UNIT 1 COGNITIVE PSYCHOLOGY

"Mind and world … have evolved together, and in consequence are something of a mutual fit".

– William James

Structure

1.0 INTRODUCTION

Cognitive psychology is the study of mental processes such as perceiving, remembering, and reasoning. Why do psychologists study mental processes? Since the beginning of recorded history, people have expressed curiosity about the operation of the mind, largely because they believed that behaviour is the result of mental processes. For example, how are we to understand the very behaviour in which you are engaged at this moment, reading this course book? At one level, we are interested in explaining your ability to comprehend what you are reading, and in so doing, we are likely to appeal to processes of perception of words and computation of meaning. At another level, we might explain your motivation for reading in terms of your goal to complete this course, which in turn is motivated by your goal of obtaining a degree in order to follow some plan that you have for a career. The point is that your behaviour of reading this book is determined in part by your intent to meet some goal and fulfill some plan. Intentionality, goals, and plans are mental phenomena that affect behaviour. Further, the specific behaviour, in this case, reading, is understood by appeal to the specific mental processes involved in perception and comprehension of text. In short, the study of mental processes is important because these processes are responsible for much of our behaviours. In this unit you will be studying the definition and description of cognitive psychology, distinctive research methods, domains of cognitive psychology, metaphor of cognition etc.

1.1 OBJECTIVES

After reading this unit, you will be able to:

- Field of cognitive psychology;
- Provide a foundation on which to build an understanding of the topics in cognitive psychology;
- Describes some of the intellectual history of the study of human thinking; and
- Emphasises some of the issues and concerns that arise when we think about how people think.

1.2 COGNITIVE PSYCHOLOGY: AN INTRODUCTION

Cognitive psychology is the study of how people perceive, learn, remember, and think about information. A cognitive psychologist might study how people perceive various shapes, why they remember some facts but forget others, or how they learn language. Consider some examples of everyday experiences that are also of theoretical interest to cognitive psychologists:

How many times have you carefully proofread written work, only to be embarrassed later by an obvious error you overlooked?

Many times what we see is determined as much by the context in which it occurs as by what is actually there, an issue of pattern recognition.

Have you noticed the difficulty of simultaneously taking notes in class and understanding a lecture?

Explanations of this kind of difficulties are found in the discussion of attention.

When you dial the telephone directory assistance for a telephone number and do not have a pen to note it down, why do you have to repeat the number until you have dialed it? And why you have to make your call again to enquire the number if someone talks to you before you dial the number?

These are problems associated with the short term memory.

Do you remember the experience of working on a problem or a puzzle that you were unable to solve, but after taking a break from the problem, you subsequently obtained a solution?

This phenomenon, known as incubation effect, along with other commonly experienced events is an aspect of problem solving.

Why do objects look farther away on foggy days than they really are? This discrepancy of perception can be dangerous, even deceiving drivers into having accidents.

These are just a few of the many examples of everyday experiences which are discussed and explored by the experiments and theory of cognitive psychology.

Two points about these examples should be considered as we attempt to gain an overview of cognitive psychology.

1) All represent instances of difficulty or failure of mental processes. We rarely think of them unless they fail to work. Failure of mental processes are immediately noticed because they can be frustrating, embarrassing, and sometimes even dangerous and, consequently, such failures become useful tools for the psychological analysis of mental phenomena.

2) Cognitive psychology is interested in what is generally called mental phenomena. In this sense, the examples just discussed are consistent with the dictionary definition of cognitive psychology: "the scientific study of the mind".

While it is hoped that examples help clarify the definition, questions undoubtedly remain concerning how one goes about this 'scientific study of mind'. To address these questions, here's a brief discussion of the scientific methods, followed by an extensive description of the important historical events leading up to modern cognitive psychology.

Next is a brief overview of the major methods, issues, and content areas of cognitive psychology.

1.3 RESEARCH METHODS IN COGNITIVE PSYCHOLOGY

This consists of the various research methods that we use in cognitive psychology. Every research has a goal and it is achieved through appropriate methodology. Let us see what are the goals of research.

1.3.1 Goals of Research

To better understand the specific methods used by cognitive psychologists, one must grasp the goals of research in cognitive psychology. Briefly, those goals include data gathering, data analysis, theory development, hypothesis formulation, hypothesis testing, and perhaps even application to settings outside the research environment. However, most cognitive psychologists want to understand more than cognition. They also seek to understand the *how* and the *why* of thinking. That is, researchers seek ways to explain cognition as well as describe it. To move beyond descriptions, cognitive psychologists must leap from what is observed directly to what can be inferred regarding observations.

1.3.2 Distinctive Research Methods

Cognitive psychologists use various methods to explore how humans think. These methods include (i) laboratory or other controlled experiments, (ii) psychobiological research, (iii) self-reports, case studies, naturalistic observation, and (iv) computer simulations and artificial intelligence. Each method offers distinctive advantages and disadvantages.

i) ***Experiments on Human Behaviour:*** In controlled experimental designs, an experimenter conducts research, typically in a laboratory setting. The experimenter controls as many aspects of the experimental situation as possible. There are basically two kinds of variables in any given experiment – *independent variables* and *dependent variables*. The irrelevant variables are held constant and are called control variables. In implementing experimental method, the experimenter must use a representative and random sample of the population of interest. S/he must also exert rigorous control over the experimental conditions. If those requisites for the experimental method are fulfilled, the experimenter may be able to infer probable causality. This influence is of the effects of the independent variable (the treatment) on the dependent variable (the outcome) for the given population.

ii) ***Psychobiological Research:*** Through *psychobiological research*, investigators study the relationship between cognitive performance and cerebral events and situations. The various specific techniques used in the psychobiological research generally fall into three categories. The first category is that of techniques for studying an individual's brain *post-mortem*, relating the individual's cognitive function prior to death to observable features of the brain. The second category is techniques for studying images showing structures of or activities in the brain of an individual who is known to have a particular cognitive deficit. The third is techniques for obtaining information about cerebral processes during the normal performance of a cognitive activity (e.g. by using brain imaging techniques).

iii) ***Self-Reports, Case Studies, and Naturalistic Observation:*** Individual experiments and psychobiological studies often focus on precise specification of discrete aspects of cognition across individuals. To obtain richly textured information about how particular individuals think in a broad range of contexts, researchers may use *self-reports* (an individual's own account of cognitive processes), *case studies* (in-depth studies of individuals), and *naturalistic observation* (detailed studies of cognitive performance in everyday situations and no laboratory contexts). On the one hand, experimental research is most useful for testing hypotheses. On the other hand, research based on qualitative methods is often particularly useful for the formulation of hypotheses. These methods are also useful to generate descriptions of rare events or processes that we have no other way to measure.

iv) ***Computer Simulations and Artificial Intelligence:*** Digital computers played a fundamental role in the emergence of the study of cognitive psychology. One kind of influence is indirect though models of human cognition based on models of how computers process information. Another kind is direct, that is through computer simulations and artificial intelligence. In computer simulations, researchers program computers to imitate a given human function or process. Some researchers even have attempted to create computer models of the entire cognitive architecture of the human mind. Their models have stimulated heated discussions regarding how the human mind may function as a whole. Sometimes the distinction between simulation and artificial intelligence is blurred. It is also possible to combine the two approaches.

Cognitive psychologists often broaden and deepen their understanding of cognition through research in cognitive science. Cognitive science is a cross-disciplinary field that uses ideas and methods from cognitive psychology, psychobiology, artificial intelligence, philosophy, linguistics, and anthropology. Cognitive psychologists use these ideas and methods to focus on the study of how humans acquire and use knowledge. They also work in collaboration with other psychologists, such as social psychologists (in the field of social cognition), psychologists who study motivation and emotion, and engineering psychologists (who study human-machine interactions).

1.4 DOMAINS OF COGNITIVE PSYCHOLOGY

Modern cognitive psychology freely, draws theories and techniques; from twelve principal areas of research (see Figure 1.1). Each area, in brief, is described below:

i) ***Cognitive Neuroscience:*** Only within the past few years have cognitive psychologists and cognitive neuroscientists formed a close working relationship. Thus far, this union has produced some of the most provocative developments in the study of our mental character. Cognitive psychologists are seeking neurological explanations for their findings, and neuroscientists are turning to cognitive psychologists to explain observations made in their laboratories. Every part of the cognitive process from sensation to memory is supported by basic electrochemical processes taking place in the brain and nervous system.

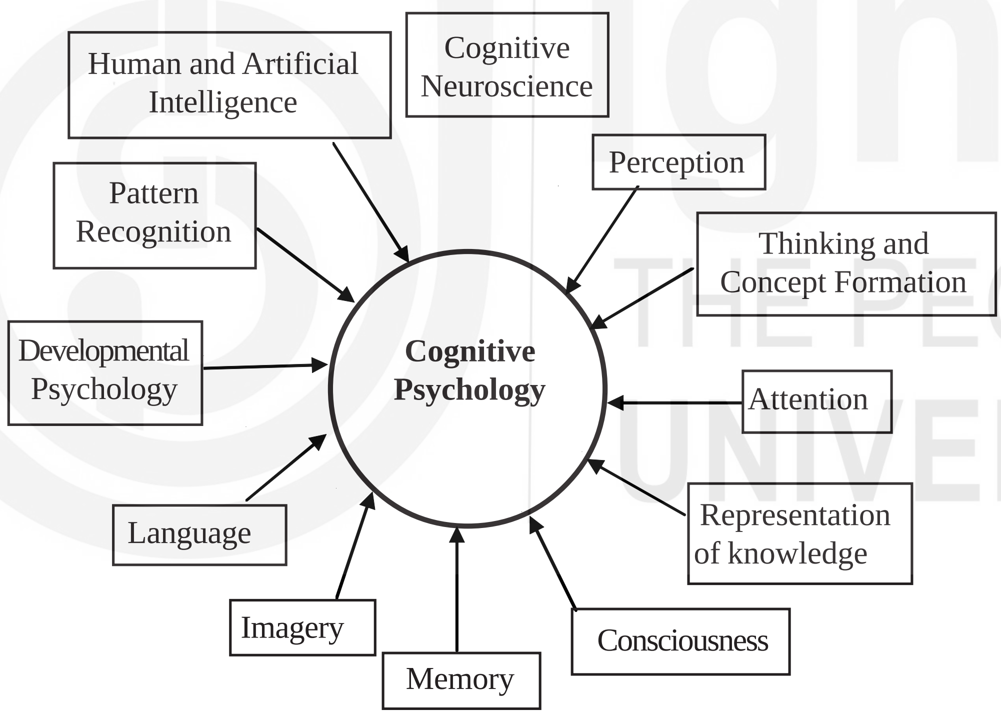

Fig. 1.1: Principal research areas of cognitive psychology

ii) ***Perception:*** The branch of psychology directly involved with the detection and interpretation of sensory stimuli is perception. From experiments in perception, we have a good understanding of the sensitivity of the human organism to sensory signals and more important to cognitive psychology of the way we interpret sensory signals. The experimental study of perception has helped identify many of the parts of this process. However, the study of perception alone does not adequately account for the expected performance; other cognitive systems are involved, including pattern recognition, attention, consciousness, and memory.

