

"A CRITIQUE OF MEMORY RESEARCH"

by

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The work presented in this thesis has been composed
entirely by myself.


Jesus Figueroa Nazuno.

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To: Mariana, Libertad

Razon y fuerza de mi vida.

ABSTRACT

The present relation between theory and experimentation in the area of memory is discussed, and as a result it is suggested that there is a crisis in this field of work. On the one hand, there are some theories which are supposed to be guides for research as exemplified by the theory of Shiffrin and Atkinson, and on the other hand there are a great deal of problems, or phenomena, which are open to research and cannot be explained using contemporary theories. It is concluded that the lack of relation between the explanations and the phenomena is the major source of the crisis. This conclusion is supported here with an experimental analysis of the ideas of trace, flow of information and stores. One of the indications of possible solution to the crisis, is the experimental evidence in favour of the idea of memory as a reconstructive process. A conceptual structure for further work is presented, which could be considered as an intermediate step to relate in the future, in a clearer way, several phenomena and explanations. This conceptual structure suggests the use of a different interpretation of memory functions; suggests the use of the idea of processes of manipulation of information, and points out the difficulties in trying to elaborate accounts of representation.

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"MY STYLE IS NOT ONE OF TEARING THINGS DOWN;
IT'S PUTTING ORDER TO THINGS"

PROF. HENRY HILL

"TRUTH IS NEVER PURE, AND RARELY SIMPLE"

O. WILDE

"THE IMPORTANCE OF BEING ERNEST"

GENERAL INTRODUCTION

"God not only plays dice, He sometimes throws
the dice where they cannot be found."

"UNUS CONTRA MUNDUM"

GENERAL INTRODUCTION

The basic aim of this work is to consider some aspects of the present state of memory research, mainly the relation between theories and experiments, from a point of view which is not completely theoretical nor completely experimental. The reason for taking up this intermediate position is that neither a purely theoretical nor a purely experimental analysis would capture the relationship between theory and experiment, one that is particularly important in that area of research.

From a theoretical point of view, the first problem we meet concerns the nature of theories in psychology generally. In this subject developments of general theories have had many limitations which include, among others, a lack of specification of what a theory or a model is, and the arbitrary adoption of examples from other sciences. It has even been claimed that theories are not necessary, Skinner (1950). Against this position it is important to point out examples of theoretical work in other disciplines from which important achievements have derived. Consider the part played by theory construction in the physical sciences, for example, where mathematical formalisms are more important. Another example is afforded by biological theories such as the theory of evolution, which has provided a powerful working tool even without it being mathematically formalised. Moreover, there is the research in astronomy and economics which has been guided entirely by theory, experiments being ruled out by either logical or practical necessity.

In the particular case of memory, the theories being used or that have been used in the past, are in some cases too simple or specific; or they are related to particular experimental paradigms; they are the product of ideologies or psychological schools, or even just the random result of experimental work. Theoretical work in this area is not well developed. Indeed a number of scientists have already expressed discontent over the situation: it has even been said that there is not much difference between the theories used today and the theories proposed around the time of Plato or of Ebbinghaus. It has also been said that the best that can be done with theories of memory is "to forget them" (Jenkins 1974).

One of the basic assumptions of the work presented here is that theory in recent memory research has reached critical state and that it is necessary to do something about it. In our search for a possible solution to this problem we will begin by analysing one of the best examples of a contemporary theory, in order to see how much such a theory can help to interpret the problems that characterize our knowledge or lack of it, concerning memory phenomena. A broader aim of our study will be that of providing a guide for future research in this area.

The study of memory confronts, or should confront, several broad problems, such as our poor understanding of what consciousness is; our lack of information with regard to the way that either voluntary or involuntary learning takes place, and the question concerning the relationship

of memory to other psychological phenomena. Also it is necessary to clarify the metaphores used both to describe information (or representation) and to study the manipulations of information that take place in memory, since they are particularly obscure. The decision to make problems the basis from which to develop theories of memory will have two important outcomes. On the one hand, it is the kind of problem that can be analysed by means of a theory that will reveal its limitations, and on the other hand, it is these very problems that determine the directions in which the research will go.

The mathematician, Hilbert (1902), elaborated a list of problems which, according to him, confronted mathematics at the end of the last century. This list not only gave structure to knowledge at the time, but also had a profound impact on the subsequent development of mathematics. The idea of delineating a list of problems for the analysis of the present state of the psychology of memory, as part of this thesis, was inspired by Hilbert's example. However, the nature of problems in mathematics is different from the nature of problems in the experimental sciences, not only in the way the problems are posed, but in the way that answers to these problems are formulated. Accordingly, it is difficult to determine the criteria to use for setting up such a list. In our attempt to do so we have held in mind developments in other areas of knowledge, not only within psychology, but in other disciplines also, that could indicate possible common phenomena. For

example, we have considered the need for ecological validity in psychological explanations, whereby phenomena are to be explained in relation to the natural complex environment in which humans have to survive. But there necessarily remains an element of arbitrariness in the way that we have organised our list of problems within the following categories:

- A) Fundamental problems concerning the relation between theory and experiment
- B) Problems on the nature of representation or information is stored and used
- C) Problems concerning the control and manipulation of information
- D) Parametric problems in systematic research
- E) Problems related to other areas of psychology.

This organization will facilitate the evaluation of the theory we have chosen to analyse by way of an example, namely the theory of Shiffrin and Atkinson (1969), which we will refer to as the "orthodox theory". It will also enable us to indicate the direction that could be followed in future research.

A detailed analysis is unnecessary for demonstrating that there is no direct relation between the orthodox theory and what is considered in this work as the most relevant problems that the psychology of memory needs to tackle, such as, the characteristics and functioning of consciousness; the relation between memory and other phenomena; memory and the central nervous system; sleep;

language; logical thinking; emotion; problem solving, and so on, and the existence of several phenomena, which, though they are an evident part of everyday life, have not been interpreted successfully so far (i.e. reminiscence, fluctuation of memory, voluntary forgetting, memory for plans, and so on). By examining the extent to which such problems fall within the domain of the orthodox theory we will gain a measure of its limitations. The outcome will be very important, since this theory is considered as one of the most representative and successful theories that is available at the moment. When we examine that relationship we find that the orthodox theory is indeed limited in its explanatory range. Possibly this is attributable to the origins of the theory in attempts to explain a rather limited set of phenomena to do mainly with short- and long-term memory. On the other hand, the orthodox theory also has certain strengths that are not easy to find in other theories: it gives importance to the manipulation of information and it places emphasis on the development of theoretical as well as experimental aspects of research. Also, it is important to point out the interest of its authors in continuing to develop the theory by incorporating a series of new elements. However, whether or not we take the limited range of explanation to be a strength or a weakness, there will remain doubts concerning the basic assumptions upon which it is constructed. The general assumptions of the orthodox theory concern the concept of trace, the concept of levels

of processing or stages, and the concept of passive stores that are incapable of generating "new" information. A detailed analysis of these assumptions leads to the conclusion that they may well be invalid. The concept of memory trace is not clear and it is difficult to observe the so called stages of memory, beginning with iconic and proceeding to long-term memory. It is also possible to find some examples of the way that new information may be generated by the manipulation of old information only.

After examining the orthodox theory and the problems that confront the study of memory, in chapters I and II, we turn in chapter III to experimental evidence bearing upon the basic assumptions of the orthodox theory. In experiments I and II the phenomenon of iconic memory was studied, a phenomenon found in most current models of memory. This form of memory is considered to be the first stage in information processing. It may be considered to be the clearest example of the idea of "memory trace". If this is so, iconic memory is a system (or store) which maintains the information given to the subjects, for a very short period of time, independently of the characteristics of that information. In order to test whether this strict idea of a memory trace is valid, subjects were presented with letters, and with a series of figures that may be considered to be novel stimuli. Two different experimental techniques were used for the analysis of the results, one devised by Estes (1965) and the other being a modification of the technique used by

Sperling (1960). In both experiments the responses given by subjects were not a function of memory span, and in the condition in which letters were presented the results were similar to those obtained in the experiments on iconic memory so far reported. (i.e. Sperling 1960; Rumelhart 1970; Estes and Taylor 1966). But when subjects received novel stimuli the results were quite different and the phenomenon of iconic memory (or trace) was not found. A logical analysis of this result seems to indicate the existence of a misleading assumption found in most experiments in human memory which use as stimuli material already known to the subjects, such as letters or numbers. It is not difficult to show that a great number of learning experiments (and forgetting experiments) do not seem to demonstrate how new items are learned, but how old material is reorganised. The results of experiments I and II lead to the conclusion that the idea of a trace in the strict sense of the term, as well as the idea of different stages in memory, from iconic to long-term memory, needs to be reconsidered carefully.

In a third experiment the idea of memory as a reconstructive process, postulated by Bartlett (1932), was considered as a possible alternative to the orthodox theory. The idea of "reconstruction" is that subjects, when presented with certain kinds of task, call upon information from the past in the form of a representation (e.g. "image": Bartlett 1932), and are capable of extracting and reporting certain specific information which they

probably did not know prior to the task by manipulating the representation. During the experiment the subjects were asked to reply to a series of questions such as "How many letters are there in your father's surname?", or "how many angles does the letter 'E' have? One group were presented with stimulus cards and asked to count the number of items, such as the angles on a given letter. The results of this experiment seem to indicate that there is a linear relation between the number of items to be reported and the reaction time: the more items to be reported the longer is the reaction time. This relation was found in both experimental conditions. It is possible to suggest then, that the subjects in the condition where they did not have the stimuli present, used something, such as an image, in order to arrive at the answer. That is, the kinds of question asked of the subjects required them to generate a spatial image: count the relevant items, and generate a new response. The results of this experiment could be taken as indicative that memory really has reconstructive characteristics (i.e. there is an active change in both the content of the information acquired and possibly the ability to generate new information), and that to generate an answer requires not only stores, but also different processes of manipulation of information.

In another experiment (IV), the hypothesis regarding images as a form of representation was explored in detail. Employing the psychophysical technique of successive

comparisons, the use of simple images (circles) was studied in a reaction time task requiring comparative judgements (bigger/smaller). It was observed that it is not possible to sustain, in the strict sense, the hypothesis of a linear relation between reaction time and the expansion or contraction of images in a manner analogous to Shepherd's (1975) idea of the mental rotation of images. The results seem to require that we draw a distinction between three kinds of processes. In the first, where the comparison is easy, the reaction time is constant (flat). In the second there is possibly, a relation between difference in size of the circles and the reaction time. And in the third, the difference between circles is so small that one might offer the interpretation that the images do not have enough fidelity to the original stimuli to allow for a precise comparison. The results of this experiment suggest that images may be the means whereby information is both represented and manipulated, but that in the same experimental situation, using the same stimuli, different forms of information processing may occur i.e. images may not be used. The results also seem to suggest that even when images are used, they may not be faithful copies of the external item. These results indicate the need to study carefully the phenomena of representation and especially the need to avoid premature confrontations between different interpretations of representation (e.g. image v. propositions).

In general the results of these experiments can be summarized by saying that in the experiments on iconic memory the idea of 'trace' cannot be supported when novel stimuli are used. It could be proposed, on the basis of these results, that iconic memory is not one of the first processes in the manipulation of information, but one of the later stages of comparison between the stimuli and what is already in store. The results obtained with the use of novel stimuli could be taken as an indication of the existence of a misleading assumption in memory experiments which employ letters, or nonsense syllables, or other kinds of material already known by the subject, since in these experiments it could be said that learning (or forgetting) in the strict sense is not taking place, but rather that there is only a reorganization of something already known. Moreover, an alternative point of view to one that emphasizes stages or memory boxes, is to be found in Bartlett's idea of reconstruction. There is evidence suggesting that reconstruction of information, which may involve the use of images, is likely to occur, and that it is possible to alter and generate new information without any direct learning being required. However, it is also possible to see in the results obtained that images as a form of representation play a limited role, and in some cases of the processing of information, this form of manipulation is not used. Together, these results suggest therefore, that the orthodox theory may have important limitations that make it unreliable as a basis for the interpretation of memory phenomena.

The orthodox theory was used to analyse the present state of memory research and it was found that not only does it not cover many of the problems confronting us in this area, but also that the basic assumptions of the theory seem to be somewhat unclear or at least partially mistaken. It could be suggested that the next step is to modify the orthodox theory in order to correct for its deficiencies. A number of explicit ways of making such a modification could be proposed, ranging from changes to some of its parts to its total transformation into a new theory, one whose domain of interpretation extends to the problems previously posed, as well as the experimental evidence presented in Chapter III, together with a great deal of additional experimental data found in the literature. This task, however, is very difficult and it is even possible that psychology is not yet prepared for it, that the elements needed for this task are not yet available. In this thesis something much more modest is proposed. It consists in the presentation of a conceptual structure that may provide a bridge for further work towards an integrated theory. In order to understand what a conceptual structure is, an example is given, using Ebbinghaus's conceptual structure and some other examples of this particular kind of research tool that has been used in recent years. Basically, a conceptual structure gives a general view: some methodological considerations; the most important variables to study, and an interpretation of some phenomena. One of

the most important changes proposed in the conceptual framework is the introduction, in a specific and clear form, of the idea of an active memory rather than a system of stores. The form proposed here considers that memory has a series of functions in addition to, and possibly more important than, the storage of information. These functions are related to the idea of a humanbeing as an inhabitant of a complex environment in which a constant series of problems must be solved for his survival. This kind of human being seems different to the one idealised in the orthodox theory, which proposes memory as an abstract entity separated from psychological functions and from a real environment. Based on this argument we propose, together with examples, which we consider to be the most important functions of memory, such as the construction of a model of action, the generation of hypotheses and the storage of information. In order for such functions to be possible, the system of memory requires processes to allow for storage, modification and comparison of information, and so on. In contemporary literature experimental evidence is found for these processes, among which some of the most important are perhaps scanning, comparing and labelling.

As a concluding step towards our proposal for a conceptual structure, the storage of information is discussed together with the limitations in the concept of representation in contemporary accounts. Some of the general characteristics that an interpretation of representation must have are also given.

In a few words, it could be said that memory cannot be considered as a "tabula rasa", but as a system that is constantly processing and using information (even probably, when a person is asleep). It could be said that a theory that assumes information to be processed in a series of steps, from the most simple to the most complex (i.e. from icon to long-term memory) does not take into account that, in a great number of situations, what a person is doing probably is generating hypotheses before events take place, and in many cases of a learning situation, not only storing the information, but also using it to make comparisons and reorganizing it in various ways.

The conceptual structure proposed contains some of the necessary elements for an improvement in our understanding of the memory system. It is possible to suggest that in future it is going to be possible to find in psychology (as in other areas of knowledge), scientists who are dedicated exclusively to theoretical work, dedicated that is, to the development and perfection of theories, not confusing this activity with other activities not directly relevant to theoretical psychology, such as work in philosophical psychology and mathematical psychology, reviews of the literature and general criticisms which, in many cases, do not produce anything more than noise and confusion. But for the moment, we will have to content ourselves with a kind of theoretical-experimental study in which it is not yet clear what are the rules of the game, or what tools are available, or in the worst case, whether it is a game that psychologists will want to play.

CHAPTER I

THEORETICAL PSYCHOLOGY

"After reviewing the literature on Memory if a person is not thoroughly confused, it is probably because he does not know much about it."

I will sing you the song
Of a man who went to war,
Who was wounded in the mountains
Who just fought to win some land.
Our General told us,
"Fight on with great valour
We are going to give you land,
As soon as we make the revolution."
If they come looking for me
To make another revolution
I'll tell them, "Sorry, I'm busy
Planting the fields of the landlord."

A. THEORETICAL PSYCHOLOGY

1. The Functions of Theoretical Psychology

The general function of psychology is not the mere accumulation of data, but the extension and development of our understanding of psychological phenomena, in co-operation with other related disciplines. Within this general framework, theoretical psychology has two sub-functions:

- (i) the elucidation of key psychological ideas;
- (ii) the organisation of those ideas.

It is true that new data may raise new questions but, in this work, the aim is precisely not to multiply the unknown, but rather to provide a scheme or model for answering questions in general. Current psychology is in need, not of fragmentation by the anarchic propagation of questions but of unification. The main task of theory in psychology is to meet this need.

The specific way in which this function takes place is in the form of models or theories, which are tools that help organize data, phenomena and observations, etc. into conceptual formulae. These formulae contain the characteristics of and interactions among the events studied. According to the richness of the formula's description it can be considered a model or a theory, this classification depends on the generality of the event being studied. In psychology, the distinction between a theory and a model is to some degree arbitrary. In a general sense it could be said that models are specific

conceptual formulae referring to particular events, whereas theories refer to general events.

The function of theoretical psychology is to construct, modify and analyse models and theories in psychology. The kind of models or theories "constructed" or "used" is varied and cannot be limited to a definition. A simpler way to describe the kind of theory and models used in psychology is to point out some examples such as the theory of learning of Hull (1943) and the theory of perception of Gibson (1966) or the model of short-term memory by Murdock (1974). In all these examples the validity of the theory as well as its utility and explanatory force, do not depend on specifying whether they are theories or models but in the "skill" of the "originator"; perhaps more important are the quality of the data obtained and perspicacity of the experiments. Many theories and models have been useful in the development of psychology which of course have been due to the activity of certain scientists. The function of theoretical psychology is therefore to develop models and theories not as a by-product of experimentation but as a specific activity. One of the clearest examples of theoretical psychology can be found in the work of Fodor (1975) who has presented a possible theory of representation which, as he points out, is a form of "speculative psychology." In the work presented here when reference to theoretical psychology is made, it is to the kind of work done by Fodor (op.cit). Fodor tried to describe the "language" in which information is represented

and manipulated. He gives some of the characteristics of this kind of representation, the "internal language", which he considers different from the language that people talk. He proposed that some characteristics of the process of representation are present in the system from birth; he also emphasised the logical characteristics of the system. It is difficult to describe which are the rules that Fodor used to make his "theory", the only thing that can be seen is the end-product, which, like any other theory or model, can be useful as a tool for developing experimental hypotheses and for interpreting previous data.

It is important to emphasise that the task involved in theoretical psychology (or speculative psychology) is to develop theories or models that can be used to unify data, promote research and try to give explanations. In order to clarify what theoretical psychology is, let us describe briefly some relations and distinctions, such as the difference between theories and so-called "schools", philosophical work, and various formalizations, and so on.

2. Psychological Schools and Theories

Psychological theories must be clearly distinguished from psychological schools, membership of which depends merely on the holding in common of a series of epistemological and methodological elements; an example is given by varieties of behaviourism represented by Skinner, Watson and Guthrie. Gestalt Psychology, although having more the characteristics of a theory, is just a school, as is

Cognitive Psychology which, however, is harder to characterise because of the apparent lack of consensus, except for the adoption of the name, by its members. Some members, like Neisser and Norman, are central. Others call themselves "neo-mentalists", yet are operationalists and have a very strict behavioural methodology, for example, Kendler and Kendler (1975) and Paivio (1975). The approach of many cognitivists, such as the contributors to Estes (1975), have indeed evolved from behaviourism, though perhaps none so dramatically as Premack (1976) who was previously a Skinnerian.

The most difficult case of all is Piaget who, although a member of the cognitive school, is, in a sense, unique. Piaget's work has received both support, and, especially recently, criticism on empirical grounds. However, we are not here concerned with its empirical validity, but with the type and range of application of the theory it embodies. Piaget has shown more interest than any other psychologist in theory "per se" and has put forward theoretical claims in metaphysics, epistemology, logic, mathematics and biology.

3. Limits of a Single Theory

It may be supposed that the development of scientific psychology has resulted in a "collage". In this "collage" each of the various schools and theories although radically different, would reflect some degree of truth or rationality. This supposition would, however, carry the implication that

a unified theory is impossible (e.g. Beloff 1973, Koch 1964 and Krech 1970). The situation gets really complicated if we include, for example, Russian psychology, which has greatly developed in the last few years. The schools of Pavlov and Vygotsky have ramified and multiplied in an astonishing way. There are also many other new forms of theoretical and experimental work; for example, the psychology of the Republic of Georgia (Cole and Maltzman 1969) and that of the Republic of the Ukraine (Holowinsky 1978).

If in addition to the above, other areas, like Social Psychology and Neurophysiology, are included, a unified theory definitely becomes very difficult to visualise, and instead several theories have to be suggested each for different aspects of psychology. This in no way means, however, that hundreds of theories, or lots of miniature models have to be made, as is the case at the moment. Unfortunately theoretical psychology nowadays is very limited: it seems that the old interest in the search for laws is not very great; and that interest in theories has waned. Nevertheless, it is not so difficult to find certain regularities that could be called laws; an example of this, from French psychology, is the work by Flores (1970), who, in a chapter discussing the present state of memory research, described a series of laws of memory mainly originating from the beginning of the century, for example as, Jost's, Ballar's, Von Restorff's Effect, etc.etc.

Another way of analysing the state of theoretical

psychology is to see where places - devoted in a more or less organised way to this kind of work - can be found. There are only two: The Institute of Theoretical Psychology at the University of Alberta and The Institute of Genetic Epistemology in Geneva (dominated by the psychology of J. Piaget). Until a few years ago the University of Edinburgh had a Sub-Department of Theoretical Psychology centred mainly around Dr. Longuet-Higgins and his co-workers in artificial intelligence, but this is now defunct. Therefore, at the moment there are probably only two places where there is a reasonably systematic approach to this kind of work. The same can be said for the places where a psychologist can receive training in theoretical work. Giorgi (1974) was commissioned by the A.P.A. (American Psychological Association - Philosophical Psychology Section) to report which Educational Establishments in the United States and Canada offered students some training in theoretical psychology. He found that, out of 160 Departments of Psychology, only 10 gave such facilities at the undergraduate level and a mere five departments gave a degree in Philosophical Psychology.

One kind of training related to theoretical psychology is that given in mathematical psychology at some universities in America and the United Kingdom, where there is strong emphasis on the use of mathematical tools. This kind of training is, however, rather different from training in theoretical psychology, for it is limited in scope and refers only to the use of mathematical tools rather than to training in theoretical psychology as such.

4. Theoretical Psychology and Philosophy

For many years it was believed that the philosophy of science was going to give a "manual" of how to make theories, and it is only in the last few years that philosophy of science has restricted its task (e.g. Lakatos 1974, Putnam 1973). The philosophical analysis of the implications of a theory seems to be subsequent to the construction of the same, and in some cases it is the theories of particular areas of science which have changed philosophy and not vice versa (See Capek 1961). The theory of relativity and quantum mechanics are very well known cases. This does not mean that scientific activity and theoretical work are not profoundly influenced by philosophical concepts. A recent result of philosophical research (the philosophy of science and other related areas of knowledge) is the demonstration of how scientific work is profoundly influenced by specific metaphysical schemes. This has been one of the major contributions of Kuhn (1970) and of Popper (1963). Philosophical work and theoretical work in psychology (or in any other area, e.g. physics, biology and so on) are different mainly in relation to the task of elaborating models or theories about particular events.

5. Theoretical Psychology and Formalisation

One important aspect of theory construction is the difference between theories in physics and other areas, where there is the help of mathematical tools, and theories

which are nonetheless theoretical, in spite of the lack of such tools. In the case of a theory using mathematics, it is important to point out that, in most cases there is a series of fundamental ideas, behind the mathematical formalism. Further, it is thought that mathematical formalism does not require interpretation, except in a few cases, e.g. that of quantum mechanics (Jammer 1974). However, during the development of theories in physics there have been several occasions where a formal element has been arbitrarily introduced in response to a theoretical need, and, with time, and the development of research, an empirical counterpart to the element has been found.

It is important to remember that there can be a simple or complex theory without there being a need for formalism.

A distinct and familiar case is the theory of evolution which is a scheme of high complexity and explanatory power but which is not a formal theory, though it is complete (using the scientific and not the mathematical sense of "complete", which is not to deny that it may be modified). There are also other specific cases, like geology, where for a few years, there has only been a simple yet highly powerful non-mathematical theory: the theory of tectonic plates. The case of geology is very heartening for psychology, since, until a few years ago, it was merely a descriptive science without theories, or general schemes, and without much power to make predictions. The theory of tectonic plates has, however, changed things radically. Another very interesting and illustrative aspect of this

theory is the fact that it is centred around the postulation of hypothetical constructs: tectonic plates which have not been seen, and of whose existence there is only indirect evidence.

The theories of economics provide examples of conceptual theories that have the power to predict and explain phenomena, but without the opportunity for experimental verification. In some cases the application of economic measures supported by the theory alters the functioning of the economic system in a significant way, even though the latter is the product of the interaction of many variables.

These examples are illustrations of theoretical work and show how it is possible to suggest that theory without mathematics is possible. This is sometimes forgotten when thinking about psychological theories.

6. Theoretical work in other areas of knowledge

It is probably useful to see how theory works in other areas of science and to try to draw some conclusions.

Physics is an interesting area with very good examples of theories. As has already been mentioned, theoretical work in physics is superficially different from that of other areas of science because it is possible to formalize it to a very high degree. However, when it is analysed in detail it is not so very different from the theoretical work done in other areas of knowledge (for example in psychology).

Let us start by saying that one of the most important aspects that can be observed is the distance (not to be confused with separation) between theoretical physics and experimental physics. It is possible for the theoretical physicist to dedicate himself to theory and the organization of knowledge, rather than merely to the search for new data. The relation between theory and experimentation is complex; it is interesting to note that experimental knowledge sometimes precedes and sometimes succeeds theoretical knowledge. But even in physics, where theoretical work is so advanced, there are no recipes for constructing theories. As a result, a careful search through manuals and books of physics only reveals an emphasis on mathematical tools. In physics, as in psychology, there just are no guides to the construction of theories.

One thing alone is obvious; new and better theories are constantly coming along. When one asks physicists how they construct such theories, their responses are useful, even if they are ambiguous and vague. They usually say that they "try to generalize to new situations", or "look for borderline cases", or "try to apply a particular theory to different situations and see if it works". Others say that they "define the problem clearly", and so on. In most cases, the perfect definition of problems and the making of a series of basic assumptions are felt to be the principal characteristics of theoretical work.

Astronomy is another interesting example, mainly because it is not an experimental science, whereas

psychology is. Theories in astronomy are nevertheless either acceptable or not in a very clear way. In the field of astronomy, pressure to make a general theory to explain phenomena is created when new observations emerge. Astronomers' theories are based on a series of general assumptions which can be tested in one way or another. An interesting aspect of astronomy is the constant use of old data in research and the development of new theories; unlike the situation found in psychology, and to a lesser extent in other areas of knowledge. A great number of catalogues of photographs and other kinds of old observations can still be found in constant use by modern astronomers.

