Introduction

How is it that if someone speaks your name, you immediately hear it even though you are not consciously attending to it? Certain automatic brain processes have taken place for this to occur, and these processes are studied by cognitive psychologists.

Cognitivism involves the study of mental processes such as sensation, perception, attention, encoding and memory that behaviourists were reluctant to study, because cognition occurs inside the 'black box' of the brain.

Cognitivists believe that learning results from organizing and processing information effectively. If educators understand how learners process information, they can design learning experiences that optimize this activity. For example, an awareness of how learners transfer short-term memories into meaningful knowledge is likely to be useful in the classroom.

The development of cognitivism

Four factors influenced the development of cognitivism as a separate discipline in psychology:

- the development of experimental psychology;
- the move from an interest in external behaviours to internal brain processes;
- the inadequacy of behaviourism to explain language acquisition;
- the development of computers and an interest in artificial intelligence.

Experimental psychology

There is a long tradition of experimental memory research by psychologists beginning in the 1880s with Hermann Ebbinghaus, who used nonsense syllables and words to investigate how memory is laid down (Davey 2004: 235).

The British psychologist Frederic Bartlett, who wrote a book called *Remembering* in 1932, is best known for his development of the concept of 'schema'. G.A. Miller wrote a classic article, 'The magical number seven, plus or minus two', which investigated short-term memory as a separate cognitive entity (Miller 1956). This early work on memory paved the way for more sustained research, such as that by Atkinson and Shiffrin (1968) or Baddeley and Hitch (1974) discussed later in the chapter.

The shift from behaviourism to cognitivism

Behaviourists came to realize that not all learning could be explained by Pavlov's and Watson's theories of simple stimulus–response and reinforcement. In 1927 Köhler demonstrated that apes solved problems through a form of thinking he termed 'insightful behaviourism' (Köhler 1925).

Neo-behaviourists such as Tolman expanded this mental focus to a consideration of purposive behaviour in animals and people. He demonstrated that rats build up a mental representation or cognitive map of their environment and develop expectations rather than a set of inflexible links between stimuli and response (Tolman 1948).

Language acquisition

Evidence of human cognition came from contested theories of language acquisition. Skinner's book *Verbal Behavior* (1957) claimed that language was an activity shaped by the stimulus–response mechanism. The structural linguist Naom Chomsky challenged this by arguing that stimulus–response does not explain how children can generate sentences they have not heard before.

Computers and artificial intelligence

Computer scientists in the 1950s were interested in mental processes that could be reproduced by machines. The computer came to be used as a metaphor for cognitive function, and the brain came to be seen as a computing device. For example, cognitive theory employs an information-processing, input-process-output model, similar to that used in the computer industry (see Figure 3.1).

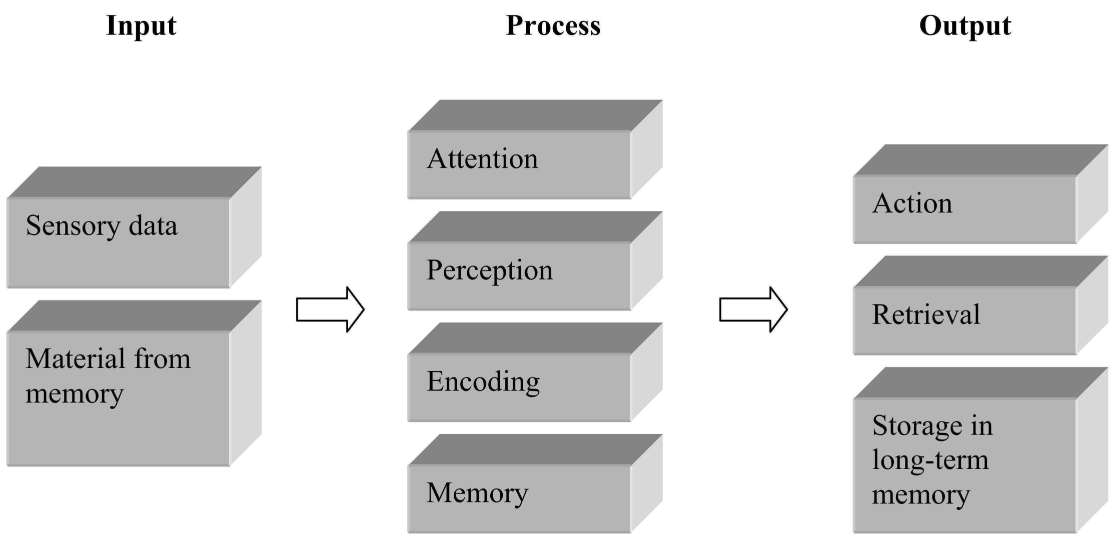

Figure 3.1 Input-process-output model of brain processes.