iii) ***Pattern Recognition:*** Environmental stimuli rarely are perceived as single sensory events; they usually are perceived as part of a more meaningful pattern. The things we sense – see, hear, feel, taste, or smell—are almost always part of a complex pattern of sensory stimuli. Think about the problem of reading. Reading is a complex effort in which the reader is required to form a meaningful pattern from an otherwise meaningless array of lines and curves. By organising the stimuli that make up letters and words, the reader may then access meaning from his or her memory. The entire process takes place in a fraction of a second, and considering all the neuroanatomical and cognitive systems involved, this feat – performed daily by all sorts of people – is wondrous.

iv) ***Attention:*** Although we are information-gathering creatures, it is evident that under normal circumstances we are also highly selective in the amount and type of information to which we attend. Our capacity to process information seems to be limited to two levels – sensory and cognitive. If too many sensory clues are imposed upon us at any given time, we can become overloaded; if we try to process too many events in memory, we can become overloaded, which may cause a breakdown in performance. All of us have felt the same way at one time or another.

v) ***Consciousness:*** Consciousness is defined as "the current awareness, of external or internal circumstances." Rejected as being "unscientific" by the behaviourists, the word *consciousness* and the concept it represents simply did not fade away. For most people, consciousness and unconscious thoughts (such as you might have on a first date) are very real. For example, when you glance at your watch while studying and it reads "10:42 (P.M.)," you are conscious, or, aware, of that external signal. However, your reading of the time also brings up another conscious thought, one that was initially activated by reading the time but is from "inside." That conscious thought might be, "It's getting late: I'd better finish this chapter and go to bed". Consciousness has gained new respectability recently and now is a concept studied seriously in modern cognitive psychology.

vi) ***Memory:*** Memory and perception work together. The information available to us comes from our perception, short-term memory, and long-term memory. Most obvious long-term storage is the knowledge of the language. We draw words from LTM and more or less use them correctly. In a fleeting second, we are able to recall information about an event of years before. Such information does not come from an immediate perceptual experience; it is stored along with a vast number of other facts in the LTM.

vii) ***Representation of Knowledge:*** Fundamental of all human cognition is the representation of knowledge: how information is symbolised and combined with the things stored in the brain. This part of cognition has two aspects: the conceptual representation of knowledge in mind and the way the brain stores and process information. The conceptual representation in different individuals can be considerably different. In spite of these inherent dissimilarities between representations of knowledge, most humans do experience and depict experience in similar enough ways to get along well in the world. The content of this information is also hugely different. But our neurological web entraps information and experiences and holds them in structures that are similar in all human brains.

viii) ***Imagery:*** Cognitive psychologists are especially interested in the topic of internal representations of knowledge. The mental images of the environment are formed in the form of a *cognitive map*, a type of internal representation of the juxtaposed buildings, streets, street signs, spotlights, and so on. From the cognitive maps, we are able to draw out significant cues. Although the experimental study of mental imagery is relatively new to psychology, some significant research has recently been reported.

ix) ***Language:*** One form of knowledge shared by all human societies is the knowledge of language. Language is the principal means by which we acquire and express knowledge; thus, the study of how language is used is a central concern of cognitive psychology. Human language development represents a unique kind of abstraction, which is basic to cognition. Language processing is an important component of information processing and storage. Language also influences perception, a fundamental aspect of cognition.

x) ***Developmental Psychology:*** Developmental psychology is another important area of cognitive psychology that has been intensely studied. Recent studies and theories in developmental cognitive psychology have greatly expanded our understanding of how cognitive structures develop. As adults, we have all lived through childhood and adolescence and we share maturational experiences with all members of our species.

xi) ***Thinking and Concept Formation:*** Thinking is the crown jewel of cognition. Thinking is the process by which a new mental representation is formed through the transformation of information. Advances in cognitive psychology have led to a formidable arsenal of research techniques and theoretical models. An ability to think and form concepts is an important aspect of cognition. Similar concepts help in the understanding and processing of information. There is a considerable body of knowledge about the laws and processes of concept formation.

xii) ***Human and Artificial Intelligence:*** Human intelligence includes the ability to acquire, recall, and use knowledge to understand concrete and abstract concepts and the relationships among objects and ideas, to understand a language, to follow instructions, to convert verbal descriptions into actions, and to behave according to the rules, and to use knowledge in a meaningful way.

The specialty within the computer science called artificial intelligence has had a major influence on the development of cognitive science, especially since the design of programs requires knowledge of how we process information. Cognitive psychology also addresses to find out whether a perfect robot can simulate human behaviour.

1.5 A BRIEF HISTORY OF COGNITIVE PSYCHOLOGY

As we have learned, a great portion of cognitive psychology deals with how knowledge is represented in the mind. In this section on the history of cognitive psychology we will review three major periods (for a detailed history see Solso & MacLin, 2000; Wilson & Keil, 1999). First, we will deal with traditional ideas from a very early period. Then we touch on the way knowledge and thinking was conceptualised by Renaissance scholars. Finally, we will deal with the modern period with emphasis on current ideas and methods.

1.5.1 Early Thoughts on Thinking

Where did knowledge come from, and how is it represented in the mind? That eternal question is fundamental to cognitive psychology as it has been through the ages of humankind. Basically, two answers have been proposed. The *empiricists* maintain that knowledge comes from experience, and the *nativists* suggest that knowledge is based on innate characteristics of the brain. From a scientific perspective, neither case can be definitively proved, so the argument continues without clear resolution. With these issues clearly before us, let's consider the way ancient philosophers and early psychologists grappled with the issue. The fascination with knowledge can be traced to the earliest writings. Early theories were concerned with the seat of thought and memory. Ancient Egyptian hieroglyphics suggest their authors believed that knowledge was localised in the heart—a view shared by the early Greek philosopher Aristotle but not by Plato, who held that the brain was the locus of knowledge.

1.5.2 Cognition in the Renaissance and Beyond

Renaissance philosophers and theologians seemed generally satisfied that knowledge was located in the brain. They considered that knowledge was acquired not only through the physical senses (*mundus sensibilis* – touch, taste, smell, vision, and hearing) but also from divine sources *(mundus intellectualis—Deus)*.

During the eighteenth century, when philosophic psychology was brought to the point where , scientific psychology could assume a role, the British empiricists, George Berkeley, David Hume, and, later, James Mill and his son John Stuart Mill suggested that internal representation is of three types: (1) direct sensory events, (2) faint copies of percepts, or those that are stored in memory; and (3) transformation of these faint copies, as in associated thought. These notions are the basis of much current research in cognitive psychology.

During the nineteenth century, the early psychologists like Gustav Fechner, Franz Brentano, Hermann Helmholtz, Wilhelm Wundt, G; E. Muller, Oswald Kulpe, Hermann Ebbinghaus, Sir Francis Galton, Edward Titchener, and William James and others started to break away from philosophy to form a discipline based on empirical results rather than on speculation. By the last half of the nineteenth century, theories of the representation of knowledge were clearly dichotomous: that emphasised the structure of mental representation (Wundt, Titchner); and the processes or acts (Brentano).

About the same time in America, James critically analysed the new psychology that was developing in Germany. He established the first' psychological laboratory in America, wrote the definitive work in psychology in 1890 *(Principles of Psychology)*, and developed a well-reasoned model of the mind. Perhaps James's most direct link with modem cognitive psychology is in his view of memory, in which both structure and process play an important role. F. C. Donders and James Cattell, contemporaries of James's, performed experiments using the perception of brief visual displays as a means of determining the time required for mental operations. The technique, subject matter, procedures, and even the interpretation of results of these early scientists seem to have anticipated the emergence of the cognitive psychology a half-century later.

1.5.3 Cognitive Psychology in Early Twentieth Century

The representation of knowledge took a radical turn with the advent of twentieth-century behaviourism and Gestalt psychology. The behaviourist views of human and animal psychology were cast in a framework of stimulus-response (S-R) psychology, and Gestalt theorists built elaborate conceptualisations of internal representation within the context of isomorphism – one-to-one relationship between representation and reality.

Psychological studies of mental processes as conceptualised in the late nineteenth century suddenly became unfashionable, displaced by behaviourism. Studies of internal mental operations and structures such as attention, consciousness, memory, and thinking were laid to rest and remained so for about fifty years. To the behaviourists, internal states were subsumed under the label of "intervening variable," that mediated the effects of stimuli on responses and were neglected in favor of making observations on behaviour rather than on the mental processes.

In 1932, some years before the cognitive revolution swept across psychology, learning psychologist Edward Tolman from the University of California at Berkeley published *Purposive Behavior in Animals and Men.* In this seminal work, Tolman observed that what rats learn in a maze is the layout of the land rather than simply a series of S-R connections. The animal, according to Tolman's interpretation, gradually developed a "picture" of his environment that was later used to find the goal. This picture was called a cognitive map. Tolman's postulate about cognitive maps in animals did anticipate the contemporary preoccupation with how knowledge is represented in a cognitive structure.

Also in 1932 Sir Frederick Bartlett from Cambridge University wrote *Remembering* in which he rejected the then popular view that memory and forgetting can be studied by means of nonsense syllables, as had been advocated by Ebbinghaus in Germany during the previous century. In the study of human memory, Bartlett argued, the use of rich and meaningful material under naturalistic conditions would yield far more significant conclusions. Bartlett introduced the concept of schema as a unifying theme that describes the essence of an experience. Schema theory plays a central role in modern theories of memory. The fecund ideas of Tolman in America and Bartlett in England highly influenced the thinking of future cognitive psychologists.

1.5.4 Cognitive Psychology—As it is Today

In the 1950s interest again began to focus on attention, memory, pattern recognition, images, semantic organisation, language processes, thinking, and even consciousness (the most dogmatically eschewed concept), as well as other "cognitive" topics once considered outside the boundary of experimental psychology (vis-à-vis.behaviourism). New journals and professional groups were founded as psychologists began more and more to turn to cognitive psychology. As cognitive psychology became established with even greater clarity, it was plain that this was a brand of psychology different from that in vogue during the 1930s and 1940s. Among the most important forces accounting for this neocognitive revolution were the following:

The "failure" of behaviourism. Behaviorism, which generally studied overt responses to stimuli, failed to account for the diversity of human behaviour as in the case of language. Furthermore, there were some topics ignored by the behaviourists that seemed to be profoundly related to human psychology. These included memory, attention, consciousness, thinking, and imagery. It was apparent that internal mental processes were very real parts of psychology and required investigation.

The emergence of communication theory. Communication theory prompted experiments in signal detection, attention, cybernetics, and information theory – areas of significance to cognitive psychology.

Modem linguistics. New ways of viewing language and grammatical structure became incorporated into attitudes concerning cognitions.

Memory research. Research in verbal learning and semantic organisation provided a sturdy empirical base for theories of memory, which led to the development of models of memory systems and the appearance of testable models of other cognitive processes.

Computer science and other technological advances. Computer science, and especially a subdivision of it—artificial intelligence—caused reexamination of basic postulates of problem solving and memory processing and storage, as well as of 'language processing and acquisition. Research capabilities were greatly expanded by new experimental devices.

Cognitive development. Psychologists interested in development psychology discovered an orderly unfolding of abilities with maturation. Notable among developmental psychologists during this period was Jean Piaget, who described how children develop an appreciation for concepts from infancy to adolescence. Such progress of abilities seems to be natural.