Economics is another area of knowledge where theoretical work is of very great interest since there is no experimentation (as in the case of astronomy), but where not only are predictions frequently found, but also changes of society may result from interventions of economists. Another aspect of economics which deserves attention is the use of highly complex mathematical models (econometrics), even though the data contain errors and are not very precise (Morgenstern, 1963). There is a very interesting lesson to learn from this. It is sometimes thought that the basis of mathematical models is the precision of measurement, whereas, in economics on the contrary, the indicators used have a high percentage of error.

7. Theoretical work as a specific activity

Granted a positive attitude towards theoretical work and the knowledge both that there are no specific rules for theory construction and that one can find conceptual theories, we are led to the following suggestion: given the complexity of theoretical work, a systematic effort is necessary if a psychological theory is to be made.

One of the best ways to encourage theoretical work is to have a group of researchers dedicated to this task.

B. EXAMPLES OF THEORETICAL WORK IN PSYCHOLOGY

There has, of course, been some theoretical work done in psychology and this has contributed to its progress by clarifying certain areas of work. Theoretical work, which is not to be confused with reviews of the present state of any area of knowledge (as is often the case in many papers in the Annual Review of Psychology), will be illustrated below.

One of the many examples of theoretical work in psychology is that of S. Koch (1954), in his analysis and criticism of the learning theory of C. L. Hull (1943). This theory was, as has been said (Hilgard and Bower, 1975), of great importance in the 30's through the 50's. At this time the major learning theories were represented on the one hand by Hull and on the other by Tolman. Gestalt psychology was also considered by some to be important. As Koch points out, his work was a complete and detailed attempt to analyse Hull's theory and it was probably one

of the most important factors contributing to the decline of Hulleian theory (Hilgard and Bower, 1975).

In other cases theoretical work has been more constructive. The work by Miller, Galanter and Pribram (1960), was the beginning of so-called "information processing" models. Another case of theoretical work which has had some impact was that expounded by Hebb (1949). Hebb proposed the "Cell Assemblies" theory which has influenced an area where theoretical work is considered dangerous and where the rule is to stay close to the results and facts.

Another example of theoretical work which still has an influence is Gestalt theory which, along with a series of demonstrations of the existence of certain phenomena, has retained its value. Nevertheless it cannot really be said that Gestalt psychology is a complete theory, even though it has a large number of theoretical elements; rather it is a bridge between the past and the present by means of a psychological model of some considerable general power.

Paradoxically, in some cases it even happens that certain theoretical work itself helps to limit theory. An example of this is the paper written by McCorquodale and Meehl (1948) on the distinction between hypothetical constructs and intervening variables which, whilst being totally theoretical, had the effect of actually limiting theory.

Psychophysics is another area of work which could be,

and at the time of its original conception actually was, considered as theoretical, in the same way as mathematics. Nowadays, a century later, Fechner's same family of functions are still used as a mathematical model of wider application. The great number of phenomena, which can be described with this kind of psychophysical functions, go from phenomena of sensory codification, (e.g. Stevens 1957), relations between intensities of stimuli and their psychological report (classic psychophysics), in very different modalities and with a large variety of forms of stimulation, (e.g. Stevens 1966), to estimations of subjective time (e.g. Eisler 1976) and even phenomena of personal involvement in social issues (e.g. Lunberg et al 1972). Although the range of applications of psychophysical formulae has been vast, it is very difficult to find an interpretation of the formalism which is not very complex from a mathematical point of view. Moreover its psychological meaning is not very clear and it seems that even if there is a great deal of power in the generalization to other phenomena, there is not very much of interest in its interpretation.

In some cases it is even possible to find the concepts behind, and the general idea of, theoretical psychology explicitly stated, and even to find a supposed guide for theoretical work, as for example the book by Greeno (1968) initially appears to be. It cannot be denied that the aim expressed in this book is of great interest and that it agrees with the ideas expressed in this work, as regards theoretical psychology. However, in actual fact, the

help given is limited to describing mathematical tools which have been used in the past and in trying to make formal models in specific areas of research, rather than saying very much about how to make theories. Therefore, like many others, the book is only interesting as regards the applications of mathematical models to the description of psychological phenomena or the discussion of specific experiments in mathematical psychology.

Another very interesting case of theoretical work, is Lashley's (1951) paper on serial behaviour. This work has led to research which has in general been considered important because it delimited a particular problem area; but even though the article is well-known and oft quoted, the problem it raised is still unresolved.

Theoretical work has sometimes taken the form of advertising certain philosophical schools, or even, in certain cases, a particular way of thinking in psychology; an example of this is the Symposium on Motivation at the University of Nebraska, Arnold (1976), which started with the question: what is the paradigm of psychology? Several paradigms were proposed, ranging from that of existentialists, and Marxists, to that of the behaviourists. The impossibility of a paradigm was even considered.

From the example given, it can be seen that theoretical work does exist in psychology and that it has an important role to play. In most cases, however, it has taken the form of supplementary work tacked onto accounts not directly concerned with theoretical issues. Another aspect that

has been illustrated is that, even if it is possible to classify many aspects of theoretical work, it is not easy to characterize and to describe them in a specific way. It seems that although one can recognise theoretical work, one cannot easily describe its unifying factor in an explicit way.

C. THE STATE OF THEORETICAL WORK IN MEMORY

One's opinion of the state of present research is greatly influenced by one's personal taste and the psychological school of work to which one belongs, as can be seen in different papers dedicated to this subject in recent years. In some cases the papers are totally pessimistic: Tulving and Madigan (1970), for example, state that there have been no changes since the work of Ebbinghaus. Other authors talk of a crisis in memory research (Jenkins 1963) and yet others, analysing the more important concepts and phenomena in current research, say that there is nothing new, and that most of the concepts and phenomena discussed today were well known at the beginning of this century (e.g. Murray, 1976; Moniou-Vakali, 1974; Brown and Deffenbacher, 1975; Stigler, 1978). Still other psychologists say that research is perverted by phenomena external to the research itself, such as certain political ideologies, (e.g. Kvale, 1975, Bakan, 1977).

An influential psychologist has said that the entire approach to this problem during the last 20 or 30 years has been completely wrong and that the best that can be

done is "to forget it" (Jenkins, 1974). In other cases a "revolution" in psychology is mentioned (Warren, 1971), with the emergence of a new paradigm as much in learning and memory in particular, as in psychology in general (Weimer and Palermo, 1973). Yet others consider that the mathematical models used in memory and learning at present, are but a gradual evolution of the work of Hull, (Greeno and Bjork, 1973). To go even further, it can be suggested that the basic mathematical functions for learning and memory accorded to Hull (1943), are the same ones that had already been described more than a century before by the philosopher Herbert (Bakan, 1952).

Many different authors have arrived at the conclusion that memory research is in serious difficulty. An inspection of the literature reveals that attacks on current work have been completely misdirected (Ach, 1968) and that there has been a retreat from associationist theoretical positions, most notably by some who were formerly in the vanguard of that movement (Jenkins, 1974). Also, there have been assertions that, since Ebbinghaus, there has been no advancement (Tulving and Madigan, 1970) and calls to reorganize and theorize, since there is a wealth of data but a poverty of explanations (Nowell, 1973). Further, have been assertions that the concept of memory is neither required nor helpful in the analysis of behaviour (Branch, 1977); there have been claims that the study of verbal behaviour is putting the "cart before the horse" (Weimer, 1974); assertions that the study of memory has only been

a by-product of the study of language (Herriot, 1975); and recognition that there are many important phenomena to study and explain, but that simple problems must be tackled first (Murdock, 1974). There is clear empirical evidence that adult human subjects cannot learn by operant or classical conditioning as such (Brewer, 1974). Also prominent associationist (S-R) theorists are using non-associative explanatory mechanisms and phenomena, to solve their theoretico-experimental problems. Postman (1972) for instance, has had to postulate "selector mechanisms", and Underwood (1966) postulates "rules". There have also been suggestions that recent theories make little advance on Aristotle's theory of memory (Maniov-Vakali, 1974).

Of course, there are some researchers who think that there have been advances and that there are many new discoveries and theories, which are powerful, explanatory and predictive, for example Peterson, 1977; Postman, 1971, 1975; Baddeley, 1976; and Cotton, 1976.

All these papers are reviews of the general state of the area of memory and are not mere footnotes in experimental articles. This suggests on the one hand, activity in the field, and on the other, the contradictory state of research. The existence of contradictions and crisis is not something entirely negative, on the contrary, it points to a vitality in the area; but proper steps must, of course, be taken to resolve the contradictions.

1. A Case Study

One of the possible alternatives to solving the contradictions of memory research and theorizing is to take a theory that one considers one of the best and study how well it functions as a tool. There are different points of view that can be considered. One approach is to ask how much is the theory helping both to generate research and to discover new phenomena or new areas of research. Another approach is to try to see if the theory is wide enough to include the explanation of many different phenomena. A third point might be to consider whether the theory is sound, that is, how true are the assumptions forming the structure of the theory. The idea of taking a particular theory is the main idea of the work presented here.

A good candidate for this sort of analysis is the theory of Atkinson and Shiffrin (1968) and Shiffrin and Atkinson (1969) this theory (which is going to be called from now on for the purpose of this analysis; The Orthodox Theory) has been described as the only one that can receive the name of "theory" of memory. For instance Tulving and Madigan (1970) said "... we believe it to be the most ambitious and most highly developed theory". This theory represents in an articulated form the most important ideas and developments in memory. Shiffrin (1975) commented that this theory surprisingly, has many similarities with the models of other authors (Bjork, Craik, Massard and Murdock). Another characteristic of this theory is its

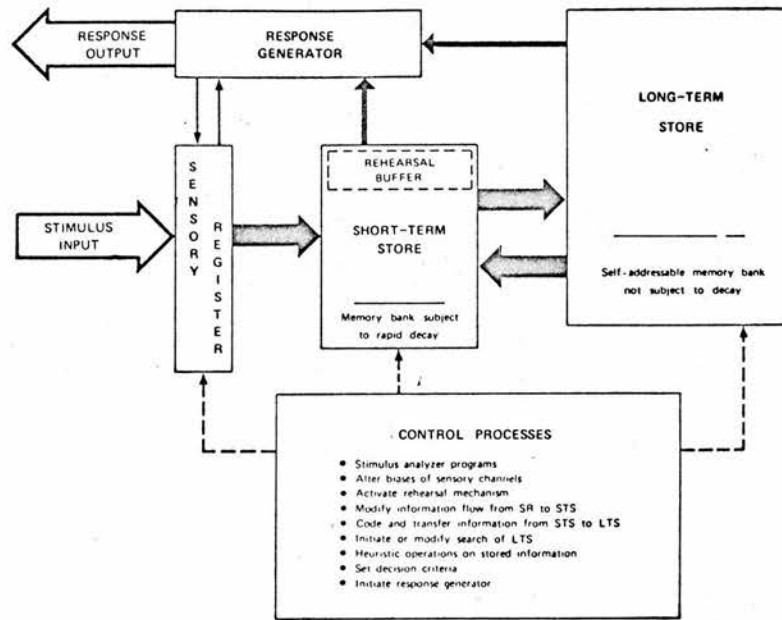
flexibility in producing and incorporating new data. For these reasons it is possible to use it as a representative of theoretical work in memory research. In order to avoid misunderstandings, the analysis of this theory is going to concern only its theoretical aspects, following in detail one of the best descriptions of the theory, by Atkinson and

Wescourt (1975): ...The memory system to be described is extremely general. The intent is that it be capable of supporting a broad range of cognitive activities, from perception to language comprehension, that, in common, depend on the utilization of stored information... The central theoretical elements of the system have appeared in other theories. The most basic construct in the system is the feature. Features are values on dimensions in terms of which information can be represented. Ordered sets of features comprise information codes. A code is an internal representation that defines a unit of experience - most simply an object in the system's environment. Codes are linked (connected, associated) together to form memory structures. These structures "represent" knowledge and events within the system. Codes and structures are stored in different memory stores of the system. These stores are characterized by their internal structures and by the storage and retrieval processes that are used to manipulate information. The system also has control processes that regulate the representation, and storage and retrieval processes with respect to the context of the system's activities. Control processes act to develop efficient strategies for performing tasks under changing conditions... The three main divisions of memory are the sensory register (SR), short-term store (STS) and long-term store (LTS). Information enters the system via its receptors and is transmitted to the SR in a relatively unprocessed form. The mosaic of sensory information in the SR is subject to pattern recognition processes that extract features and synthesize them to form codes. The information in the SR is lost rapidly either by decay or by being "written over" by new input. The STS is a working memory of limited capacity. Information is copied into STS either from the output of the pattern recognition process or from LTS. Information is lost from STS unless maintained by particular control processes like rehearsal or

imagery. The contents of STS may be thought of as a person's "current state of consciousness"... Information is represented in the memory system as codes. Each code is an ordered list of features that define an arbitrary unit of experience (an object, a relation, an abstract concept) on some set of dimensions. Two main classes of codes are distinguished on the basis of the types of features that comprise them: perceptual codes (p-codes) and conceptual codes (c-codes). The p-codes are generated from the mosaic of sensory information in the SR by pattern recognition processes... The p-codes play an important role in the internal representation of objects and relations in the environment. However they are not sufficient for the operation of human memory... There is a higher-order type of code that we will call a c-code. Let a concept be a collection of memory structures containing information about a particular object, relation, or another concept; for example, the concept of 'table' is the information stored in memory from experiences with various tables. Then a c-code is a characterization of a concept as an ordered list of conceptual features-- it is, in a sense, an abbreviation of the concept.. How might memory be structured to allow rapid access to c-codes when words denoting concepts or objects are perceived? The perceptual features of the p-code produced when a table is seen could be similar to the conceptual features of the c-codes of the concept table, but there could be no such relation between the c-code and the word "table" since the word is an arbitrary symbol for the concept. Thus, there must be arbitrary links between the c-code and the p-codes of its symbols. Such links are defined in a functional partition of LTS that we will call the conceptual store (CS). Located in the CS are special memory structures called nodes. Each CS node is a collection of the alternative p-codes for the word and object (if any) that correspond to the c-code that is also stored at the node. For example, the node for table contains the c-code that is an abbreviation of the concept table and linked to it are various p-codes that are produced when a table is seen, when the printed word "table" is seen, when the auditory word "table" is heard, etc... New information is stored in memory by linking together copies of codes that represent physical or conceptual events to form memory structures. Memory structures are first built in STS and are then copied into LTS. Memory structures (as distinct from nodes) are

stored in a functional partition of LTS called the event-knowledge store (EKS). The EKS is distinguished from the CS in two main ways. First, memory structures in EKS represent a wide range of relationships between different code types, as compared to CS nodes. A CS node represents a simple linking of the abbreviated meaning of a concept to the alternative internal codings produced by perception of physical symbols or exemplars of that concept. An EKS memory structure, on the other hand, may have many internal organizations that reflect the relations between physical referents and/or abstract concepts in events and knowledge... We have represented a view of how different theoretical constructs, each developed from a consideration of some aspect of memory, can be integrated into a system that, in principle, is capable of accounting for a broad range of cognitive activities. The constructs of the system are in accord with both data and logical considerations of how memory must operate. The work of Sperling (1960) in vision and Massaro (1972) in audition agree with the notions of a SR and pre-perceptual representation. The idea of alternative internal codes is central to the explanation of studies of same-different recognition (Posner, 1969). The CS and c-codes reflect studies of recognition memory (Atkinson, Herrmann and Westcourt, 1974), semantic decision-time (Rips, Shoben and Smith, 1973), and the requirements of a language understanding system that must have rapid access to the information needed to parse input (Schank, 1972). Other constructs (for example, those involving content-addressable storage and the representation of processes) reflect the influence of research in computer science and artificial intelligence (See Fig. 1).

As we can appreciate, this theory is an integration of many ideas and experiments in contemporary research, and therefore representative of theoretical work. However it is necessary to see if this theory can accommodate and cope with critical phenomena and experiments from a theoretical point of view. This analysis will be done in Chapter II. But it is also important to establish if the assumptions of the theory are valid. This analysis will be done in



■ A flow chart of the memory system. (Solid lines indicate paths of information transfer. Dashed lines indicate connections which permit comparison of information arrays residing in different parts of the system; they also indicate paths along which control signals may be sent which activate information transfer, rehearsal mechanisms, etc.)

Fig. 1: (After Shiffrin and Atkinson, 1969).

Chapter III, paying attention mainly to the concepts of store and sensory register (iconic memory), the idea of the flow of information from SR to STS and LTS, and other assumptions, drawing on some experiments which derive from this theory. It is important to consider this analysis not only in relation to the particular theory in question, but also in relation to memory research in general. The lengthy quotation from a description of the orthodox theory by its authors was given because it contains a detailed example of current thinking about memory. The authors of this theory have also stated that: "... the description of the memory system serves to introduce a language that is generally useful for thinking about memory. The memory system reflects that perception, simple retention and complex cognitive activities all require the representation, storage and retrieval of information and it constitutes a way of talking about them in terms of these commonalities. Thus, it provides a means for thinking about different problems with a single vocabulary..." (Atkinson and Wescours, 1975).

It is precisely this way of thinking which, as will be argued herein is limited, even though nowadays in psychology it is one of the most representative forms of research in memory. However there are other approaches to an understanding of memory phenomena which are theoretico-experimental, some of which we will describe briefly below.

D. OTHER MODELS AND THEORIES

1. In the Associationist Model

The source of the associationist model lies in the original work of Ebbinghaus (1885), but it received a strong impulse from the work of Hull and his students. For many years this was the representative of models in memory research. Its basic concepts are: (1) the concept of association applied to different phenomena, for example, intra-list or remote association; (2) the concept of interference, as an explanation of forgetting; and, (3) The concept of mediation which, with its attendant experimental achievement was very important, and lay at the core of associationist models, being necessary to explain many phenomena of memory within the S-R approach. This approach to memory fostered an experimental tradition using nonsense-syllables but, in a more elaborated form, it began to be used by associationists to study complex problems, for example, clustering and internal organization (e.g. Kausler 1974).

The influence of this approach has, however decreased enormously, both because of inherent limitations of such models, and crises which have emerged in the course of experiments and their interpretations (e.g. Jenkins 1963, 1974; Postman 1971). Some of the most outstanding researchers in this school have tried to reformulate the general model, in order to explain new phenomena (Underwood and Ekstrand, 1966; Underwood, 1969; Postman, 1975) while others have withdrawn completely and have changed their

interpretation and approach (e.g. Jenkins, 1974).

Even though this school has had its crises, its influence can still be observed, in the great number of experiments it has provoked. The most descriptive comments about it was made by Shallice (1973), who refers to the period when this school was in vogue as "the dark ages of the verbal learning approach to memory". However, the great amount of experimentation done in its name does represent a serious challenge to the theorist; as does the influence of its strict methodology.

2. Models of Artificial Intelligence

The emergence of modern linguistics and the work in artificial intelligence has contributed to a new form of research and possibly a new form of model construction whose origin lies, in a very important sense, in the EPAM Model of Feigenbaum and Feldman (1963). This model embodies a series of assumptions about the mechanisms of memory, and these make possible the simulation, using a computer, of a series of classical experiments in psychology. At the moment, this kind of work is very important, and some researchers that were working previously with other kinds of models have changed to this area of work; examples are Norman and Rumelhart (1975), Kintsch (1974) and Anderson (1976).

These models embody a series of assumptions with implications for the construction of theories; they concern themselves with the possible relations between words

in complex nets of associations; and use rules similar to syntactic rules, and certain procedural steps (programs) by means of which it is possible to modify, store or generate verbal responses. In most cases there is an emphasis upon the organization of information rather than on its acquisition. Such emphasis in these models is relevant to the question of how information is represented or codified in humans.

Most researchers working within this approach believe that, in the future, they will propose specific theories and test hypotheses, as well as study in more natural conditions, phenomena not directly related to memory, but which are the result of its manifestation, such as answering a question, or more generally, knowing a language. In general they are characterized by an interest in diverse things like knowledge, problem solving, semantics, and so on (e.g. Norman and Rumelhart, 1975). We will probably have to wait some time to see if they are able to do what they plan, and to cope with such an ambitious programme.

It is interesting to see that one of the more active researchers within this approach, one who has developed several simulations, is now very critical of his earlier work and states that it is very difficult to know whether the assumptions of the model are correct, whether they are implemented correctly and which are the best for the model (Anderson, 1976).

3. Models of Animal Learning

For many years most learning studies were done with animals. These studies began with the hypothesis that the basic mechanisms of learning were present in rats, cats, dogs, etc. and that they could be investigated in those subjects in a more straightforward way than was possible with humans. By this means a series of 'strange' variables, like language, were avoided. This approach was entirely within the behaviourist and neo-behaviourist schools. The amount of research as well as the interest in building a general theory was very great. A clear example of a general theory of learning is found in Hull and another in Tolman and their followers; though there were also, of course, other researchers and groups of lesser importance.

The behaviourist approach to the problem of learning is undoubtedly one that belongs to the past. The reasons for its decline in importance are very complex, but its theoretical influence however, is still very strong, in different ways; for example, the concept of hypothesis making, and confirmation in rats (Krech, 1932) is an ancestor of a great number of concepts and pieces of work (e.g. Bruner et al, 1956; Levine, 1975). Similarly the experiments on paired-associate learning which can be identified with, or at least closely compared with, classical conditioning, have been influential (Dixon and Horton, 1968); and, in the same way, it is still possible to detect a strong influence of the old controversy between gradual and all-or-none learning (Restle, 1965).

The influence of behaviourism was very strong in the associationist account of memory, but recently it has decreased; for example, in some cases, the existence of classical conditioning or instrumental learning in adult humans is denied (Brewer, 1974). In other cases the concepts once used in research on human memory, are the ones now used to explain animal learning (e.g. Medin et al, 1976).

Besides these general approaches to theoretical work in memory, there is other work which, in one way or another, attacks the same problem from different points of view and with different methodologies.

4. Other Points of View

Attention should be drawn to the great quantity of neurophysiological research centred around the problem of memory and learning, and the search for its specific bases (chemical and electrical). A general way of describing these works is to compare them with the search for the "engram" as did Lashley (1950). On the basis of 20 years of research, Lashley concluded that it might well be said that memory did not exist. Recently, this situation has changed a great deal (e.g. Rosenzweig and Bennett, 1976). But in spite of abundant research in this area, progress has been slight, and from the point of view of memory theory, neurophysiological work has contributed little or nothing. Neurophysiology is one of the areas in which theoretical work has the most to offer psychology, because of the great number of isolated findings. Some form of synthesis and orientation, as well as some systematization

of what is known, is manifestly needed.

It must be pointed out that there are some other areas of work that are difficult to classify, such as the work on neuronal-networks. This approach assumes the forms of interconnection between neurons and tries to simulate models of specific functions of information storage by using simple forms of binary logic or sophisticated forms of non-binary logic. The origin of this approach is found in the work of McCulloch and Pitts (1943) but it has advanced a long way from there. In its simpler form, it studies how many, and which, are the characteristics that the "ideal neuron" has to have in order to store specific amounts of information. In the more advanced work, the question of the storage of information is not settled arbitrarily, but information is considered to be stored on the basis of certain of its characteristics, that is associative memory (Kohonen, 1977). According to this conception of the storage of information, the physical position of the store is not independent of the content of the information (as it usually is in a computer), but rather the content of the information and its place of storage are closely related ("content-addressed"). In other cases, these kinds of neuronal-networks are used to study pattern recognition by using what are generally known as perceptrons (Minsky and Papert, 1969; Amari, 1977; Scott, 1977).

One very interesting aspect of this kind of work was the influence of Hebb's book (1949) as a source of inspiration. A second interesting aspect is the minor importance

or impact that this kind of work has made on psychological research, probably due to the complexity of the mathematical and logical tools that are used.

CHAPTER II

THE STATEMENT OF PROBLEMS IN THE PSYCHOLOGY OF MEMORY

".... we lose track of what we have already accomplished and simply go round in circles, discovering and rediscovering the same phenomena."

Baddeley (1977)

"At every crossway on the road that leads to the future; each progressive spirit is opposed by thousand men appointed to guard the past.

Maeterlick

A. INTRODUCTION

There are several reasons that motivate the search of relevant problems to investigate in the area of memory. One of them is to generate more research by means of confronting current models or theories with relevant phenomena in order to see if these theories offer some explanation. By making explicit the problems a theory might have, not only can the theory be validated but at the same time more research can be generated. Another reason for focussing on problems in memory research is that, since the phenomena studied are complex, it is necessary to specify which are the most relevant problems, and what should be the priorities of research. One of the criteria that seems to be relevant in psychology is "ecological validity". Neisser (1976) says that "... because psychology is about people it cannot shirk the responsibility of dealing with fundamental questions about human nature... Theory has something to say about what people do in real culturally significant situations... If theory lacks these qualities, if it does not have what is nowadays called 'ecological validity' it will be abandoned sooner or later." Therefore it seems necessary to consider ecological validity as another criteria in the evaluation of theories and the search of problems, but many theories nowadays do not fulfil this requirement. Another reason motivating the search for problems is related to the first one, and concerns the vast number of phenomena which still have not been tackled

experimentally. These range from the study of consciousness to countless phenomena of memory in everyday life.

Researchers seem to have taken refuge in known phenomena and in the laboratory and to have avoided both big philosophical questions as well as phenomena from everyday life (which cannot easily be taken into the laboratory to be studied systematically and carefully). A very high proportion of memory research (and it's the same in other fields of science) concerns the study of known phenomena, or parametric studies, i.e. not the discovery or search for new things, but the repetition of what is already known (Tulving and Madigan, 1970). However, even in this kind of work, results often are not clear. It is often very difficult, even when a replicable experiment is found, to explain what the principle behind the possibility of replication is, or what significance this might have.

Another reason that motivates the search for problems refers to the evaluation of the progress made in psychology, which, as some propose has not been very outstanding.

According to Tulving (1977): "... the absence of progress in the realm of concepts is another phenomena: the history of our science knows no generally acknowledged solutions to problems. It is difficult to think of a single instance where a problem generally perceived to be such by the majority of the practioners in the field, was explained by one investigator and the explanation accepted by most others... Some readers of the present essay undoubtedly will think that my assessment of the situation is not entirely realistic. All that such readers need to do to prove my posit as untenable is to compose a list - even a short list - of problems that have been solved or explained in a non-trivial or relatively permanent sense..."

What is presented here exemplifies Tulving's idea, but in the form of open problems.

As has been pointed out before, the study of the problems has another meaning, not only the one proposed by Tulving.

Yet another reason to point out problems relates to the previous ones, and is to specify which problems can be useful to researchers beginning to work in this field. Some in this condition might ask what characteristics does this list have that others do not have. The answer is simple: there are no other lists of problems available that could be of some use or guide to those beginning to study or do research in this area. It should be remembered that most models of memory are not a source of problems, but only of explanations of data and specific experiments (e.g. Norman, 1970; Bower, 1977). In order to clarify the characteristics of the problems let us analyse briefly their function, origin and how they are used in other areas of knowledge.

