UNIT 4 MODELS OF INFORMATION PROCESSING

"Information is a source of learning. But unless it is organised, processed, and available to the right people in a format for decision making, it is a burden, not a benefit."

– William Pollard

Structure

4.0 INTRODUCTION

Cognition as a psychological area of study goes far beyond simply the taking in and retrieving information. Neisser (1967), one of the most influential researchers in cognition, defined it as the study of how people encode, structure, store, retrieve, use or otherwise learn knowledge. The information processing approach to human cognition remains very popular in the field of psychology.

Information processing is the change (processing) of information in any manner detectable by an observer. Within the field of cognitive psychology, information processing is an approach to the goal of understanding human thinking. It arose in the 1940s and 1950s. The essence of the approach is to see cognition as being essentially computational in nature, with *mind* being the *software* and the brain being the *hardware*.

One of the primary areas of cognition studied by researches is memory. By the 1960s research in memory had reached a high state of activity, and it was about this time that some formalised comprehensive theories of memory were beginning to be formulated. There are many hypotheses and suggestions as to how this integration occurs, and many new theories have built upon established beliefs in this area. Currently, there is widespread consensus on several aspects of information processing; however, there are many dissentions in reference to specifics on how the brain actually codes or manipulates information as it is stored in memory. This section considers a few of the more viable memory theories of that time.

4.1 OBJECTIVES

After reading this unit, you will be able to:

- define information processing approach;
- discussing the various models of information processing;
- explain levels of recall; and
- describe levels of processing.

4.2 WAUGH AND NORMAN'S MODEL OF PRIMARY AND SECONDARY MEMORY

The first modern behavioural model to travel down memory lane, and one whose concept of primary memory has served as a departure point for most modern theories, was developed by Waugh and Norman (1965). The theory is dualistic; *primary memory* (PM), a short-term storage system, is conceptualised as being independent of *secondary memory* (SM), a longer-term storage system. Waugh and Norman borrowed freely from William James's dichotomy of primary and secondary memory and illustrated their theory by means of the model shown in Figure below, which encouraged the memory metaphor of boxes in the head that soon proliferated in the literature of cognitive psychology.

What Waugh and Norman did that James never attempted was to quantify properties of primary memory. This short-term storage system was taken to have very limited capacity, so that loss of information from it was postulated to occur not as a simple function of time but (once the storage capacity was exhausted) by displacement of old items by new ones. PM could be conceptualised as a storage compartment much like a vertical file, in which information is stored in a slot or, if all the slots are filled, displaces an item occupying one of the slots.

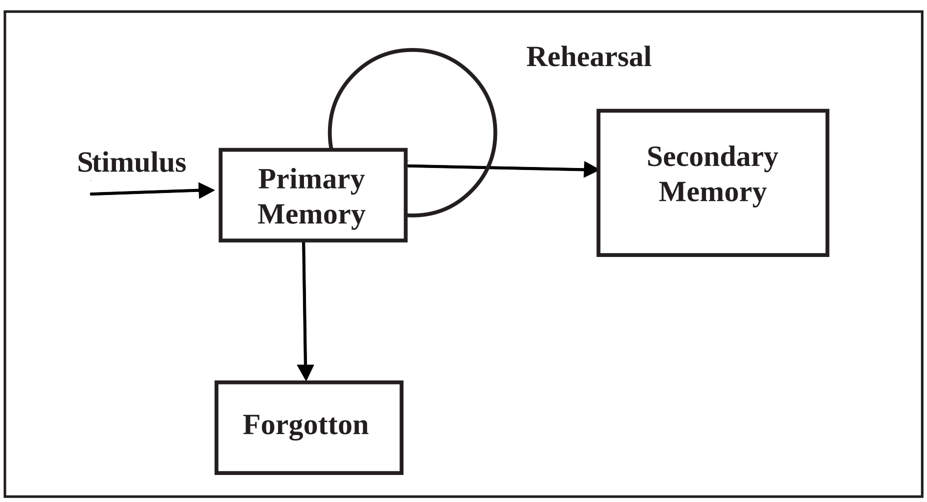

Fig. 1.4.1: Model of Primary and Secondary Memory (*Adapted from Waugh and Norman (1965)*

Waugh and Norman traced the fate of items in PM (primary memory) by using lists of sixteen digits, that were read to subjects at the rate of one digit per second or four digits per second. The purpose of presenting digits every second or quarter second was to determine whether forgetting was a function of decay (presumed to be due to time) or interference in PM.