Principles of cognition

In this section, we consider the five basic processes involved in cognition – sensation, perception, attention, encoding and memory – all of which have implications for the learning process.

Sensation

By sensation, we mean the process through which stimuli from the external environment are held very briefly in sensory registers before being transferred for further processing. For example, visual information is available for only about half a second, and fewer than ten items can be held at any one time. Auditory information is retained long enough for language processing to occur (Massaro 1993).

Perception

Perception is the process by which we interpret and make sense of the things that are presented to our senses. This involves:

- pattern recognition;
- object recognition;
- bottom-up or top-down processing;
- unconscious perception.

Pattern recognition

Early in the twentieth century, Gestalt theorists, who studied holistic aspects of cognition, identified strategies by which people group perceptions of pattern. Patterns are perceived according to the four laws of perception (see Figure 3.2):

Proximity – we have a tendency to perceive closed figures rather than fragmented or unconnected objects.

Similarity – we tend to perceive smooth continuous lines rather than sudden changes in direction.

Continuity – similar information, objects, elements and so on are generally categorized and grouped together.

Closure – objects close to each other may be grouped together.

Object recognition

Whereas patterns are two-dimensional, objects are three-dimensional. Marr (1982) proposed a theory of how we recognize three-dimensional objects, from an increasing range of visual cues as an artist might build up a picture, starting with an outline and adding detail:

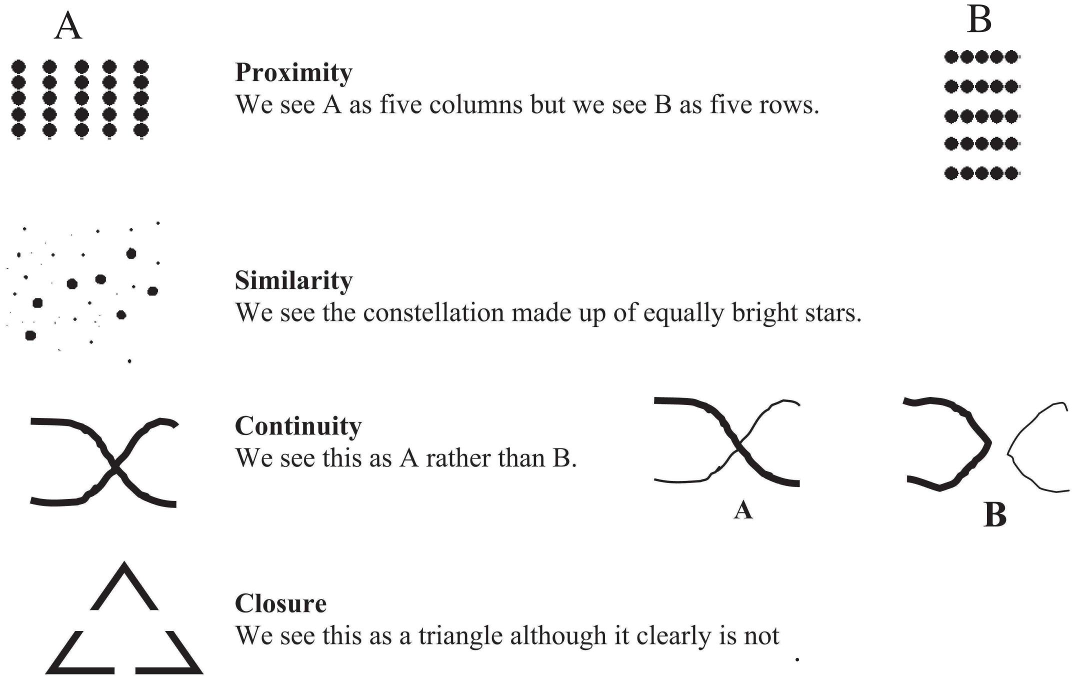

Figure 3.2 Perceptual categorization.
Source: based on Andrade and May (2004:30).

2-D (*Primal sketch*)	We see patterns, lines, corners and some black and white shading.
2.5-D	We see some depth information, texture gradients and binocular cues.
3-D	We see 3-D nature and spatial relationships between objects and the scene.

Bottom-up or top-down processing

A key debate in cognition relates to whether it is:

- bottom-up – all the information needed for perception is provided by the sensory stimulus; or
- top-down – contextual knowledge and reasoning processes are used to make sense of sensory input.

The American psychologist James Gibson (1950) argued for the bottom-up theory, developing his ideas while making training films for pilots. He claimed that pilots use environmental cues to gauge distance and depth, arguing that all the information the pilots needed came not from their prior knowledge but from the following invariant cues:

Interposition	closer objects obscure more distant ones;
Texture gradient	closer objects appear more textured than distant ones;

Linear perspective	parallel lines converge as they recede;
Relative retinal size	distant objects appear smaller;
Motion cues	objects appear to move if the observer is moving (motion parallax);
Optical flow pattern	images such as the ground or sky flow as the observer approaches a point.