From the earliest concepts of representational knowledge to recent research, knowledge has been thought to rely heavily on sensory inputs. That theme runs from the Greek philosophers, through Renaissance scholars, to contemporary cognitive psychologists. But are internal representations of the world identical to the physical properties of the world? Evidence is increasing that many internal representations of reality are not the same as the external reality—that is, they are not isomorphic. Tolman's work with laboratory animals and Bartlett's work with human subjects suggest that information from the senses is stored as an abstract representation. Furthermore, studies of neurology clearly show that information from the outside world is sensed and stored as in a neurochemical code.

1.6 KEY ISSUES IN THE STUDY OF COGNITIVE PSYCHOLOGY

If the important ideas are reviewed, it is observed that some major themes underlie all of cognitive psychology. Some of these issues are discussed dialectically here:

Nature versus Nurture – Which is more influential in human cognition – nature or nurture? If we believe that innate characteristics of human cognition are more important, we might focus our research on studying innate characteristics of cognition. If we believe that the environment plays an important role in cognition, we might conduct research exploring how distinctive characteristics of environment seem to influence cognition.

Rationalism versus Empiricism – How should we discover the truth about ourselves and about the world around us? Should we do so by trying to reason logically, based on what we already know? Or should we do so by observing and testing our observations of what we can perceive through our senses? And how can we combine theory with empirical methods to learn the most we can about cognitive phenomena?

Structures versus Processes - Should we study the structures (contents, attributes, and products) of the human mind? Or should we focus on processes of human thinking?

Domain generality versus Domain specificity – Are the processes we observe limited to single domains, or are they general across a variety of domains? Do observations in one domain apply also to all domains, or do they apply only to specific domains observed?

Validity of causal inferences versus Ecological validity – Should we study cognition by using highly controlled experiments that increase the probability of valid inferences regarding causality? Or should we use more naturalistic techniques?

Applied versus Basic research – Should we conduct research into fundamental cognitive processes? Or should we study ways in which to help people use cognition effectively in practical situations?

Biological versus Behavioural methods – Should we study the brain and its functions directly, perhaps even scanning the brain while people are performing cognitive tasks? Or should we study people’s behaviour in cognitive tasks, looking at measures such as percentage correct and reaction time?

Note that these questions can be posed in the “either/or” form of thesis/antithesis, or in the both/and form of a synthesis of views or methods, which often proves more useful than one extreme position or another.

1.7 KEY IDEAS IN COGNITIVE PSYCHOLOGY

Certain key ideas seem to keep emerging in cognitive psychology, regardless of the particular phenomenon one studies. Here are what might be considered the five major ideas:

Data in cognitive psychology can be fully understood only in the context of an explanatory theory, but theories are empty without empirical data.

Cognition is generally adaptive but not in all specific instances.

Cognitive processes interact with each other and with noncognitive processes.

Cognition needs to be studied through a variety of scientific methods.

All basic research in cognitive psychology may lead to applications, and all applied research may lead to basic understandings.

> **Activity:** Think about some of the fields of cognitive psychology to which these key themes and issues may apply.

1.7.1 Computer Metaphor and Human Cognition

Although Pascal, Descartes, and others dreamt of computing machines centuries ago, it was not until the development of high-speed digital computers more than fifty years ago that practical machines were invented. These machines gained enormous acceptance and are presently used in virtually every aspect of modern life. Originally, such devices were thought to be wonderful number crunchers capable of performing a multitude of complex mathematical operations in a fraction of the time required by humans. However, it was quickly discovered that they could perform functions that resembled human problem solving.

However, what computers do well (perform high-speed mathematical functions and abide by rule-governed logic) humans do poorly, relatively speaking. And what humans do well (form generalisations, make inferences, understand complex patterns, and have emotions) computers do poorly, or not at all. Despite this problem, a second generation of cognitive-computer scientists is working toward building computers that looked something like a brain.

These new computers are sometimes called neural networks and act more like humans than the earlier versions. They are able to make generalisations and understand complex visual patterns, are slow at math, and make witless mistakes. Although they still do not have emotions, they are nevertheless a mark of success. We now know that there are fundamental differences between the internal workings of computers and the internal workings of the brain. Nevertheless, the computer metaphor continues to have a profound and generally positive impact on the development of cognitive psychology.

1.7.2 Cognitive Science

Three powerful areas of scientific development, namely, computer science, neuroscience, and cognitive psychology, converge to create a new science called cognitive science. The boundaries between these disciplines are sometimes hard to distinguish, that is, some cognitive psychologists may be closer to neuroscience, others to computer science. One thing is clear, that is the science of human cognition is undergoing a radical transformation as a result of major changes in computer technology and brain science. Cognitive psychology makes full use of recent discoveries in neuroscience and computer science that illuminate the cognitive properties of the human species.

1.7.3 Neuroscience and Cognitive Psychology

During the early stages of cognitive psychology, little attention was given to physiological psychology or neuroanatomy. Much of the early information on the brain and its functions resulted from head traumas incurred during wars and accidents. The central issue neurologists struggled with was whether the brain was a holistic organ, with operations distributed throughout its infrastructure, or whether activities were localised and tied to specific regions. For example, did learning a specific act take place in a localised area of the brain, or was learning distributed throughout many parts of the brain? Among the most prominent of the scientists who wrestled with these issues was Karl Lashley (1929). Recently, progress has been made in the field of neuroscience, which comprises both the structural aspects of the brain and its peripheral components, as well as the functional aspects.

With the beginning of the twenty-first century, cognitive psychology seems poised to make another paradigm shift. While the traditional topics of perception, memory, language, problem solving, and thinking and the method of experimental analysis are still central to the cognitive theme. As is well known, the use of neuro cognitive imagery promises to become one of the major means of investigating cognitive functions in this century.

Neuro cognitive techniques, which have been developing very rapidly in the past several decades, allow us to see deeper and more clearly into the brain— and the brain is believed to be the engine of cognition. Virtually every area of cognition has been investigated with neuro cognitive techniques. These, techniques, MRI, PET, EEG, and the like, show not only the structures of cognition but also the processes involved. And, in many instance, the results have been remarkable. While this trend is likely to continue and grow, it is important to recognise the central themes in cognition mentioned above.

1.8 LET US SUM UP

Cognitive psychology is the study of how people perceive, learn, remember, and think about information. A cognitive psychologist might study how people perceive various shapes, why they remember some facts but forget others, or how they learn language.

Cognitive psychology is interested in what is generally called mental phenomena. In this sense, cognitive psychology IS the scientific study of the mind. Then we took up the various research methods that we use in cognitive psychology. Every research has a goal and it is achieved through appropriate methodology. It was noted that the goals of research in cognitive psychology was to find the how and why of thinking. It was pointed out that there are distinctive research methods in cognitive psychology. Each method has distinctive advantages and disadvantages. It was also noted that Cognitive psychologists often broaden and deepen their understanding of cognition through research in cognitive science. Cognitive science is a cross-disciplinary field that uses ideas and methods from cognitive psychology, psychobiology, artificial intelligence, philosophy, linguistics, and anthropology.

Modern cognitive psychology freely, draws theories and techniques; from twelve principal areas of research, namely cognitive neurosiceince, human and artificial intelligence, perception, thinking and concept formation, pattern recognition, developmental psychology, attention, language, representation of knowledge, imagery, memory and consciousness. Then we dealt with a brief history of cognitive psychology and highlighted the early thoughts on thinking, renaissance and beyond and the status of cognitive psychology as of today. We then discussed some of the key issues in cognitive psychology highlighting nature vs. nurture, rationalism vs. empiricism, structure vs. processes etc.

1.9 UNIT END QUESTIONS

1) Describe the major historical schools of psychological thought leading up to the development of cognitive psychology.

2) Analyse how various research methods in cognitive psychology reflect empirist and rationalist approaches to gaining knowledge.

3) Design a rough sketch of a cognitive-psychological investigation involving one of the research methods described in this chapter. Highlight both the advantages and disadvantages of using this particular method for your investigation.

4) Describe Cognitive Psychology as it is today. How might you speculate that the field will change in the next 50 years?

5) How might an insight gained from basic research lead to practical use in an everyday setting?

6) Describe some real life situations related to different domains of cognitive psychology.

7) How might an insight gained from applied research lead to deepened understanding of fundamental features of cognition?

8) What was the importance of the computer to the development of cognitive psychology?

9) Next time you visit a supermarket or mall, pause for a few moments and observe the various examples of cognitive psychology which surround you. Pay particular attention to: 1) the use of forms and colours to gain attention, 2) your own reaction to environmental cues, 3) the use of memory in understanding language, context, and the interpretation of the sights and sounds of your environment. Note down your impressions of these matters and read them over in about a week. What principles discussed in this chapter apply?

1.10 SUGGESTED READINGS AND REFERENCES

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UNIT 2 INFORMATION PROCESSING IN LEARNING AND MEMORY

"The mechanisms of learning and memory are at the essence of how the brain works."

— Brown

Structure

2.0 INTRODUCTION

One of the most fascinating and mysterious properties of the brain is its capacity to learn, or its ability to change in response to experience and to retain that knowledge throughout an organism's lifetime. The ability to learn and to establish new memories is fundamental to our very existence; we rely on memory to engage in effective actions, to understand the words we read, to recognise the objects we see, to decode the auditory signals representing speech, and even to provide us with a personal identity and sense of self. Memory plays such an important and ubiquitous role that it is often taken for granted—the only time most people pay attention to their memory is when it fails, as too often happens through brain injury or disease.

2.1 OBJECTIVES

After reading this unit, you will be able to:

- Define the concept of learning and memory;
- Explain types of memory;
- Explain cognitive information processing; and
- Explain the theories of information processing.

2.2 LEARNING AND MEMORY

Learning is acquiring new knowledge, behaviours, skills, values, preferences or understanding, and may involve synthesising and processing different types of information. Benjamin Bloom (1965) has suggested three domains of learning

1) *Cognitive* – to recall, calculate, discuss, analyse, problem solve, etc.; *psychomotor* – to dance, swim, ski, dive, drive a car, ride a bike, etc.; and *affective* – to like something or someone, love, appreciate, fear, hate, worship, etc. These domains are not mutually exclusive. For example, in learning to play chess, the person will have to learn the rules of the game (cognitive domain); but he also has to learn how to set up the chess pieces on the chessboard and also how to properly hold and move a chess piece (psychomotor). Furthermore, later in the game the person may even learn to love the game itself, value its applications in life, and appreciate its history (affective domain).

2) *Memory* is usually divided into three storage systems: sensory, short-term, and long-term.

   i) *Sensory Memory* - Sensory memory is affiliated with the transduction of energy (change from one form of energy to another). The environment makes available a variety of sources of information (light, sound, smell, heat, cold, etc.), but the brain only understands electrical stimulation. The body has special sensory receptor cells that transduce this external energy to something the brain can understand. In the process of transduction, a memory is created. This memory is very short (less than 1/2 second for vision; about 3 seconds for hearing).