If forgetting was a function of decay, then less recall could be expected with the slower rate (one digit per second); if forgetting was a function of interference in PM, then no difference in recall could be expected according to the presentation rate. The same amount of information is presented at both presentation rates, which, by Waugh and Norman's logic, allows the same time for decay to occur. It might be argued that even at one item per second, subjects would allow extra experimental information to enter their PM, but later experimentation (Norman, 1966) in which presentation rates varied from one to ten digits (for a given period), yielded data consistent with a rate of forgetting expected from the original model. The rate of forgetting for the two presentation rates is similar. Interference seems to be a greater factor than decay in forgetting in PM.

Waugh and Norman's system makes good sense. PM holds verbal information and is available for verbatim recall; this is true in our ordinary conversation. We can recall that last part of a sentence we have just heard with complete accuracy, even if we were barely paying attention to what was said. However, to recall the same information sometime later is impossible unless we rehearse it, which makes it available through SM.

4.3 ATKINSON AND SHIFFRIN'S THE STAGE MODEL

Traditionally, the most widely used model of information processing is the stage theory model, based on the work of Atkinson and Shiffrin (1968). The key elements of this model are that it views learning and memory as discontinuous and multi-staged. It is hypothesised that as new information is taken in, it is in some way manipulated before it is stored. The stage theory model, as shown in Figure 1.4.2, recognises three types or stages of memory: sensory memory, short-term or working memory, and long-term memory.

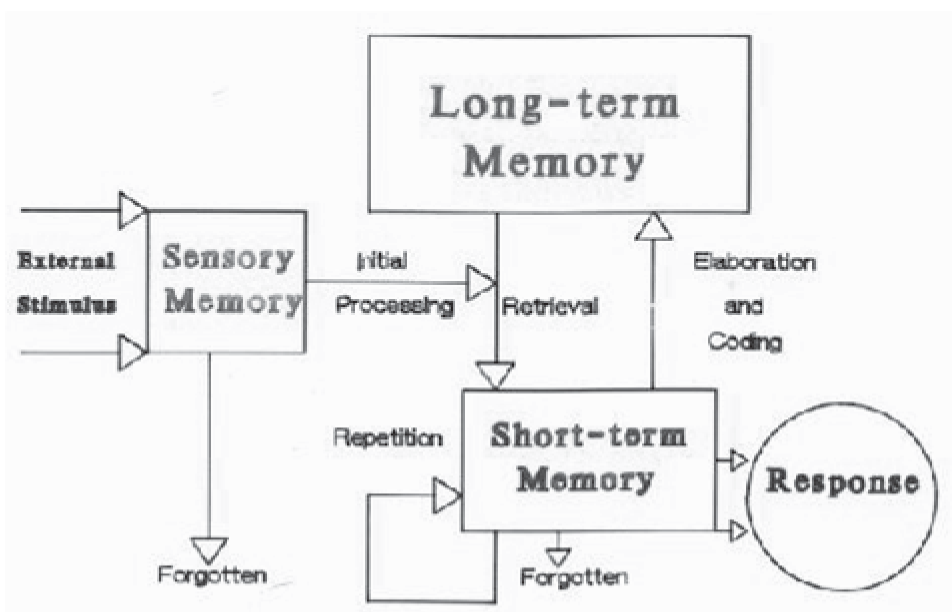

Fig. 1.4.2: A stage model of memory (*Adapted from Atkinson and Shiffrin 1969)*

In the Atkinson-Shiffrin model, memory starts with a sensory input from the environment. This input is held for a very brief time – several seconds at most – in a *sensory register* associated with the sensory channels (vision, hearing, touch, and so forth). This occurs in as little as ½ second for visual stimuli (Sperling, 1960), and about 4 or 5 seconds for auditory stimuli (Darwin et al., 1972). The transfer of new information quickly to the next stage of processing is of critical importance, and sensory memory acts as a portal for all information that is to become part of memory. There are many ways to ensure transfer and many methods for facilitating that transfer. To this end, attention and automaticity are the two major influences on sensory memory, and much work has been done to understand the impact of each on information processing.