The English psychologist Richard Gregory (1980) argues against this bottom-up model and claims that higher-order processes such as inference, deduction and knowledge of context are necessary for perception. He cites letter and word recognition from incomplete information as an example of top-down processing. Some of his evidence is based on visual illusions and ambiguous images that need to be interpreted on the basis of previous experience and expectation. For example, in a

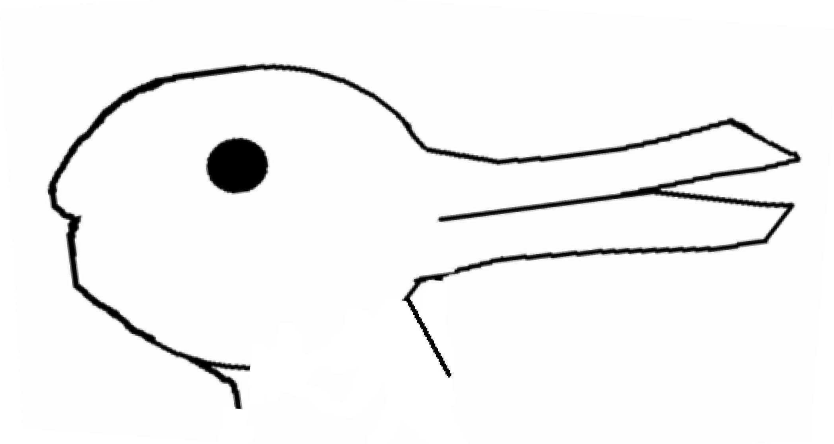

Figure 3.3 Rabbit or duck?
Source: based on Andrade and May (2004:3).

book about small furry animals, the image in Figure 3.3 would be perceived as a rabbit, whereas it would be seen as a duck in a book about birds.

A common-sense compromise suggests that bottom-up and top-down approaches are both involved in perception. At the initial stage, the bottom-up approach is needed to establish the sensory data and the invariants. This is followed by a top-down interpretation that adds contextual and higher-order inferences and deductions. Learning often requires this mixed approach.

Unconscious perception

This aspect of cognition is the ability to perceive phenomena to which we are not consciously attending, such as being aware that one's name has been spoken. Unconscious perception is thought to be involved in subliminal learning, which has been the focus of a thriving industry in motivational tapes and CDs that aims to activate the process (Andrade 2005: 556).

Attention

As we have seen, cognition begins with the perception of sensory inputs. This is followed by attention – the cognitive process of selectively concentrating on one thing while ignoring others. 'Attention acts as a means of focusing limited mental resources on the information and cognitive processes that are most salient at a given moment' (Sternberg 1999: 69). It determines what reaches conscious awareness. So, how are we able to focus on one stimulus and avoid being overloaded with information? We do this first with controlled and automatic processes and then through focus.

Controlled and automatic processes

Controlled processes require intentional effort and conscious awareness. Automatic processes, on the other hand, require little intention or effort and are usually outside conscious awareness and control. They can be performed rapidly and at the same time as other processes. A learner driver finds that driving is a highly controlled process that demands full attention, but for an experienced driver the process is automatic.

Automatic processes often develop as a result of skilled practice. Errors may occur when automatic processes are carried out inappropriately – for example, driving to work when you meant to drive to the bank.

Focus

How do we focus attention on one piece of information to the exclusion of others? This is a topic of obvious interest to the educator.

Three types of theory have been used to explain the processes of selective attention (see Figure 3.4). The first was proposed by Broadbent (1958), who thought that a filter or bottleneck operated immediately after incoming information was registered by the senses; this prevents us being overwhelmed by sensory data. Alternatively, Treisman (1964) argued that all sensory information is processed beyond the sensory stage, but unattended messages are not filtered but weakened (or 'attenuated'). This explains how you might hear your own name spoken in a crowded room – stimuli such as names are so strong that they reach awareness, even if faintly. Finally, Kahneman (1973) suggested that instead of filters or weakened messages, only a limited number of messages can be processed. That is, only a certain amount of attention is available at any one time so the amount of attention a message receives depends on its importance. If attention is divided, it will be directed to where it is needed most.

A later theory (Navon and Gopher 1979) suggested that there might be separate banks for different types of processing – visual and auditory. Two tasks will interfere if only both are drawing on the same bank.