   The sensory memory retains an exact copy of what is seen or heard (visual and auditory). It is absolutely critical that the learner attend to the information at this initial stage in order to transfer it to the next one. There are two major concepts for getting information into STM: *first*, individuals are more likely to pay attention to a stimulus if it has an interesting feature. *Second*, individuals are more likely to pay attention if the stimulus activates a known pattern.

   ii) *Short-Term Memory (STM)* - After entering sensory memory, a limited amount of information is transferred into short-term memory. Selective attention determines what information moves from *sensory memory* to *short-term memory*. STM is most often stored as sounds, especially in recalling words, but may be stored as images. It works basically the same as a computer's RAM (Random Access Memory) in that it provides a working space for short computations and then transfers it to other parts of the memory system or discards it. STM is vulnerable to interruption or interference. STM is characterised by:

   A limited capacity of up to seven pieces of independent information (Miller,1956).

   The brief duration of these items last from 3 to 20 seconds.

   Decay appears to be the primary mechanism of memory loss.

Miller's Magic Number - George Miller's classic 1956 study found that the amount of information which can be remembered on one exposure is between five and nine items, depending on the information. Applying a range of +2 or -2, the number 7 became known as *Miller's Magic Number*, the number of items which can be held in Short-Term Memory at any one time. Miller himself stated that his magic number was for items with one aspect. His work is based on subjects listening to a number of auditory tones that varied only in pitch. Each tone was presented separately, and the subject was asked to identify each tone relative to the others s/he had already heard, by assigning it a number. After about five or six tones, subjects began to get confused, and their capacity for making further tone judgments broke down. He found this to be true of a number of other tasks. But if more aspects are included, then we can remember more, depending upon our familiarity and the complexity of the subject (in Miller's research, there was only one aspect — the tone). For example, we can remember way more human faces as there are a number of aspects, such as hair color, hair style, shape of face, facial hair, etc. We remember phone numbers by their aspects of 2 or more groupings, i.e. chunking. We don't really remember "seven" numbers. We remember the first group of three and then the other grouping of four numbers. If it is long distance, then we add an area code. So we actually remember 10 numbers by breaking it into groups of three.

Within STM, there are three basic operations:

Iconic memory - The ability to hold visual images.

Acoustic memory - The ability to hold sounds. Acoustic memory can be held longer than iconic memory.

Working memory - Short-term memory is also called working memory and relates to what we are thinking about at any given moment in time. In Freudian terms, this is conscious memory. It is created by our paying attention to an external stimulus, an internal thought, or both. An active process to keep it until it is put to use (think of a phone number you'll repeat to yourself until you can dial it on the phone). Note that the goal is not really to move the information from STM to LTM, but merely put the information to immediate use.

iii) *Long-Term Memory (LTM)* - This is relatively permanent storage. Information is stored on the basis of meaning and importance. The process of transferring information from STM to LTM involves the encoding or consolidation of information. This is not a function of time, that is, the longer a memory stayed in STM, the more likely it was to be placed into LTM; but on organising complex information in STM before it can be encoded into LTM. In this process of organisation, the meaningfulness or emotional content of an item may play a greater role in its retention into LTM. We must find ways to make learning relevant and meaningful enough for the learner to make the important transfer of information to long-term memory.

Also, on a more concrete level, the use of chunking has been proven to be a significant aid for enhancing the STM transfer to LTM. Remember, STM's capacity is limited to about seven items, regardless of the complexity of those items. Chunking allows the brain to automatically group certain items together, hence the ability to remember and learn better.

The knowledge we store in LTM affects our perceptions of the world, and influences what information in the environment we attend to. LTM provides the framework to which we attach new knowledge. It contrasts with short-term and perceptual memory in that information can be stored for extended periods of time and the limits of its capacity are not known.

Schemas are mental models of the world. Information in LTM is stored in interrelated networks of these schemas. These, in turn, form intricate knowledge structures. Related schemas are linked together, and information that activates one schema also activates others that are closely linked. This is how we recall relevant knowledge when similar information is presented. These schemas guide us by diverting our attention to relevant information and allow us to disregard what is not important.

Since LTM storage is organised into schemas, instructional designers should activating existing schemas before presenting new information can be helpful in processing of the new information. This can be done in a variety of ways, including graphic organisers, curiosity-arousing questions, movies, etc.

LTM also has a strong influence on perception through *top-down processing* - our prior knowledge affects how we perceive sensory information. Our expectations regarding a particular sensory experience influence how we interpret it. This is how we develop bias. Also, most optical illusions take advantage of this fact. An important factor for retention of learned information in LTM is rehearsal that provides transfer of learning.

2.3 COGNITIVE INFORMATION PROCESSING

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 began in the 1940s and 1950s. Educators are very interested in the study of how humans learn. This is because how one learns, acquires new information, and retains previous information guides selection of long-term learning objectives and methods of effective instruction. To this end, cognition as a psychological area of study goes far beyond simply the taking in and retrieving information. It is a broad field dedicated to the study of the mind holistically. 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. Cognitive psychologists hypothesise an intervening variable or set of variables between environment and behaviour—which contrasts it with behavioural theories.

2.3.1 Principles of the Information Processing

Even though there are widely varying views within cognitive psychology, there is general agreement among most cognitive psychologists on some basic principles of the information processing system (Huitt, 2000).

The *first* is the assumption of a limited capacity of the mental system. This means that the amount of information that can be processed by the system is constrained in some very important ways. Bottlenecks, or restrictions in the flow and processing of information, occur at very specific points (e.g., Broadbent, 1975; Case, 1978).

A *second* principle is that a control mechanism is required to oversee the encoding, transformation, processing, storage, retrieval and utilisation of information (e.g., Atkinson & Shiffrin, 1971). That is, not all of the processing capacity of the system is available; an executive function that oversees this process will use up some of this capability. When one is learning a new task or is confronted with a new environment, the executive function requires more processing power than when one is doing a routine task or is in a familiar environment.

A *third* principle is that there is a two-way flow of information as we try to make sense of the world around us. We constantly use information that we gather through the senses (often referred to as *bottom-up processing*) and information we have stored in memory (often called *top-down processing*) in a dynamic process as we construct meaning about our environment and our relations to it. This is somewhat analogous to the difference between inductive reasoning (going from specific instances to a general conclusion) and deductive reasoning (going from a general principle to specific examples.) A similar distinction can be made between using information we derive from the senses and that generated by our imaginations.

A *fourth* principle generally accepted by cognitive psychologists is that the human organism has been genetically prepared to process and organise information in specific ways. For example, a human infant is more likely to look at a human face than any other stimulus. Other research has discovered additional biological predispositions to process information. For example, language development is similar in all human infants regardless of language spoken by adults or the area in which they live (e.g., rural versus urban, Asia versus Europe.) All human infants with normal hearing babble and coo, generate first words, begin the use of telegraphic speech (example, ball gone), and overgeneralise (e.g., using "goed to the store" when they learn the verbs) at approximately the same ages(Discussed in detail in Block 3).

2.4 INFORMATION PROCESSING IN LEARNING AND MEMORY

One of the primary areas of cognition studied by researches is memory. 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.

Schacter and Tulving (as cited in Driscoll, 2001) state that "a memory system is defined in terms of its brain mechanisms, the kind of information it processes, and the principles of its operation". This suggests that memory is the combined total of all mental experiences. In this light, memory is a built store that must be accessed in some way in order for effective recall or retrieval to occur. It is premised on the belief that memory is a multi-faceted, if not multi-staged, system of connections and representations that encompass a lifetime's accumulation of perceptions.

Eliasmith (2001) defines memory as the "general ability, or faculty that enables us to interpret the perceptual world to help organise responses to changes that take place in the world". It is implied by this definition that there must be a tangible structure in which to incorporate new stimuli into memory. The form of this structure has been the source of much debate, and there seems to be no absolute agreement on what shape a memory structure actually takes, but there are many theories on what constitutes both the memory structure and the knowledge unit.

Winn and Snyder (2001) attribute the idea that memory is organised into structures to the work of Sir Frederick Charles Bartlett. Bartlett's work established two consistent patterns regarding recall. First, memory is inaccurate. His second finding, though, brought about somewhat of a revolution in traditional thinking about memory. Bartlett suggested that the inaccuracy of memory is systematic. A systematic difference makes allowable the scientific study of inaccuracy, and this suggestion led to an entirely new mode of thought on memory. What accounted for systematic inaccuracies in memory were the intervening influences of previous information and the experiences of the person. This demonstrates that knowledge units are not simply stored and then left alone, but that they are retained, manipulated, and changed as new knowledge is acquired.

2.4.1 Cognitive Information Processing Model (CIP) of Learning

Information theorists approach learning primarily through a study of memory. The following Cognitive Information Processing model (CIP) of learning presents a well-established paradigm of cognitive-behavioural psychology. The model articulates the limited capacity of "working memory." Working memory is tasked with the burden of processing incoming information, transferring information to long-term memory and retrieval of information from long-term memory. The concept of "cognitive load" — the amount of work imposed on working memory by a learning task — is based on observations of the functions of working memory.

Information processing in memory can be viewed from a computer model perspective. Like the computer, the human mind takes in information, performs operations on it to change its form and content, stores the information, retrieves it when needed, and generates responses to it. Processing involves *encoding* (gathering and representing information); *storage* (holding information); and *retrieval* (getting the information when needed). The entire system is guided by a *control process* that determines how and when information will flow through the system. Some theorists suggest that the operation of the brain resembles a large number of computers all operating at the same time (in parallel).

2.4.2 Development of Memory and Information Processing

As previously stated, cognition is the encoding, structuring, storing, retrieving, using, or otherwise learning knowledge (Neisser, 1967). There are important developmental aspects for each of these activities. According to Flavell et al. (2002), from an information processing perspective some of the most important are:

- Brain changes brought about by biological maturation or experience;
- Increased processing capacity, speed, and efficiency as a result of both maturation and knowledge development;
- Modifications of connections in a neural network;
- New emergent concepts arising from repeated self-organisation as a result of adapting to the demands of a changing environment; and
- Increased capacity for problem-solving and metacognition.

Encoding - Encoding occurs during the initial processing of a stimulus or event. Maturation and experience influence this process. In terms of maturation, Dempster (1981) suggests that the adult capacity for short-term memory of 5 + 2 digits might be as much as 2 digits lower for children aged 5 and 1 digit lower for children aged 9. As for experience, in a series of well-known studies of expertise, novices remember new information less well than experts (e.g., Chi, 1978; Schneider, Korkel, & Winert, 1989). One of the most important differences between novices and experts is the structure and organisation of domain-specific knowledge.

Structuring and Organising - Structuring and organising information occur as the learner processes and stores information. The learner's ability changes over time as a result of both maturation and experience. When presented with information they are asked to remember, younger children do not rehearse information in order to remember it. As they get into school, they begin to develop or are taught various strategies. At first these strategies are only used when prompted by someone else, but as the child becomes more competent in their use and uses them more frequently, the child will increasingly use the strategies spontaneously (Flavell et al., 2002).

One of the most important information processing capacities a child develops is the ability to organise information; this is, in turn, influenced by the child's ability to categorise. As is the case with other information-processing capacities, this ability changes with both maturation and experience.

One of the basic types of categorisation is the grouping of specific events, ideas, people, things, etc. into concepts. Rosch and his colleagues (e.g., Mervis & Rosch, 1981; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) demonstrated two fundamental features to the development of concepts: the ease of identifying similarities of members of the concept and distinguishing differences between members that are not. For example, the development of the concept of animal would be more difficult than developing the concept of dog or cat because it would be easier to identify similarities among dogs or cats and differences between cats and dogs than it would be to identify similarities among all animals or to differentiate all animals from all plants.