B. CONTEXT OF THE STUDY OF PROBLEMS

One of several tasks that integrates scientific activity is that of establishing problems. In most cases this task is done before the construction of an experimental hypothesis about the behaviour of a series of variables. Usually the hypothesis is a simple attempt to state a question clearly. However, the form of question determines to some extent, the form of answer which is appropriate.

Formulating a problem may in itself be enough to show whether or not finding an answer will be feasible.

Nowadays it is realised that scientific questions are profoundly influenced by metaphysical as well as theoretical concepts. It is no longer supposed possible to do experiments (or make observations) from a naive vantage point, preceding any sort of theory (Agassi, 1975). As regards posing or finding problems, like many other scientific processes, there are no perfect or complete algorithms that can be suggested contrary to the opinion of Nordbeck (1971). The end product of different stages of scientific work are powerfully influenced by a vast number of factors which range from the education or training of the scientist to a great number of sociological factors (formation of groups, prestige, location, personality, etc.).

In the last few years the activity of research itself has been systematically studied, and it has become evident on one hand that it is unexpectedly complex, and on the other that there is a lack of rules, or algorithms, for its better accomplishment. As a result the analysis of problems and theories used in science has assumed greater importance, and is not now considered an exclusive activity of philosophers but as part of the scientist's job. It has been found that there are no "assumed" scientific "steps" to "follow", which guarantee taking the scientist forward on the road to knowledge.

The advances obtained by, for example, the sociology of science (Kuhn, 1970) and the clarification of certain

problems in the philosophy of science make it seem unlikely that it is possible to give rules for scientific work. Feyerabend (1975), Bunge (1967) and Harding (1975) have conclusively demonstrated the limitations of positivist and empiricist philosophical schools with the result that scientists have begun to place more emphasis on the advance of theories and or semi-theoretical systems, and less on the accumulation of data. Of course the effect of these advances and the study of the functions of science has had an uneven impact upon different areas of knowledge, but in psychology, its impact has been very strong and new conceptual tools are beginning to be used. It is inside this new less strictly formalised context that we are going to see the role played by problems in science.

C. TECHNIQUES IN THE DEFINITION OF PROBLEMS

There are several alternative ways of deciding which problems are fundamental at any given moment, but there is no algorithm which specifies the steps to follow; on the contrary, we do not even know which are the basic strategies. What is certain is that there are several possible ways of specifying and deciding which are the central problems in an area of knowledge. One of the simplest possible techniques is the so-called Adelphi method (Fusfeld and Foster, 1971) which has been applied to very different situations and problems, scientific as well as technological, (Linstone and Turoff, 1975); it consists in asking a committee of "experts", using special questionnaires, which are the most



important problems relating to certain phenomena. The pre-requisites of this kind of approach are, first, to have "experts" with the ability to select those problems in the area of interest, and second, the conviction that the opinion of a group of "experts" is more representative than the opinion of a single individual.

Even though it is simple to use, and has a simple rationale, this procedure does not have much impact on the development of scientific problems. However, there are several other sophisticated ways in which experts can control not only the statement of problems, but also very many aspects of contemporary research, for example, by the allocation of research grants, direction of research centres and by holding editorial positions on boards of scientific journals. This kind of control over the problems to be investigated seems to be the most powerful. It seems strange that, even though it is known and criticised, the Adelphi method is not accepted, since it is merely a systematization of what has been happening randomly for a long time.

In other cases, and this is especially true of the development of psychology, a different approach has been used for determining which are the central problems in a specific area of knowledge. According to this approach, easily stated problems have to be solved before general ones can be stated. For example, when NASA decided to put a man on the moon, the general target had to be divided into several sub-problems which had first to be solved one

by one. Other examples are the construction of the atomic bomb, radar or the first computer, in each of these, many preliminary technological and scientific problems had to be solved before the final product was obtainable. A body of background knowledge about the problems existed in advance, but the actual solution was accelerated by the proximity of war.

In all these cases, both the general statement of the problem and the relevant body of knowledge was there in advance; this suggested the feasibility of the specific military projects. A not unrelated problem in psychology is that posed by Lashley (1950), as the search for the Engram. The problem's importance does not seem to be recognised, the will to solve it does not seem to exist, and only the isolated efforts of independent scientists are observed from time to time, without a real general statement and effort to reach the target.

Yet another approach to the statement of problems has been the computer simulation of complex social and economical phenomena, (McCleod, 1968). Initially, only series of assumptions and some general data are needed to later direct a search for more specific missing data to make the model work, and thus simulate the phenomena under study (Forrester, 1971). The simulation with general data gives a way of approaching the phenomenon under study and, at the same time, indicates the missing data as well as its own theoretical limitations.

D. THE STATEMENT OF PROBLEMS AS RESULT OF THEORETICAL ACTIVITY

Without denying the importance of the techniques already mentioned, let us consider the classic form of doing theoretical work. This is the study of both old and new, relevant literature, theories, models, other relevant sciences, aspects of the philosophy of science, general philosophy and the history of psychology. This systematic work allows the psychologist to establish which are the most important problems to study in the psychology of memory. As mentioned above, there are no specific tools or rules for doing theoretical work. These simply do not exist in any body of knowledge in which theoretical work is done; in psychology in particular, there is not only a lack of systematic theoretical activity but a distrust even of its possibility. However, some general ideas from the philosophy of science, can possibly be of some use.

E. PROBLEMS

There are two ways of bringing out the importance of problems in science; the first is to argue about the importance of their construction, and the need for their statement, and to stress the need for recognition of the non-explicit assumptions upon which they are based. One can dispute the importance of a problem's generality, which characterizes and differentiates it from a hypothesis, and one can distinguish formal problems (by definition mathematical and deductive), from other problems of science, which involve conceptual analysis, etc. This first kind of analysis is both important and necessary, but it is

limited by the state of affairs already mentioned: lack of rules or algorithms for scientific research. This is why we will use the second form, which consists in looking at the function or the effects of establishing problems, in bringing about the advance of knowledge.

1. Problems in Mathematics

The area where the function and the utility of establishing problems is most clearly illustrated is mathematics, where right from the beginning such an approach has been very important.

The Pythagoreans (approximately 5th century B.C.) discovered the problem of incommensurable ratios (expressed in modern mathematics as irrational numbers) and thus provoked the first big crisis in the history of mathematics (Bar-Hillel, 1964; Kline, 1972). Another problem, which produced the second crisis, was the concept of infinity (in particular the development of calculus) at the beginning of the 19th century. The third crisis, which occurred at the beginning of this century and affected the basis of mathematics and logic, was produced by the problems brought forward by the formal demonstration of the limits of the use of axioms in mathematics. In all these cases, the knowledge of the problem as well as its description in a clear and comprehensible way, has had a profound effect on research and subsequent development.

Another famous problem, that associated with the quadrature of the circle, was only demonstrated to be

insoluble after 2000 years of research by Lindemann. It was in trying to solve this apparently trivial problem, that significant advances were achieved in geometry (Kline, 1972). Incidentally, the demonstration of the insolubility of a problem is very interesting, since it seems that such a situation is only possible in mathematics.

At the beginning of the Renaissance in Italy, a group of mathematicians dedicated themselves to exchanging problems; apart from the social interest of this mathematical duel, the situation brought about many achievements including the systematization of algebra and the theory of equations.

The suspicion that the 5th axiom of Euclid was independent of the others, brought another problem. Its test and study (by Bolyai, Gauss and Lobachevski) led to the development of a new series of geometries whose existence has had a profound effect in modern physics.

The role played by problems in mathematics (and other areas of scientific research) is very complicated, and it is not simply confined to stimulating the finding of, or demonstrating the impossibility of, a solution. For example, the assertion by Fermat that Diophantine equations do not have a solution has remained a constant source of interest, (Edwards 1977; Kline, 1977) even though it was merely written as a note in a book that he was reading. Fermat wrote that he had the proof, but because of lack of space did not write it down. Subsequent attempts to solve this problem have had quite an effect on the theory

of numbers, a branch of one of the more abstract areas of mathematics.

At the other extreme is the problem of finding a mathematical system which describes three bodies in movement. This is a problem of applied mathematics to which no general solution has been found. The ingenuity of men has, however, enabled them to solve a series of specific problems where two artificial satellites need to have a physical contact, i.e. where there is a situation in which three bodies (the earth and the two satellites) are in movement even though there is no general solution to the problem.

These examples from mathematics enable us to illustrate several interesting points, 1) problems have played a fundamental role in the development of mathematics; 2) the range of problems is broad, going from "pure" problems to those of everyday life; 3) mathematical problems are special; 4) some problems have a profound impact on science and technology; 5) in some cases there are no general solutions known to a problem although partial solutions can be found; 6) it is plausible that there is a continuity between mathematical and scientific problems.

The most interesting case in mathematics, one whose effects are possibly unique, is the list of problems drawn up by D. Hilbert in 1900, (1902). The comprehensiveness of the list is its outstanding feature. It is interesting to note that this was a general list; it attempted to include all mathematics, not just a single particular branch, and that these problems were the result of a theoretical and systematic search.

Of course mathematical solutions to problems are different from those in other sciences, since total solution is a possibility, whilst in other areas only partial solutions can be given and in many cases they are constrained by a theoretical structure.

2. Problems in Science

Problems have always existed in science in either an explicit or an implicit form and have been a constant stimulus to research. For example, the problem of the transmutation of metals was the central question of alchemy which was itself responsible for the development of a great deal of basic chemical knowledge. Even though the problem was fundamentally misconceived and involved an appeal to 'magic' its impact on the origin and development of chemistry was immense. From another point of view it is now known that the transmutation of metals is after all possible. In fact it occurs in nuclear fission. This example shows just how complicated the function of problems may be.

A more concrete example of influential problems are the 31 queries stated by Newton (1952) in his book "Opticks"; these problems virtually dictated physicists' work for many years (Bunge, 1967). In physics the emergence of problems at both a theoretical and an experimental level brings with it the possibility of interesting predictions. The most distinct examples are found in the physics of small particles. E. Fermi for instance, in his calculations concerning nuclear structure, always

found that a small amount of energy was missing. At first he considered this due to a mistake in his numerical calculations or a loss of a small quantity of energy, but finally, he postulated that it was a very special particle - the neutrino. Twenty years later the existence of the neutrino was experimentally demonstrated.

Another interesting case, not only of problems but of their relations with theories, is seen in the emergence of the Periodic Table of Elements. The origin of this Table was the problem of putting the chemical substances known at that time, in order, together with Mendeleev's conviction that some system of order had to exist. This Table, however, not only ordered knowledge but provoked research and the later discoveries of new elements. From then on the search was not random, but was done bearing in mind specific characteristics that, in view of the continuity, the new elements had to have.

As we have just seen, problems appear in very different forms. These vary from the formal statements given by Hilbert in mathematics, to the problem of the transmutation of metals that is generally considered to have originated in human greed. Between these two extremes, are problems that have their origin in more profound philosophical questions (like, what are the basic elements of matter?; what are the basic mechanisms of life? etc.). There are also technological problems, like: how to simultaneously destroy the greatest number of people in the most effective way? With this last case, the complexity of the relation between different components of science is illustrated.

We can see, for example, the construction of the atom bomb as a response to a technological problem based on the knowledge of matter (nuclear physics).

The time is now past when problems of science could be classified as either pure or applied, two options now seen as intimately related; for instance the automatic translation of languages was an applied problem that was, thanks to computers, believed to be almost solved. This belief was, however, wildly over-optimistic; to solve this problem many other problems have first to be solved.

F. EXAMPLES OF THE FUNCTION OF PROBLEMS IN PSYCHOLOGY

It is an historical fact that a series of numerical discrepancies in the everyday work of the Greenwich Observatory, initiated the study of reaction times, individual differences, and other variables which affect the making of precise measurements (Boring, 1950). Fechner (as described by Boring, 1950) tried to find the relation between body and mind until one day (22nd October 1850) he thought of measuring sensations and relating the intensity of the stimuli with the intensity of the response in a mathematical form. In some cases for practical, and in others for philosophical, reasons, a series of philosophical questions came to belong to psychology. Psychologists then, trying to find answers, imitated other disciplines and adopted the scientific method.

W. James, explicitly stated a series of problems in his book Principles of Psychology, where he reviewed the

current state of knowledge and discussed a series of problems which were to guide American psychology for many years. Some of the experiments and ideas are still important today, for example, the treatment of attention as one of the fundamental aspects of the study of thinking produced a discussion which is still continuing (Neisser, 1976).

Several things which happened with the beginning of experimental psychology at the end of the last century, should be pointed out. First, there was a transformation of certain problems from being philosophical to being scientific, with the attendant availability of new ways (like experimentation) to give answers; second, many problems previously thought to lie in the domain of other areas of knowledge, like astronomy, or physiology, were recognised as essentially psychological (mental); third, a great number of questions were solved by using the new scientific method.

The problems posed at that time, not being tackled exclusively by experimental techniques, required the combination of theoretical analysis with the postulation of unobservable processes like attention; this way of answering questions was spurned during the obscurantism produced by behaviourism, which was only interested in problems of behaviour and performance. For instance, in the 1920's, the problem of attention was shelved, only to be rediscovered as a new problem in the 1950's. Another case is the study of images (Kessel, 1972; Holt, 1964),

and related phenomena that were considered very important in psychology until the 1960's and then rediscovered and subjected to theoretico-experimental study. To be precise, it can be seen that it is problems which are fundamental in producing advances or changes in schools and theories in psychology. It was the problem of the interpretation of introspection as posed by Wundt that produced the Wurzburg school, the so-called "new" psychology, with its emphasis on the study of thinking. Similarly a series of problems in this school were the origins of Gestalt psychology. When Watson criticized the mentalist psychology of Titchener, what he criticized was the way in which problems were solved and not the problems themselves (Boring, 1950). At the present time it is very difficult to explain data entirely on the basis of the relation between stimulus and response, and this has given way to the cognitive school of psychology.

Using Kuhn's terminology (1970), we may say changes in science are produced by crises; however, in psychology a change in paradigm does not necessarily entail an advance, as is pointed out by Lipsey (1974). The situation is different in physics where the change from classical Newtonian physics to the relativistic physics necessarily produced an advance.

G. GENERAL CRITERIA IN THE SELECTION OF PROBLEMS OF MEMORY

The sources of the most important problems in the psychology of memory can be classified in three general groups:

1. The development, outside the field of the psychology of memory, of theories and experiments whose discoveries throw some light on problems of memory.
2. The lack of adequate explanations for many experimental data in the psychology of memory (many of the problems raised are classical whether they are recent or old).
3. Problems that have not been tackled by experimental research. In some cases, these can be described as problems of everyday life, in others as old philosophical dilemmas.

It might be suggested that any problem being studied by experimental psychologists should be included in this work, but this is not the case, because the fact that a real or an artificial (laboratory-created) phenomena is being studied does not imply that it is relevant, or has any role in the development of knowledge; it simply points to the fact that researchers are, within limits, free to study whatever they want. On the other hand, several problems studied are entirely the result of certain kinds of social structures, political ideologies or philosophies, as has been clearly indicated by Rose and Rose (1974) and Kvale (1976). It is a similar mistake to think that all published experiments concern problems relevant to the development of knowledge. It is well understood that some reasons for publishing experiments are quite external to the search for knowledge. It has to be pointed out that the choice of problems for discussion is not impartial but has been influenced by a series of factors which limit one's view of what the most important problems are.

H. SPECIFIC INFLUENCES ON THE SELECTION OF MEMORY PROBLEMS

Possibly the most important influences on the selection of problems are external to the research itself. These influences may, of course, be positive as well as negative.

1. Philosophy

One of the achievements of post logical positivist philosophy of science has been to clearly and precisely indicate the metaphysical bases of many scientific problems and theories. This goes far beyond both the positivist idea that knowledge can be obtained by means of research (experimentalism), and the demonstration that all concepts and ideas in science are susceptible to experimental tests.

An extension of this point of view, is the belief that in experimental sciences it is possible (and necessary) to use modern logical methods like axiomatization, (Luce, 1959; Laming, 1973; Taylor, 1968), and what has been called the logic of partial truths (Krajewski, 1977). This last point is tied up with the positive influence of non-Anglo-Saxon schools, like the one represented by Bachelard (1971) and some Russian philosophers (Mahasiah, 1973; Blakeley, 1975), which have tended to encourage the abandoning of binary logical systems (or two value logic). The importance of Kuhn (1970) is the discovery that science is a phenomenon strongly influenced by sociological aspects, as has been mentioned elsewhere. He differs from some other authors who still consider science from a formal idealized point of view (e.g. Popper, 1972).

A great deal of deliberation in recent philosophy has been dedicated to discussing how arbitrary and unguided by rules scientific work is, (Feyerabend, 1975) in contrast to other methodologists who think it possible to give easily followable rules (or recipes) for research. This by no means makes science less serious or less rigid but on the contrary, demonstrates how minimal is our knowledge of this human activity. A concrete example of this 'recipe' influence is behaviourism (in its different forms) which stated that if several methodological steps were rigidly followed and there was experimental rigour, knowledge would automatically be obtained; in fact the only thing that was obtained was masses of data (some irrelevant). It cannot be said, however, that behaviourism was simply the result of the philosophy in fashion at the time, since, although positivism was the fashionable philosophy from the 20's to the 50's, in many other areas of knowledge it was not used at all.

2. Russian Psychology

It is very important for any psychologist to try to see developments of his science wherever they are in the world and not to restrict himself arbitrarily to his country or the influence of one of the superpowers. Even though difficult, it is not impossible to find out which are the most important developments in soviet and oriental psychology. When this information is obtained, the vitality of this research and the interest, not only of

its data but also of its general approach is easily seen, partly because the relation between studies of animals and ones of humans is heavily stressed, as well as the study of other related phenomena.

A clear example can be seen in the work of two memory schools; one is represented by Smirnov (1973) who studied and demonstrated the fundamental role of the division in memory of voluntary and involuntary recall, as well as the influence of comprehension on studies with humans. Other interesting aspects of this school are the use of material and natural conditions, and the importance given to images.

The other soviet school of memory research is that represented by Beritashvili (1971), who studied the biological basis of memory, found what appeared to him to be imagery in dogs, cats and other animals, and demonstrated the continuity from the most simple problems of conditioning to images. These studies are very important since they are studies about the neurophysiological evolution of images and are more extensive and detailed than the classical works of Hunter (1913). It is not possible here to review all the dynamics of Soviet psychology in general, or even the work on memory in particular, however its importance and influence on the selection of problems of memory must be stressed.

3. Ethology

There is no doubt that one of the most important influences on modern psychology comes from ethology, not

only at a theoretical level but also concerning the number of phenomena demonstrated. Ethology brought about a change in the simple naive vision that existed concerning not only perception and learning but also other social phenomena. When ethology is evaluated against comparative psychology, it is clear that more relevant and important results come from the former even though both areas started more or less at the same time (independently).

4. Linguistics

The relation between linguistics and the psychology of memory is rather strange. According to Chomsky (1968) linguistics is part of psychology, but at the moment a large part of the theory of linguistics is mathematical and formal, whilst in psychology there are very few theories of this kind. Another interesting aspect is the way that linguistics has heavily influenced aspects of memory theory, for example the works of Norman and Rumelhart (1975) and Kintsch (1970). Nevertheless there seems to be some confusion: language is the product of a series of processes, (which are not very well understood), and yet some people use that product as it were an explanation itself: (For example, the explanation of certain semantic phenomena by laws or syntactic rules (Fodor, 1977)). However, the development of linguistics has had a very good influence mainly in demonstrating the utility of theories and their possibility in "non-exact" areas of science.

5. Artificial Intelligence (AI)

Even though it is fashionable to maintain that AI and

cognitive psychology are closely related and influence each other, and that AI work is inside a cognitive psychology framework, this is not the case. On the contrary, it is a fundamental role of theoretical psychology to state that these two fields of work are quite different. The explicit and implicit assumptions of AI are radically different from those of cognitive psychology, Allport (1975, 1977).

There are some cases where certain specific AI work is very relevant to problems of memory, but this is only the case where there are theoretical concepts. Another example where AI and psychology relate comes from physiology. Campbell and Robson (1968), and Ginsburg (1975) hypothesise that the visual system is composed of a series of filters, a concept taken from electronic engineering. They use computer simulations to test this hypothesis, and on the way, explain many optical illusions. It is in this kind of work where AI is useful, but only then when there are specific theoretical concepts to be tested rather than, as in much AI, where processes are assumed but not specified.

AI work is based on a series of ideas which are not strictly part of the theory of computation, but rather are taken from linguistics (nets of interrelated concepts) or old psychology (schemata and frames). All of these are very important in their original form but not as reinterpreted by artificial intelligence. AI shows an interest in theories, but makes the mistake of thinking that, in one way or another, the programs and languages which are

used in AI are themselves theories. At the moment psychologists are using many ideas and concepts taken from AI, or from computation, (these are two different bodies of knowledge) but the usefulness of doing so remains to be proven. It is difficult at the moment to find psychologists seriously criticising the use of AI work, two of the few exceptions being the works by Neisser (1972, 1976) and Allport (1977) who deny the possibility of using this work to construct psychological theories.

6. Piagetian Psychology

The influence of Piaget is extensive, not only experimentally, but more fundamentally in the kind of theory he presents. Piaget's kind of approach has highlighted three fundamental aspects of phenomena and problems of psychology:

1. the evolutionary character of psychological processes;
2. the constant interrelations between different processes;
3. the complex and non simplistic nature of explanations of processes

On the other hand, some aspects of the Genevan research, like the emphasis placed on verbal responses of children (introspection), are rather limited. Work by T. Bower (1977) has demonstrated both the limitations of empirical evidence and the inadequacy of the notion of stages of cognitive development inside a Piagetian scheme.

A second aspect which limits Piaget's influence on the present work (and probably on others) is the lack of a systematic presentation by him of the main points of his theories. There is also a lack of good reviews of his work done by other people. The work of Piaget and Inhelder (1973) in memory is a clear example both of how processes are interrelated and of their complexity. It is important to emphasise that one of the few influences (and references) that Piaget acknowledges in his works is that of Bartlett.

7. Infant Psychology

This is one of the areas most influential on both the statement of problems of memory and theories. In the last few years the work on this area (T. Bower, 1977) clearly shows how rich and complex these processes are and how explanations for many phenomena of memory may be found in this kind period.

8. Animal Learning

Recent experiments in this area have resulted in a series of new problems whose impact is not yet being felt. The original idea of animal learning research was that it was possible to study learning processes in animals, in simple experimental set ups with few variables; since it was supposed that the basic mechanisms of learning were common to all different animals. However our ideas of the processes involved and the kinds of learning necessary have been significantly altered due to:

1. the phenomena of classical conditioning, which do not adjust themselves to the "normal" parameters of this kind of learning, for example, the phenomenon known as the "Sauce Bernaise", (described by Wickelgren, 1977).
2. the suspicion that the first stage of operant conditioning is itself a phenomenon of classical conditioning (Hinde and Stevenson-Hinde, 1973).
3. the complex interrelations between learning by imitation and inherited biological mechanisms (Hinde and Stevenson-Hinde, 1973).
4. the demonstration in primates of learning of complex behaviours like certain forms of "language" (Rumbaugh, 1977; Premack, 1976).
5. the experimental evidence that animals are possibly aware of what they are doing (Griffin, 1976).
6. the study of very simple animals like molluscs (especially aplysias) where neuronal nets which control specific aspects of reflexes have been found and where the existence of neurophysiological mechanisms which can interrupt not only reflex responses but also habituation, (and active dishabituation) in an active form (Kandel and Spencer, 1968) have been demonstrated.

There are two important conclusions:

- i. Animal studies are both complex and important. The inadequacy of the mechanisms proposed so far leads one to say that a more "cognitive" kind of interpretation is needed for these data, using

"cognitive" in the sense of Tolman i.e. "more complex" and with the participation of more "active" phenomena, Medin (1976).

- ii. It is not known whether there are enough adequate interpretations of classical and experimental conditioning experiments. It is not possible to give a theoretical explanation of these conditioning mechanisms.

This is the reason why this kind of work forces us to see problems in memory from another point of view; not only in animal research but also in humans.

I. PROBLEMS IN THE PSYCHOLOGY OF MEMORY

To penetrate right into the business of stating problems is far from easy. Psychology, by the very nature of its methodology and objectives, is difficult and there is little by way of guidance from the philosophy of science.

One of the few guides that can be used, to a certain extent, is the classical work of Hilbert (1902). This kind of statement of problems had quite an effect in mathematics at the time and is possible to see the continuing impact in the present research (Fang, 1970).

The differences between formal and other problems in science has already been mentioned. These same factors limit the statements of problems in the psychology of memory (and in other areas of psychology).

Some comments are necessary before the problems are presented:

- the number of problems vary, it is not possible to give a definitive number.
- some of the problems (the first ones in each categorie) are more important than others.
- the language used is general, there are no attempts to give definitions.
- it is difficult to establish whether a problem has been solved, the only thing that can be said is that there is some knowledge concerning it.
- in some cases problems are mentioned, and references given, mainly of those working on, or with data relevant to, those problems.
- in some cases the problems mentioned are being investigated but a theoretical analysis and interpretation is still required.

In order to simplify the use of these problems in the evaluation of the orthodox theory as well as in the analysis of the possible areas of development of memory research, the problems have been classified in:

- A) Fundamental problems concerning the relationship between theory and experiment.
- B) Problems on the nature of representation or how information is stored and used.
- C) Problems concerning the control and manipulation of information.
- D) Parametric problems in systematic research.
- E) Problems related to other areas of psychology.

As it has been mentioned, this classification is arbitrary and many of the problems can be considered in relation with one or more of the five categories given above. But more important than a classification this set of problems can be used as a guide in research. The categories are more or less in order of relative importance, since for instance, it is going to be difficult to explain the problem of voluntary forgetting without advancing in the knowledge about the characteristic of the working memory and in general about thinking.

A) Fundamental problems concerning the relationship between theory and experiment

These problems can be described as those which any future theory has to make reference of, and there must be attempts to explain them. Any attempt to eliminate any of these subjects in the theory has to be justified. In some of these problems it might be possible to find clear and precise theoretical developments. On the other hand some of these problems are about a conception of memory which is different from the present ideas about memory (i.e. voluntary forgetting) as a passive system.

1. The Problem of Consciousness

It is difficult to find another problem as important as this, yet at the same time, as difficult to tackle in a theoretico-experimental way.

At times in the history of psychology, it was considered that consciousness was THE phenomenon that

psychology studied, Boring (1933, 1950), Klein (1970), Kuhlman (1906). However, differing conditions changed its epistemological status. It is possible that certain advances in the study of consciousness could be made at the moment, with the help of new theoretico-experimental tools. For example, Shallice (1972) and Culbertson (1960) suggested the use of a series of analogies from cybernetics and mathematics (the theory of networks) which could allow us to postulate a mechanism of dominance in a mathematical system through which certain characteristics of the "principal controller" could be given. Another possibility lies in the work on memory in children, which attempts to study the way information is stored, i.e. whether we in some sense "know" rules of behaviour, or whether behaviour is based on rules that are not verbally reportable. In these situations the information stored is tied up with the possibility of saying or showing that the subject does or does not know that he has it stored.