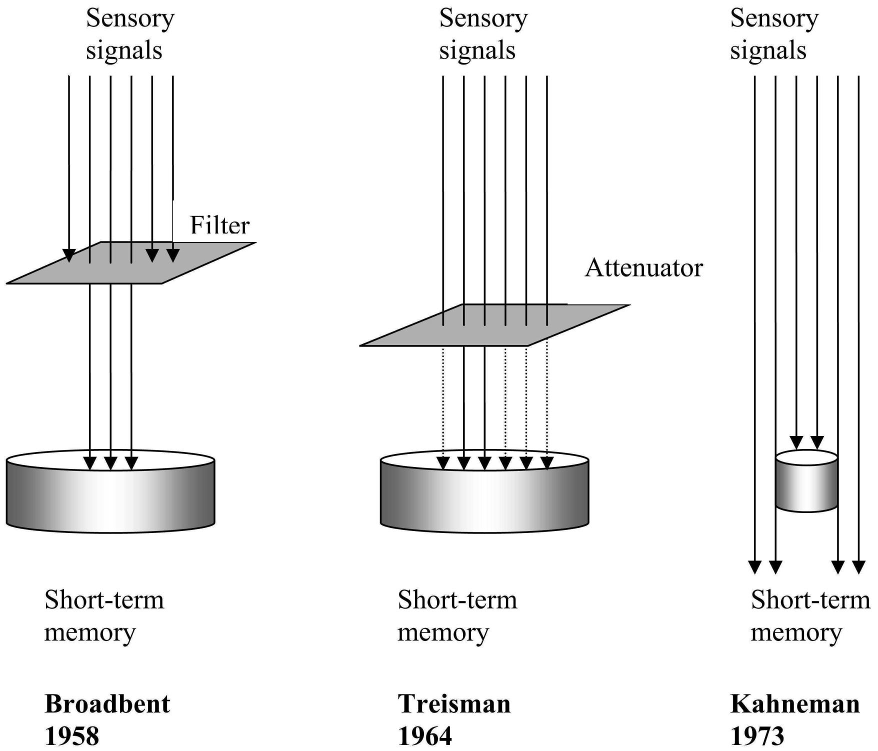

Figure 3.4 Theories of selective attention.
Source: based on Naish (2005).

Encoding

Having perceived and then attended to stimuli, we need to encode information by organizing it in the form of a mental representation, or schema. It could be argued that learning involves the process of encoding experience. For example, research has shown that instructions to organize material can be as effective as instructions to learn it. In one study, three groups of participants were given packs of cards containing words.

- Group 1 was asked to organize the pack in a meaningful way (recall was not mentioned).
- Group 2 was asked to learn the words for recall.
- Group 3 was asked to organize the pack and learn the words.

When the groups were asked to recall the words, there was no difference in their performance. For group 1, the very act of organizing the pack precipitated learning (Mandler 1967).

Schemata

A schema is 'a mental framework or organized pattern of thought about some aspect of the world such as class of people, events, situations or objects' (Bartlett 1932, quoted in Davey 2004: 231).

Schemata are like templates developed from previous experience, into which information can be organized. They mean that people do not have to reinterpret the world every time they encounter it. Schemata have 'slots' that can contain either fixed or variable values. Schemata can be:

Cultural	knowledge of a familiar culture;
Person-related	expectations about a familiar person;
Self-related	beliefs we hold about ourselves;
Role-related	knowledge of roles played;
Scenes	descriptions of layouts or contents of a location;
Scripts	representations of a typical sequence of events.

(Schank and Abelson 1977)

An example of schema for dining in a restaurant could be as follows:

Schema:	Type of restaurant, location, style, cuisine and clientele;
Scenes:	The layout of the restaurant, tables, chairs, décor, waiters;
Script:	Travelling to the restaurant, being allocated a space, having the food cooked, being served and paying for the meal;
Slots:	Type of restaurant, type of décor, type of food.

The idea of schemata was neatly demonstrated in a study in which participants were asked to look around a house from a burglar's perspective or from an estate agent's perspective (Anderson and Pichert 1978). The two groups' recall was very different, with the 'burglars' noting open windows and broken locks, and the estate agents noting decorative problems and room sizes. Different schemata had been applied to the same information to achieve different goals.

The encoding of experience and the generation of schemata involve two components:

- The *bottom-up* inflow of information from the external world, mediated through attention and perception;
- the *top-down* action of prior knowledge that helps to interpret the bottom-up input. In this component, repeated experience is generalized as schemata (or 'accreted'), and new experience causes old schemata to be improved ('tuned'). Inconsistent experience can cause old schemata to be replaced by new ('reconstructed').

Schemata construction involves structuring material so that tuning or reconstruction is facilitated (see Figure 3.5). These processes offer some insight into learners' interpretations.

Memory

Memory is our ability to retain and recall information. Although we may think of memory as one particular faculty, it involves different kinds of inter-related systems: sensory, short-term (STM) and long-term (LTM). Each of these has a different purpose (see Table 3.1).