Information that is attended to and recognised in the sensory register may be passed on to second stage of information processing, i.e. *short-term memory (STM)* or *working memory*, where it is held for perhaps 20 or 30 seconds. This stage is often viewed as active or conscious memory because it is the part of memory that is being actively processed while new information is being taken in. Some of the information reaching short-term memory is processed by being rehearsed – that is, by having attention focused on it, perhaps by being repeated over and over (maintenance rehearsal), or perhaps by being processed in some other way that will link it up with other information already stored in memory (elaborate rehearsal). Generally 5 + 2 number of units can be processed at any given time in STM.

Information that is rehearsed may then be passed along to *long-term memory (LTM*); information not so processed is lost. When items of information are placed in long-term memory, they are organised into categories, where they may reside for days, months, years, or for a lifetime. When you remember something, a representation of the item is withdrawn, or *retrieved*, from long-term memory.

Organisations of long-term memory - Each of the memory unit or structures represented in the mind is distinct and serves a different operational function. However, it is evident that some type of very specialised categorisation system exists within the human mind. One of the first to make this idea explicit was Bruner (as cited in Anderson, 1998). "Based upon the idea of categorisation, Bruner's theory states 'To perceive is to categorise, to conceptualise is to categorise, to learn is to form categories, to make decisions is to categorise'".

Tulving (1972) was the first to distinguish between *episodic* and *semantic* memory. "Episodic memories are those which give a subject the sense of remembering the actual situation, or event" (Eliasmith, 2001). Episodic memory's store is centered on personal experience and specific events. It is entirely circumstantial and it is not generally used for the processing of new information except as a sort of backdrop. *Semantic memory*, in contrast, deals with general, abstract information and can be recalled independently of how it was learned. It is semantic memory that is the central focus of most current study because it houses the concepts, strategies and other structures that are typically used for encoding new information. Most researchers now combine these two in a broader category labeled declarative.

Other researchers have identified additional organisational types. For example, Abbott lists *declarative* and *procedural* while Huitt (2000), citing the work of Paivio (1971, 1986) adds *imagery* to this list. However, Pylyshyn (2002) states that imagery is not a distinct organisational structure, but follows the rules that apply to semantic and episodic memory. Abbott (2002) and Huitt (2000) define *declarative memory* as that which can be talked about or verbalised. It is, then, the sum of stored information that can be readily retrieved and put into words in conscious thought and sharing. As previously stated, declarative memory can be subdivided into both semantic and episodic memories. *Procedural memory* can be thought of as "how to" knowledge (Huitt, 2000). It is the type of long-term memory sometimes associated with information that has reached a state of automaticity, but it not limited to this. This type of memory is defined in terms of learned skills and the ability to recall instruction-like memory. Paivio (1971, 1986) describes *imagery* as the memory structure for collecting and storing information related to pictures. It captures information much like a photograph and can be extremely useful for context and visual presentation of information.

Information Processing in Three Stage Model - Atkinson and Shiffrin make an important distinction between the concepts of memory and memory stores; they use the term *memory* to refer to the data being retained, while store refers to the structural component that contains the information. Simply indicating how long an item has been retained does not necessarily reveal where it is located in the structure of memory.

Information processing from one store to another is largely controlled by the subject. Information briefly held in the sensory register is scanned by the subject, and selected information is introduced into the STS. Transfer of information from the STS was regarded as capable of taking place so long as it was held there. Atkinson and Shiffrin postulated that information might enter the long-term store directly from the sensory register.

4.4 LEVEL OF RECALL

In a report by P. I. Zinchenko (1962, 1981), a Russian psychologist, the matter of how a subject interacts with the material to be learned and committed to memory was introduced. The basic notion was that words encoded by deep means would be retained in incidental memory better than if encoded by other, superficial means. Thus the memorability of words was profoundly influenced by the goal of the subject at the time the material was presented. Different goals were thought to activate different systems of connections because subjects have different orientations toward the material.