In neurophysiology certain examples can be found showing how problems are studied without worrying too much about their definition or complexity, (Buser and Rougeul-Buser 1978). For example in the work of Sperry (1977), the central aim of study has always been to find the physical basis of consciousness, looking to see whether or not it is present in subjects with differing neurological lesions. In other cases the basis of this process has been studied using simple distinctions, like talking of the two cerebral hemispheres, (Desiraju 1976).

Problems in this area have reached a state where some people hypothesise which are the specific structures involved in the process of consciousness (Diamond and Blizard, 1977). Even though the way used to analyse consciousness in this kind of research is merely to distinguish between its presence and absence without specifying it in detail, the results are still encouraging.

Another kind of approach to this problem is the one given by Griffin (1976) who studies whether animals have a certain form of awareness of their behaviour, or of the possible effects in the future of certain behaviour. This kind of approach presupposes that primitive forms of consciousness can be found in animals and it is an interesting way of tackling the problem.

These cases are illustrative of some of the ways in which this particular problem can be studied, without using classical philosophical discussions, which have in many cases been sterile. The strategy that has been followed by these authors, is to decompose the problem into subunits, for example, to say that one of the forms in which the process operates is as a control which can answer 'yes' or 'no' to the question X (e.g. 'do you know the rivers of Europe?'), where, in a sense, the system does not need to laboriously search its memory to see whether or not it has the information; but rather has something like a catalogue of the information that it contains. In other cases, a central "demon" which takes decisions in the recognition of patterns (Lindsay and Norman, 1972) is hypothesised. This

kind of study, supposing the existence of demons, ghosts, or homunculi, has a useful function in science, as is acknowledged by Arbib (1972) (or in physics by Maxwell).

The foundation for new developments concerning consciousness will possibly consist of the following realisations:

1. That consciousness is constituted by several processes of information manipulation.
2. That it is a system which controls other activities in order to handle information.
3. That these processes are implicit in the different forms in which information is elaborated.
4. That processes of which it can be said that in one way or another there is conscious control, and other processes that are automatic and of which there is no conscious control, must be distinguished.
5. That the almost total loss of the process itself, in certain (clinical) cases, is a way of approaching the study of the problem of consciousness.
6. That this process concerns the manipulation of information tied to real events; it is not an empty process "in vacuo".
7. That this process is one of the many forms of manipulation and control of information.
8. That this process must be assumed in order to explain results in perception, learning and the study of thinking which cannot be explained otherwise.

Another way of studying the problem of consciousness is to use a behavioural point of view, but rather than

making reference to behaviour, to use instead mathematical models, (theory of filters) as is done in theories of attention. This approach is very interesting since for several years (from the 20's to the 50's) it was left on one side. Now it is reappearing (Neisser, 1967, 1976). The study of attention involves the (human and animal) ability to select a part of the total number of stimuli as "useful" or "relevant". This selection is not a function of the characteristics of the stimuli, but is a central decision. The study of attention is related to many other aspects of research in memory and other areas of work.

2. The Problem of the Physical Basis of Memory

This is among the most important problems of memory, not only because there is no relevant research, but because it is treated quite differently in psychology to the way it is treated in other areas of science. In some cases, for example in neurophysiology, there is a great deal of research and a great quantity of data about memory, but no theory at all (Rosenzweig and Bennett, 1976). In other cases there are models and theories about the phenomena and processes related to memory, but no importance is placed upon the form which those processes take as regards their physical embodiment; in artificial intelligence for example, this problem is sometimes even considered irrelevant (Anderson, 1976). In other cases, formal theories deny the importance of memory and its physical basis, (Suppes, 1969).

The dangers of forgetting this problem are very real and include the construction of completely dualist theories (in the philosophical sense) where the problem of memory and that of its basis are considered to be independent, as well as the disorganized search for data without a guiding theory or the construction of models and analogies in which the kind of physical base suggested is incompatible with physiological knowledge. To acknowledge the existence of this problem does not entail accepting a reductionist thesis nor that all psychological processes are biological processes, nor to be even more extreme, the result of physico-chemical processes.

It is important to tackle the problem of memory and its basis in a unified way and not as more or less independent subject of study. It is clear, furthermore, that this problem is addressed more to theory than to the search for data, and that it concerns the way in which two general areas of research with different methods of study and experimental analysis relate to each other.

3. The Problem of the Intentionality of Learning and Memory

There is some experimental evidence relevant to this kind of problem, (Bjork, 1972; Katona, 1940) in particular the work of the Russian memory school (Smirnov, 1973; Kots, 1977) which maintains that voluntary (or intentional) processes are one of the most important variables facilitating both learning and forgetting. The main obstacle to the solution of this problem has been the difficulty of

defining the process, as well as manipulating it experimentally. However, it has been possible experimentally, to demonstrate some of the characteristics of this process in a limited way (Bartlett, 1932).

The possibility of researching further into this area depends, to a certain extent, on how liberated researchers can become from behaviourist psychology. On the other hand, the problem of intentional, or voluntary, behaviour, is one found in many other areas of work (Kimble and Perlmutter, 1970).

4. The Problem of Voluntary Forgetting

This problem can be considered as the counterpart of the previous one. For theoretical reasons, it may be supposed that there is a basic mechanism of intentionality, related to other processes in different ways and this is specially true in this case. The problem could be tackled by looking at the great amount of information that humans can receive, for example, in one day, and realizing that, for reasons of economy, it is necessary to separate certain irrelevant from other, relevant, information (by means of attention) and then to forget the irrelevant information.

Forgetting is not simply the passive erasing of things from a memory store, but rather an active process, in the sense that the activation of certain mechanisms is required in order to forget (Luria, 1968). The case of something very difficult to forget, e.g. a traumatic experience, shows it necessary to suppose an active process is required in order to forget.

5. The Problem of the Reorganization of Information

Clearly one of the characteristics of the functioning of memory is that it works with elements already learned in the past; what it does is to acquire and then reorganize already known elements. In a sense, adult humans do not learn at all but merely modify elements already known. Bartlett (1932) said that this kind of memory work was the rule and not, as is still generally considered, an exception. For example, in the case of nonsense syllables, what is learned is not a completely new entity but a combination of elements already known (letters); this analysis can be extended to a great many phenomena where subjects supposedly learn but in fact are just reorganizing known information.

This problem appears to raise a paradox. On the one hand, learning seems to presuppose the acquisition of something new, and, on the other, it is really difficult to find situations where something really new is being presented to the subjects. For this reason, the problem should ideally be divided in two; the problem of the reorganization of information; and the learning of new elements. The process of reorganization is very important, but it has been ignored as an experimental problem and few relevant studies can be found (Scandura, 1970; G. Bower, 1972).

If there is a problem of reorganization, it seems logical to ask whether the laws of reorganization are themselves learned or whether they are inherited. However, the distinction between reorganization given by inherited

factors versus learned reorganization is very simplistic; the literature suggests that there are two kinds, but their relations are not clear, especially in relation to memory.

It is important to point out the difference between the organization of information like the grouping of elements in categories, given by the subjects, and subjective categories (Cofer, 1976). In these cases the association of ideas or clustering (as it was called a few years ago) is involved, (Bousfield, 1953). Here the way in which 'new' elements are presented in the form of new combinations, is emphasised, what the subjects have to learn is supposedly a new stimulus. In all these cases, it is here suggested that what the subjects are really learning are known elements. The question of the reorganization of information concerns how a series of known elements can be reorganized into new combinations like the 5th symphony or Hamlet. Extreme cases of this form of reorganization of elements have often been considered as creativity; however if the activity is considered as a very complex form of reorganization of old information, it is possible to penetrate to its origins and the way it works without simply postulating a 'faculty' as is the case if we attribute creativity. Another case in which the process of reorganization is clearly illustrated with very interesting implications, is the study of language in primates and other animals (Premack, 1976). Sometimes reorganization of information may be caused by the presentation of environmental stimuli, at others it is an active process

on the part of the subjects who combine, modify or make new classes.

To emphasise the existence of this phenomenon does not, of course, say anything about its origins, it only points out its neglected importance for research. In a sense, it could be said that there is a process of re-organization whose function is to operate on information. The following section is going to describe how that information can have two completely different origins.

6. The Problem of Defining the Basic Units of Memory

From the experimental point of view, this problem originates in the work of Ebbinghaus (1885), and one of its latest manifestations is found in Simon (1974). During this long period of research, the idea that there are something like minimal physical units called "atoms", has persisted, and there have even been attempts to define these units by means of physical measurement. In physics, and many other areas of knowledge too, this kind of approach has long since been abandoned, as it has been found that these units are composed of other sub-units. The basic idea of finding units is itself a simplification which only leads to the use of more complicated theoretical structures. In other words, the nature of the supposedly simple events is in fact complicated and requires complex ideas and tools. This is not to deny that atoms (or other experimental particles) are, from a naive point of view, the "bricks" of the Universe, but the idea that these

bricks are simple seems unacceptable. The same could possibly be said of the psychological study of memory, when it is asked what the elemental parts of memory are. Perhaps there are no fundamental particles as such, although grouped elements form interesting phenomena for study. For example, a series of lines, ordered in a certain way, are called letters and are considered as such in so far as they can form words etc.; however the lines are not the 'basic' elements; a series of dots ordered in a certain way could be said to be the basic elements of lines. One could go on for ever trying to find 'fundamental' elements in this way.

This strategy of trying to find something simple in order to explain complex phenomena is based on the principle of parsimony, which has been demonstrated to be useful in psychology but not so useful in physics and other disciplines. This is not to deny that certain phenomena precede others (like atoms precede molecules). It is from this point of view that the study of different elements of memory is going to be considered and that is why the problem of organization receives more attention than the problem of elements. Certain events can be studied as events preceeding others but that does not mean that, by themselves, they have much importance. It may be that some forms of codification of environmental information precede others. Perhaps humans store certain events which are elements of more complex information structures.

An alternative way of approaching this problem is to suppose that memory works, not by the use of elements and by building new combinations, but on the contrary, by using general events, and actively constructing or defining new sub-categories. An illustrative example of this can be found in children, who do not learn a total of sounds in order to say a certain word, but from a set of different sounds (words) begin to form categories of certain parts of that total in order to derive the elements. Generally speaking, the process of constructing new structures by the combination of new elements, and by the categorization of large amounts of events, in order to define new sub-classes, are not two different processes, but two forms of describing the reorganization which results in the enrichment of the stored information. The first way of describing reorganization in memory has guided much research; but the second way, even though it raises the same number of problems, seems to be more interesting.

The problem of the elements of memory, if it is studied as a completely psychological problem, as it has been up to now, does not make as much sense, considering the problem in relation to the physical basis of the "engram". It is in relation to neurophysiology, that the solution of this problem stops the search for "ghosts" (bits or chunks) and becomes realistic, linked up with a central problem of neurophysiology - the study of neuronal codes.

7. The Problem of Simulation in Memory

Organisms have the capacity, in one way or another, to simulate "in memory" a series of events which have not happened or the effects of certain behaviours which they have not performed. This is the classical phenomenon of covert trial and error behaviour. The idea that humans can solve problems without needing to actually perform, or have any overt behaviour, raises this problem. Subjects may use past information (which is remembered), and present information (which is perceived) in order to solve certain kinds of problems. This kind of phenomenon has much in common with the previous problem; in both there are conceptual and behavioural variables involved, yet, for human beings at least, both are part of a single phenomenon.

To suppose internal simulation does not say how it happens, and it is a theoretical blunder to use the visualization of objects by the eye as a close analogy of similar internal visualization (imagery). It may be supposed that some ways or other of representing objects are used, but where temporal and spatial dimensions are concerned, they cannot be identical or even similar to the way in which objects are manipulated by overt motor behaviour. Empirical evidence shows that the way in which these simulations are done is rich in information, but the language of simulation (brain language) is not known. The phenomenon of simulation does not exclusively involve problem solving, it is a process which takes place constantly in order to manipulate stored information.

An example of simulation in memory is given by the following situation: when an athlete runs to catch a ball in the air there are three bodies in movement, one static and two dynamics, (this is a classical problem in physics). The athlete, as well as many other humans and even animals, easily solves this problem, yet the mathematical algorithm method needed to solve the problem is not known, making it very difficult to program a computer to solve the problem, even though humans solve it, and, to do so, have to simulate their position in advance in relation to the position of the ball and place themselves where the ball is going to fall.

B. Problems on the nature of representation or how information is stored and used

Over the last few years, there has been interest in this area of research but even though few have been the results which can be considered as relevant and clear.

8. The Problem of the Supra-Organization of Information

A problem different from, but related to, the previous one, is the supra-organization of information (the way in which information is organized in large categories, or as it has been called, concept learning). The first traces of organization are found in the way in which information is acquired. There are certain forms of temporal and spatial relations inherent in the data, these relations may be preserved in the organism perhaps forming the first

elements of supra-organization. In other cases the organization is learned, two or more different independent elements being grouped together in the same category, possibly with the introduction of a label or arbitrary name (like "flowers", "machines", and so on).

The way in which categories are formed is very difficult to explain; simple explanations like generalization of stimuli or concepts like pattern recognition cannot be used, since supra-categories include elements with totally different physical characteristics, Tulving and Donaldson (1972). The important problem is not, however, how these supra-categories are formed, a field which has generated a great deal of research, but how the facility of access to information grouped in big categories is possible. What form of codification classifying the search for information can be supposed? However, the problem is even more complicated than this. In many situations it is difficult even to know into which category something has been classified in memory, and it is then necessary to make a hypothesis involving yet another mechanism to help in the search for information.

Another area which could be of great relevance to this process is the study of meanings in special languages. It may be supposed that context affects meaning, as is the case with "net", "fruit", "a certain way", "a certain taste", etc. The events integrated in this net of meaning are not simple phenomena like colours, but many and varied phenomena. In the same way, these events are not

exclusively defined by a single concept and a single event may satisfy the definition of many different concepts. This problem provides a strategy for studying important phenomena. On the other hand, the concept of supra-organization refers to other situations as well, like motor skills, where a group of motor movements form a supra-category which is different to the individual units which make it up, the new skill being unable in an automatic way, Stelmach (1976), Scandura (1970). This supra-categorization of elements can also be seen at a simpler level as with certain motor behaviours where the elements are different or changing but the supra-category remains the same, (Bernstein, 1967). The processes related to this problem are not two different concepts or pieces of behaviour, but probably a unified process.

9. The Problem of Performance and Change in Memory

Several researchers (Bartlett, 1932; Piaget and Inhelder, 1973; and Koffka, 1935) have maintained that memory is not static (static-trace) but that on the contrary, one of its main characteristics is being dynamic. Even though this idea is important, researchers have not regarded it as such; and this may be one reason why, at the present, it is so difficult to know whether or not there is an internal representation or code, or, even more, how to study possible changes in such a representation. Another reason could be methodological; the form in which subjects are asked to answer questions in experiments is

restricted and systematized. Perhaps what is needed is a free way of answering so that changes in memory can emerge. The analysis of such answers is however very difficult (Riley, 1962).

This problem, is, however, being researched; Kvale (1974) has demonstrated in different experiments not only that there are changes of memory, but also that it is possible to predict and control the direction of change. He has also apparently demonstrated that changes are dynamic, for which some other empirical evidence can be found in the above mentioned works of Piaget and Bartlett.

It is relevant to emphasise that the theoretical implications of this problem are very important, as has been suggested before (Kvale, 1974). These are probably more influenced by the dominant philosophy of present Anglo-American psychology, than by the reality of research as has also been suggested by Neisser (1967). It is possible that AI studies, on the one hand, and the work on short and long term memory, on the other, limit the study of this kind of problem, by their methodology, philosophical conception and the kind of theories which they propose.

10. The Problem of Tacit Knowledge

This problem can be illustrated in the following way: if a subject is given a text to read, and he is afterwards asked to write exactly what he read, the subject is capable of accurately pointing out where his report and the original text differ, but he is incapable of filling in the missing

parts. In other words, the subject knows the complete text, but is incapable of generating it (Flores, 1970). In other cases, subjects can point out that one photograph (or something) is missing from a series presented before, but cannot name it. This kind of phenomena is very common in everyday life, but knowledge concerning it is scarce. Another more sophisticated example of this problem arises when a person (for example, an artist) has an idea of what he wants but does not have the details to integrate the idea. As can be seen, this problem is difficult to specify, but it still seems to represent a real phenomenon which has to be studied. There are, however, some approaches to its research (Polanyi, 1966; Reber and Lewis, 1977).

11. The Problem of Associative Memory

One of the easiest ways of appreciating the critical state of current theories and research in memory is to look at the theoretical status of the associative memory model. The basic explanatory concept in S-R psychology was that of association. Nowadays it is said that this kind of explanation has been abandoned, but its presence can still be felt in one way or another, for instance, association has been transformed into programs for computers (Anderson and Bower, 1973; Anderson, 1976; Kintsch, 1974) and the change of associations to linguistic structures has been modelled (Collins and Quillian, 1969). In these cases the abandoning of association has been a purely verbal matter, the very same phenomenon and its laws have been adopted under a different name.

The theoretical and experimental limitations of the notion of the association of ideas are numerous and were expressed many years ago (Boring, 1950), but the model and its new forms are still being used, Rapaport (1974). This is probably due to the fact that in psychology there has not been an effort to separate psychological theory from the philosophy which nurtured it. It is difficult to forget the "doctrinal tyranny of associationism" as Asch (1968) clearly indicated.

Dixon and Horton (1968) give many examples of how S-R psychologists have found this associationistic approach not only limited, but wrong. However, years have gone by and this model is still in use. The most depressing aspect of this problem is that computer scientists (Kohonen, 1977; Jacks, 1971) have taken over this model and tried (without much success) to apply it to new forms of storage of information in computers. When they do not succeed in doing so, and find it difficult to understand why, they consider the failing due to the limitation in programming techniques rather than a mistake in the fundamentals of the theory they are using.

It may be asked why, if the limitations of this theory have been clear since the time of the English associationists, the conception has been so popular. The limitations of this theory have been explicit since around 1891 in the famous "Hoffding-step", in the examples and illustrations of Gestalt psychology and in the self-criticisms of the followers of the stimulus-response approach, and yet it

is still in use. The answer may be that, even though the theory is limited and even wrong, the phenomena to which it refers are real, though not understood. What is needed is a systematic theoretical study describing the phenomenon but with a structure different to the one already proposed.

One of the latest developments in the theory of memory is the distinction between semantic and episodic memory (Tulving and Donaldson, 1972) - an important categorization. However, even when the internal functioning of the semantic memory has been described, the kinds of models used are essentially associative descriptions (Anderson and Bower, 1973). This leaves us with the original problem of explaining associations.

As can be seen, this problem requires a theoretical effort; the phenomena described are very interesting and important to the theory of learning and memory, but the explanations given are limited. One way of clarifying the problem may be to relate it to habituation from a neuro-physiological point of view, and to consider the origins of associative phenomena as complex habituations; in this way association would not only be related to the repetition of the external events, but also to the repetition of internal "activity", as another form of habituation.

12. The Problem of Images

The history of the status of this concept is well known, (Paivio, 1971) and it has had the useful effect of promoting the abandoning of behaviourist ideas. However

the way in which it is analysed varies from the interpretation of imagery as an internal dream to its interpretation as a digital process (Pylyshyn, 1973). There is evidence to suggest that subjects are capable of using the tempero-spatial information they have in different tasks, what is not clear is how subjects manipulate that information.

Apart from the usual problems of interpretation, there are many special problems in the use of this kind of information, for example, musicians are capable of manipulating "sounds" in different ways, and the same is true of blind persons. When this problem is taken out of the laboratory, the possibilities of research multiply, since examples of the performance of subjects can be used as a source of information for hypothesis and data, Hannay (1971). In the same way work in physiological psychology is a rich source of possible interpretations of this phenomena, (Pribram 1972, 1977). The problem of studying mental images is tied up with the problem of representation. Perhaps it may usefully be said that mental images are the trivial parts of the problem of internal representation, the real emphasis is on codes and codification itself.

A phenomenon familiar for many years is that exemplified by the following situation: a subject is asked to imagine a banana. At the same time, on a screen placed in front of him, a faint picture of the target object is projected. The subject is asked to describe the fruit, and in many cases the percepts and the self generated image correspond perfectly (Perky, 1910). This same experiment

has been replicated with better controls, with the same results (Segal and Fusella, 1970). The relation between this data and hallucinations, where people behave in response to their internal events as if they were external and real, is interesting. The implications of these experiments, together with other data (Shepard 1978) are that the distinction between external and internal events is not as clear as had been supposed. A more concrete example of this phenomenon is the study of attitudes where the subject's behaviour is a result of his/her attitudes, as opposed to external factors.

13. The Problem of the Effect of Old Information and Meaning on New Learning

One of the most difficult early problems of memory research was that of minimising the effects of meaning and previous learning on memorization (Boring, 1950). After years of research the situation is still the same; it is difficult to control these variables, and these effects are particularly unwanted in the area of research purporting to study how completely new information is acquired. Others think that what most affects how something new is memorized is, how the so-called new material is related to the known information, i.e. that it is the interaction between the old and the new which may be able to help us understand the functioning of memory.

One reason why it is difficult to find completely new material for adult subjects could be that most experiments

are done with nonsense syllables, where the letters are known and only their combination is different. In this sense, many experiments on adult humans are studies about the reorganization of information and not really about "pure" learning at all.

It is perhaps because there is no "pure" information that experimenters can report that subjects are capable of recognising 10,000 pictures that have been presented only once (Standing, 1973), or of having more than 90% of answers correct in experiments on associated pairs, when 2,200 pairs of words have been presented (Wallace et al, 1957).

This paradoxical situation suggests the use of the problem itself to find a solution; that is, to study a fundamental variable of the information already known, and see how this affects learning. It seems that perhaps the only way in which this process of learning could really be studied is in infants.

It is important to know the characteristic of the information available from the beginning to adult humans, that is, to know how much the system contains before trying to increase its contents. It may seem a bit pessimistic to say that adult subjects do not learn anything new, but merely reorganise old material; but if one thinks strictly of what is new, and what is old, and of what the known elements are, then this conclusion inexorably follows. Note that there are no criteria for saying whether a person is learning, or is incrementing his memory, since no quantitative measurements have been devised;

specifically quantitative experiments, where the state of the system is described in a numerical form, are no longer in fashion. Among many other reasons accounting for the lack of quantification of complex phenomena, is the fact that the tools used, like bits or chunks, etc., are simple. Progress is needed in developing more sophisticated forms of quantification in order to find such relations and to be able to express them in a numerical form (Cavanagh, 1972; Simon, 1974).

14. The Problem of Relations within Knowledge and Internal Contradictions

When subjects' performance in everyday life is emphasized, two aspects are apparent; first is the great amount of information that a normal person has; second is that this information is not always manipulated in a logical way. This is obvious in the behaviour and decisions taken by people, for example, when subjects know that smoking is a health hazard and yet cannot stop smoking. The same applies to other habits like driving without a seat belt, and so on. There are other everyday examples. People often complain "If I only had known how to do it.." leading one to conclude that having all the elements of knowledge, guarantees the correct and appropriate answer; on the contrary, in many situations, people behave in illogical and contradictory ways. No doubt there are many variables involved in this phenomenon, but nevertheless, the centre issue of the problem can be

studied from the point of view of memory.

The process of relating information may be active, and the fact that subjects have the knowledge and the logical ability to correctly manipulate information does not guarantee they will do so; effort and/or external pressure are required to bring this about. The existence of these phenomena is important for the understanding of logical processes.

C. Problems concerning the control and manipulation of information.

Even though a great deal of research is said to be about "information processing" the definition and explanation of what is information and what is control of information are not clear and much less the multiple forms of processing that could be mentioned. This is the reason why the study of processes and controls which are independent of the kind of information have to be analysed carefully.

15. The Problem of Memory for Plans or Memory for the Future

The underlying idea of memory researchers is that memory is a complex process of storing past events. However, it may be that memory does not only bring back past information or skills but also organizes events forming sequences of future behaviour. Examples of this latter organization are: the way one remembers the day's appointments; the way (some) lecturers can explain the central

ideas of a subject by means of an automatically generated but coherent and logical talk, or, to take a more general case, the way a person decides on a series of general goals to attain during a year, without planning specific steps. In this sense, it may be that there is a memory process for the future, operating by general control of the influx of information.

Lashley (1951) stated this problem clearly: what has to be stressed is that the problem of serial order involves not only motor behaviour or verbal syntax, but more general plans (sometimes mere schemes). One of the most important extensions of this problem concerns that aspect of linguistic syntax similar to the phenomenon of serial order. This takes us to the next problem.

16. The Problem of Complex Learning Without Awareness

Could it be that humans learn and perform behaviours controlled by rules without themselves knowing, or being aware of, these rules? This question, which is so important for psychology, has not been studied by many people, and there are only a few relevant experimental studies (Smith, 1973; Foss, 1968; Bernted and Dixon, 1969; Eriksen, 1960), which demonstrate the possibility of this kind of learning. A positive response given to this question would have great consequences, for example, for the study of the relation between deep and surface structure studied in linguistics. However, even though there are a few experiments which support the claim for this kind of learning knowledge of how it operates is limited. For instance,

it is not known whether children are capable of this kind of learning, whether it begins at a certain stage, and so on. In the same way, its importance, in terms of more global (e.g. social) behaviour, is not known, and neither is whether new learning can modify the rules themselves.

17. The Problem of Cross Modal Functions in Memory

An example of the limits imposed on contemporary experiments by the lack of theories, is the confusion between different perceptual modalities and the way in which information is represented and processed in them. Most researchers believe that the information given to a sensory modality is codified in a specific way, resulting in different codes for different modalities. This belief only demonstrates the gulf between neurophysiology and psychology. In neurophysiology it is well known that once stimuli are received by the nervous system they are transformed into a series of electro-chemical events (e.g. axon potentials) which are the same for all sensory modalities; that means, that there must be a single code used in the brain (although it is not known) (Wallach and Averbach 1955). This supports the idea that it is a mistake to talk of different forms of representation, for example, visual or verbal memory, where the distinction is made in terms of the way in which the stimuli are represented. In reality it is not possible that the brain has two or more different forms of storing this information. From a theoretical point of view, the codes of the brain can be considered, as single, and the way in which these codes

are stored as well as the way in which they are manipulated can be considered as a series of electrophysiological processes. If this were taken more into consideration in psychology, it would considerably influence the ways in which theories are proposed. No doubt, this problem does present a series of difficulties to research since our knowledge of how the brain works is limited. However there are clear examples of how it is possible to investigate these problems from the point of view expressed above.