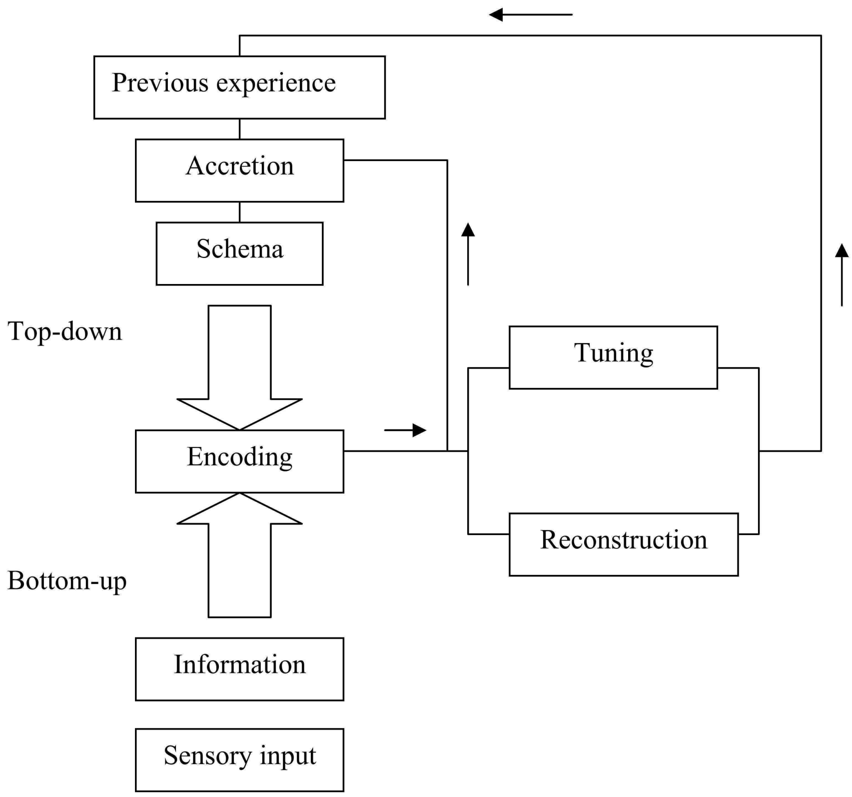

Figure 3.5 How experience is encoded.

Table 3.1 Different types of memory systems

Memory type	**Amount of data**	**Duration**
Sensory	Very large	Very short
STM	Limited	Short
LTM	Very large	Very long

In addition, Tulving (1985) subdivides LTM into:

Episodic memories of things that have happened;

Semantic memories of facts, concepts and principles;

Procedural knowledge of how to do things.

For example, when asked by a teacher about the events of a field trip, a learner makes conscious use of episodic memory. Semantic memory is used to recall a complex scientific equation, and procedural memory is used to carry out a familiar experimental technique in the laboratory.

People suffering from amnesia may have badly damaged episodic memories of past life yet their semantic memory (of language, say) and their procedural memory may be perfect (Baddeley and Wilson 1988). A particularly striking example of evidence of separate short-term and long-term memories is seen in the comparison between two amnesiacs, referred to as H.M. and K.F. The short-term memory of H.M. was normal in that he could recall sequences of letters and numbers given to him, but his long-term memory was practically non-existent. He could not remember where he lived or recognize a photograph of himself, nor could he recall the name of the Prime Minister (Postle and Corkin 1998). K.F. was the exact opposite: she could remember only one item in short-term memory tests, but her long-term memory was normal (Shallice and Warrington 1970).

The way memory operates has been described according to three major theoretical models: modal, working memory and deep and surface processing. There is also the neural network model, which tries to encompass memory, knowledge acquisition and cognition as a whole.

The modal model

Atkinson and Shiffrin (1968) proposed a modal model containing two separate

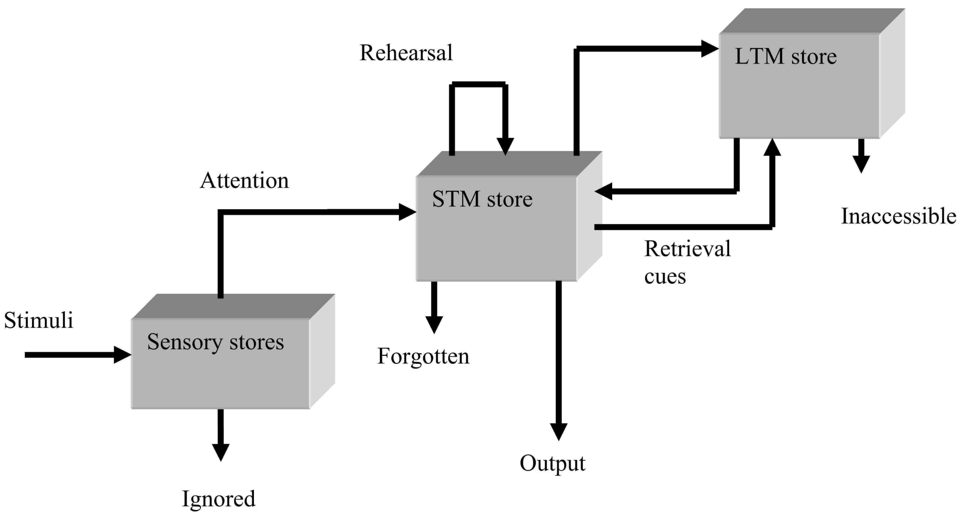

Figure 3.6 Modal model of memory.
Source: based on Atkinson and Shiffrin (1968)