The thesis was tested in an experiment in which subjects were given ten series of four words. The first word was to be connected to one of the other words, but the instructions varied for each of three groups. An example of a series is *HOUSE—WINDOW—BUILDING—FISH.* In the first condition the subjects were asked to identify the word whose meaning was different from the first word *(HOUSE—FISH).* In a second condition subjects were asked to make a concrete connection between the first word and one of the other words *[HOUSE—WINDOW).* In the third condition the subjects were asked to make a "logical" connection between the first word and one of the other three words *[HOUSE—BUILDING]*.

Zinchenko thought that by altering the instructions the subjects would not only have different goals toward the material but also be required to examine each item for meaning. After a brief interrupting task, the subjects were asked to recall the items. In the condition in which subjects formed logical connections between the first word and another word, recall of the target word occurred with greater frequency than the other conditions. Recall of the concrete relationship words was greater than the no-meaning condition.

Thus the level of recall (LOR), as Zinchenko called it, is determined by the goal of an action. In the experiment cited, we can see that when subjects were given a learning set, or instructions to process material at different levels (to use contemporary jargon), recall of the material was affected greatly. Because the original paper was published in Russian and not widely distributed, it has not been incorporated into the larger framework of memory models. Nevertheless, as we shall see, the experiment presented by Zinchenko, because of its theoretical importance to the concept of levels of processing, which has had a profound influence on cognitive psychology, has important consequences for our conceptualisation of human memory.

4.5 LEVELS OF PROCESSING: CRAIK AND LOCKHART

It is likely that progress in the early stages of scientific development is made more by reaction and counterreaction than by the discovery of great immutable truths. Craik and Lockhart's (1972) *levels-of-processing (LOP) model*, as a reaction against the boxes-in-the-head scheme of memory, is consistent with that view. They take the position that data can be better described by a concept of memory based on levels of processing. The general idea is that incoming stimuli are subjected to a series of analyses starting with shallow sensory analysis and proceeding to deeper, more complex, abstract, and semantic analyses.

Whether a stimulus is processed at a shallow or deep stage depends on the nature of the stimulus and the time available for processing. An item processed at a deep level is less likely to be forgotten than one processed at a shallow level. At the earliest level, incoming stimuli are subjected to sensory and featural analyses; at a deeper level, the item may be recognised by means of pattern recognition and extraction of meaning; at a still deeper level, it may engage the subject's long-term associations.

With deeper processing a greater degree of semantic or cognitive analysis is undertaken. Consider word recognition, for example. At the preliminary stages, the visual configuration may be analysed according to such physical or sensory features as lines and angles. Later stages are concerned with matching the stimuli with stored information—for example, recognition that one of the letters corresponds to the pattern identified as *A*. At the highest level, the recognised pattern "may trigger associations, images or stories on the basis of the subject's past experience with the word" (Craik & Lockhart, 1972).

The significant issue, in Craik and Lockhart's view, is that we are capable of perceiving at meaningful levels *before* we analyse information at a more primitive level. Thus, levels of processing are more a "spread" of processing, with highly familiar, meaningful stimuli more likely to be processed at a deeper level than less meaningful stimuli.

That we can perceive at a deeper level before analysing at a shallow level casts grave doubts on the original levels-of-processing formulation. Perhaps we are dealing simply with different types of processing, with the types not following any constant sequence. If all types are equally accessible to the incoming stimulus, then the notion of levels could be replaced by a system that drops the notion of levels or depth but retains some of Craik and Lockhart's ideas about rehearsal and about the formation of memory traces.

A model that is closer to their original idea is shown in Figure 1.4.3. This figure depicts the memory activation involved in proofreading a passage as contrasted with that involved in reading the same passage for the gist of the material. Proofreading, that is, looking at the surface of the passage, involves elaborate shallow processing and minimal semantic processing.

Reading for gist, that is, trying to get the essential points, involves minimal shallow processing, or "maintenance rehearsal" (held in memory without elaboration), but elaborate semantic processing. Another example of this latter kind of memory activity would be a typist who concentrates on responding to letter sequences but has very little understanding of the material being typed.