This has important implications as we design learning activities for children and youth that can help them develop their organisational and storage capacities.

Storage and Retrieval - How much information can be stored and retrieved relative to a stimulus or event also changes over time. For example, prior to about age 7 months an infant will not seek an object that has been shown and then removed from view. The infant has encoded the object (such as a rattle) and will reach for it, but seems to lose interest as soon as it is no longer in view. At about 7 months attains what is called "object permanence" and will begin to seek the object if it is removed from view.

A series of studies by Bauer, Mandler and associates (as cited in Flavell et al., 2002) demonstrates a child's increasing ability to perform simple multiple-act sequences. By age 13 months infants can reproduce three-act sequences; by age 24 months this has increased to five-act sequences; and by age 30 months to eight separate actions. As children gain language skills, their ability to store and recall more complex events increases. This is shown first in autobiographical accounts of daily activities and then to events they may have witnessed or heard about.

Flavell et al. (2002) made four observations about strategy development:

Strategy development is not linear. When developing any particular strategy, development will often stall or even regress before it becomes systematically and correctly used.

A strategy will continue to develop after it is first demonstrated in its mature form. This continued development may take months or even years.

Children show considerable variability in their use of strategies. Children often go back and forth in their use of strategies, changing strategies even after they have been found to work well.

Children differ in their abilities to integrate different strategies into a coherent pattern for successful learning. Children must be given ample opportunity to create successful learning programs that work for them.

2.5 THEORIES OF INFORMATION PROCESSING

There are important theories which explain information processing. Some of the major theories are presented in the following section.

2.5.1 Designing Instruction that Incorporates Best Practices for Information Processing

The understanding of how the mind processes and stores information is invaluable to educators as they plan for instruction. If there is little to no understanding of the information processing skills of the students with whom one is working, it would be almost impossible to design instruction that contributes to high levels of learning and achievement. However, attempting to understand the myriad theories of information processing and cognitive development can be overwhelming and contradictory. There are means of structuring instruction, though that can incorporate the best of all of these ideas, and in order to help students reach higher-level thinking and learning skills, educators must draw from all of these theories.

If learning is to occur, educators must ensure that new information is processed in such a way that it can be retained in long-term memory. In order to achieve this, elaboration and connection must occur between previously learned memory and new information. It has been established that the more deeply information is processed and the more connections that can be made between new information and existing memory structures, the more information will be retained in long-term memory. Therefore, in order to make new material meaningful, instruction must be presented in such a way that students can easily access and connect previous learning and experiences with the new material. One of the most often cited references to levels of elaboration for instructional purposes is the Taxonomy of the Cognitive Domain developed by Bloom and his colleagues (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956) and recently revised by Anderson and Krathwohl (2000).

2.5.2 Bloom's Taxonomy of Cognitive Domain

Bloom et al. (1965) proposed that information processing can be classified in six levels, each more complex than the previous. The first level is labeled *knowing* and simply requires a learner to repeat back what was heard or seen. This involves very little elaboration. The second level is labeled *comprehension* and requires some rudimentary levels of understanding that might involve having the student summarize or paraphrase some information. Again, this requires only modest levels of elaboration. The next two levels, *application* and *analysis*, involve more elaboration and show a significant impact on long-term learning when they are used during the learning process. Application involves using the concepts or principles to solve a problem, while analysis involves understanding the relationship among the parts and how they are organised into a whole. The last two levels, *synthesis* and *evaluation*, are the most complex and require the highest levels of elaboration. Synthesis involves putting the parts or components together in an original manner, while evaluation is the process of making judgments based on comparison to a standard.

Research has confirmed that the first four levels are indeed a hierarchy, while there seems to be a problem with the ordering of the two highest levels (Hummel & Huitt, 1994). Anderson and Krathwohl (2000) propose that the ordering is reversed, with evaluation being less difficult than synthesis, while Huitt (2000) proposes that they are both at the same level of difficulty though they incorporate different types of processing. There seems to be consensus that both synthesis and evaluation are based on analysis or the ability to compare and contrast parts of a whole and understand the relationship among parts.

2.5.3 Sternberg's Information Processing Approach

Another theorist firmly grounded in the information processing approach is Sternberg (1988). Sternberg's theory suggests that development is skills-based and continuous rather than staged and discontinuous as stage theorists believe, and his focus is on intelligence. This focus on intelligence separates his ideas from stage theorists because it rejects the idea of incremental stages, but rather suggests that development occurs in the same way throughout life differentiated only by the expertise of the learner to process new information. First, and very importantly, Sternberg's model does not differentiate between child and adult learning. Also, he deals solely with information processing aspects of development and does not incorporate any facets of biological development into his theory. Cognitive development is viewed as a novice to expert progression; as one becomes better at interaction and learning, one is able to learn more and at higher levels. Development changes as a result of feedback, self-monitoring, and automatisation. In this theory, intelligence is comprised of three kinds of information processing components: metacomponents, performance components, and knowledge-acquisition components.

In Sternberg's (1988) model, each of these three components works together to facilitate learning and cognitive development. Metacomponents are executive in nature. They guide the planning and decision making in reference to problem solving situations; they serve to identify the problem and connect it with experiences from the past. There is, however, no action directly related to metacomponents, they simply direct what actions will follow. Performance components are the actions taken in the completion of a problem-solving task. Performance components go beyond metacomponents in that they perform the function also of weighing the merit and or consequences of actions in comparison to other options rather than simply identifying options. Sternberg's third proposed type of intelligence is the knowledge-acquisition component. This type is characterised by the ability to learn new information in order to solve a potential problem. This type is much more abstract and may or may not be directly related to a current problem-solving task (Driscoll, 2001). This three-leveled view of intelligence comprises the componential aspect of Sternberg's theory, but this is only one of three parts to his larger triarchic theory of intelligence (Kearsley, 2001).

Sternberg's (1988) theory adds the components of feedback to theories of cognitive development; this suggests that an individual's social interaction has some impact on cognitive development. In fact, one of the three parts of his theory is based on the context in which learning takes place; this subpart of the theory "specifies that intelligent behaviour is defined by the sociocultural context in which it takes place and involves adaptation to the environment, selection of better environments, and shaping of the present environment" (Kearsley, 2001). The addition of social context as a factor in cognitive development links Sternberg to the interactional theories of development of Bruner (1977, 1986) and Vygotsky (1978). These theories, and others of this type, are premised on the assumption that learning does not occur in a vacuum. Therefore, one must discuss the social and cultural contexts of learning. Driscoll (2001) says, "Of central importance is viewing education as more than curriculum and instructional strategies. Rather, one must consider the broader context in how culture shapes the mind and provides the toolkit by which individuals construct worlds and their conceptions of themselves and their powers".

These theories all work under the assumption that new information can most effectively be learned if the material can be matched to memory structures already in place (Winn and Snyder, 2001). 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. This in-place structural system allows for differing levels of complexity of information processing. The formation of and continual building of these structures, then, is critical in order for learners to process information in various ways and at higher levels.

2.6 LET US SUM UP

One of the most fascinating and mysterious properties of the brain is its capacity to learn, or its ability to change in response to experience and to retain that knowledge throughout an organism's lifetime. The ability to learn and to establish new memories is fundamental to our very existence; we rely on memory to engage in effective actions, to understand the words we read, to recognise the objects we see, to decode the auditory signals representing speech, and even to provide us with a personal identity and sense of self.

Learning is acquiring new knowledge, behaviours, skills, values, preferences or understanding, and may involve synthesising and processing different types of information.

Memory is usually divided into three storage systems: sensory, short-term, and long-term.

We then discussed Miller's Magic number. We pointed out how within STM, there are 3 basic operations, viz., iconic memory, acoustic memory and working memory. Long Term Memory has been then presented which includes schemas etc. Then the principles of information processing was taken up and and highlighted the limited capacity of the mental system and secondlhy the control mechanism is required to oversee the encoding, transformation, processing storage etc.

Then we dealt with information processing in learning and memory. It was pointed out that from an information processing perspective some of the most important aspects include

- Brain changes brought about by biological maturation or experience;
- Increased processing capacity, speed, and efficiency as a result of both maturation and knowledge development;
- Modifications of connections in a neural network;
- New emergent concepts arising from repeated self-organisation as a result of adapting to the demands of a changing environment; and
- Increased capacity for problem-solving and metacognition.

Then we discussed about encoding which involves structuring, organising, storage, retrieval etc. This was followed by theories of informationprocessing which highlighted Bloom's Taxonomy and Sternberg's information processing theory. It was pointed out that that new information can most effectively be learned if the material can be matched to memory structures already in place. 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.

2.7 UNIT END QUESTIONS

1) Describe two characteristics each of sensory memory, short term memory, and long term memory.
2) Discuss the information processing approaches of learning and memory.
3) How would you design a study program to process the information so that it can be retained in long term memory?
4) Describe the development of memory with reference to information processing.

4) How would your life be different if you could greatly enhance your memory skills?

5) What are the basic principles of information processing?

6) What are the three things you have learned about memory that can help you learn new information so that you can effectively recall the information over the long-term?

2.8 SUGGESTED READINGS AND REFERENCES

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UNIT 3 NEUROPSYCHOLOGICAL BASIS OF LEARNING AND MEMORY

"It's a sense of flooding the brain too quickly. The brain has this disruption, and the short-term memory isn't converting into long-term memory."

– John Hamilton

Structure

3.0 INTRODUCTION

What is the relationship between learning and memory? Learning is the process of acquiring new information, whereas memory refers to the persistence of learning in a state that can be revealed at a later time (Squire, 1987). Learning, then, has an outcome, and we refer to that as *memory*. To put it another way, learning happens when a memory is created or is strengthened by repetition. This need not involve the conscious attempt to learn. Learning can occur and performance can improve simply from more exposure to information or to a task. For example, we remember the details of a person's face better by seeing it more, without having to try to consciously memorize facial features.

Learning and memory can be subdivided into major hypothetical stages: encoding, storage, and retrieval. Encoding refers to the processing of incoming information to be stored. The encoding stage has two separate steps: acquisition and consolidation. Acquisition registers inputs in sensory buffers and sensory analysis stages, while consolidation creates a stronger representation over time. Storage, the result of acquisition and consolidation, creates and maintains a permanent record. Finally, retrieval utilises stored information to create a conscious representation or to execute a learned behaviour like a motor act.

We search for the neural correlates of learning and memory in many ways: a) through case studies which reveal what is and is not lost in amnesia; b) by developing animal models of memory in simple (invertebrates) and complex systems (nonhuman primates); c) and with brain imaging to investigate normal encoding, retrieval, and recall in healthy humans. In this chapter we will explore all these methods in brief in order to understand the neural basis of learning and memory.

3.1 OBJECTIVES

After reading this unit, you will be able to:

- Describe the process of memory in the brain;
- Define neurological issues related to memory;
- Define neuropsychological basis of learning and memory;
- Explain the neural processes of learning and memory.

3.2 MEMORY AND BRAIN

The field of the cognitive and experimental psychology of memory is rich with theory and data and has produced a consistent set of concepts about the organisation of human memory. The neuro scientific studies of memory are important, both to understand how they have contributed to general theories of memory, and to investigate how specific neural circuits and systems enable the learning and retention of specific forms of knowledge.

