 2012).

INTERACTIVE EXERCISE: Remember/know procedure

Diana et al. (2007) provided a theoretical account of the brain areas involved in recognition memory in their binding-of-item-and-context model:

- The perirhinal cortex receives information about specific items ("what" information needed for familiarity judgements).
- The parahippocampal cortex receives information about context ("where" information useful for recollection judgements).
- The hippocampus receives what and where information (both of great importance to episodic memory) and binds them to form item-context associations that permit recollection.

Recall memory

Staresina and Davachi (2006) found similar brain areas were associated with free recall and recognition tasks. However, successful free recall was associated with higher levels of brain activity, suggesting that it may be more "difficult" than recognition.

According to Schacter and Addis (2007), episodic memory is a fundamentally constructive process that is prone to various kinds of errors and illusions. This is because:

- It requires too much processing to produce a semi-permanent record.
- We want to access the gist or essence rather than trivial details.
- Imagining future events or scenarios is important.

We typically remember the gist of what we have experienced previously. Our tendency to remember gist increases with age. Brainerd and Mojardin (1998) found that false recognition on a sentence recognition task increased with age. Imagining future events involves the same processes as those involved in remembering past events (Addis & Schacter, 2012). Race et al. (2011) pointed out that hippocampal damage may be associated with impaired imagining of future events for two reasons:

- The damage may reduce the ability to access detailed information from episodic memory and then construct an imaginary future event.
- The damage may reduce patients' ability to construct narratives describing imaginary events.

Episodic memory may be assessed using recall or recognition tasks. Recognition memory in turn may rely on either recollection or familiarity. The hippocampus seems to be particularly important for recollection. Our tendency to remember the gist of events increases with age. Episodic memory is a constructive process, and may engage similar brain processes as when individuals imagine future events.

- **Semantic memory**

Our organised general knowledge about the world is stored in semantic memory. *Concepts* are mental representations of categories of objects or items. Concepts are organised into hierarchical networks with three levels (Rosch et al., 1976): superordinate categories; basic-level categories; and subordinate categories. Rosch and Mervis (1975) found members in a category can vary in their typicality. Verification times are faster for more typical members – the *typicality effect*. Categorisation performance is most accurate and fastest at the superordinate level (Prass et al., 2013). Given that concepts are likely to be activated in association with goals, Barsalou (2009, 2012) proposed the *situated simulation theory*. Results indicate that, when participants list characteristics of concepts, they list perceptual qualities (Wu & Barsalou, 2009) and settings associated with the concepts (Barsalou & Wiemer-Hastings, 2005). Shebani and Pulvermuller (2013) also found evidence for the role of the motor system in processing action verbs.

Pobric et al. (2010b) proposed the *hub-and-spoke* model. The spokes consist of several modality-specific regions involving sensory and motor processing. Each concept has a hub, which is a modality-independent unified conceptual representation that integrates the knowledge. The hubs are located in the anterior temporal lobes. Damage to these hubs causes category-specific deficits.

It is assumed we have *schemas* – organised packets of knowledge – stored in semantic memory. Scripts are a special form of schema relating to information about sequences of events. Scripts involve processing in the frontal lobes (Cosentino et al., 2006) as they relate to planning.

Semantic memory is highly organised or structured. Early models envisaged semantic knowledge as being stored in hierarchical networks, or being organised according to semantic relatedness. Later models were feature-based and distinguished between perceptual and functional features of objects and concepts. The fact that some patients have category-specific deficits suggests different kinds of knowledge are indeed stored in different parts of the brain. Modality-specific information forms an important part of object representations, but there is still debate as to whether additional amodal concept “hubs” exist in addition to modality-specific information. Neuroimaging evidence, and studies from patients with semantic dementia, provide support for the existence of amodal hubs.

- **Non-declarative memory**

Non-declarative memory is expressed by behaviour and does not involve conscious recollection. There are two non-declarative memory systems:

1. The *perceptual representation system* – a collection of domain-specific modules that operate on perceptual information about the form and structure of words and objects. *Repetition priming* occurs within this system. Stimulus processing is faster on the second and successive presentation of a stimulus.
2. *Procedural memory* (skill learning) refers to the learning of motor and cognitive skills across a wide range of situations. This type of learning generalises.