A different approach to the solution of cross modal function problems in memory comes from experiments of cross modal matching in animals (Davenport et al, 1973; Wright, 1970). Here the animals have to compare two stimuli presented in two different modalities, and respond, for example, if the stimuli are equal (or different). Since, in these experiments, the participation of "language" is minimal, the way in which the stimuli are codified is not specific, and comparisons may be drawn. Averbach and Sperling (1974) have demonstrated that visual and spatial information have a common form of representation in humans. In the same way Bower (1977) has suggested, theoretically and experimentally, that babies have a single way of representing and, on the other hand, studies in psychophysics (Stevens, 1966; Teghtsoonian, 1971) have demonstrated by other techniques, the possibility of a unique form of codification.

These examples illustrate that the problem has interesting and important implications for the study of memory, in spite of its difficulties.

18. The Problem of Probabilistic Aspects of Memory

Many aspects of the memory process use probabilistic analysis. Classical examples are those of attention and pattern recognition. In both cases it might be thought that to accomplish this kind of task the brain has to perform a statistical analysis, based on stored information and inputs to make an evaluation of a probabilistic kind and generate a response. On similar lines, it may be that the occurrence of certain events in everyday life with a greater or smaller degree of probability facilitates certain kinds of responses. Examples of this are the experiments on word frequency effect (Broadbent, 1967; Treisman, 1978; Morton, 1969), showing that the words most frequently used in everyday life are the most easily recognised and used in experiments on memory. However this effect may lie not in the words themselves, but in the way they are presented (Oldfield and Wingfield, 1964). Furthermore, it is not only the frequency of external events in general which is statistical. Probabilistic relations in particular situations are also important. Different contexts facilitate differently structured sets of information; for example, for children, school facilitates a different set of memory events from that facilitated by a theatre.

The use of probabilistic concepts has two uses in memory, one as an analytical tool and the other, perhaps more importantly, as a theoretical model (Estes, 1976). In this latter connection, probabilistic operations are particularly useful in facilitating the manipulation of

information being described in a series of processes. Examples of this kind of use of models are given by Godden (1976) who proposed that subjects have "a statistical model of the world that is considerably more optimal than has previously been suggested", or by Peterson and Beach (1967) who also consider that "men are intuitive statisticians". With this problem the lack of experiments is not so relevant as the correct utilization and interpretation of the data which is available. It is necessary to relate studies of attention, in which these concepts are frequently used, to models of memory (as well as other areas of research).

19. The Problem of the Control of Information

The models of Shiffrin and Atkinson (1969) and of Norman (1969) had the most important characteristic of emphasising the necessity of control mechanisms in information processing. Even though this idea of systems of control of processes was to be found in many forms in psychology, the explicit discovery of it in computer technology had a very healthy effect on the development of models (Norman, 1970). However there has not been much research on it.

Shiffrin and Atkinson (1969) have referred to at least nine processes of the control of information which have not been systematically studied and on which research has been limited, for instance, the process of scanning. Of course, there is a danger in postulating too many mechanisms for the control of information, almost one

mechanism for every different task, but it is very difficult to find only two or three mechanisms adequate for all necessary information control; Schneider and Shiffrin (1977) consequently emphasised the initiation of processes rather than the processes themselves.

Of course the question of how these processes begin is very interesting since it alludes to the question of automatic or voluntary control. However the study of the control of information is rather more specific and refers to the postulation of different processes some of which are possibly innate, and some learned, and it is even possible that some forms of optimising the control of information (Hunter, 1964) could be proposed.

The processes of information control postulated, and investigated, at the moment are very imprecise, and often taken from computer science, or are very mechanical descriptions, as is the case when imagery is considered as an internal dream or digital process. Perhaps these kinds of intermediate postulations must be proposed before more sophisticated models, like the filter model of Ginsburg (1975) to explain optical illusions, can be.

D. Parametric problems in systematic research

These problems are a clear indication of the lack of systematic data collection necessary to help future research. For instance lets ask how are the persons called mnemonists distributed in a certain population? Or what are the curves of forgetting and recognition for odours? These

kind of parametric data are the ones that help to make mathematical models. Maybe if this data were available, the possibility of having models of this kind would be increased.

20. The Problem of Training the Memory

The history of this problem is long and rich and there are several so-called techniques for improving the memory or the amount of information stored (Yates, 1966). How the efficacy of the old techniques (e.g. loci) has been demonstrated in a strict way (G. Bower, 1970; Hoffman and Senter, 1978). If it is true that our knowledge of memory has increased, it should be possible to demonstrate this by creating new "technologies" to help us improve memory. However the contribution that research is making to practical memorization, or even to educational psychology in general, is little, perhaps because our knowledge of the way in which memory works is not very clear, or because real efforts to develop new technology have not been made.

No doubt there is social pressure on psychologists to solve educational problems, to contribute to the training of people, to better confront the problems of sophisticated technologies and to solve the problems of developing societies, but psychologists cannot give much advice and in the few cases they do give it, it is of doubtful, even poor, quality. Their recipes for the improvement of memory sometimes go back 2000 years (Higbee, 1977, Yates, 1966).

21. The Problem of the Mnemonists

In essence this problem centres on how the performance of these talented people is produced. Is it the product of training or of genetic characteristics? There is no doubt of its existence: several studies relate different cases (for a short review see Baddeley, 1976) and there are several relevant anecdotes (Barlow, 1952). The study of these subjects, as well as the literature about them, gives a clear example of a memory phenomenon which evidently has important implications for a theory of memory. However it has not been studied as it should be. As Brow and Deffenbacher (1975) indicate, some of the more extensive studies in this area have been ignored by researchers. Two aspects of this problem are particularly interesting, one is how much the "capacities" of mnemonists differ from those of normal subjects, and the other is how possible it is to increase the performance of normal subjects, so that their performance would equal that of mnemonists.

Wallace et al (1957) suggest that normal subjects can memorize 2,200 words and Standing (1973) reports that they can recognize 10,000 photographs, both in more than 90% of cases. These studies, as well as careful observations of people in every day life, indicate that sometimes the performance of the mnemonist is not so special or different from that of normal subjects, but more studies are needed in order to be certain of this.

Related to this problem is that of the "supercalculist" (Hunter, 1964) where a vast memory is combined with an

enormous capacity to handle information. The effect of training is clear in these subjects as is the use of many learned strategies to solve complicated numerical operations.

22. The Problem of the Fluctuation of Memory

Some researchers (Hunter, 1964; Wickelgren, 1977) have shown that it is more or less easy to find inhibition or facilitation of memory, if subjects are under the effect of transitory states like emotions or alcohol. Memory fluctuations can be seen in other situations, for example, certain places facilitate memory of events that are otherwise not remembered, even though, in those instances, the place and the event are not directly related.

In other cases, there is evidence that remembering something can make the generation of other related memories more easy (Coltheart et al, 1975). This could give evidence on how information is stored: perhaps the transitory states are codified together with certain events, and afterwards this relation facilitates or generates the response. This kind of relation is easily seen in emotional states.

23. The Problem of Forwards Association

This problem has been studied for many years (Kausler, 1974) and extensive empirical evidence exists concerning it, yet its theoretical relevance has not been appreciated for models of memory. In its "pure" form, this phenomenon refers to the facilitating effect that an event (e.g. a nonsense syllable) has on the memorization of something

afterwards presented. This must not be confused with backwards inhibition, which is probably not its counterpart, each being controlled by a different mechanism (Dixon and Horton, 1968). Neither does this phenomenon refer exclusively to verbal learning, (as originally studied), there are other situations where it is possibly present as well, for example, in operant conditioning where reinforcement has an effect on a behaviour that just happened.

In spite of the simplicity of this phenomenon, its interpretation and generalization in terms of memory is very important. One interesting aspect of the problem is that it was very well studied inside a S-R (Stimulus-Response) approach about 10 or 20 years ago, when it was part of the "associationistic theory of memory" in its more or less pure form: however, the problem is still of great importance even though its origins are found in a theoretical model which very few persons nowadays accept.

24. The Problem of Reminiscence

The idea that research within the S-R conceptual framework is limited to problems inside the theory and is isolated from classical problems, is mistaken (Underwood, 1948; Brown, 1976). The difference between the classical ideas of reminiscence (Flores, 1970; Buxton, 1943), and the studies within the S-R approach, consists in a change of name. What was known as reminiscence is, in the "more objective" methodology, called "spontaneous recovery". Within the S-R tradition, little progress was made, mainly

due to the difficulty of explaining it with the simple and parsimonious ideas used to explain forgetfulness, interference or the decay of the trace. Recent experiments re-confirm the existence of this phenomenon (Brown, 1976). The relation between this work and the classical studies of Pavlov, who found that after an extinction of a response it reappeared in a spontaneous way, may be seen.

The implications of this problem are profound since, in a sense, there is no forgetting: all learned information is to be found in the system, the difficulty is in recovering it. This may be shown by three different lines of evidence: amnesia, state dependent learning, and repression. By means of different types of manipulation it can be demonstrated that all learned information is in the system, but that there are variables and processes which limit the use of it.

This phenomena also yields interesting data concerning the codification of stored events, and the existence and functioning of voluntary actions in memory. Experiments in this area, indicate the difference between the concepts of memory store and memory processes, and show that it is necessary to postulate and study processes which manipulate stored events. If it is true that stored information and processes of manipulation are so complicated, it may be possible to confirm the studies of Piaget and Inhelder (1973), who found that, in some cases, performance in memory tasks, improves with time. This conflicts with currently held beliefs. This fertile idea opens up a new field of ways in which phenomena can be conceptualized and performed.

25. The Problem of the Memory of Simple Sensations

Our understanding of memory is fragmentary and this can nowhere be seen more clearly than in this area of study. Knowledge here is scarce, possibly because memory for simple sensations (e.g. smell, taste, pain, etc.) is not very important in humans for survival. For many animals, of course, the role of this information is crucial.

At the moment, there is no data about the functions of forgetting this kind of information, nor data about the interaction of it with other kinds of information. This suggests the need for more experimentation in this area. Any valid theory of human memory has to deal with the handling of this kind of information rather than to limit itself, as present models do, to data taken only from the visual and auditory systems.

26. The Problem of Temporal Coding

A variable always present in experiments is the dimension of time. However, in spite of its importance, the way in which humans process and use this dimension is far from clear. The idea that time is measured by a physiological and/or psychological clock is inadequate and it may be that the time dimension is independent both of external events (physical time) and internal physiological ones (bio-rhythm). In the case of memory, a series of processes determine particular ways of interpreting information (Michotte, 1963). The kind of temporal relations that affect codification may be classified in two ways. First

there are the temporal relations restricted to experimental situations, e.g. backward and forward masking (at a perceptual level as well as that of information) and inter- and intra-list associations. Second, there are the general temporal relations on which learned responses are dependent, e.g. the answer to: "which was the first, the independence of the United States or the French revolution?", where temporal relation not contained in the information presented, but rather learned.

The processes of the manipulation of temporal variables, as well as the effects of these variables on these and other processes of memory, have not been sufficiently studied.

E. Problems related to other areas of psychology

Some researchers who could be called "specialists" sometimes seem to forget that the classifications of different "areas of research" are largely artificial and are not real divisions in the objects of study. On the other hand it is necessary to have some flexibility in order to be able to find relations with other areas and with other phenomena, (having in mind that this task is very difficult).

27. The Problem of the Relation Between Memory and Sleep (with reference to dreams)

A problem completely opaque with regard both to data and explanation is that of what happens to all the information that humans have stored when they are asleep. The only certain thing is that the machine cannot be said to

be "turned off", having a period of rest. There are two different sources of evidence that several things related to the manipulation of information occur during sleep; the first from the literature, gives evidence that dreams occur even though subjects often cannot report them; secondly, the experiments of Jenkins and Dallenbach (1925) suggest that performance in a memory task is improved after a period of sleep (Cohen 1974).

Other interesting phenomena are related to this problem. In most cases (although not always), people can report what they dream, but what is strange is that in many cases this is not possible immediately on waking up, but only later on, when they suddenly remember what they dreamed. In other cases, people maintain that they never dream, a claim which just does not seem to be true from the evidence of physiological signs of sleep.

Another interesting phenomena is that some subjects report in their dreams people, situations or real objects, whose interrelations are odd; they dream with big units, specific objects, situations, and so on, rather than with simple elements like colours, sounds, odours, etc. This may give clues on the one hand about how information is stored, and on the other, about the functioning of consciousness. Many people report that they have solved complex problems during sleep; this phenomena is well documented at the level of verbal reports (Koestler, 1964), and suggests that, in one way or another, processing and manipulation of information continues during sleep.

The questions which can be drawn out of this problem are varied and very interesting; for example, do animals and infants dream? Could one economise on hours of sleep in order to increase working or training time? What sorts of mechanism keep working during sleep? And so on.

28. The Problem of Memory and Language

Even though linguistics is nowadays considered as an important independent branch of research, and in spite of the importance of verbal learning research in the past decade, the psychological process whereby humans acquire grammar and syntax is very little understood (in contrast to the linguistic product which is acquired). It is important to distinguish between grammar and semantics from the linguistic point of view (Steklis et al, 1976), as formal descriptions of abstract structures, and grammar and semantics from the psychological point of view, as descriptions of how the brain works).

In other words, it is probably very useful to investigate how information is codified and how it is learned, this may help to organise elements of our theory of memory and in turn explain aspects of the behavioural aspects of language, Rumbaugh (1977). In the same way, it is possible that more light could be thrown on the problem of memory were it known how stored information is interrelated in memory.

29. The Problem of the Memory of Logical Operations

With the publication of the book by Piaget and Inhelder in 1968 (English version 1973), a new area of

research was opened up which has still not been assimilated in the psychological literature. The basic idea is that memory does not work with information presented in the way of a simple store, but that in the very act of perception, several operations form new configurations of information. In the same way, information already stored can be modified in several ways. The operations made on the information can be stored for later use or modification. This way of studying memory in relation to logical operations is completely different to the way in which it has been studied previously, with the possible exception of the work of Bartlett (1932).

A significant criticism of this kind of work is its dependence on verbal response and the emphasis on the behavioural performance of a child with a pattern of stimuli. It has been seen lately, that when more sophisticated research techniques are used, unexpected abilities are found in younger children (T. Bower, 1977). However, the ideas underlying this kind of experiment are very rich and relevant to memory research. For example, it could be that logical operations are themselves a way of codifying information, or else the result of operations (the ones that are going to be stored). A potential development might be the attempt to understand and find operations more complex than the ones Piaget studied, which are basically classifying operations or logical operations concerning quantity, quality and number - all operations of mathematical logic. It may be that these are not the

only ones human beings use, perhaps there are others to be discovered. It is important too, to discover the actual nature of the operations done in humans, as well as their stages of development; for example, in mathematics, a series of operations have been discovered, which are of great use in the manipulation of mathematical entities, and which do not correspond to the operations human beings are supposed to use.

In conclusion, it may be that it is precisely the richness and complexity of operations done on information that allows memory its great capacity to generate complex behavioural patterns. In the same way, the operations on information, which are beginning to attract attention, are those which create so-called human knowledge.

30. The Problem of the Effect of Emotional Marking on Memory

One interesting phenomenon found in some people is the ability to remember situations or events that have high emotional content (Dutta 1975). It seems that, in these cases, emotional factors are powerful elements which facilitate codification and easy recall (Brown and Kulik 1977). On the other hand, there is also a negative effect: emotional states sometimes exert negative influences on learning. For instance, punishment has negative effects not only on performance but on generalization to new situations (Wickelgren, 1977).

For many years, the concept of drive reduction was a fundamental element in theory and research. After a great

of research, it was demonstrated that drive reduction (and motivation) is not important to explain learning and its study was put on one side; nevertheless, nowadays, it is necessary to reinstate the problem (though in a new way), and to point out that memory and certain motivations or drives can be intimately related, and can facilitate or inhibit learning.

It has already been mentioned that, on the one hand, emotional states may facilitate or make recall more difficult; on the other, it can be postulated that there is an active process involved in the forgetting of situations which may produce emotional states (e.g. a car accident). In most cases, people recall the situation perfectly and many of its details, without re-experiencing the original emotional state (although this does sometimes occur).

There are complex relations between memory and emotion but the situation is quite different to what was thought several years ago. This demands a restatement of both the data and its interpretation. It is also of interest that certain emotional states can be provoked and controlled by means of chemicals. This could facilitate the study of the relations between neurophysiology and memory. It may also be possible to provoke emotional states without using chemical products or causing any actual damage to the subjects, and to study the ensuing effect on memory. The actual situations of much human learning can be realistically reproduced in this way, since in many everyday learning situations people are under the influence of emotional states. This variable has received little attention.

31. The Problem of Working Memory

Since the time of Greek "psychology", (Sorabji 1972) there have been metaphors referring to the existence of a place where people perform a series of operations with information. For example, if somebody is asked to multiply 23 by 68, in his "mind", the subject can, with effort, give the correct answer. Supposedly that person did the operation of multiplication by applying a known series of rules to use stored information, like using multiplication tables. Several examples of this kind of operation on information can be given, nevertheless this process is quite different to the one of "recalling" (e.g. what happened last Christmas) where information from the store or "a place" is merely moved or "read" (imagery).

There are several important aspects of the Greek metaphor:

1. It points out that a place exists where the manipulation of information takes place;
2. It supposes that the result of this manipulation is something new, that is, was not as such in memory before;
3. That it is an active process of manipulating data;
4. That it requires an effort;
5. That it is done consciously;
6. That it is a serial process where only a series of manipulations can take place, one by one, rather than several at the same time.

This metaphor is not simplistic. For a long time it was suggested, for instance, that there is no physical

place where this manipulation of information takes place, but that it was a process performed in different structures, a result of many specific individual activities.

It has also been suggested that there is parallel processing of information as well as serial. Sometimes the way these processes work has been confused or mixed up with the memory buffer, or, at others, with short- and long-term memory. Even though there are difficulties, in defining this problem, as well as studying it (Baddley and Hitch, 1974), the research into it is completely open.

In some ways, this problem is similar to that of consciousness, which has been discussed above, and it is also related to the study of imagery. The study of working memory is a good candidate for helping us to understand the great problem of consciousness. Moreover, it can also help in the study of problem solving, or the even more general problem of thinking, since it concerns stored information, and rules of manipulation of this information, which are two areas where data is available.

To achieve results with this problem, it must be realised that the concept of memory as a store of information is limited in use and that it is better to give it a more active role. Even though there is evidence in the contemporary literature for both parallel and serial processing (Sternberg, 1975; Theios, 1973) the full implications of these data have not been incorporated into present models. More generally, the more realistic study of memory as an active entity is only just beginning.

F. CONCLUSION

Searching for problems is difficult and complex, but the result of doing so is to allow one to see the limitations of present work as well as to gain a perspective on future research. It also allows one to see that questions from the long history of science are still unanswered, although there have been attempts to explain and understand them.

A positive aspect of searching for problems is the number of questions it causes to be posed. These can be taken into the laboratory and thus help make experimental work more creative rather than being limited to the repetition - with minor changes - of old research. From this point of view, finding problems is a form of progress.

There is some merit in saying that even a single new small fact demonstrated experimentally is important, since replication of results, and clearly stated facts, are needed, and that a series of more general questions is not relevant to this. However, the emphasis on performing perfectly controlled experiments can lead to a sterile field of endeavour, where many experiments with many different interpretations are gathered, many of them with irrelevant conclusions and lacking coherence.

The most important aspect of this list of problems is as a system which can be used to test the variability or limitations of the models and theories of memory, in particular the orthodox theory. For the present, the intention is not to carry on a logical analysis or to

evaluate the validity of the experiments which give support to the different aspects of the orthodox theory; rather, interest is centred on possible relations among the postulated mechanisms and processes related to the questions developed in the list given above. Although it is naive to ask for a theory to explain all known experimental phenomena, it is also naive to consider that it is only useful to explain certain phenomena, mainly for those for which the theory was created. It is not necessary to be very critical in order to see that the orthodox theory and the problems posed do not have a very close relation, except perhaps where they both employ similar language. The biggest difficulty is that the problems are many and varied and are also related to problems in everyday life, e.g. dreams, emotional marking, voluntary forgetting and so on. On the other hand, the orthodox theory seems to be related more to events in a laboratory, e.g. short term memory, transfer of information from one place to another and so on. Another difference between the problems and the orthodox theory is centred around situations which can be considered simpler and normal and does not explain special situations such as mnemonists, tacit knowledge and others. Another characteristic of the orthodox theory is that it is related to a school of thought about memory which is in a way associationist or based on stimulus-response doctrine. Several kinds of phenomena are outwith the scope of this general approach to memory. For instance, it has difficulty interpreting phenomena such as reminiscence or the possibility

of changes in memory (e.g. Bushke, 1974). This kind of difficulty illustrates the restrictions that a theory imposes on the form and kind of experiments that will be made by its followers.

One of the points that is interesting to point out is the possibility that memory could be studied not as a product but as a means of dealing with situations in everyday life. This approach emphasizes the limits of the orthodox theory. Some phenomena (which often have not been well studied), such as memory for logical operations, are clear examples of the limits of the orthodox theory. These limitations suggest the necessity of the search for better ways to relate memory to other areas of psychology. One way to describe this limitation of the orthodox model is to say that it is a passive system, which does not take into account a number of situations, human memory processes, not only collect information and store it, but the information is altered, modified and where possible, the generation of new information takes place.

Summarizing, it could be suggested that the limits of the orthodox theory:

a) Are based in a series of experiments and are interested in some limited aspects of memory research; however, as time went by the authors have modified the theory in such a way that nowadays it incorporates a great deal of explanations which allow the interpretation of a greater number of experiments, but even though the basic structure

has not been altered and the theory still maintains the idea of trace and the basic characteristic of stages in the flow of information.

b) As it was previously mentioned, the orthodox theory introduced the idea of processes of control of information, however it does not give a detailed analysis of these processes with the exception of one experimental study of the difference between controlled and automatic processes (i.e. Shneider and Shiffrin, 1977), but not realising all the potentialities of these processes. If all the examples of process available in the literature are analysed carefully, a different kind of memory theory could be presented, which could be more active, as discussed in chapter IV.

c) As it is common in the psychological literature influenced by the positivism and the experimentalism, the authors of the orthodox theory are more concerned about the development of specific predictions, details, particular experiments and mathematical models than to explain and generalize the theory to other problems, (as it is even recognized by the same Shiffrin, 1977, after an evaluation of the theory).

d) The theory is centred around the purest phenomena of laboratory and no attention is payed to limiting cases or to the application of the theory to phenomena more related to everyday life or to phenomena where there is a participation of other psychological phenomena.

e) Most of the experimental evidence of the orthodox theory is found in experiments where letters or nonsense

syllables are used, and as it will be described later (see chapter III), this can lead to serious mistakes in the interpretation of the results. In other words, the orthodox theory is not flexible enough to interpret and be able to cover a wide range of phenomena and problems found in human beings as most of the problems described in this chapter.

In some cases the problems that have been referred to are not empirical, but theoretical. For instance, in the case of the physical basis of memory the possible relations between psychology and neurophysiology are unclear, not because a theory unifying both areas of work has been searched for, but because the two areas are usually regarded as embodying two separate theories, since they employ different sets of experiments. To resolve this difficulty requires not only more attention and study but possibly a point of view less dualist or at least with a clearer and more explicit dualism.

It is not possible to state that everything is wrong in the orthodox theory, on the contrary, in a certain way the orthodox memory theory can be considered to be one of the best examples of theoretical psychology. In particular the developers of this theory can be described as a good example of devoted researchers interested in data and at the same time interested in developing better and more powerful models. The orthodox theory has been modified according to new evidence, and new aspects have been incorporated into it. However, the limits of the orthodox

theory are clear, primarily those aspects emphasized herein, that is the limited range of phenomena covered by it.

An important question can be posed at this juncture, if the orthodox theory does not have a sufficient range, wide enough to cover the problems of memory, would it not be easier to extend the theory instead of proposing a new one? The answer depends on the potentialities that could be discovered within the theory, especially if in the basis of the theory, the necessary elements can be found for substitutions and extensions.

As has already been mentioned in chapter I, some authors have a negative attitude about all areas of memory research. However, the critical articles are not enough, it seems necessary to use better arguments than logical analysis, which was the purpose for the list of problems proposed here.

One of the functions of this list is to serve as a test for theories of memory. It is then necessary to demonstrate empirically the mistakes and limitations of the assumptions of the orthodox theory as a step towards improving the theory. This will be done in the next chapter.

CHAPTER III

EXPERIMENTAL SECTION

A. INTRODUCTION

- I. On Iconic Memory
- II. On Reconstructive Memory
- III. On the Levels and Limits of Representation

B. GENERAL DISCUSSION OF THE EXPERIMENTAL SECTION

We didn't go to the moon to get rocks
We didn't go to the moon to get scientific
Information, we didn't go to improve
Electronic techniques. We went there
Simply to beat the Russians.

Astronaut Buzz Aldrin

The Observer, 10 Oct.
1977.

A. INTRODUCTION

The present state of memory research can be characterized as very active, possibly as one of the areas where there are a great many scientists discovering (or at least trying) new and interesting phenomena. However, the results obtained in the experiments do not give a clear picture easy to interpret. This is mainly because there are a great deal of isolated data which only indicates the complexity of the phenomenon in study. At the same time it is difficult to find theoretical developments, in the form of models or theories to be used to put order or give a general perspective. It is not difficult to find that models using boxes and arrows (as the one described in Chapter I) and its relatives like the level of processing, working memories, information processing systems, and so on, are not capable of giving an interpretation or answer to the question posed by Newell (1973) about how are we going to put together all this data. It is possible that this question is in the mind of many researchers in this area, worried about the "general picture" and not only interested in the "new data". But it could be thought that in general this situation of confusion in the general picture, is due to the present models and theories which are limited. Maybe it is necessary to substitute them by better "pictures". The idea of proposing the use of a new model or theory is not simply the interest in a change (as a fashion change) or by the simple desire of having a "scientific revolution". The reasons to abandon a model or theory have to be scientific or philosophic. In the particular case of the models and theories

of memory (as in any other area of research) the logic and conceptual limitations have to be demonstrated by means of theoretical analysis, or the limits in the assumptions or ideas behind the models have to be demonstrated experimentally. In fact several authors are trying in one way or another to demonstrate the logic or conceptual limitations of the present theories, (some of which have been already mentioned in Chapter I). One of the most interesting analysis in relation to this problem and the subject of this chapter, is found in the paper by Roedinger (1978) who after a detailed analysis of the models and theories used in the literature, found that all the interpretations used can be reduced to 30 metaphors, as the metaphor of stores as boxes, or the metaphor of images as pictures, or to consider flow of information as electric current and so on. But the most interesting conclusion is that most of the metaphors can be reduced to the idea of trace. If it is true that a great deal of the interpretations of memory available nowadays are metaphors, it is easy to suggest that there are not enough metaphors to explain many experimental phenomena, and possibly that another kind of tool is necessary in the construction of interpretations to explain the data. In addition it is possible that part of the problem is related to the idea of trace, which as discussed later, has a long history and a strong influence in contemporary research.