3.2.1 Human Memory, Brain Damage and Amnesia

Deficits in memory as a function of brain damage, disease, or psychological trauma are known as amnesia. Amnesia can involve either the inability to learn new things or a loss of previous knowledge, or both. It can differentially affect short-term/ working memory and long-term memory abilities. Thus, by examining amnesia in conjunction with cognitive theories derived from experiments on normal subjects, we can understand the organisation of memory at a functional and a neural level. Much compelling information about the organisation of human memory during amnesia was first derived from medical treatments that left patients amnesic. The history is fascinating, and so let's begin by turning back the clock more than fifty years.

3.2.2 Brain Surgery and Memory Loss

In the late 1940s and early 1950s, surgeons attempted to treat neurological and psychiatric disease using a variety of neurosurgical procedures, including prefrontal lobotomy (removing or disconnecting the prefrontal lobe), corpus callosotomy (surgically sectioning the corpus callosum), amygdalotomies (removing the amygdala), and temporal lobe resection (removal of the temporal lobe) (Figure 1.3.1). These surgical procedures opened a new window on human brain function as they revealed, usually quite by accident, fundamentally important principles of the organisation of human cognition. One surgical procedure relevant to memory was removal of the medial portion of the temporal lobe, including the hippocampal formation.

In 1953 at a medical conference, the neurosurgeon William Beecher Scoville from the Montreal Neurological Institute reported on bilateral removal of the medial temporal lobe in one epileptic patient and several schizophrenic patients. Shortly thereafter he wrote:

Bilateral resection of the uncus, and amygdalum alone, or in conjunction with the entire pyriform amygdaloid hippocampal complex, has resulted in no marked physiologic or behavioural changes with the one exception of a very grave, recent memory loss, so severe as to prevent the patient from remembering the locations of the rooms in which he lives, the names of his close associates, or even the way to the toilet.... (Scoville, 1954).

Scoville and psychologist Brenda Milner did the neuropsychological examination of ten patients. Milner found that memory impairments in the patients having medial temporal lobe resections as part of their treatment were in relation to how much of the medial temporal lobe was removed. The farther posterior along the medial temporal lobe the resection was, the worse the amnesia. Strikingly, however, only *bilateral* resection of the hippocampus resulted in severe amnesia. In comparison, in one patient whose entire right medial temporal lobe (hippocampus and hippocampal gyrus) was removed, no residual memory deficit was found (Figure 1.3.1). But the interesting patient was the young man who had had bilateral medial temporal resection.

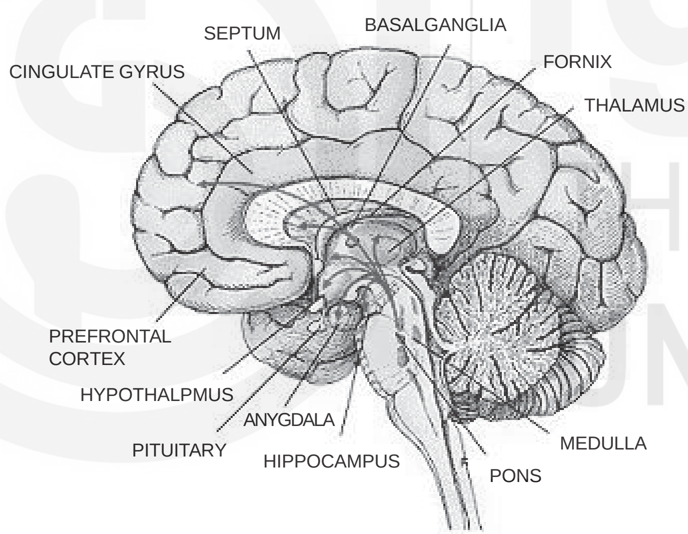

Fig. 1.3.1: Medial view of Human Brain (Source: Net)

The case history of patient H.M. – H.M. was a young man who suffered from a difficult-to-treat from of epilepsy that progressed in severity during his teen years. Over the years his physicians had treated him with the available drugs to minimize his seizures, but these drugs were largely ineffective for him. As his seizures worsened in his twenties, he decided to try a then-radical new therapy that involved surgery. At that time neurologists knew that many seizures originated in the medial portions of the temporal lobe and from there spread to other areas of the brain, leading to violent seizures and often loss of consciousness. It was also becoming increasingly clear that surgically removing the brain region in which the seizure activity originated, the so-called seizure focus, could help patients with epilepsy. The decision in H.M.'s case was to remove his medial temporal lobe bilaterally, in a procedure called temporal lobectomy

Following recovery from this major neurosurgical procedure, H.M.'s epilepsy did improve. The surgery was a success, both with regard to his surviving the risks associated with any surgery of the brain and with regard to the epilepsy. However, physicians, family, and friends began to realise that H.M. was experiencing new difficulties. For example, a year and a half after the surgery, which was performed in September 1953, H.M. displayed clear problems with his memory. Although it was April 1955 and H.M. was 29 years old, he reported his age to be 27. H.M. would say he did not remember ever meeting certain individuals, even when he actually spoke to them a few minutes earlier and they merely left the room, returning after a short delay! H.M. was profoundly amnesic—that is, he suffered from disorders of memory. However, H.M. did not have the kind of amnesia one sees depicted in television shows or movies, where the character has a total loss of all prior memories. Indeed, H.M. knew who he was and could remember things about his life—that is, up until a period prior to his surgery. However, it became increasingly clear that H.M. could not form new long-term memories.

Formal neuropsychological tests were performed on H.M. to establish the nature of his cognitive deficits. These tests showed that his intelligence was well above normal after the surgery. He also had no perceptual or language problems and seemed generally fine, with no changes in his personality or motivation. However, when memory tests were administered, H.M. scored well below normal. The bilateral removal of H.M.'s medial temporal lobe produced a highly selective deficit in his memory ability, leaving other cognitive functions intact. H.M. had normal short-term memory (sensory registers and working memory), but he developed a severe and permanent inability to acquire and store new information (Figure 1.3.2). The transfer of information from short-term storage to long-term memory was disrupted.

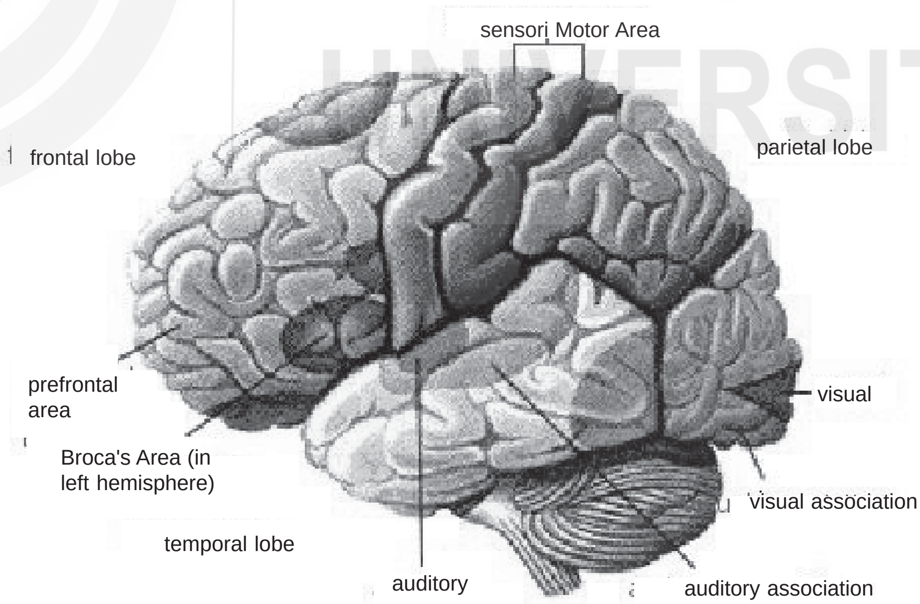

Fig. 1.3.2: Major Areas of the Brain (Source: InterNet)

3.2.3 Amnesia and the Medial Temporal Lobe

Which region or regions of the medial temporal lobe were critical for supporting the long-term memory ability lost in H.M.? The medial temporal area includes the amygdala, the hippocampus, the entorhinal cortex, and the surrounding parahippocampal and perirhinal cortical areas (Figure 1.3.1).

For the past 40 years, scientists studying H.M. used surgical reports of his lesions to guide theories of memory and "amnesia and their neural bases. Reports by Scoville, who performed the surgery, indicated that all of H.M.'s hippocampus in each hemisphere had been removed. H.M.'s brain and surgical lesions were re-evaluated with improved accuracy with high-resolution neuroimaging methods such as magnetic resonance imaging (MRI), and it was found that in addition to the hippocampus, some of H.M.'s surrounding cortex was also removed.

Is damage to the hippocampus sufficient to block the formation of new long-term memories? Consider another patient, R.B., who lost his memory after an ischemic episode (reduction of blood to brain) during bypass surgery. R.B. developed dense anterograde amnesia similar to H.M.'s. He could not form new long-term memories. He also had retrograde amnesia that extended back to 1 to 2 years, slightly less severe than H.M.'s retrograde loss. After his death, R.B.'s brain was donated for study, permitting a detailed analysis of the extent of his neuroanatomical damage. In R.B.'s case, lesions were found to be restricted to his hippocampus; within each hippocampus, R.B. had sustained a specific lesion restricted to the CA1 pyramidal cells.

These findings in patient R.B. support the idea that the hippocampus is crucial in forming new long-term memories. R.B.'s case also supports the distinction between areas that store long-term memories and the role of the hippocampus in forming new memories. Even though retrograde amnesia is associated with medial temporal lobe damage, it is temporally limited and does not affect long term memories of events that happened more than a few years prior to the amnesia-inducing event.

3.3 MEMORY CONSOLIDATION AND HIPPOCAMPUS

Memories are solidified in long-term stores over days, weeks, months, and years. This process is referred to as consolidation, an old concept that refers to how long term memory develops over time after initial acquisition. From a cognitive neuroscience perspective, consolidation is conceived of as biological changes that underlie the long-term retention of learned information, and we can ask what brain structures and systems support this process.

Because damage to the medial temporal lobe does not wipe out most of the declarative memories formed over a lifetime, we know that the hippocampus is not the repository of stored knowledge. Rather, the medial temporal lobe appears to support the process of forming new memories; that is, the hippocampal region is critical for the consolidation of information in long term memory. The strongest evidence that the hippocampus is involved in consolidation comes from the fact that amnesics have retrograde amnesia for memories from one to a few years prior to the damage to the medial temporal lobe or diencephalon, a pattern that does not support a storage role but rather a role in consolidation.

What might consolidation entail at the neural level? One idea is that consolidation strengthens the associations between multiple stimulus inputs and activations of previously stored information. The hippocampus is hypothesised to coordinate this strengthening, but the effects are believed to take place in the neocortex. The idea is that once consolidation is complete, the hippocampus is no longer required for storage or retrieval. Nonetheless, keep in mind that although the memories are stored in the neocortex, the hippocampus is crucial for consolidation.

Alcoholic Korsakoff's Syndrome and Diencephalic Amnesia - The medial temporal lobe is not the only area of interest in human memory. Amnesia emerges from brain damage in other regions too. For example, damage to midline structures of the diencephalon of the brain causes amnesia. The prime structures are the dorsomedial nucleus of the thalamus and the mammillary bodies (Figure 1.3.2). Damage to these midline subcortical regions can be caused by stroke, tumors, and metabolic problems like those brought on by chronic alcoholism as well as by trauma.