As a result of some studies (Craik & Watkins, 1973; and Lockhart, Craik, & Jacoby, 1975), the idea that stimuli are always processed through an unvarying sequence of stages was abandoned, while the general principle that some sensory processing must precede semantic analysis was retained.

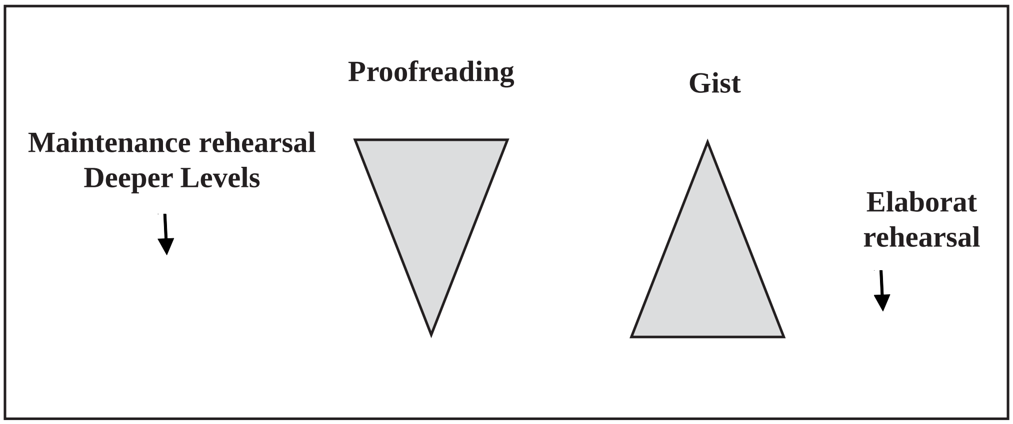

Fig. 1.4.3: Memory activation in two kind of reading. (Adapted from Solso, 2006)

Levels of Processing versus Information Processing. Information-processing models of memory have generally stressed structural components (for example, sensory store, STM, and LTM) dealing with processing (for example, attention, coding, rehearsal, transformation of information, and forgetting) as operations that are tied (sometimes uniquely) to the structural components. However, another approach is to postulate process and then to formulate a memory system in terms of these operations. Craik and Lockhart have taken just such a position, and their implicit criticism of the information processing model (along with Neisser, 1976) suggests that it is falling on hard times.

Where information-processing models of memory stress the sequence of stages through which information is moved and processed, this alternate viewpoint argues that memory traces are formed as a by -product of perceptual processing. Thus, the durability of memory is conceptualised as a function of the depth of processing. Information that is not given full attention and is analysed only to a shallow level is soon forgotten; information that is deeply processed—attended to, fully analysed and enriched by associations or images—is long lasting. The levels-of-processing model is not free of criticism (see Craik & Tulving, 1975; and Baddeley, 1978). The criticism includes that (1) it seems to say little more than that meaningful events are well remembered, a mundane conclusion; (2) it is vague and generally untestable; and (3) it is circular in that any events that are well remembered are designated "deeply processed," with no objective and independent index of depth available.

One clear difference between the boxes-in-the-head theory (Waugh and Norman, and Atkinson and Shiffrin) and the levels-of-processing theory (Craik and Lockhart) is their respective notions concerning rehearsal. In the former, rehearsal, or repetition, of information in STM serves the function of transferring it to a longer-lasting memory store; in the latter, rehearsal is conceptualised as either maintaining information at one level of analysis or elaborating information by processing it to a deeper level. The first type, maintenance rehearsal, will not lead to better retention.

Craik and Tulving (1975) tested the idea that words that are deeply processed should be recalled better than those that are less so. They did this by having subjects simply rate words as to their structural, phonemic, or semantic aspects. Craik and Tulving measured both the time to make a decision and recognition of the rated words. The data obtained are interpreted as showing that (1) deeper processing takes longer to accomplish and (2) recognition of encoded words increases as a function of the level to which they are processed, with those words engaging semantic aspects better recognised than those engaging only the phonological or structural aspects. Using slightly different tasks, D'Agostino, O'Neill, and Paivio (1977); Klein and Saltz (1976); and Schulman (1974) obtained similar results.