Supposing that it could be possible to give an experimental demonstration of the limits in the models and present theories, apart from the logic and conceptual arguments found in the literature, there is no doubt that if the

demonstration fulfils the characteristics of experimental rigidity and solidity required, this demonstration would be a very significant contribution to research. Nowadays there are only a few persons who believe that one experiment is enough to decide if a model or theory is false. However an experiment giving an experimental evidence of the limits of the models and theories can initiate a series of systematic efforts to elucidate the basis of the present models. Supposing that it is possible to present a considerable amount of solid and well founded logic and experimental arguments against a theory, even though at the end, the only thing remaining would be more data and more ignorance; and this is not the basic idea of research which tries to gather more knowledge. The ideal situation would be perhaps to demonstrate that something is wrong and at the same time, what is more important, give an indication of another direction and also give evidence in favour of the alternative suggested.

Due to these several reasons just mentioned, in the third chapter a series of experiments are going to be presented which can be classified in two groups. The experiments I and II are an attempt to evaluate some of the most important assumptions of the present models of memory, as the one described in Chapter I which can be considered as a prototype of the theories and models of memory. In particular these two experiments are an attempt to analyse the concept of trace which is clearly exemplified in the experiments in iconic memory. The second group is composed of experiments III and IV which are an attempt to give empirical evidence in favour

of a different kind of idea about memory and that are one of the possible alternatives to the orthodox models (see Chapter I) and that can be described as a "more cognitive position" which was originated by Bartlett (1972). It is difficult to find experimental evidence about these ideas and at the same time it can be considered as one of the theoretical interpretations of more popularity over the last few years.

These two groups of experiments are an attempt to fulfil the characteristics mentioned of an experimental study in relation to the orthodox theory of memory (Chapter I). That is, to give evidence against it on one hand and on the other evidence in favour of a possible alternative. It is for this reason that the experiments are different and are classified in two groups.

The experiment I is an attempt to see if the kind of material or stimuli used, (novel versus old or familiar) has an effect in a situation of iconic memory using the technique of Estes (1965). The results of this experiment indicated that in order to have more arguments against the idea of trace, and to be sure of the conclusions it was necessary to do another study (experiment II) following another methodology, as the one originally used in the experiments on iconic memory. It is possible to say that the experiment I is a study which questions the assumptions of the models of memory not only for its results but also for the logic of the problem. However given the importance of the problem it is important to have more empirical evidence in order to demonstrate using the conditions and the original methodology, the problems involved in the interpretation of iconic memory.

Experiment III is an attempt to give evidence in favour of an alternative view of memory, which was originally presented by Bartlett (1932) and that nowadays can be tested with more sophisticated and quantitative methodologies. It is surprising that even though Bartlett has received nowadays a lot of attention for his ideas, one of the most important aspects of his theory, in general, the reconstructive aspect, has not received much experimental support.

Experiment IV is directed towards the study of some specific aspects of the possible form in which Bartlett suggests that representation takes place, that is with images. This experiment is directed towards the study of some of the limits and characteristics of the images and is related to the contemporary discussion about the possible ideas of how to interpret representation, mainly making reference to the position of Shepard (1978). The results of this experiment are more specific, and even throw some light on the difficulties found in the study images.

It is important to remember that this work is directed towards theoretical aspects of memory research, but since the area of theoretical psychology is not sufficiently developed to maintain an exclusive theoretical level of discussion (or speculative psychology - Fodor 1975), it is necessary to introduce experimental evidence. However, it seems important not to forget that the attempt of this work is towards the development of models or theories. It is important to recognize that the task of discussing and developing models and theories is very difficult; it is for this reason that in the following chapter (Chapter IV) some generalisations are going to be described, which can serve as directives in the development of a possible conceptual structure, to help in the future construction of better theories and models. This possibility is considered as remote, not for lack of results or ideas, but for lack of interest in theoretical work.

I - ON ICONIC MEMORY

Abstract

Introduction

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Abstract

The concept of a static trace of memory is one of the most important ideas in which contemporary models of memory are based. A specific demonstration can be found in the experiments of iconic memory. In this work a review of the literature about the origins of the concept of static trace is presented, and it is suggested that the experiments in this area have been done under the influence of a misleading assumption, whereby letters are considered to be novel stimuli. Two different techniques were used to replicate the studies of Sperling, using letters and novel stimuli. In this case different results were found according to the familiarity of the subject with the stimuli. This was taken as evidence to suggest that iconic memory cannot be found if novel stimulation is used, which could mean that iconic memory may not be the first independent step in processing information, since it seems to depend on the novelty of the stimulation. The results of the two experiments reported here question a great deal of other experiments in memory where letters are used as stimuli, and suggest a limitation of memory models and in general of the ideas of a static trace, in its strict sense, flow of information and stores.

INTRODUCTION

It is possible to suggest that the phenomenon called "Iconic memory" plays an essential role in so-called "cognitive psychology", (Neisser, 1967). As well as in memory research (Coltheart, 1976). The origin of the idea behind this phenomenon can be divided in two for its analysis. The first part refers to the concept of a "memory trace" found in philosophical psychology which has a long history. The second part refers to the transformation of these ideas into a scientific problem, which took place at the end of last century.

1. The Concept of Trace

From the point of view of the development of philosophical psychology and in particular from the point of view of the study of memory, the concept of trace has played a very important role. Since the beginning it has represented a theoretical point of view mainly in the development of the present conception of psychology.

There are two ways in which this theory of memory trace can be interpreted. The first, in its literal sense, refers to "one of the earliest and most tenacious views of the physical basis of memory", (Gomulicki, 1953). This view considers the brain as a wax tablet upon which, like a stylus, sensory impressions engrave physical traces which persist until effaced by time. The second way in which the trace concept can be considered is to propose, in a more general way, a physical process intimately related to

the memory trace. This is done in a more metaphorical way, nevertheless denying, the participation of other metaphysical entities. In this way, the limitations of the proposed physical substrate are recognized and considered a problem due to lack of knowledge which does not deserve to be ignored simply because of this.

Since the concept of trace was postulated it has had a very complicated history (as Gomulicki, 1953) puts it. For instance, Zeno the Stoic (340-265 B.C.) extended Socrates' and Plato's ideas and made explicit the concept later known as "tabula rasa". Another important development was done by Aristotle who used for the first time the concept of trace in a strict sense assigning to the heart and the blood ("pneuma") the functions which today are assigned to the brain and the nervous system. He considered that sensory impressions were transmitted from the sense organs to the heart by movements in the pneuma. Movements persisted, though on a decreased scale, after the external stimuli had ceased. In the same way Aristotle explained memory and imagination as movements of the pneuma. This idea of the heart as the principal organ of psychological phenomena was often discussed. Eristratus, (c310-250 B.C.) working with Herophilus (330-280 B.C.) carried out dissections of the human brain and thereby studied some of its characteristics and connections. They accepted that some functions could be ascribed to the heart, but others, the ones referred to as "mental" processes, were ascribed to the brain.

Later on, Galen (A.D. 138-201) was more specific and named specific parts of the brain for certain functions (e.g. memory). By this time, there were many concepts of trace and many interpretations of the concept. At the same time the first attempts to apply the idea of memory in a more practical sense began to emerge. Thus began the development of techniques for memorising, or mnemo-techniques, although little attention was paid to the substratum of the phenomenon, (e.g. Cicero 106-43 B.C.); Quintillian, first century A.D.; for detailed review see Yates, 1966).

2. Evolution of the Concept of Trace

The discussion and the study of memory continued with the introduction of new interpretations, such as those given by the Christian philosophers, represented for example by Saint Augustine (A.D. 354-430), who maintained a dualist point of view, giving some psychological phenomena to the soul and some to the brain.

This development continued and was enriched in the XVIIth and XVIIIth centuries, primarily by early attempts to give a more detailed explanation of the workings of memory. For instance, memory traces were related to electric and magnetic phenomena (Zanotti, 1693-1777). At the same time, the first attempts to quantify memory phenomena started: for instance, it was estimated by Von Haller (1708-1777) that one third of a second was required to produce an idea. On the basis of this estimation,

Haller and others computed that in fifty years an individual would accumulate some 1,577,800,000 traces or ideas. More or less at the same time Hamilton stated that the number of elements that a person can enumerate without counting, the so-called span of apprehension, was more or less 7. (Mandler, 1974). By the end of the XVIIIth century, the number of developments and different points of view had multiplied greatly, e.g. (Burnham, 1888-1889); Gomulicki, 1953; Klein, 1970).

A concept which was present since the origins of the concept of trace was the idea of association, which became increasingly important in the development of experimental psychology, in the XIXth century.

As can be appreciated from the above historical sketch the idea of trace has had a long history, and is indeed a very old idea. Its most important aspect as an explanatory idea is that it allows interpretations which attempt to describe the physical basis of memory. These interpretations have been either strict or general, but that has been a function of the amount of specific data about the processes involved. It is important to point out that since its beginnings, the concept of trace has been considered as something static, which is not modified: a trace only disappears gradually, or is substituted for another trace. In a general way the trace concept has been seen as the substrate or fundamental interpretation of memory processes.

The transformation of philosophical ideas into psychological problems is clear in the origins of modern psychology,

(e.g. Fechner; Wundt and so on). Ebbinghaus (1885), recognised in the introduction of his book that his interest was to quantify the phenomenon of forgetfulness, in the same way as Fechner (1860) had done for sensations. Although Ebbinghaus does not state so explicitly his theory and experiments have their origins in the concept of trace.

One important aspect of memory research in scientific psychology is the attempt to control and isolate the static aspect of memory, whose influence can be felt nowadays. This static approach to memory has only been interrupted by sporadic attempts to elaborate alternative points of view, (e.g. Bartlett, 1932) attempts which have met with little success. Only in the last few years is it possible to see that other alternative explanations are emerging, (e.g. Neisser, 1967; Piaget and Inhelder, 1973).

The origins of the modern use of the concept of trace can be found to a great extent in Sperling's (1960) work. Originally his work was not directly related to the concept of trace, but nowadays is seen to represent the best example of the application of this concept to memory. The approach derived from Sperling has been described and analysed in detail by Dick (1974) Coltheart (1976) and Holding (1975).

3. The Original Experiments of G. Sperling

The original question asked in Sperling's series of experiments was "how much can be seen in a single brief exposure of stimuli?" Besides the theoretical importance of the question, Sperling (1960) suggested that it has

practical value for the study of reading. In previous reports to which Sperling makes reference, it was suggested in several ways that the subjects insisted on having seen more than they could report. This made Sperling propose a general hypothesis that "more is seen than can be reported". It was in this way that the classical studies of span of apprehension began to be concerned not only with perception but also with memory. It was suggested that a subject had more information available than he could report. Therefore, the problem was to demonstrate that this was true. The hypothesis that the subjects can report only a certain number of events led to a very important experimental manipulation; subjects were asked to give a 'partial report' of what they had just seen rather than try to report all the stimuli presented. Apparently, the idea of a partial report was taken from ordinary schoolroom examinations, where teachers ask questions which are about only a sample of the total amount of information the students are expected to have. However, analysing the answers, an estimate of the knowledge of the student can be given. It was with this logic in mind that the idea of a partial report emerged. It became relevant to indicate to the subjects after the stimuli had been presented, which stimuli he had to report. The stimuli consisted of a matrix of 3x3 or 4x4 letters presented in a tachistoscope. The matrix was drawn on white cards which were viewed at a distance of 45 cm. The subjects' answers consisted of

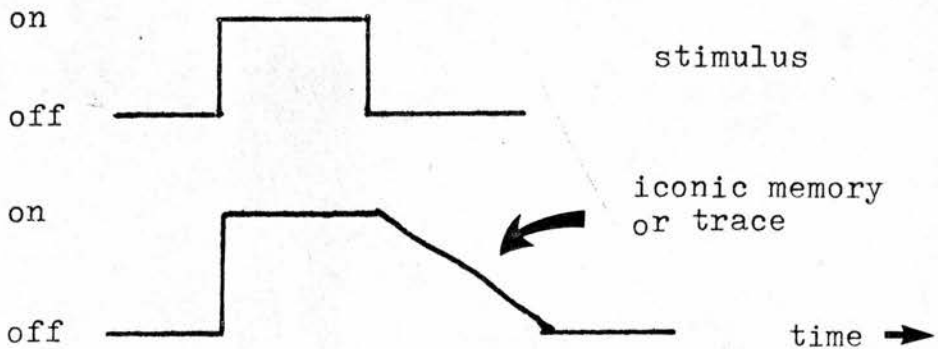
writing the line of letters indicated by a cue. The cue originally used was a tone of 0.5 sec which began after the stimuli had been presented. This tone could be low (250Hz) or high (2,500 Hz). This difference in tone indicated which part of the stimuli (the low or high line) the subject had to report. In other experiments, an intermediate tone (650 Hz) was introduced, in this case the middle line was the one to be reported. The delay between turning off the stimuli and the cue was a very important variable to study. Delays of 0.1 to 1.0 sec were used. The answer was considered a sample of the total amount of stimuli presented. Therefore, if the subject reported 90% of the sample, this was interpreted as if the subject was in fact capable of reporting 90% of the total amount of stimuli.

Sperling used five subjects and tested them continuously for several weeks. In his experiments Sperling indicated that his subjects report an average of 9.8 of 12 letters presented. This performance decayed gradually with delay: it was observed that with a delay of up to 300 msec between the stimulus and the cue the amount of letters reported was the same as the normal span (4.5 letters), when the subjects were asked to report all the letters without the technique of partial report. The results suggested that in fact the subjects remember more letters than the ones they can report for approximately 300 msec.

These experimental results were interpreted by

Sperling to support the idea of an "image" of the stimulus, which is available to subjects after the extinction of the stimulus. He concluded that the high accuracy of the partial report observed in the experiments does not depend on the order of report or the position of the letters, but rather it depends on the ability of the observer to read this "visual image" that persists for a fraction of a second after the stimulus has been turned off.

Following Rummelhart (1970), we may represent the interpretation of a visual image that persists in the following way:



Sperling's results were replicated in several laboratories and subsequently his interpretation was incorporated into many general theories of memory.

4. Later Developments

In order to avoid confusion in our own description of this phenomenon let us use a contemporary terminology and point of view (e.g. Dick, 1974; Holding, 1975). The first significant experimental development was the replication of Sperling's original studies by Aberbach and Coriel (1961). In this case a visual mark was used instead of a tone. The mark used was a bar or a circle indicating

the place where the stimuli to be reported were. In this case the same results reported by Sperling were obtained.

Mackworth (1963) also obtained the same results and did a detailed study of the effects of the time of presentation of the stimuli. He found that these have a significant effect only in some cases. However he did not maintain the same levels of luminance throughout the experiment, which makes the interpretation of his results about this point, difficult, to interpret.

The next step in the development of the concept of iconic memory was done with use of different methodologies. For instance a vibrotactile cue was applied to the subjects' fingers to indicate which part of the stimuli display he had to report (Smith and Ramunas, 1971). In this case similar results were obtained. A different approach was the one used by Estes and Taylor (1964); Estes (1965) and Estes and Taylor (1966). They developed a technique in which the subjects had to answer 'yes' or 'no' to the presence or absence of a stimulus known by the subject in advance, (called the target stimulus). By means of a statistical analysis, the number of stimuli perceived by the subject were determined. Again the results obtained with this technique agreed with the previous ones. Rumelhart (1970) analysing iconic memory which produced similar results, used temporal integration of fragmented forms. This technique was developed by Eriksen and Collons (1967). His experiments involved the presentation of two fields in rapid succession, both fields containing

a group of "random" dots patterns. When both fields were superimposed, three letters could be seen. Manipulation of time between the presentation of fields gave similar results to the ones obtained with other techniques.

Haver and Standing (1970) devised another technique. Subjects were presented with a 3x3 matrix of letters which they did not have to report, and at the same time with a clicking sound. The subject could change the time at which the click was on, and his task was to make the sound coincide first with the beginning of the stimulus (letters) and second with its disappearance. The subjects were expected to synchronize the click with their impression of the stimulus and not really with the stimulus per se: that is, it was supposed that the subjects reacted to the trace which persisted after the stimulus had actually been turned off. Analysing the differences in time, the experiments confirmed that subjects did not respond directly to the physical presence of the stimulus, but to something considered to be the trace. These studies were confirmed soon after by Efron (1970).

From a methodological point of view, it seems that the phenomenon is not an artefact of the technique used, since different techniques lead to the same results. Therefore, the next step was to see which are the most important variables involved. One of the most important variables, in relation to the subject's performance seems to do with the characteristics of the post-exposure field; that is, with what appears in the tachitoscope after the stimulus.

Sperling (1960, 1963) and Aberbach and Sperling (1961) found that a dark post exposure field decreases the number of correct responses. Turvey (1973), Turvey et al (1974) and Dick (1974) consider that this variable is the one that most affects the trace in iconic memory.

Changing the time of exposure of the stimuli between 15-500 msec, Sperling (1960) found that there was no change in the number of letters reported. However, Dick (1974) said that although this variable can be important, the necessary experiments to establish it have not been carried out.

The kind of material used as stimuli, that is letters, numbers, colours, position, etc. is another important variable which can indicate the kind of processes involved. Different experiments using different stimuli agrees with the original experiments which used letters or numbers. von Wright (1968) used colour and Mewhort et al (1969) used letters with a different degree of similarity to the ones used in English and found that experience improves performance. Holding (1970) found different performances using English letters or Arabic characters, English speaking persons performing poorly with Arabic characters. Hayer, (1974) found that using simple shapes like circles or 4 or 8 sided shapes, led to different results. As the complexity of the stimulus increased, the performance decreased.

As can be seen from this brief review iconic memory is a reproducible phenomenon which is affected by several variables.

A logical extension of the study of iconic memory was to see if the phenomenon could be observed in other sensory modalities than vision. Crowder and Morton, (1969) have worked in the auditory system and called this phenomenon acoustic storage. However, the results are not very clear and several alternative explanations can be given. Some extensions of this work have been done, unfortunately without much success in establishing the phenomenon (e.g. Treisman and Rostron, 1972).

5. The Concept of Iconic Memory

It is important to analyse what is the status and modern interpretation given to the iconic memory concept. As has been emphasised, iconic memory so far has been analysed with a present perspective in order to study a series of experiments which are nowadays grouped under the term "iconic memory". Neisser (1967) proposed this term, but several other names have also been given, in some cases suggesting a different interpretation. For instance, it has been called sensory register (Atkinson and Shiffrin, 1968); visual persistence (Coltheart, 1976); sensory storage (Holding, 1975); visual memory (Sperling, 1963) and iconic storage (Heyer, 1974). In all these cases reference is made to the same experiments and phenomena; however, the differences in name are something other than personal choice and refer possibly to different interpretations of the phenomena. About the history and evolution of the concept, Dick (1974) states that "theorising about

Sperling's work came more slowly, but Neisser's theoretical discussion served to solidify the notion of a rapid decaying memory". He continues saying that in general terms, "iconic memory can be described as a large capacity, short duration image". This description is, in a way, the "official doctrine" on iconic memory (e.g. Bower, 1977).

"The official doctrine" is that the iconic memory process is the first step in human information processing. It is supposed that iconic memory is a store which contains precategorical information, where part of the information is lost if it is not transferred to another stage for its elaboration. Sperling (1963, 1976) was the first to try to give a detailed explanation of the different characteristics of information processing. In his attempts to produce a model he proposed a simple scheme with a visual information store (viz) that receives light patterns and stores them for a limited time (trace). A second 'scan' mechanism, is supposed to take certain elements from the vis and keep them by rehearsal. Also an auditory information store was proposed (Sperling, 1963). This simple model was used as the basis for more elaborate ones, (Sperling, 1967) and postulating six different long-term memories, he stated that "the proper development of all six of these long term memories is a prerequisite for the effective operation of all the information processing system".

However, as Holding (1975) comments, none of the attempts to develop a general model to explain information

processing, had much impact in research. From the point of view of the experiments, it has been more important to differentiate iconic memory from other phenomena such as visual persistence. Coltheart (1976) states that these phenomena are identical, however in his experiments, non-sense stimuli, such as lights or moving points are used; whereas in the others more complex information such as letters, colours or numbers are used.

Also from an experimental point of view, there have been attempts to distinguish between the afterimages and the trace, (or icon). It could be that the traces left by stimuli, called icons are simply negative afterimages. However, this kind of afterimage can be observed in dark post-exposure fields in a tachistoscope precisely where iconic memory decreases significantly (Sperling 1963). If the icon and the negative afterimage were the same, the icon could be facilitated in a dark field. On the contrary, iconic memory is found in illuminated fields where it is not possible to observe negative afterimages (Julesz, 1971). Such a clear difference has not been observed between the icon and a positive afterimage, and it is possible that they could belong to the same class of phenomena, or be the same thing (Dick, 1974). However, this has not been studied systematically.

Another interesting distinction which has been investigated is that between iconic memory and short-term memory. Both kinds of memory have been studied under different circumstances, subjects being presented with different

stimuli in varying quantities. In the iconic memory stage it has been postulated that information is pre-categorical information, whereas in the short-term memory stage it has been proposed that information is categorical. Studying the relation between these two memory stages Turvey (1966) asked the subjects to retain 5 letters, 5 numbers or 5 binary digits while doing a typical Sperling iconic memory task with letters. He found that the information held in memory did not affect the partial report of the subjects in the Sperling task. He suggested therefore, that short term memory did not affect iconic memory, but that iconic memory could interfere with short-term memory. These studies have been replicated and extended by Doost and Turvey (1971) and Spencer (1971). Phillips (1974) did a detailed and extensive study and found that different nonsense stimuli produced different curves of forgetfulness. He proposed two distinct classes of visual memory: a high capacity sensory storage which is tied to spatial position and is maskable and brief, and a schematic short-term visual memory which is not tied to spatial position, is protected against masking, and which becomes less effective over a few seconds, but not over the first 600 msec. However the distinctions between the visual short term memory stage and the iconic memory stage is not yet clear. In general the first few stages in human information processing are still rather poorly understood.

6. Criticisms of Iconic Memory

Iconic memory, as a phenomena and as a concept is established strongly in the experimental literature, although its relations with the rest of the stages involved in human information processing are at the moment subjected to a great speculation (Bower, 1977). Although iconic memory has its place in the psychological literature, it has been criticised (Holding, 1972, 1975). These criticisms, however, have themselves been rejected for lack of clear arguments and experimental support (Coltheart et al, 1974; Coltheart, 1975). In fact part of Holding's criticism is both tenable and presents some important implications in the thesis be presented here.

In his first criticism, Holding (1970) referred to the ways in which data were analysed in the original experiments partial report. He emphasised that if the trials were not carefully balanced, subjects might be able to predict which column in the matrix of letters they were going to be asked to report. In that way the subjects will pay attention only to that column, thus invalidating the results. Holding designed an experiment where he could manipulate directly the guessing behaviour of the subjects and found that this manipulation affected performance. However, although this argument applies to Sperling's (1960) experiments, it does not apply to others, such as Averbach and Coriel (1961).

Holding (1972) reported another experiment, in this case in a situation similar to Sperling's (1960) original experiment, in which he found that performance was similar

to that already reported if he used the English alphabet but if he used Arabic characters performance deteriorated. Although these results are interesting and could indicate that iconic memory is dependent on information already known by the subject, other interpretations can be given. For instance, Coltheart, et al (1974) indicated that if a subject is not familiar with the stimuli he cannot rehearse and transfer this information to a short-term memory. Although the criticism made of Holding's experiment (1972) is valid, that is the subjects are limited in the number of events that can transfer to STM, the implications are important that is the study of iconic memory using novel stimuli. 'Iconic memory' has been described as one of the most representative forms of the idea of 'trace' nowadays, the concept having therefore, ancient origins. The usefulness of this concept in the development of psychology cannot be denied. It has been an important factor in the development of the idea of memory as a phenomenon based on certain physical processes (neurophysiological) and not in the soul or mind, as an entity different and separated from the body (or brain). In a more specific way, iconic memory represents in the contemporary literature, the first step in a long chain of vicissitudes which information suffers during its processing. However, in the experiments on iconic memory, a misleading assumption can be found which it is very important to point out. This mistake may derive from the kind of theory used. It consists in assuming that the subjects are acquiring new information. In all

cases where the stimuli are familiar (letters; numbers) the only thing that can be concluded is that the subject is learning a new combination of the information he already has. The idea that in these situations the subject is learning something new started with Ebbinghaus (1885), and since then a great number of workers have made the same misleading assumption. Even nowadays, psychologists are trying to study processes of acquisition of information using stimuli which in strict sense are not novel. If this is so, it is very important to study whether iconic memory is still observed in the absence of familiar stimuli, that is, using completely novel stimuli. This of course, presents a methodological problem, since the information given has to be easily reported by the subject, in other words, the answers should not be affected by the difficulty in generating or transforming the output. And at the same time the same conditions as in other experiments have to be repeated. The following experiment is an attempt to solve this methodological problem and to investigate whether iconic memory can still be observed in the absence of familiar stimuli.

7. Methodological Considerations

In iconic memory experiments, it is possible that the results might be different when novel material is presented. The problem is to find an optimal experimental situation where the generation of a response does not call for a difficult transformation.

As was previously mentioned one of the techniques used to replicate experiments of iconic memory was that devised by Estes (op cit). This technique allows for short tachistoscopic presentation (e.g. 100 msec) of a matrix of 3x3 or 4x4 letters where one or two target stimuli are present in the set of letters. The target stimuli are letters which the subject knows at the beginning of the experiment. The subject has to indicate whether the target stimuli were present or not in the matrix just presented. The position and the use of the stimuli are presented in all possible combinations. The other stimuli of the matrix were selected at random. Estes and Taylor (1964) reported that with this technique the problem of retention loss is minimized since it is not necessary for the subject to give an extensive verbal report as in other techniques.

The choice of statistical analysis for this type of experiment is very important. Since subjects had to indicate which of two stimuli were present on the screen, in the first place it was possible to see if the answers were given at random and; and the second place, to calculate the number of elements processed (detected) by the subject. As the authors put it, "for most theoretical purposes it is desirable to convert the raw data in terms of proportions of correct responses into estimates of number of elements effectively processed at various display sizes. To do this the successes achievable were corrected for guessing

behaviour according to the formula:

$$P_c = \frac{P}{D} + (1 - \frac{P}{D}) \frac{1}{2}$$

where P_c represents probability of correct response; P the number of elements effectively processed and D the number of elements in the display. The basis of this relation is that since the critical elements are randomly placed in the displays, the probability that the critical element falls among the P elements perceived is P/D ; and when the critical element does not fall among those perceived, the probability of a correct response is $\frac{1}{2}$ since both critical elements occurred equally often in random sequence. Replacing P_c by the observed proportion of correct detections at a given display size, it is possible to solve the question for P and thus obtain an estimate for this theoretical quantity in terms of observables:

$$P = (2P_c - 1) D$$

This technique has been used by Estes and Taylor (1966) to reproduce the original studies of Sperling (1960) and it was found that their data agree. This technique has also been used to study other aspects of memory and stimulus detection. (e.g. Estes, 1972; Estes, 1974; Welford, et al, 1968).