In the last half of the nineteenth century, the Russian psychiatrist Sergei Korsakoff reported an anterograde and retrograde amnesia associated with alcoholism. Long term alcohol abuse can lead to vitamin deficiencies that cause brain damage. Patients suffering from alcoholic Korsakoff's syndrome have degeneration in the diencephalon, especially the dorsomedial nucleus of the thalamus and the mammillary bodies. It remains unclear whether the dorsomedial thalamic nucleus, the mammillary bodies, or both are necessary for the patients' amnesia. Nonetheless, damage to the diencephalon can produce amnesia.

3.4 ANTERIOR AND LATERAL TEMPORAL LOBES AND MEMORY

If, as suggested earlier, the neocortex is crucial for the storage of memories, then it should be possible to demonstrate retrograde amnesia with cortical damage, even though most amnesias are anterograde. In line with this proposal, amnesia can be caused by damage to regions of the neocortex.

One region of special interest is the temporal neocortex outside the medial temporal lobe. Lesions that damage the lateral cortex of the anterior temporal lobe, near the anterior pole, lead to a dense amnesia that includes severe retrograde amnesia; in such cases the entorhinal cortex and perihippocampal cortex may be involved. The retrograde amnesia may be severe, extending back many decades before the amnesia-inducing event occurred or encompassing the patient's entire life. Various forms of damage can lead to this condition. Progressive neurological diseases like Alzheimer's, and herpes simplex encephalitis involving viral infection of the brain are two such conditions.

Some patients with dense retrograde amnesia might still form new long-term memories. This type of amnesia is called *isolated* retrograde amnesia. It is particularly related to damage of the anterior temporal lobe. This portion of the temporal lobe is not, therefore, essential for acquiring new information.

Are these lateral and anterior regions of the temporal lobe the sites of storage of long-term declarative memories? The answer is maybe, but another view is that these regions may be particularly important for the retrieval of information from long-term stores. Where then are memories stored? More recent evidence from neuroimaging studies suggests that memories are stored as distributed representations throughout neocortex, involving the regions that originally encoded the perceptual information and regions representing information that was associated with this incoming information (as noted in the last section, the medial temporal lobe may coordinate the consolidation of this information over time).

3.5 ANIMAL MODELS OF MEMORY

Studies in monkeys with lesions to the hippocampus and surrounding cortex have been invaluable in learning about the contributions of the medial temporal lobe to primate memory systems. In general, the goal of such research is to develop animal models of human memory and amnesia. Through research, such models are providing key information on relations between specific memory and brain structures. Several animal species, ranging from invertebrates to monkeys, have been investigated *for* clues to human memory and its functional neuroanatomy and neurobiology; it is likely that monkeys will contribute the most directly applicable knowledge about human processes at the systems level given the similarity among primate brains. We must always keep in mind, however, that the gross organisation and functional capabilities of the brains of monkeys and humans differ significantly. Thus, animal models of cognitive processes like memory are perhaps most informative when linked with studies in humans.

One of the key questions in memory research was how much the hippocampus alone, as compared with surrounding structures in the medial temporal lobe, participated in the memory deficits of patients like H.M. In other words, what structures of the medial temporal lobe system are involved in episodic memory? For example, does the amygdala influence memory deficits in amnesics? Data from amnesics indicate that the amygdala is not part of the brain's episodic memory system, although it has a role in emotion and emotional memories.

To verify this, surgical lesions were created in the medial temporal lobe and amygdala of monkeys, to cause memory impairment. In classic work by Mortimer Mishkin (1978) at the National Institute of Mental Health (NIMH), the hippocampus or the amygdala, or both the hippocampus and the amygdala, of monkeys were removed surgically. He found that the amount of impairment, as measured on tests, varied according to what was lesioned.

In his early work, Mishkin found that in the monkey, memory was impaired only if the lesion included the hippocampus and amygdala. This led to the idea that the amygdala was a key structure in memory. The idea does not fit well with data from amnesics like R.B., who had anterograde amnesia caused by a lesion restricted to neurons of the hippocampus and no damage to the amygdala. Stuart Zola and colleagues (1993) at the University of California at San Diego investigated this dilemma. They performed more selective lesions of the brains of monkeys by distinguishing between the amygdala and hippocampus, as well as the surrounding cortex near each structure. They surgically created lesions of the amygdala, the entorhinal cortex, or the surrounding neocortex of the parahippocampal gyrus and the perirhipal cortex (Brodmann's areas 35 and 36) (Figure 1.3.3).

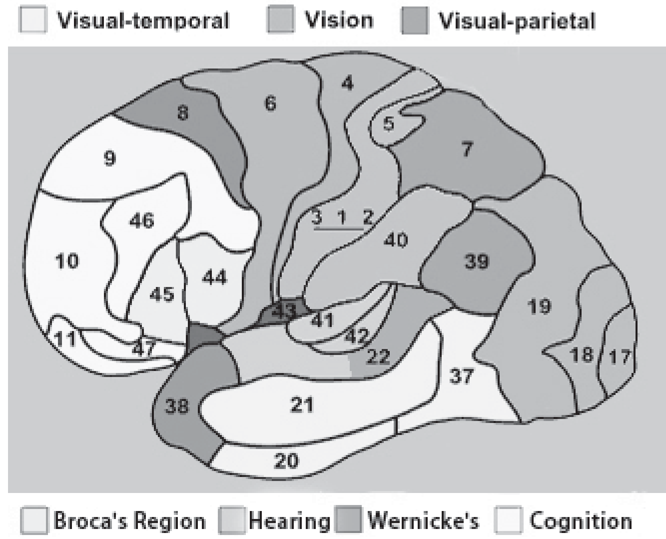

Fig. 1.3.3: Broca's areas of the Brain (Source: Net)

They found that lesions of the hippocampus and amygdala produced the most severe memory deficits only when the cortex surrounding these regions was also lesioned. When lesions of the hippocampus and amygdala were made but the surrounding cortex was spared, the presence or absence of the amygdala lesion did not affect the monkey's memory. The amygdala, then, could not be part of the system that supported the acquisition of long-term memory.

In subsequent investigations, Zola and his colleagues selectively created lesions of the surrounding cortex in the perirhinal, entorhinal, and parahippocampal regions. This worsened memory performance in delayed nonmatching to sample tests. Follow-up work showed that lesions of only the parahippocampal and perirhinal cortices also produced significant memory deficit.

How does this make sense in relation to R.B's profound anterograde amnesia with damage limited to the hippocampus and not involving the surrounding para-hippocampal or perirhinal cortex? The parahippocampal and perirhinal areas receive information from the visual, auditor, and somatosensory association cortex and send these inputs to the hippocampus, and from there to other cortical regions. The hippocampus cannot function properly if these vital connections are damaged. But more than this, we now also know that these regions are involved in much processing themselves, and hence lesions restricted to the hippocampus do not produce as severe a form of amnesia as do lesions that include surrounding cortex.

In summary, the data from animals are highly consistent with evidence from amnesic patients such as R.B. and H.M. that implicates the hippocampal system in the medial temporal lobe and the associated cortex as critical for forming long-term memories. Lesions that damage the hippocampus directly, or damage the input-output relation of the hippocampus with the neocortex, produce severe memory impairments. The amygdala is not a crucial part of the system for episodic memory but is important for emotional memory. Moreover, the animal data match well with those from amnesics with regard to the preservation of short-term memory processes after the medial temporal lobe has been damaged; monkeys memory deficits in the delay mismatching to sample task became more pronounced as the interval between the sample and test increased. The medial temporal lobe, then, is not essential for short-term or working memory processes.

As we noted earlier, the medial temporal lobe is not the locus of long-term storage because retrograde amnesia is not total after damage to this area; rather, the medial temporal lobe is a key component in organising and consolidating long-term memory that is permanently stored in a distributed fashion in the neocortex.

3.6 IMAGING THE HUMAN BRAIN AND MEMORY

The work described so far has dealt with evidence from humans and animals with brain damage. These data are consistent with regard to the role of the medial temporal lobe in memory. Over the past decade, there has been an exponential increase in studies of normal subjects using functional brain imaging methods. The results are quite provocative and are confirming and extending the findings from lesion studies. In the following, we review recent studies of the brain organisation of episodic memory, semantic memory, procedural memory, and the perceptual representation system (PRS).

3.6.1 Episodic Encoding and Retrieval

Given the purported role of the hippocampus system in encoding memory in long-term stores, researchers have eagerly addressed this issue using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). One such line of work involved face encoding and recognition. The question was whether the Hippocampus becomes active when encoding new information. James Haxby, Leslie Ungerleider, and their colleagues (1996) at the NIMH presented subjects with pictures of either faces or nonsense patterns, and, using PET, investigated memory performance. In different conditions subjects were required to remember (encode) the face, recognise the face, and perceptually analyse the face by comparing two faces. During these periods, PET scans recorded changes in regional cerebral blood flow triggered by local neuronal activity.

These investigators observed that the right hippocampus region was activated during encoding of the face but not during recognition, where retrieval processes should have been engaged. These data are consistent with those from amnesic patients who had medial temporal lobe damage that led to anterograde amnesia but preserved distant retrograde memories. Encoding also activated the left prefrontal cortex, whereas recognition activated the right prefrontal cortex. Thus, we have more support for the hippocampus's role in memory, as well as possible support for hemispheric asymmetries in memory functions.

Encoding and retrieval processes were lateralised in the left and right hemispheres, respectively, giving rise to a model with the acronym of HERA, which stands for "hemispheric encoding-retrieval asymmetry." This model represents the idea that encoding involves the left hemisphere more than the right, and retrieval involves the right hemisphere more than the left. Both processes predominantly involve the dorsolateral prefrontal cortex. In encoding and retrieving information from long-term memory, neocortical areas were the most activated.

Some more recent studies made use of event-related fMRI methods to track the processing of individual items as a function of the success of the encoding, as indexed by later memory performance. Anthony Wagner and his colleagues at MIT, Harvard University, and Massachusetts General Hospital (1998), and John

Gabrieli and his colleagues at Stanford (Brewer et al., 1998) conducted such studies. They presented subjects with items and scanned their brains using of MRI while they were encoding the information, and then later tested them for their memories of the items. Each research group found that event-related responses were larger in prefrontal and medial temporal regions (parahippocampal cortex) during encoding of words or pictures that were later remembered.

3.6.2 Semantic Encoding and Retrieval

The encoding and retrieval of semantic knowledge also have been studied using functional neuroimaging, and significant new findings have been uncovered. In particular, evidence for domain-specific organisation (i.e., knowledge of animate and inanimate objects is localised in different cortical regions) has proved to be a fascinating story. Unlike episodic retrieval that activates the right prefrontal cortex, semantic retrieval involves the left prefrontal cortex. The region includes Broca's area (Brodmann's area 44 extending into area 46) and the ventral lateral region (Brodmann's areas 44 and 45) (Figure 1.3.3). This lateralisation to the left hemisphere remains regardless of whether the memories being retrieved are of objects or words.