4.6 SELF REFERENCE EFFECT

New light was shed on the levels-of-processing concept when Rogers, Kuiper, and Kirker [1977) showed that self-reference is a powerful method variable. Using a method similar to that of Craik and Tulving (1975), they asked subjects to evaluate a list of forty adjectives on one of four tasks hypothesised to vary in depth, or semantic richness. Included were structural, phonemic, semantic, and self-reference tasks.

As in the Craik and Tulving study, it was assumed that words more deeply coded during rating should be recalled better than those words with shallow coding. After the subjects rated the words, they were asked to free-recall as many of the words they had rated as possible. Recall was poorest for words rated structurally and ascended through those phonemically rated and semantically rated. Self-reference words were recalled best.

The Narcissistic Trait Modifications of the original experiment have been conducted in several laboratories with the results being about the same. Some have argued that self-reference tasks are stored in some special memory system.

Certainly, if you are asked to evaluate a personality trait as being self-descriptive, such as greedy, loving, or angry, you are engaging a very powerful self-schema, an organised system of internal attributes that is constellated around the topic of "I, me, mine." We also call this the narcissistic trait. Since we all know a great deal about ourselves (and are emotionally, if not intellectually, deeply invested in ourselves) we have a rich and elaborate internal network available for storing self-information. Because of these complex internal self structures we can more easily organise new information as it might refer to ourselves than other, more mundane information (see Bellezza 1992 for several important studies on this theme). Whether or not these self-rating memories are stored in different parts of the brain remains a question, but it is a good hunch that plenty of precious brain space is given over to the narcissistic trait.

4.7 A CONNECTIONIST (PARALLEL DISTRIBUTED PROCESSING) MODEL OF MEMORY: RUMELHART AND MCCLELLAND

Many people have been associated with this model of human cognition, but David Rumelhart and James McClelland have done the most to formalise the theory.

Essentially, the model is neutrally inspired, concerned with the kind of processing mechanism that is the human mind. Is it a type of von Neumann computer – a Johniac – in which information is processed in sequential steps? Alternatively, might the human mind process information in a massively distributed, mutually interactive parallel system in which various activities are carried out simultaneously through excitation and/or inhibition of neural cells? PDPers opt for latter explanation.

“These [PDP] models assume that information processing takes place through the interactions of a large number of simple processing elements called units, each sending excitatory and inhibitory signals to other units” (McClelland, Rumelhart, & Hinton, 1986). These units may stand for possible guesses about letters in a string of words or notes on a score. In other situations, the units may stand for possible goals and actions, such as reading a particular letter or playing a specific note. Proponents suggest that PDP models are concerned with the description of the internal structure of larger units of cognitive activity, such as reading, perceiving, processing sentences, and so on.

The connectionist (or PDP) model attempts to describe memory from the even finer-grained analysis of processing units, which resemble neurons. Furthermore, the connectionist model is based on the development of laws that govern the representation of knowledge in memory. One additional feature of the PDP model of memory is that it is not just a model of memory; it is also a model for action and the representation of knowledge.

A fundamental assumption of the PDP model is that mental processes take place through a system of highly interconnected units, which take on activation values and communicate with other units. Units are simple processing elements that stand for possible hypotheses about the nature of things, such as letters in a display, the rules that govern syntax, and goals or actions (for example, the goal of typing a letter on a key board or playing a note on the piano). Units can be compared to atoms, in that both are building blocks for more complete structures and combine with others of their kind to form larger networks. A neuron in the brain is a type of unit that combines with other neurons in a parallel processing mode to form larger systems.

Units are organised into modules, much as atoms are organised into molecules. The number of units per module range from thousands to millions. Each unit receives information from other modules and, after processing, passes information to other modules. In this model, information is received, is permeated throughout the model, and leaves traces behind when it has passed through. These traces change in the strength (sometimes called weight) of the connections between individual units in the model.