A second methodological aspect necessary for testing the present hypothesis has to do with the stimulation itself. The basic idea of this experiment is to try to diminish the effects of learned information using relatively novel stimuli and compare this situation with a situation

where the subject is familiar with the stimuli. Schematically the situation could be represented as following form:

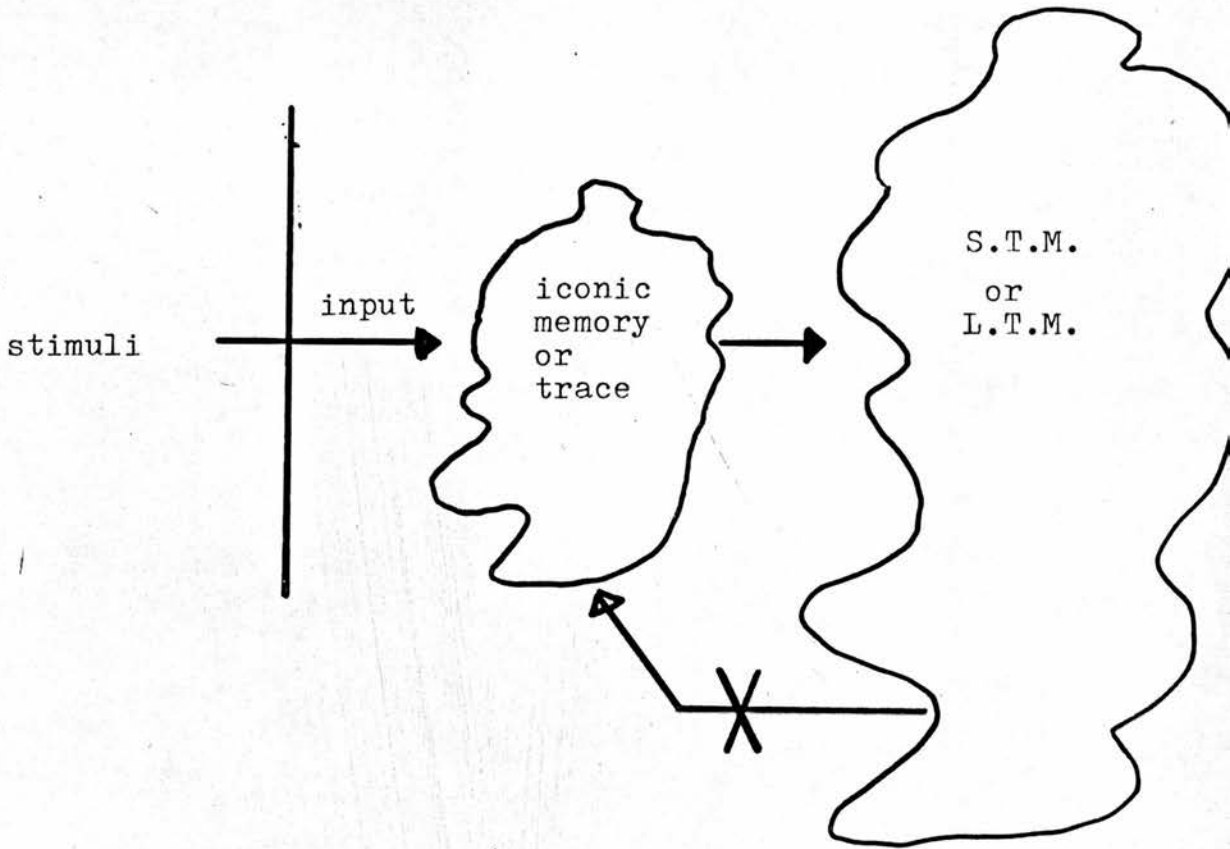


Figure 2

A kind of stimulation which can reduce variables introduced by familiar information was devised by Dick and Loader (1974). The stimuli formed by 3 vertical, 3 horizontal and 2 oblique lines which together form the following shape:

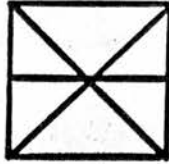


Fig. 3: Configuration from which lines were randomly selected to produce the stimuli.

The stimuli are formed taking 2 lines at random (Fig. 3). Those sets resembling a letter were discarded.



Fig. 4: Examples of the kind of stimuli used.

EXPERIMENT IMethodSubjects:

Ten volunteers, students of the University, 5 from the Department of Psychology. None had any visual defect and none wore glasses. They were randomly assigned to two groups, i.e. an experimental group who received "novel" stimuli and a control group who received familiar stimuli (letters). The subjects were naive with respect to this experiment and they were told it was an experiment on perception. Memory was not mentioned.

Procedure:

The stimuli were displayed on a two channel tachistoscope, (Colne Instruments, Co. Ltd). The first channel was continuously on, with a card with a black dot in the centre as a fixation point. In channel 2, the stimuli were presented for 50 or 200 msec. The brightness of the screen was approximately 9.5 Ft Lamberts, measured with a Macbeth Illuminometer.

The stimuli were divided into two sets, one of letters and the other of novel stimuli. The letters were combined at random into groups of 3, 6 and 9 from a set of 20 capital letters (Letraset, Block BOE, 4). The letters were transferred on to white cards. These were all consonants from the Latin alphabet; the "W" was not used. Each letter occurred in every possible position in a 3x3 matrix. Fifty four cards were made up according to the following

rules: 1 - no cards contained the same letter twice.
 2 - Where there were only three letters on a card, a line or column was avoided. The novel stimuli were made up following the procedure of Dick and Loader (1974), previously mentioned. Two lines were randomly selected from the figure containing 8 lines of the same length, (Fig. 3 and 4). All the possible combinations of two lines were selected except those resembling a letter, such as the T. The lines were drawn in cards using indian ink and a Leroy-Pen No. 5. The total number of forms obtained in this way were 20, which were distributed in the same way as the 20 letters, that is, at random in a matrix of 3x3. The size of the matrix was $5 \times 5^\circ$ (degrees) of visual field, every stimulus being $1 \times 1^\circ$ (degrees) approximately.

By the side of the tachistoscope where the subjects could see it at any time, between trials, was a card of 20 x 12.5 cm. with two target stimuli. In the case of letters, the target stimuli were F and B. In the case of novel stimuli, the targets were **└** and **┐**. The subjects had to report which of the target stimuli was present in the matrix of stimuli presented in the tachistoscope.

The probability of any of the target stimuli appearing in any of the 9 different positions in the matrix of the tachistoscope card was the same and the order of presentation of any of the target stimuli on the cards was random. The total of 54 cards was presented twice, once with a tachistoscopic presentation of 50 msec and the other with 200 msec. Half the number of subjects started with a

different 50 or 200 msec time in order to counterbalance the groups.

Approximately 4 sec before each trial, the experimenter gave the signal "ready" and then proceeded to take note of the subject's response. The experiment lasted a total of 20-30 min.

Results

Figs. 5 and 6 show the mean of the subjects' response in the two conditions, experimental (novel stimuli) and control (letters), with the two times of tachistoscopic presentation (50-200 msec) as a function of the number of stimuli presented in the display (3, 6 or 9). See Table 1.

TABLE 1: Estimate of the Amount of Processed Stimuli

Time of Presentation (msec)	Number of Stimuli on the Screen (D)	Novel Stimuli(X)	Letters(X)
50	3	2.74 \pm 0.25	3.00 \pm 0.00
	6	4.36 \pm 0.52	5.80 \pm 0.27*
	9	4.14 \pm 0.45	7.95 \pm 0.80*
200	3	2.90 \pm 0.15	3.00 \pm 0.00
	6	4.05 \pm 0.22	5.82 \pm 0.31*
	9	4.22 \pm 0.37	8.20 \pm 0.48*

*P < 0.05 (T Test)

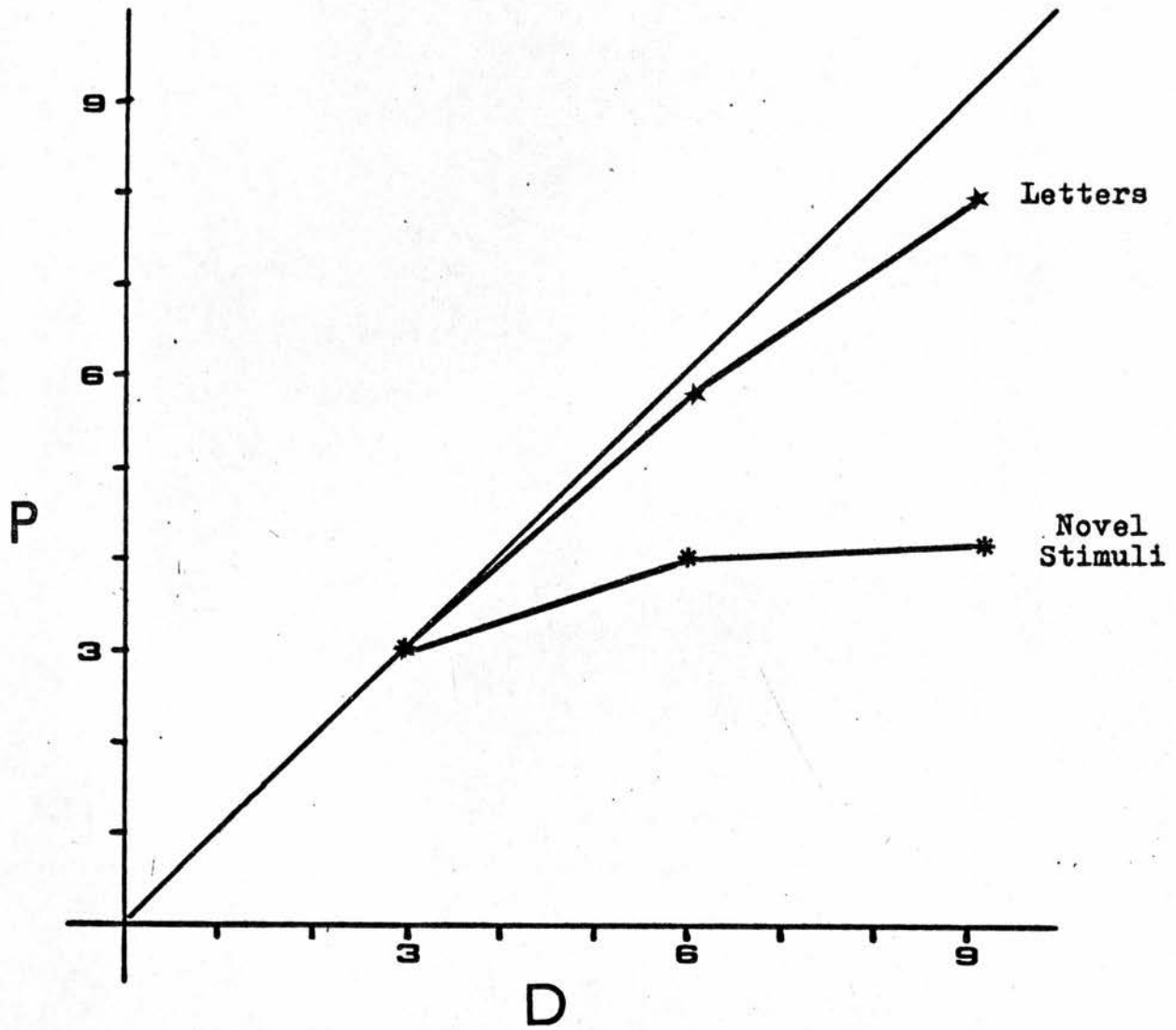


Fig. 5: Number of stimuli processed (P). Letters versus novel stimuli as function of the stimuli in the display (D), with 200 msec of presentation, using Estes' Technique.

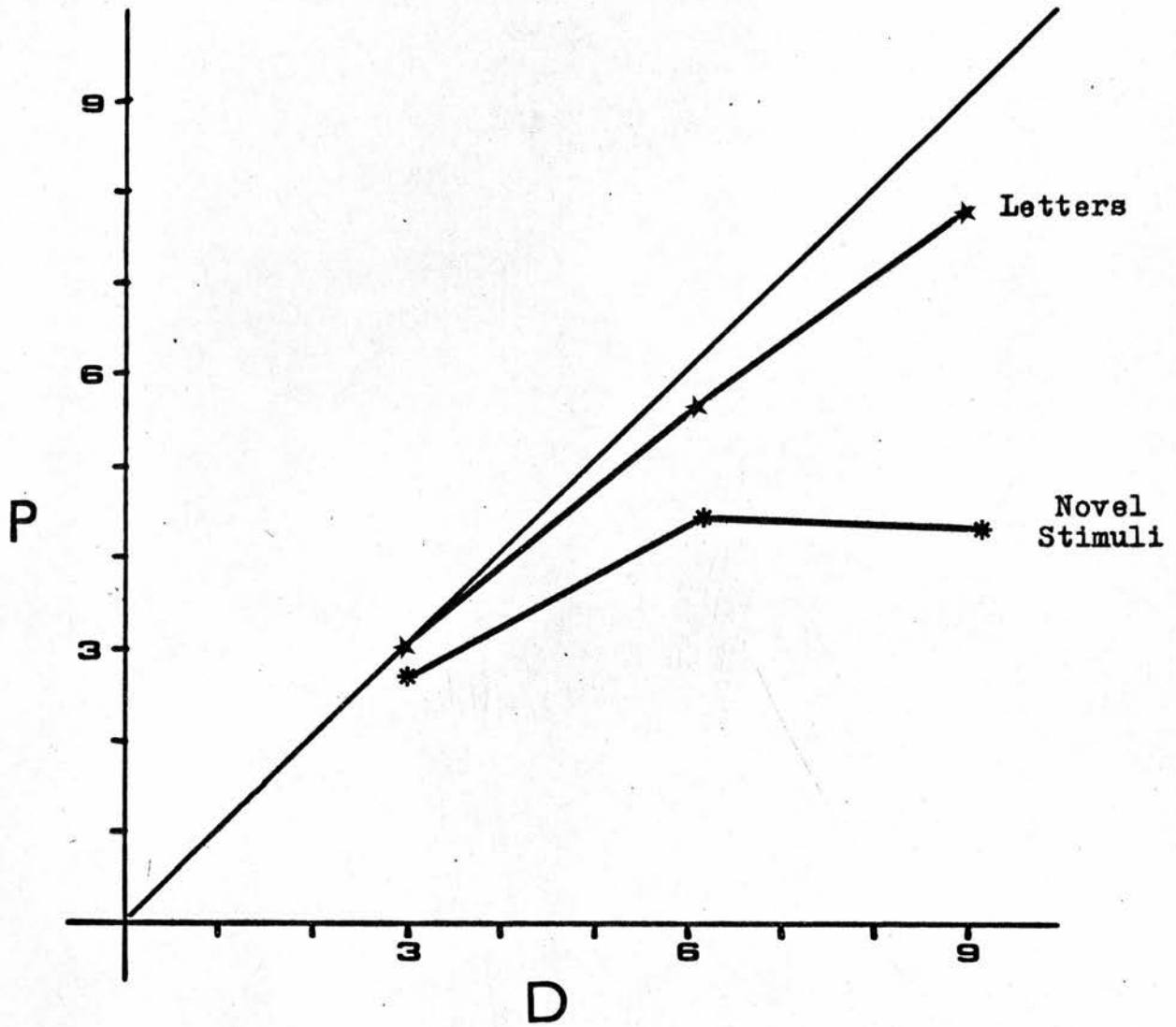


Fig. 6: Number of stimuli processed (P). Letters versus novel stimuli as function of the stimuli in the display (D), with 50 msec of presentation, using Estes' techniques.

As previously mentioned the method devised by Estes (1965) was used to calculate the number of processed stimuli. This method provides a formula which includes the number of stimuli presented (D) and the possibility of the subject guessing the responses. The statistical analysis shows that there is no difference statistically significant between the presentations of 50 and 200 msec within the groups. There is a difference statistically significant in the number of correct responses between the control and the experimental groups when the number of stimuli presented was 9. The difference was significant for both durations of tachistoscopic presentation (Table 1).

The number of letters processed in the control condition agrees with the results presented by Estes (1964) and Sperling (1960), but not the results obtained in the experimental group with novel stimulation.

There is a difference between the number of novel stimuli processed and the duration of the tachistoscopic presentation. Table 1 gives the mean values and the standard deviations obtained by the subjects on both conditions at the two times of tachistoscopic presentation. No difference was observed between the amount of processed stimuli and the duration of the presentation.

Discussion

The results obtained in this experiment suggest that the number of detected stimuli is significantly affected by the nature of the stimuli presented, (in this case, novel

stimuli versus letters). The number of novel stimuli which are processed is not significantly affected by the duration of tachistoscopic presentation given in this experiment (50, 200 msec). The number of novel stimuli processed does not appear to be influenced by the number of events on the screen, which varies from 3 to 9. However, in the case of letters, the greater number of stimuli in the display, the greater the number of letters processed.

Even though as hypothesised, there is a difference in the results according to the kind of stimuli presented, the results are not as clear as they should be, because it can be argued that this paradigm is not the same as the one used in the original experiments of iconic memory. However, the number of letters processed with the control experiment is the same as in the experiments reported by Sperling (1960), Rumelhart (1970) and Estes, (1964). Given the conditions of this experiment, it is possible to suggest that this was more a task of target stimuli recognition, than of extraction of information by iconic memory. These considerations led to the second experiment in which the original paradigm of iconic memory is replicated with a modification (in order to avoid the problem that the novel stimuli could not be reported). The modification consists of changing the subjects' responses by asking them to simply say whether the stimulus on the third presentation was the same or different as the one displayed in the same place in the first presentation. The aim of this experiment was to examine the effects of new information

on iconic memory as before, but this time following the original experimental paradigm used by Sperling.

The reason to do experiment II is found in the meaning of the results obtained, since although it is true that the difference in performance is found between novel and old information in the experiments of iconic memory, the implications are going to include a great deal of situations and phenomena, as all those situations using letters in the experiments which do not compare the results of using novel stimuli. Therefore it is important to do experiments using the same original technique.

EXPERIMENT II

Method

Subjects:

Ten volunteer students of the University, with the same characteristics as the subjects in experiment I. These subjects did not participate in any other experiment in this series.

Procedure:

The stimuli were presented on a three channel tachistoscope (Ralph-Gerhands Co. T3-B1). The brightness of the 3 screens was made equal to 9.5 Ft. Lamberts, measured with a Macbeth illuminator. The novel stimulus cards from experiment I were used as stimuli (presentation cards), and another set of new stimuli was introduced (test cards). Fifty per cent of these test cards had the same stimulus in the same place as the preceding presentation card, and

50% had a stimulus not present in any of the presentation cards. The probability of any stimulus appearing on any of the nine different positions in the matrix on the tachistoscope's card was the same and the order of presentation was random. Each trial began with a "ready" signal given by the experimenter. One second later the screen number 1 was illuminated for 50 msec, displaying the presentation stimulus. Subsequently the second screen was illuminated for an inter stimuli interval (ISI) of 50, 200 or 500 msec. Finally, the third screen was illuminated with a test stimulus on the same place as the presentation one, being either the same or a completely different one. The subject, was instructed to report whether the test stimulus was the same or different from the presentation stimulus. Each series was made of 108 trials and three replications were done, each one containing every ISI. During each series the ISI was the same, For half of the subjects it was in increasing order, and for the other half, in a decreasing order of magnitude.

Results

The analysis of the results was done as in the first experiment, correcting for the subjects' guessing factor using the formula of Estes (1964). Figures 7 and 8 and Table II show that the number of stimuli processed decreased as the ISI is increased. This could be interpreted as a phenomenon of iconic memory in agreement with data presented by Sperling (1960).

The number of processed stimuli is different and independent of both the ISI and the number of stimuli present on the screen (D). There is a significant difference statistically between the control and the experimental groups in the number of correct responses as the number of stimuli on the screen is decreased (D=3,6 or 9).
Table II.

TABLE II

I.S.I. (msec)	D	Experimental Group (Novel Stimuli)	Control Group (Letters)
50	3	1.50 \pm 0.85	3.00 \pm 0.00*
	6	1.28 \pm 0.93	5.27 \pm 0.28*
	9	1.46 \pm 0.76	5.30 \pm 0.39*
200	3	0.97 \pm 0.85	3.00 \pm 0.00*
	6	1.19 \pm 0.91	5.00 \pm 0.41*
	9	1.40 \pm 0.87	7.61 \pm 0.38*
500	3	1.65 \pm 0.76	3.00 \pm 0.00*
	6	1.40 \pm 0.90	4.70 \pm 0.37*
	9	1.15 \pm 0.82	4.65 \pm 0.35*

*P < 0.05 (T Test)

Discussion

The results obtained in this experiment suggest that processing novel stimuli is different from processing familiar stimuli, such as letters.

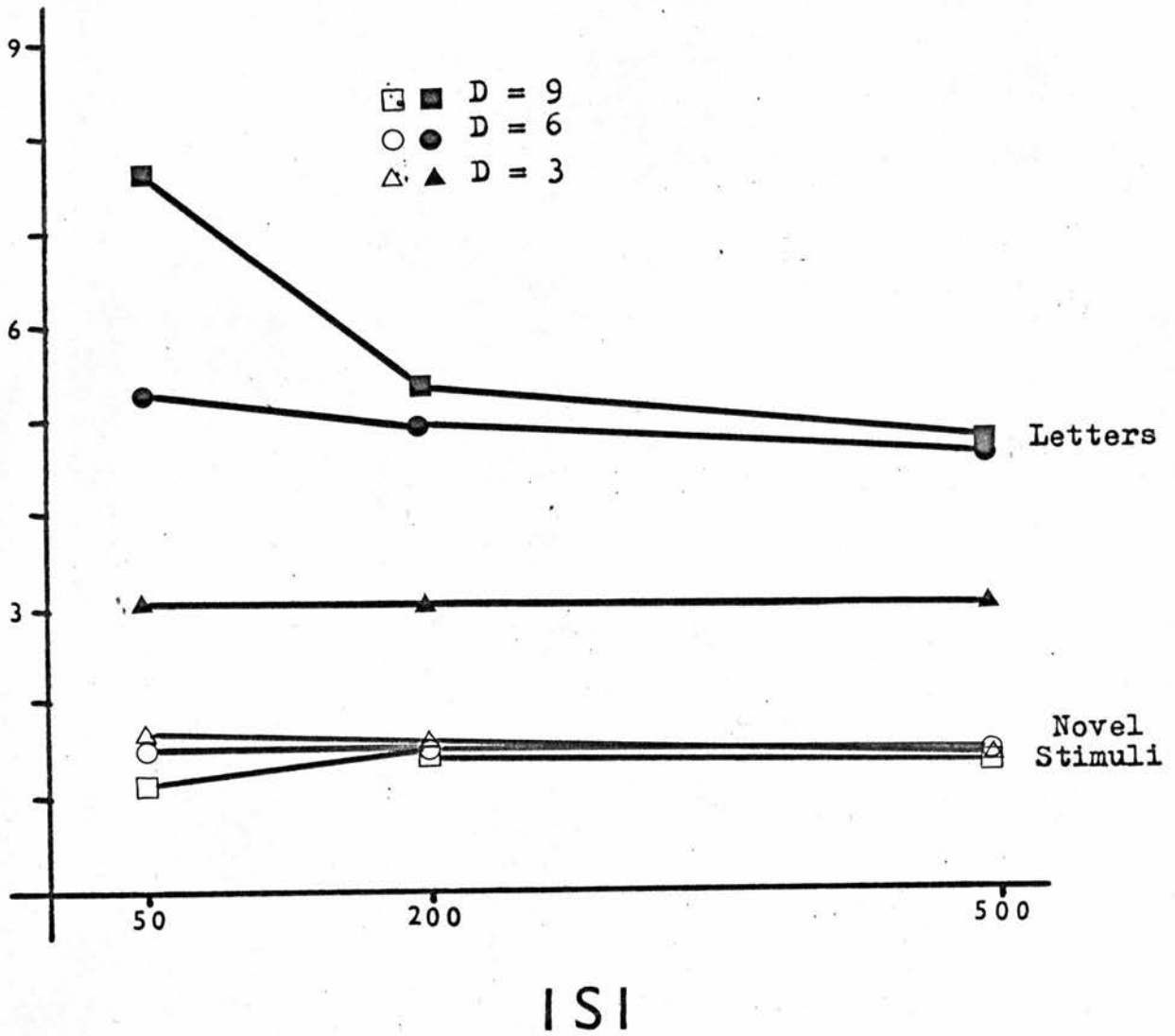


Fig. 7: Number of stimuli processed (P). Letters versus novel stimuli with 3 different inter-stimulus-interval (I.S.I.), and the amount of stimuli in the screen (D) using Sperling's Technique.