storage systems, STM and LTM, which code information differently (see Figure 3.6).

In this model, external data goes into the sensory stores before entering the STM store. Selected information is transferred from the sensory memory stores to STM. Residual information is ignored and lost.

STM is a store of limited capacity and duration. It is sometimes known as 'working memory' because it has several functions such as rehearsal, coding, decision-making and retrieval. It has a capacity of approximately 5 to 9 bits of information. Some information may be chunked in larger bits, however, and therefore more can be stored and manipulated. The life of material in STM can be prolonged briefly by repetition (rehearsal) as in the repetition of a new telephone number until it is dialled. If the information is encoded (related to prior knowledge and placed in a schema) it can be transferred to LTM stores. Otherwise it will be forgotten.

The LTM is a store of enormous capacity and indefinite duration. Information held in LTM is encoded in schemata. The strength of a particular memory will depend upon the number of associations with similar schemata and the intensity of the memory as determined by vividness and emotional impact. If material has been weakly encoded or infrequently recalled, it may be in LTM but inaccessible.

Retrieval

A process of cueing enables memories to be retrieved from LTM. A memory may be triggered by many different cues such as mnemonics and the 'method of loci' where items in a list are recalled by associating them with particular places. This method is attributed to the ancient Greek poet Simonides, who remembered the names of those killed in a fire in a banqueting hall by memorizing where they had been sitting at dinner (Bruning et al. 2004: 70–4).

Although there are certain controlling processes such as encoding and rehearsal, the modal model is essentially passive with memory stores acting merely as storage locations. It is also sequential; information must first go through STM before being transferred to LTM. This cannot explain how, for example, the amnesiac K.F. (see above) was able to lay down new long-term memories despite the absence of short-term memory capability.

Working memory

Baddeley and Hitch (1974) proposed this more dynamic model of memory, which was further developed by Baddeley (1986, 2001). The working memory model consists of three parts: the central executive, the phonological loop and the visuo-spatial scratchpad (see Figure 3.7).

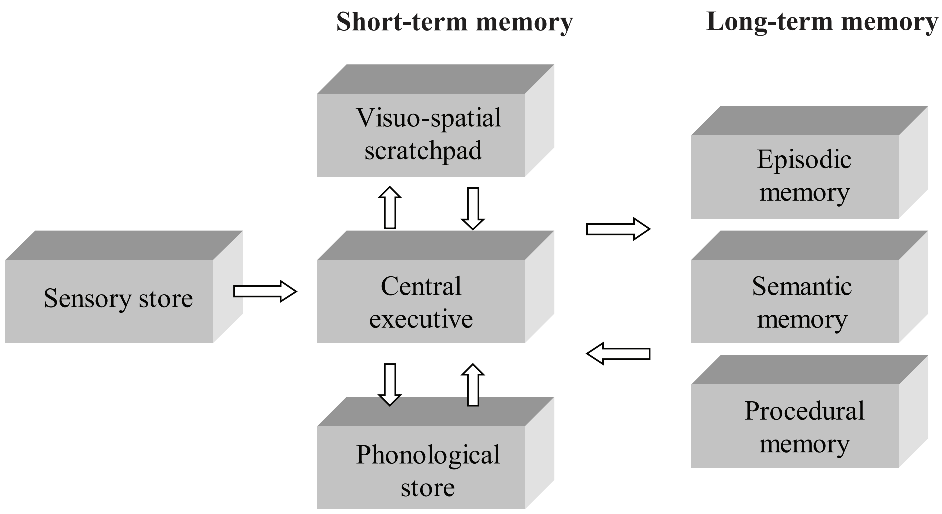

Figure 3.7 Working memory model.
Sourse: Based on Baddeley (1983).

The central executive controls what enters into STM and decides what processes will be undertaken (transfer to LTM, for example). The central executive also controls the other two components – the phonological or articulatory loop and the visuo-spatial scratchpad. Although under the overall control of the central executive, these two also have their own resources of attention and processing.

The phonological or articulatory loop is an auditory memory store that holds a limited amount of acoustic data for a brief period of a few seconds by means of rehearsal. Similarly, the visual-spatial scratchpad is a short-term store in which visual images can be examined and manipulated (for example, by rotation).