A memory trace, such as a friend's name, may be distributed over many different connections. The storage of information (for example, friend's name) is thought to be content addressable—that is, we can access the information in memory on the basis of its attributes. You can recall your friend's name if I show you a picture of him, tell you where he lives, or describe what he does. All of these attributes may be used to access the name in memory. Of course, some cues are better than others.

Even though the theory is abstract, it touches real-life activities. To continue with the example of your friend's name, suppose I ask, "What is the name of the man you play tennis with?" Such an inquiry gives at least two content-addressable cues: man and tennis partner. If you play tennis with only one man (and you know his name), then the answer should be easy. If you have many partners who are men, then the answer may be impossible.

Additional information (for example, the man with the beard, the left handed player, the guy with red tennis shorts, the dude with the rocketlike serve, the chap with the Boston terrier, and so forth) may easily focus the search. You can imagine how very narrow the search would be if all of these attributes were associated with only one person: the man you play tennis with has a beard, is left-handed, wears red tennis shorts, has a hot serve, and has a terrier.

In real life, each of these attributes may be associated with more than one person. You may know several people who have a hot serve or have a beard. If that is the case, it is possible to recall names other than the intended one. However, if the categories are specific and mutually exclusive, retrieval is likely to be accurate. How can a PDP modular concept of memory keep these interfering components from running into each other?

According to this model, information is represented in memory in terms of numerous connections with other units. If an attribute is part of a number of different memories and is activated (for example. What was your friend's name ...?), then it will tend to excite all the memories in which the attribute is a part. One way interfering components are kept from overrunning the system is to conceptualise the relationship between units as being subject to inhibitory laws. Thus, when we identify the person you play tennis with as a man, in theory we inhibit all searches for people who are women. When we add that he has a Boston terrier, then we do not search for the names of people with whom you do not play tennis and who do not own a Boston terrier.

Consider the following example of prototype learning, suggested by McClelland and Rumelhart (1986). A small boy sees many different dogs, each only once and each with a different name. All the dogs have slightly different features but can be considered a variation of the prototype dog, the epitome of "dogness." The boy forms a memory for a prototypical dog on the basis of experience with exemplar dogs. As in the case of faces, the boy is likely to recognise the prototype dog as a dog, even if he has never seen it. Of course, the boy is not likely to remember the names of each of the individual dogs, though the most recently seen dog may still be in memory.

The rationale offered by the connectionist model for prototype formation in the case of the boy and his (prototype) dog is that each time the boy sees a dog, a visual pattern of activation is produced over several of the units in the module. In contrast, the name of the dog produces a reduced pattern of activation. The combined activation of all exemplar dogs sums to the prototype dog, which may be the stable memory representation. Thus, the model, more detailed than presented here, seems to account for this form of memory quite nicely.

The connectionist model of memory has won many disciples in the past few years. Its popularity is due in part to its elegant mathematical models, its relationship to neural networks, and its flexibility in accounting for diverse forms of memories.

4.8 LET US SUM UP

In summary, there are many different theories and models of information processing that focus on different aspects of perceiving, remembering, and reasoning. There are many constant themes of information processing regardless of the specific theory to which one subscribes. Almost all ideas related to how information becomes stored in memory agree that the learner more deeply and meaningfully processes information that is presented in a context-rich manner. One of the most important agreements is that elaboration is a key to permanently storing information in a way that facilitates its quick retrieval when it is needed. Most theories hold that the mind contains some type of framework into which new information is placed. This structure is multi-leveled and has varying degrees of specificity. New information can be matched with, compared to, contrasted to, joined with, or modified to fit with existing structures. The formation of and continual building of these structures, then, is critical in order to process information. This in-place structural system allows for differing levels of complexity of information processing.

4.9 UNIT END QUESTIONS

1) Describe the Attkinson-Shiffrin model of information processing in detail.
2) Compare information processing and level of processing models of memory.
3) How does a connectionist (PDP) model handle memory?
4) What is meant by level of recall, level of processing, and self-refrence effect?
5) What are the basic principles and models of information processing?
6) How does organisation in long-term memory take place?
7) Design an experiment to compare the maintenance (shallow) and elaborate level of information processing

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