3.6.3 Procedural Memory Encoding and Retrieval

Earlier we learned that amnesics demonstrate implicit learning of motor sequences (procedural knowledge) even when they cannot form explicit memories about the stimulus sequence. Amnesics provide powerful evidence that implicit learning need not be mediated by explicit knowledge about the material.

Scott Grafton, Eliot Hazeltine, and Ivry (1995) investigated the brain basis of procedural motor learning in normal subjects. They compared conditions in which the subjects learned motor sequences implicitly during dual-task conditions, which helped to prevent subjects from explicitly noticing and learning the sequence. PET conducted during the dual-task condition demonstrated activation of the motor cortex and the supplementary motor area of the left hemisphere, and the putamen in the basal ganglia bilaterally. Also activated were the rostral prefrontal cortex and parietal cortex. Therefore, when subjects were implicitly learning the task, brain areas that control limb movements were activated. When the distracting auditory task was removed, the right dorsolateral prefrontal cortex, right pre motor cortex, right putamen, and parieto-occipital cortex were activated bilaterally.

3.6.4 Perceptual Priming and Implicit and Explicit Memory

Daniel Schacter and his colleagues (1996) at Harvard University investigated the neural bases of perceptual priming (implicit learning) in a PET study. The scanning was performed only during the task. Subjects manifested implicit priming behaviourally. No activations or deactivations were noted in the hippocampus, but blood flow in the bilateral occipital cortex, (area 19) decreased (Figure 1.3.3). The hippocampus was not activated, then, even though implicit perceptual priming was obtained.

The conclusions from this and other studies are that implicit and explicit retrieval of information is subserved by separate brain systems. Together with the face encoding data Haxby and colleagues obtained by PET, and animal and human lesion data, a reasonable conclusion is that the hippocampus encodes new information but also retrieves recent information when explicit recollection is involved. Perhaps more interestingly, deactivation *of* the visual cortex for previously seen words is a correlate of perceptual priming.

In summary, neuroimaging studies have demonstrated patterns of neuronal activation that are consistent with memory systems derived from cognitive research, studies in human amnesics, and animal models. Neuroimaging also has provided some notable new findings in the cognitive neuroscience of memory, including, for example, the hemispheric asymmetries in encoding and retrieval.

3.7 CELLULAR BASES OF LEARNING AND MEMORY

How does the activity of different brain regions change as memories are formed? Most models of the cellular bases of memory hold that it is the result of changes in the strength of synaptic interactions among neurons in neural networks. How would synaptic strength be altered to enable learning and memory? Neil Carlson (1994) described some basic physiological mechanisms for learning new information.

One basic mechanism is *Hebb's law*, named after the man who posited it, Canadian psychologist Donald Hebb, in 1949. Hebb's rule states that if a synapse between two neurons is repeatedly activated at about the same time the postsynaptic neuron fires, the structure or the chemistry of neuron changes and the synapse will be strengthened—this is known as *Hebbian learning.* A more general, and more complex, mechanism is called *long-term potentiation (LTP)*. In this process, neural circuits in the hippocampus that are subjected to repeated and intense electrical stimulation develop hippocampal cells that become more sensitive to stimuli.

That an excitatory input and postsynaptic depolarisation are needed to produce LTP is explained by the properties of the doubly gated *N-methyl-D-aspartate (NMDA) receptor* located on the dendritic spines of postsynaptic neurons that show LTP. Glutamate is the major excitatory transmitter in the hippocampus, and it can bind with NMDA and non-NMDA receptors. When 2-amino-5-phosphonopentanoate (AP5) is introduced to neurons, NMDA receptors are chemically blocked and LTP induction is prevented. But the AP5 treatment does not produce any effect on previously established LTP in these cells.

Therefore, NMDA receptors are central to producing LTP but not maintaining it. It turns out that maintenance of LTP may depend on the non-NMDA receptors.

Long-Term Potentiation and Memory Performance - This effect of enhanced response can last for weeks or even longer, suggesting to many that this could be a mechanism for long-term learning and retention (Baddeley, 1993).

Disrupting the process of long-term potentiation (say, through different drugs) also disrupts learning and remembering. Chemically blocking LTP in the hippocampus of normal mice impairs their ability to demonstrate normal place learning; thus, blocking LTP prevents normal spatial memory. In a similar way, genetic manipulations that block the cascade of molecular triggers for LTP also impair spatial learning.

These experiments provide strong evidence of impairing spatial memory by blocking NMDA receptors and preventing LTP. Moreover, we are rapidly developing a very clear understanding of the molecular processes that support synaptic plasticity, and thus learning and memory in the brain.

3.8 LET US SUM UP

The ability to acquire new information and retain it over time defines learning and memory. Cognitive theory and neuroscientific evidence argue that memory is supported by multiple cognitive and neural systems. These systems support different aspects of memory, and their distinctions in quality can be readily identified. Sensory registration, perceptual representation, working memory, procedural memory, semantic memory, and episodic memory all represent systems or subsystems for learning and memory. The brain structures that support various memory processes differ, depending on the type of information to be retained and how it is encoded and retrieved.

Despite the intriguing results from neuropsychological studies, we are far from having a complete picture of how the brain instantiates all, or even many, memory phenomenon. It is not clear which aspects of memory are localised in one place in the brain and which are distributed across different cortical regions. Tulving pointed that neuroscientists today reject the idea of studying memory as though it were a single process. Instead, they are likely to look for neurological underpinnings at a more precise level – at such processes as encoding or retrieval. The latest neuroimaging techniques clearly will continue to provide invaluable information about human memory and its neural substrates in the healthy human in the years to come.

3.9 UNIT END QUESTIONS

1) Summarize the findings of neuropsychological research on localising memory in the brain.

2) Compare and contrast the human and animal models of the study of neural basis of memory.

3) What exactly do findings from memory studies with amnesic patients tell us about the way memory operates in nonamnesic people?

4) Imagine what it would be like to recover from one of the forms of amnesia. Describe your impressions of and reactions to your newly recovered memory abilities.

5) How would you design an experiment to study the neural process of semantic memory by functional MRI technique?

6) Patient H.M. and others with damage to the medial temporal lobe develop amnesia. What form of amnesia do they develop, and what information can they retain, and what doe sthis tell us about how memories are encoded in the brain?

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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.

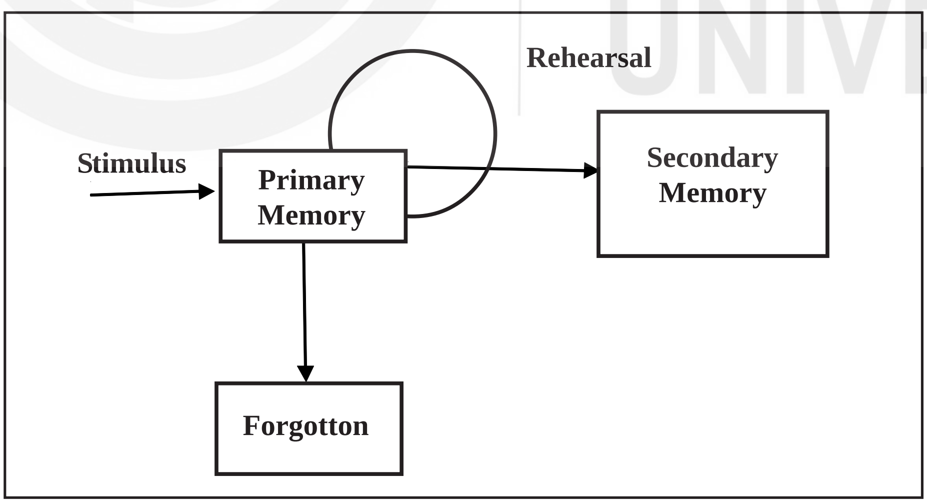

Fig. 1.4.1: Model of Primary and Secondary Memory (*Adapted from Waugh and Norman (1965)*

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.

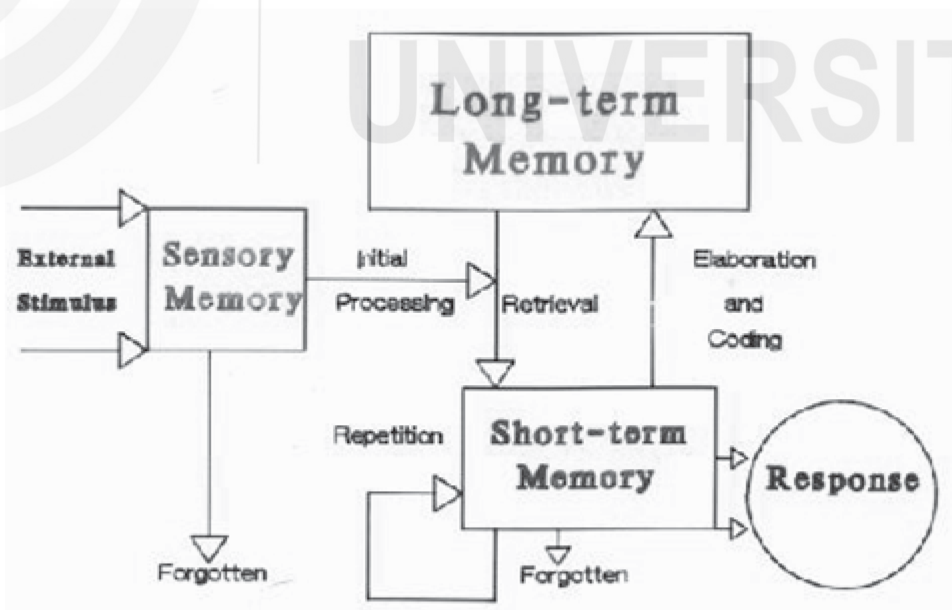

Fig. 1.4.2: A stage model of memory (*Adapted from Atkinson and Shiffrin 1969*)

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.

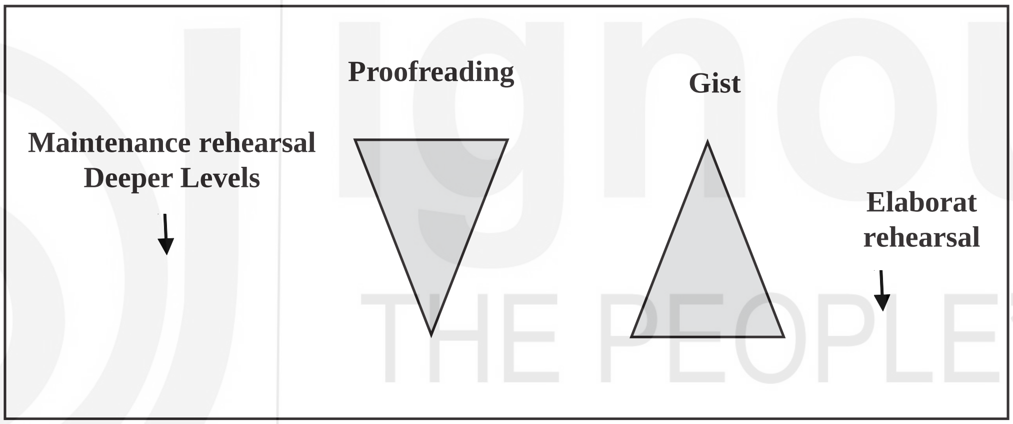

Fig. 1.4.3: Memory activation in two kind of reading. (Adapted from Solso, 2006)

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

4.10 SUGGESTED READINGS AND REFERENCES

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