In terms of learning, this model suggests that it is important for learners to look back on what they have already done. In this way, associations can be made between new material arriving bottom-up from the environment and top-down material already stored in memory. For example, people sometimes experience a 'learning plateau' when they feel unable to learn new material. One explanation is that previous material has not yet become organized and encoded in memory so the new material has no suitable synaptic connections available to it. Consistent work to embed previous learning will help new learning.

Deep and surface processing model

Developed by Craik and Lockhart (1972), this is a qualitatively different approach from the models above. It is less interested in interacting subsystems than in the depth of information-processing and its implications for memory and recall. The model proposes that incoming information is processed at different levels. The strength of encoding will determine the duration of the memory. Mere repetition, for example, leads to shallow encoding resulting in short-lived memory. Deep encoding involves the generation of connections to previous knowledge and existing schemata and results in more permanent memories.

Although this is a plausible hypothesis, there is no clear description of the processes that enable shallow encoding to lay down short-term memories and deep encoding to lay down long-term memory. The definitions appear to be circular. Nevertheless, the notion of deep and surface processing has influenced areas of learning theory, and underpins the idea of deep and surface learning developed by Ferenc Marton and Roger Säljö (1976). According to Marton and Säljö, deep learners try to understand material by linking it to already known concepts; surface learners simply remember facts, which promotes neither understanding nor retention.

Associative network models

All three models above are to some extent based on an outdated computer model that emphasizes sequential steps and central control in information-processing. But brains are not computers. Brains are much slower than computers in processing individual signals. On the other hand, brains are very good at parallel processing, with many activities going on at once. In fact, contemporary supercomputers try to be brain-like by having parallel processors linked together.

The associative network model attempts to address the deficiencies of these earlier, computer-based models by representing knowledge as a web within which memory processes operate. The networks consist of:

- nodes – individual concepts;
- links – relations between the nodes;
- activation of the links.

This model claims that knowledge is not stored as separate units. Rather, what is stored is connection strength between different ideas in the network. When people search their memories, they stimulate particular nodes. This activates the links connected to those nodes, which activate other links and so on. Thus activation spreads from node to node. Memory strength in particular areas of knowledge means strong links between nodes. When a particular node is activated, it 'lights up' a whole array of associated nodes. Figure 3.8 is an example of an associative network of ideas.

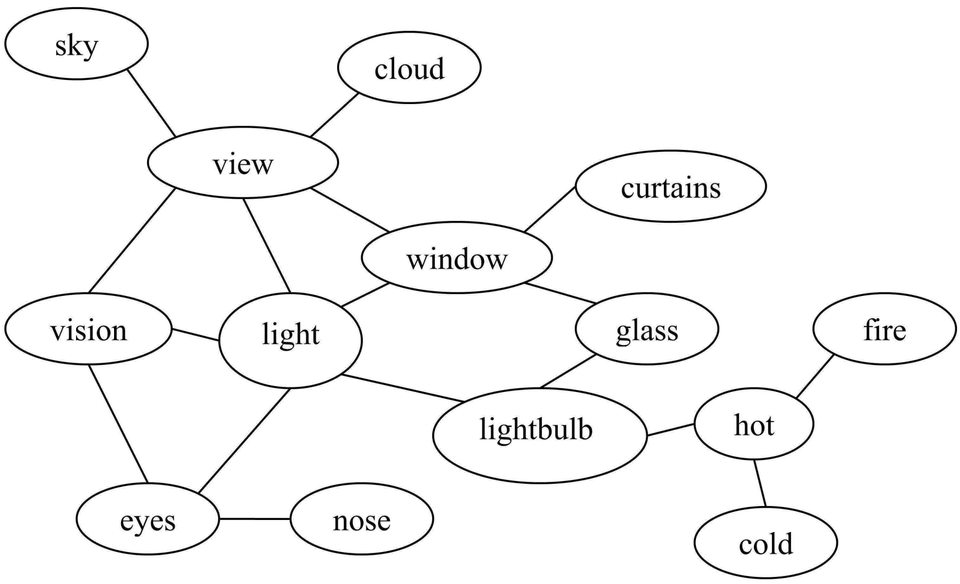

Figure 3.8 Associative network.

Practical implications of cognitivism for educators

Cognitivists maintain that learning involves developing effective ways of building schemata and processing information. Knowing how learners process information should be helpful in designing appropriate learning experiences. For cognitivists, the teacher is in control of the learning, although they also hold that people learn best when encouraged to discover information pertinent to their own needs. Thus, teachers should design material that stimulates learners' cognitive processes and encourages learners to make mental connections for themselves.

In this section, we outline some of the practical educational implications of cognitivism as they correspond to key stages in the cognitivist model of learning: sensation, perception, attention, encoding and memory.