Perceptual priming occurs when repeated presentation of a stimulus leads to facilitated processing of its perceptual features. *Conceptual priming* occurs when repeated presentation of a stimulus leads to facilitated processing of its meaning. Levy et al. (2004) found that amnesic patients and controls showed similar amounts of conceptual priming, but amnesics performed poorly on recognition memory. Insausti et al. (2013) reported a patient who showed perceptual priming but no declarative memory. The notion that perceptual priming depends on different brain systems from those involved in explicit memory is strengthened by finding a double dissociation (Gabrieli et al., 1995). However, Schacter et al. (1995) found controls showed more priming than did the amnesics when words were presented and tested in the same voice. The implication is that amnesics are poor at binding different kinds of information.

Priming is likely to be based on repetition suppression; where the brain activity decreases with stimulus repetition. Voss et al. (2008) found repetition suppression was associated with reduced activity in the left prefrontal cortex.

Foerde and Poldrack (2009) identified types of skill learning or procedural memory:

- motor skill learning
- sequence learning
- mirror tracing
- perceptual skill learning
 - mirror reading
 - probabilistic classification learning
 - artificial grammar learning.

Most tasks involve elements of both declarative and procedural memory. Reber et al. (1996) found that amnesics learn the probabilistic classification task as rapidly as do controls. Foerde et al. (2006) found that learning on the probabilistic classification task can depend on either procedural or declarative memory. Tranel et al. (1994) found that amnesic patients showed comparable learning on the pursuit rotor to controls. Cavaco et al. (2004) found that amnesics showed comparable rates of learning on everyday skill-learning tasks such as weaving and control stick tasks. Declarative and procedural memory are not entirely separate. There can be interactions between the two memory systems. Brown and Robertson (2007) found that procedural learning disrupted learning on a declarative memory task and vice versa.

Non-declarative memory does not involve conscious recollection but reveals itself through behaviour. Repetition priming and procedural memory (skill learning) are two major types of non-declarative memory that may involve separate memory systems (although there is also evidence for a single memory system). Repetition priming can take the form of perceptual or conceptual priming. There is some evidence that different processes underlie the two types of priming. Amnesic patients tend to have preserved skill learning, as well as preserved perceptual and conceptual priming. Priming leads to reduced brain activity, presumably because processing becomes more efficient when stimuli are repeated.

- **Beyond declarative and non-declarative memory**

Most memory researchers have argued for a distinction between declarative and non-declarative memory. This distinction has been useful in accounting for most findings; however, it is limited. Participants who are aware of the connection between the lists in a word-stem completion task perform better than those unaware of it, suggesting explicit and implicit memory are involved in this task (Dew & Cabeza, 2011).

RESEARCH ACTIVITY: Word-stem completion task

Henke (2010) proposed the processing-based theoretical account of memory with three processing types:

- rapid encoding of flexible associations;
- slow encoding of rigid associations;
- rapid encoding of single or unitised items.

Henke's (2010) model makes three predictions, all of which have partial support from the literature. First, the hippocampus is involved in the encoding of associations in both conscious and unconscious learning (Henke et al., 2003). Therefore, patients with hippocampal damage will find it hard to form flexible associations regardless of whether the learning is conscious or unconscious (Ryan et al., 2000). Finally, the hippocampus is not involved in familiarity judgements in recognition memory (Bowles et al., 2010).

Cabeza and Moscovitch (2013) introduced a *processing component* approach to long-term memory. There are numerous processing components and these components can be combined and recombined for specific learning purposes. Brain processes can be linked to brain regions (Dew & Cabeza, 2011):

- *cognitive process*: perceptually or conceptually driven;
- *stimulus representation*: item or relational;
- *level of intention*: controlled vs. automatic.

This approach is novel and fits neuroimaging data well, but it fails to make many concrete predictions.

Traditionally, an important distinction has been drawn between declarative and non-declarative memory systems. This distinction has been helpful in explaining the pattern of deficits observed in amnesia. However, there is increasing evidence from studies on amnesia that this distinction is limited. An attractive alternative viewpoint emphasises instead whether tasks involve forming an association or binding between concepts. The prediction is that amnesics are impaired on tasks when binding is required (even tasks of implicit memory), but may show intact memory when binding is not required.

Additional references

Rosch, E.H. & Mervis, C.B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology*, 7: 573–605.

Vargha-Khadem, F., Gadian, D.G. & Mishkin, M. (2002). Dissociations in cognitive memory: The syndrome of developmental amnesia. In A. Baddeley, J. Aggleton & M. Conway (eds), *Episodic memory: New directions in research* (pp.153–63). New York: Oxford University Press.