Sensation

Teachers and instructional designers need to consider carefully the amount and type of information they present and the speed at which it is presented. Paivio (1986) argues that the mind processes visual and auditory material along different channels and in different ways for encoding, storage and later retrieval. In order to take account of processes of sensation teachers should:

- limit competing and distracting sensory impressions;
- use materials and draw on experiences that involve all the senses;
- present information in more than one sensory mode to facilitate dual encoding;
- direct the processing of sensory information.

Perception

Information-processing is both 'bottom up' and 'top down'. Top-down processing is perhaps the more important. In order to take account of processes of perception teachers should:

- arouse perceptual interest with strongly defined material;
- emphasize the distinctiveness of material in processing;
- point out patterns in materials;
- present material in a structured form – e.g. diagrams or stories;
- place learning in context and take contextual factors into account;
- review knowledge and assist learners to see relationships between old and new;
- explore attitudes and emotional responses to a topic and deal with any negativity.

Attention

A key concern for teachers is how to direct learners' attention when there are competing sensory impressions and memory.

One way that teachers can address the issue of engaging learners' attention is by means of Howard Gardner's work on multiple intelligences (MI) theory discussed in Chapter 7, 'Intelligence'. He suggested that 'any rich, nourishing topic – any concept worth teaching – can be approached in at least five different ways that will map onto the multiple intelligences' (Gardner 1991: 245). Gardner thinks of a topic as a room with several entry points that will engage the attention of different types of learners. These entry points and the means that teachers can use to access them include the:

Narrational	by means of a story;
Logical-quantitative	by deductive reasoning;
Foundational	by discussing underlying concepts;

Aesthetic	by appeal to artistic sensitivity;
Experiential	by some direct experience.

Attention is linked to learner motivation. Keller's ARCS motivational model proposes that motivation includes four categories – attention, relevance, confidence and satisfaction (Keller 1983; Keller and Kopp 1987).

In order to gain and maintain attention teachers should:

- arouse initial interest by novelty and departure from the expected;
- present the subject in an interesting way – e.g. presenting a problem;
- vary teaching methods with exercises and activities that maintain interest;
- promote active listening in lectures or presentations.

Short-term memory

Short-term memory (STM) is limited both in capacity and duration. In order to take account of these limitations on STM teachers should:

- limit the number of lists or items to be committed to memory at one time;
- be aware that learners remember first and last items on a list better than central ones;
- group items into 'chunks' with less than ten items to be memorized at one time;
- be conscious of interference between different types of information to be learnt;
- use repetition or maintenance rehearsal to retain information for a short period.

Working memory

The concept of working memory has replaced STM as a model for more active and non-serial processing of information. Encoding is the process of organizing material and making it meaningful so that it can eventually be placed in long-term memory.

In order to activate working memory teachers should:

- tell learners which information is most important;
- begin with an overview or outline of the material to be learnt;
- state the objectives or learning outcomes of a learning session;
- develop automaticity and speed of response in learners through regular practice;
- encourage learners to use the knowledge they already possess;
- encourage reflection and meta-cognition;
- link difficult-to-remember items to more meaningful ones;
- encourage visualization – use image representations;

- use verbal memory aids such as mnemonics;
- use mind-mapping techniques;
- use guided questioning to activate existing schemata and concepts;
- match encoding strategies with material to be learned;
- understand that learners may need to make schemata explicit and challenge their own assumptions;
- present content in increasing order of complexity;
- revisit topics to strengthen retention.

Long-term memory

Long-term memory (LTM) is the permanent repository of accumulated information. Retrieval requires cues that may be sensory, cognitive or emotional. Cues create associations that activate (LTM). For example, particular songs often arouse powerful memories. In order to promote recall teachers should:

- link materials to cues that can be used to recall them;
- remind learners that cues are sufficient to recall the material;
- encourage learners to create their own cues;
- teach revision techniques;
- encourage learners to discover and use their strengths and styles.

Key ideas

- Learning does not always involve a change in behaviour.
- Cognitivism focuses on internal mental learning processes.
- The key metaphor in cognitivism is the computer model.
- This model assumes discrete stages through which information is processed.
- Learners actively process, store and retrieve information for use.
- Learners organize and interpret information to create knowledge.

Conclusions

Cognitivism presents a scientific approach to learning and offers a coherent understanding of the processes involved. It presents theoretical support for teaching practices and suggests a range of useful teaching strategies that encourage learning.

However, it could be argued that its focus on learning as an individual mental event ignores social processes and embodiment. Its treatment of teaching as a technical-rational activity ignores the element of reflective practice and artistry involved.

Cognitivism can be seen as a progressive step towards an approach that combines cognitive processes with the element of individual and shared meaning-making that is constructivism. This is explored in the next chapter.