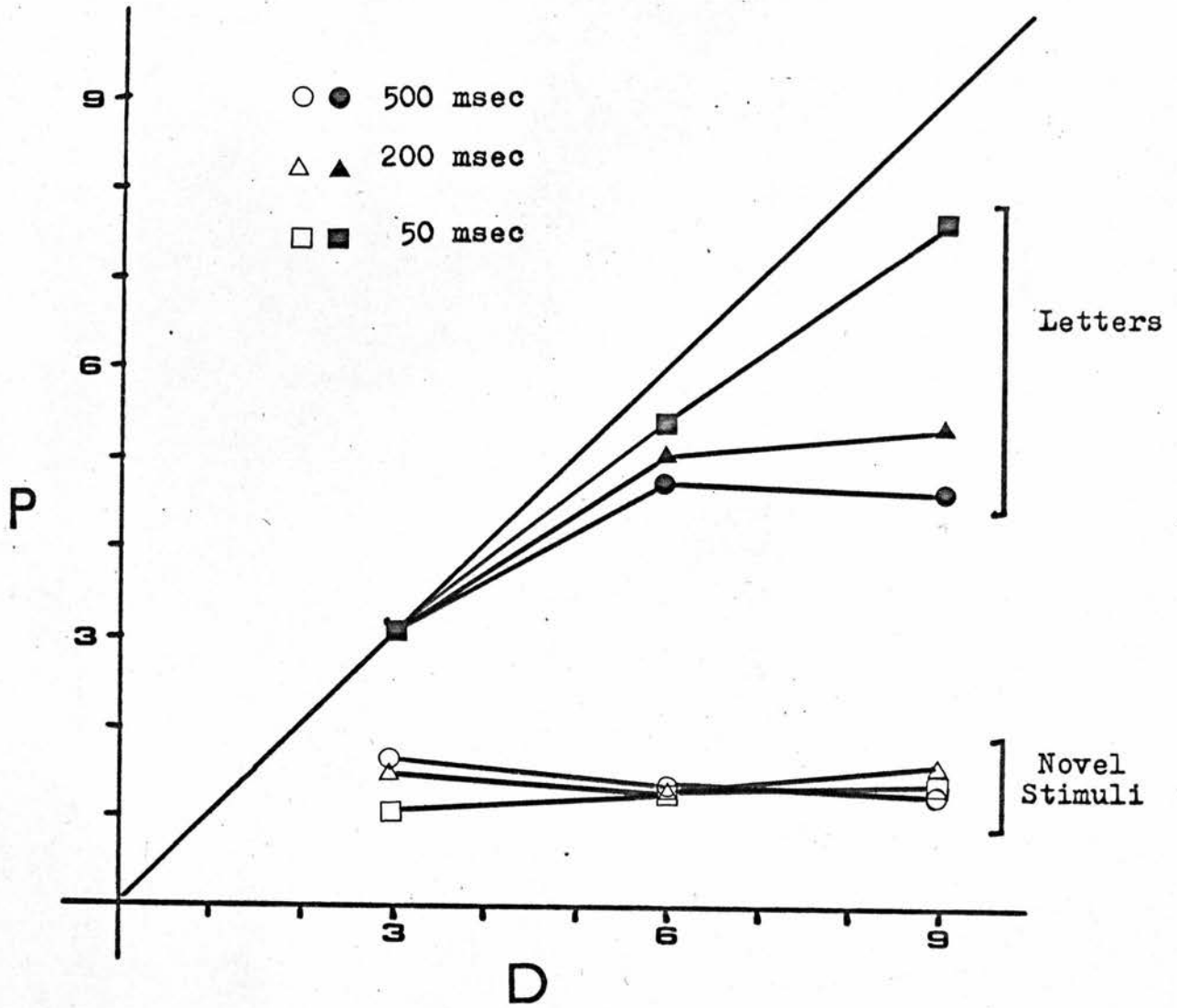


Fig. 8. Number of stimuli processed (P). Letters versus novel stimuli with 3 different inter-stimulus-interval (I.S.I.) in msec and the amount of stimuli in the screen (D) using Sperling's Technique.

CONTROL EXPERIMENT

This control experiment was done with the purpose of obtaining the span of apprehension of the subjects; these data are important since they allow us to compare the results of the experiments of iconic memory with the experiments of apprehension as an additional control.

Method

Subjects:

Six volunteer students from the University with the same characteristics as in previous experiments. Two subjects participated in the previous experiment, but more than two months had elapsed between tests.

Procedure:

The stimuli were displayed on a Cambridge two channel tachistoscope (Colne Instruments Co. Ltd.). The first channel, which was kept on continuously, contained a card with a black dot in the centre. In channel 2, the stimuli were presented for either 50 or 200 msec. The stimuli used were exactly the same as the ones used in experiments I and II. The subjects were instructed to write on paper all the stimuli they could remember. The rest of the procedure and the settings of the tachistoscope (e.g. brightness) were the same as previously.

Results

Table III present the results of this experiment.

TABLE III: Span of Apprehension

Time of Presentation (msec)	Number of Stimuli on the Screen (D)	Novel Stimuli(X)	Letters(X)
50	3	1.12 \pm 0.86	3.00 \pm 0.00 *
	6	1.57 \pm 0.71	4.40 \pm 0.21 *
	9	1.20 \pm 0.64	4.61 \pm 0.24 *
200	3	1.50 \pm 0.90	3.00 \pm 0.00 *
	6	1.36 \pm 0.83	4.52 \pm 0.10 *
	9	1.29 \pm 0.75	4.64 \pm 0.20 *

*P < 0.05 (T Test)

Discussion

The results of this experiment agree with the experiments reported by Sperling (1960) and Estes (1964), the span of apprehension with novel stimuli is very poor. This result allows a better comparison with the results obtained in the previous experiment (with letters), and allows us to make sure that the instruments do not change significantly from the ones used in other studies.

GENERAL DISCUSSION

The results of these experiments do not argue against the existence of iconic memory for letters or any other kind of postcategorical stimuli, but do indicate that if unfamiliar novel stimulation is presented, the type of processing is different. If iconic memory is found only for familiar stimuli, it is difficult to maintain that it is a store of information, that is a processing structure independent of what is stored on it.

The fact that the difference in the number of stimuli processed is found between familiar and novel stimuli, suggests the need for new interpretation of iconic memory as one which is not solely in terms of structure. Coltheart (1976) and Allport (1975) have suggested that it is necessary for all the stimuli entering the system to contact the information previously stored (possibly long term memory), in order to be processed.

In studies of visual persistence (Efron, 1970; Allport, 1970), it has been observed that the results are different if lights are used instead of letters. This is in agreement with the results obtained in the experiments reported here. It indicates that familiarity of the information somehow affects the processing of information entering the system.

Age seems to be important in visual persistence, 10 year old children, tend to have shorter visual persistence than adults, (Stanley and Molley, 1970). This could suggest that this phenomenon and iconic memory, although usually considered to be the same thing, are in fact different. If the iconic memory trace is considered only as a function of the input, there should be no difference according to age.

A problem in the interpretation of iconic memory has been to explain what happens with the information once it is in the form of a trace. Is all the information transferred to a more permanent store or only part of it? How does this process take place? Since early studies it has

been the necessity of explaining these points. Sperling (1967) interpreted this process of transference of information, postulating several steps between the trace or icon and the more permanent store. These steps include a process of scan, a buffer and a process of rehearsal as well as the participation of other processes like an auditory store. Even though it is important and necessary to interpret this problem, data has not helped on its solution (see Coltheart, 1972). Perhaps a dynamic relation should be proposed between iconic memory and the later stages of information processing, in order to integrate all the information available.

Phillips (1971) has given additional evidence for the participation of learned information in iconic memory. In his experiment, subjects had to compare nonsense words, each one made up of 7 letters. In the second word one letter was different from the first word and the subject had to indicate which one. It was found that the subjects performed differently if they were familiar with the words. Subjects with no previous experience performed less well.

In other experiments, Lefton (1973) and Merikle et al (1971), found a small difference in performance according to the order of approximation of the words to English. Scheerer (1974) analysed the position of the stimuli in the screen, and found that the amount of correct responses was related to the position of the stimuli. He related his results to the reading habits of the subjects, that is from left to right, even though the rapid presentation of the stimuli should not allow for scanning of the visual field.

There are other results pointing out that iconic memory is not only dependent on the input or stimulation that the subject receives but also related to other phenomena, such as learned information. Holding (1972) has already proposed a more complex process for iconic memory as has already been mentioned. If English speaking subjects have to report Arabic characters, their performance is poor compared to the situation where they have to report the letters of the English alphabet. These experiments have been criticised for the way that subjects were asked to give their answers. However, the results presented in this chapter agree with the hypothesis, although in this case the subjects gave their answers in a different way.

Dick and Loader (1974) found a strong effect on iconic memory according to the degree of education of the subjects. They tested adult students of the University and students in the 4th or 6th grade (primary school). They also studied other subjects; for instance, Hebrew subjects who learned the language when they were children, and subjects who learned it as adults. The authors observed that the subjects who learned the language during childhood performed better.

In all experiments where learned factors and experience were manipulated, there was always an effect on the performance of the subjects. This evidence indicates once more that there is a relation between iconic memory and learning, experience or long term memory. These reports

agree with results reported here, novel stimulation impairs iconic memory.

The basic problem in interpreting the results of iconic memory experiments lies in the idea of iconic memory itself, mainly as a static trace and in general as flow of information, where memory is regarded as only passively storing information. It could even be proposed that the experiments on iconic memory are not really studying the trace left by a stimulus, since no such trace is found with novel stimuli. In the same way it is not possible to say that iconic memory is one of the first stages in the processing of information, since it is possible to suggest that other processes are involved simultaneously, such as processes of scanning and matching between the input and what is already stored (e.g. letters). Also it is possible to suggest that the limit in the buffer which generates the response is itself involved in iconic memory. In other words, the processes studied in iconic memory could be considered as belonging to the final stages and not to the first stages in information processing. This does not suggest that iconic memory does not exist as a phenomenon, but that the level at which it is working and the processes involved are other than those previously assumed. It could be said that far from being a relatively peripheral process, iconic memory should be considered part of the more complicated central systems of information processing. These require for their explanation other processes, such as meaning, comparison, buffering and response generation, involving learned information.

II - ON RECONSTRUCTIVE MEMORY

Abstract

Experiment III

Introduction

Method

Results

Discussion

ABSTRACT

Subjects made times estimates of the number of elements in a specified set. In two of four experimental conditions the stimuli enumerated were physically available to the subjects for inspection, or open counting. In two other conditions the stimuli were not so available, and this was termed closed counting. Subjects counted objects, letters in words, or angles in letters. Mean response latencies were found in all instances to correlate positively with the number of elements correctly reported. This effect was present in both open and closed counting tasks. Mean RT's in open counting tasks were nevertheless the more rapid. Within closed counting conditions, response latencies were also found to vary with the nature of the items enumerated. The results indicate that the processes underlying both open and closed counting are fundamentally alike. In closed counting, however, prior reconstruction of an appropriate internal representation of the set seems to be a prerequisite. The major implications of these results are discussed in relation to Bartlett's (1932) theory of memory.

EXPERIMENT III

Introduction

Bartlett's studies have been made innocuous by considering them as classical (Kvale, 1975).

"... In spite of its theoretical shortcomings and the doubts that have been cast on the general validity of some of the experimental findings, Bartlett's book has remained something of a classic in modern psychology.." (Zangwill, 1972).
 "... In some ways a measure of Bartlett's stature .. nobody seriously questions the factual results of his experiments." (Broadbent, 1970).

Bartlett's influential theory of memory has given rise in the literature to a curious paradox. On one side it is widely considered one of the most significant ideas in modern psychology, as can be seen in the influence that it has had on the contemporary literature. Neisser (1967) considers that one of the most important aspects in a theory of memory (from the point of view of cognitive psychology), is what Bartlett called the reconstructive aspect. Piaget and Inhelder (1973) recognise the influence and relation that Bartlett has had in their work on memory and intelligence in children. Minsky (1974), from the point of view of artificial intelligence, has developed a specific theory about perception and visual information storage, based on Bartlett's concept of schemata. On the other hand, it is difficult to find in the literature, mainly about memory, experimental support for Bartlett's ideas. There are very few studies that have

tried to repeat his original experiments. Gauld and Stephenson (1967); Kay, (1955) and Gomulicki, (1956) have studied the same problem and their results indicate that memory is more a process of abstraction than reconstruction, and this has made it even more difficult to find work relating to Bartlett's experiments.

This situation presents a paradox since a great deal of workers refer to Bartlett as being the main influence on them, or as providing one of the major alternative approaches to the study of memory. This situation could be interpreted by supposing that Bartlett's book (1932) provides experimental evidence for a theory. However, his theory is difficult to extract or describe. For instance, Coffey (1973) comments that Bartlett "did not have a detailed or highly scientific theory, that his views were essentially an emphasis or orientation". Another way of reconciling this lack of theoretical explicitness in Bartlett's work with the extent to which it is quoted is to say that psychologists are still using a positivist point of view regarding memory phenomena. A way to illustrate this point of view, mainly the kind of material used is found in Kvale (1975) comments that "a series of isolated elements without meaning were employed in almost 90% of the experiments and thus, the material was already tailored to fit the metaphysical conception of a world constituted of unequivocal and isolated elements even before the experiments began." A positivist position together with a rigid methodology could be the reason for

the lack of development of theories and experiments following Bartlett's points of view. Inertia in research can be observed, for instance, even in such attempts Gauld and Stephenson (1967) who used the same type of stimuli as Bartlett: short stories read to the subjects like "The War of the Ghosts".

Bartlett (1932) says about memory that "... remembering is not the re-excitation of innumerable fixed lifeless and fragmentary traces, it is an imaginative reconstruction or construction built out of the relations of our attitude towards a whole active mass of organized past reactions or experience... an image is a device for picking bits out of schemes for increasing the chance of variability in the reconstruction of past stimuli and situations for surmounting the chronology of presentations.. none can set a ring around memory and explain it from within itself.." This quotation gives a taste of Bartlett's ideas. His studies took place approximately between 1914-1916 and were very simple. The most important work was done using the method of repeated reproduction. This method consists of reading twice to subjects a story of 200 to 500 words, and having them reproduce the story in writing. Time between the presentation of the story and its report was variable between 15 minutes to several months. The results of these experiments were described in a qualitative form and discussed in great detail. The author reported that there was a reduction in the number of words reported compared to the original story, that the subjects abstracted

the most important points, retaining the meaning in a condensed form eliminating and changing the words. He suggested that the subjects altered and confabulated the contents of the stories. In some cases the alterations were related to the social and cultural background of the subjects. These points suggested to Bartlett his idea that memory is an active process, rather than a fixed lifeless trace.

The explanations given by Bartlett were in turn derived from Head's (1926) concept of 'shemata'.

One of the best ways of understanding Bartlett is to contrast his ideas with those of others such as Ebbinghaus (1885) the latter's followers, like Muler and Pilzeker (1901) and Newman (1913). This task is easy since Ebbinghaus' ideas are described in a number of places. It is an important task since this school still dominates modern psychology in one way or another, and still has had an important influence on recent work in memory. The main ideas in Ebbinghaus' work are based on the notion of a trace which stores information. This trace can be erased by a new trace (interference) or can be obliterated by lack of use. It is suggested that the traces are organized by mechanisms of association and that a trace which has not disappeared completely can be strengthened by practice (rehearsal). This point of view about memory can be considered to be opposed to that of Bartlett who does not accept the idea of a static trace, having stated that memory is an active process of change and constant use,

where images are tools available to alter and modify memory contents. Bartlett proposed that information is organized in schemata. Norhtway (1940) found the following four different uses of this concept by Bartlett:

- "1) The schemata are considered to be forces within the individual which determine what the subject's reconstruction will be:

"Determination by schemata is the most fundamental of all ways by which we can be influenced by reactions and experiences which occurred sometime in the past" (p.201).

"What, precisely does the 'schema' do? Together with the preceding incoming impulse it renders a specific reaction possible. It is, therefore, producing an orientation of the organism towards whatever it is directed to at the moment. But that orientation must be dominated by the immediately preceding reaction or experience. To break away from that the 'schema' must become not merely something that works the organism, but something with which the organism can work. The organism discovers how to turn around on its own 'schemata'. In other words, it becomes conscious". (p.207).

- 2) The schemata are the forms in which the individual preserves material.

"It looks as if that presentation of material which is required in recognizing is normally a preservation of schemes, of general settings, of order or form of arrangement" (p.195).

- 3) The schemata are 'storehouses' in which content is retained while it is being reorganized.

"In fact this is one of the great functions of images in mental life: to pick items out of the 'schemata', and rid the organism of over-determination by the last preceding member of a given series" (p.209).

"All of us in reference to some of our 'schemata' have probably completed the model and now merely maintain it by repetition" (p.203).

- 4) 'Schema' is used in a way approximating the notion of the apperceptive mass.

"I think probably the term 'organized setting' approximates most closely to the notion required" (p.201). The influence of the 'schemata' is influenced by the past. In its schematic form the past operates en masse, or not strictly en masse because the latest incoming constituents which go to build up a 'scheme' have a predominant influence" (p.202).

As can be appreciated, this concept and the use given by its author, is complex. It is therefore misleading since it can receive multiple interpretations. The concept is similar to that of 'paradigm' proposed by Kuhn (1970) in the sense that it has been considered a powerful tool in research, providing it does not fall into the hands of the positivist-operationalist philosophers (or psychologists in this case).

A fundamental aspect of Bartlett's theory is its reconstructive character, that is, to consider that information can be used to generate something "new". This is the most elaborated idea of abstraction, involving reduction and store of the constant aspects of information. In the reconstruction, these constant aspects are reduced and stored, but also it is possible to change or modify the information.

Gomulicki (1956) challenged both Bartlett's theory and the data and provided support for an alternative notion of memory as abstractive rather than reconstructive. Zangwill (1972) later endorsed this view and pointed out that Bartlett's evidence of reconstructive memory was more likely a consequence of its methodology and the material used in the experiments. Other studies supporting abstractive memory have been reported, (e.g. Gauld, 1967; Kay, 1955; and Northway, 1940). One of the most interesting developments in this line of research, in favour of abstractive memory, is the one presented by Bransford and Franks (1971); in their experiments the subjects

received complex sentences which were made up of four simple ideas. A complex sentence was for instance, "The rock which rolled down the mountain crushed the tiny hut at the edge of the woods". This complex sentence can be decomposed into four simple ideas as follows: 1 - The rock rolled down the mountain. 2 - The rock crushed the hut. 3 - The hut was tiny and 4 - the hut was at the edge of the woods. One of the tasks of the subjects was to give his rating of confidence that the sentence read in the second part of the experiment has been read in the first part. The results showed that the subjects integrated the simple ideas and reported that the complex sentence had been read to them before.

Analysing these experiments and others of the same kind, Coffey concluded (1973) that he agreed with Bartlett and that "memory can be shown to be reconstructive, generative and productive". These results in support of Bartlett can be considered as the product of the improvement in methodology, since with the original method (complete stories) it was very difficult to obtain the abstractive characteristics of memory, as well as the effects of the so called confabulation.

Where such ambiguity exists concerning the general applicability of the theory, it is essential to examine its postulates in greater detail. Murdock (1974) has already pointed out that there is a pressing need to clarify the basic elements of the theory since these are difficult to tease out from Bartlett's original work.

Moves in this direction, have already been made by Meudell (1971) and Smith (1973).

Summarizing, some of the most important aspects of Bartlett's theory of memory are as follows: (A) An active process is invoked whereby information about an object, or event, stored in memory is brought to consciousness. (B) There is an active reconstruction of an internal representation or image, in consciousness of the specific object or event recalled. This process of reconstruction involves general as well as specific information previously obtained. (C) There is an active manipulation of such representation(s) or image(s), by the subjects. (D) The generation and elaboration of novel information or response, is not directly learned in advance.

In order to investigate this aspect of Bartlett's theory more precisely, it is necessary to construct tasks that meet the following criteria:

1. The presentation of each stimulus must act as a cue for the use of old material;
2. It should be considered that the only way of arriving at an appropriate decision concerning the stimulus involves the generation and active manipulation of an image of the object or event in question.
3. That the information about the object must be novel to the subject, so that it leads to a decision not previously reached by him/her.

Meudell (1971) used a paradigm meeting some of these criteria and found that an orderly relationship exists between reaction-time and the number of elements a subject

had to recall from memory. One of the major implications of this finding, which relates directly to Bartlett's theory, is that the retrieval of information, the reconstruction of an appropriate representation of the object, and the manipulation of such information, are all activities that require time for their appropriate execution. A prediction that can be derived from this is that the time taken by the subjects to decide, and respond accordingly, will vary in monotonic increasing fashion as a function of the number of items recalled. Moreover, and this is quite important, the latency of response should also reflect qualitative differences between the items recalled. More specifically, the obvious fact that some items are more difficult to remember than others could be due to their familiarity or that they are easy to relate with other familiar items in memory.

In order to test some of these implications, two different tasks involving the counting of objects, were constructed for use in the following experiment. There were two kinds of counting, 'open' and 'closed'. In open counting the elements in a figure were available to the subject for inspection. Closed counting entailed the enumeration of elements in a set not physically available for inspection.

Method

Subjects:

One hundred and twenty male and female students of the Department of Psychology of the University.

Procedure:

The subjects were told that this was an experiment in memory and that they would have to answer simple questions. They were told that a click sound would indicate the end of each spoken question. They were instructed to answer correctly and as quickly as possible without using their fingers or any other external means of counting. The experimenter recorded the latency of response as well as the answer, which in every case was a number. At the end of the experiment the subjects were encouraged to introspect freely on how they arrived at the correct answers.

The subjects were randomly assigned to four different experimental conditions: A - Closed counting of objects, B - Closed counting of angles in letters and words, C - Open counting of angles in letters and words, D - Open counting of angles in figures, thirty subjects in each condition.

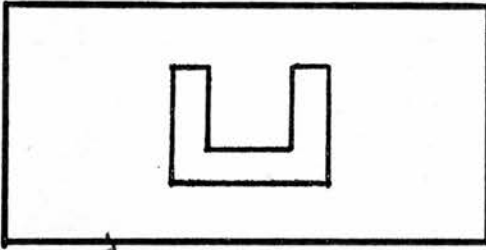
The subjects were required to answer the following questions: In condition A: 1) How many wooden objects are in your living room? 2) How many pairs of shoes do you own? 3) How many doors are in your house? 4) How many letters are there in your father's surname. 5) How many light bulbs are in your house? Condition B: The subjects were read twenty letters from the alphabet and thirteen words having between five and ten letters each. After each letter, or word, the subjects were asked to report how many angles it had.

In condition C: The same letters or words as in condition B were used, but in this case, they were printed on white cards, (10 x 15 cm). Each card contained one stimulus. The subjects were asked to count the total number of angles. In condition D twenty irregular figures were presented, one by one to the subjects. The figures were presented, one by one to the subjects. The figures were similar to those used by Vanderplas and Garvin (1959), (Fig. 9). Each figure contained a different number of angles from the others. The subjects were asked to report the number of angles in each figure.

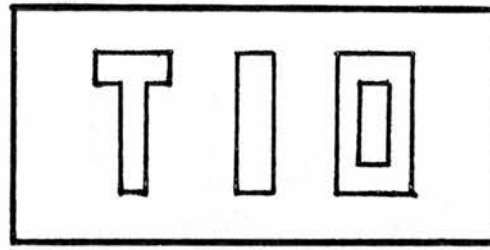
Results

The mean reaction times were tabulated for each question. Using regression analysis, the slope of the function relating the reaction-time and the number of elements recalled was obtained together with the intercept on the ordinate. The intercept values represent the average minimum reaction time to respond correctly to each of the questions in the various conditions. These values are reported in Table IV together with the slope of the function which represent the rate of counting. The Pearson product-moment correlation coefficient was calculated for the mean latency of response and the number of elements reported (Table IV). In all cases, these correlations were statistically significant.

CONDITION B



CONDITION C



CONDITION D

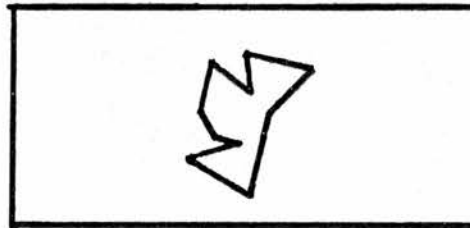


Fig. 9: The structures presented in the second condition (B) were used to show the Ss the kind of letter representations wanted from them. Under (B) and (C) are examples of the cards presented to the Ss in condition (B) and (C). Finally, under (D) is an example of the kind of figures presented to the Ss in condition (D).

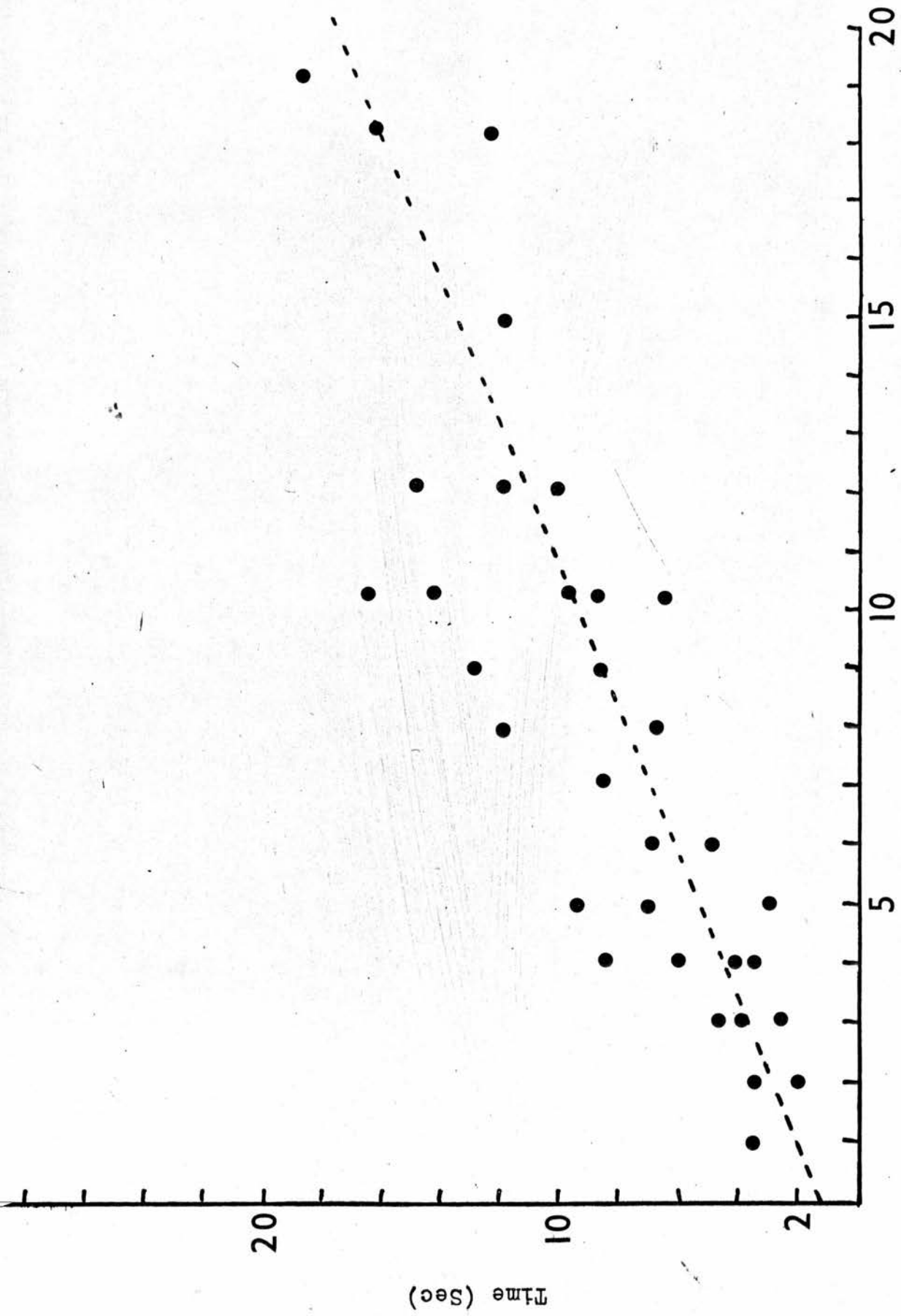


Fig. 10: Wood Objects Reported

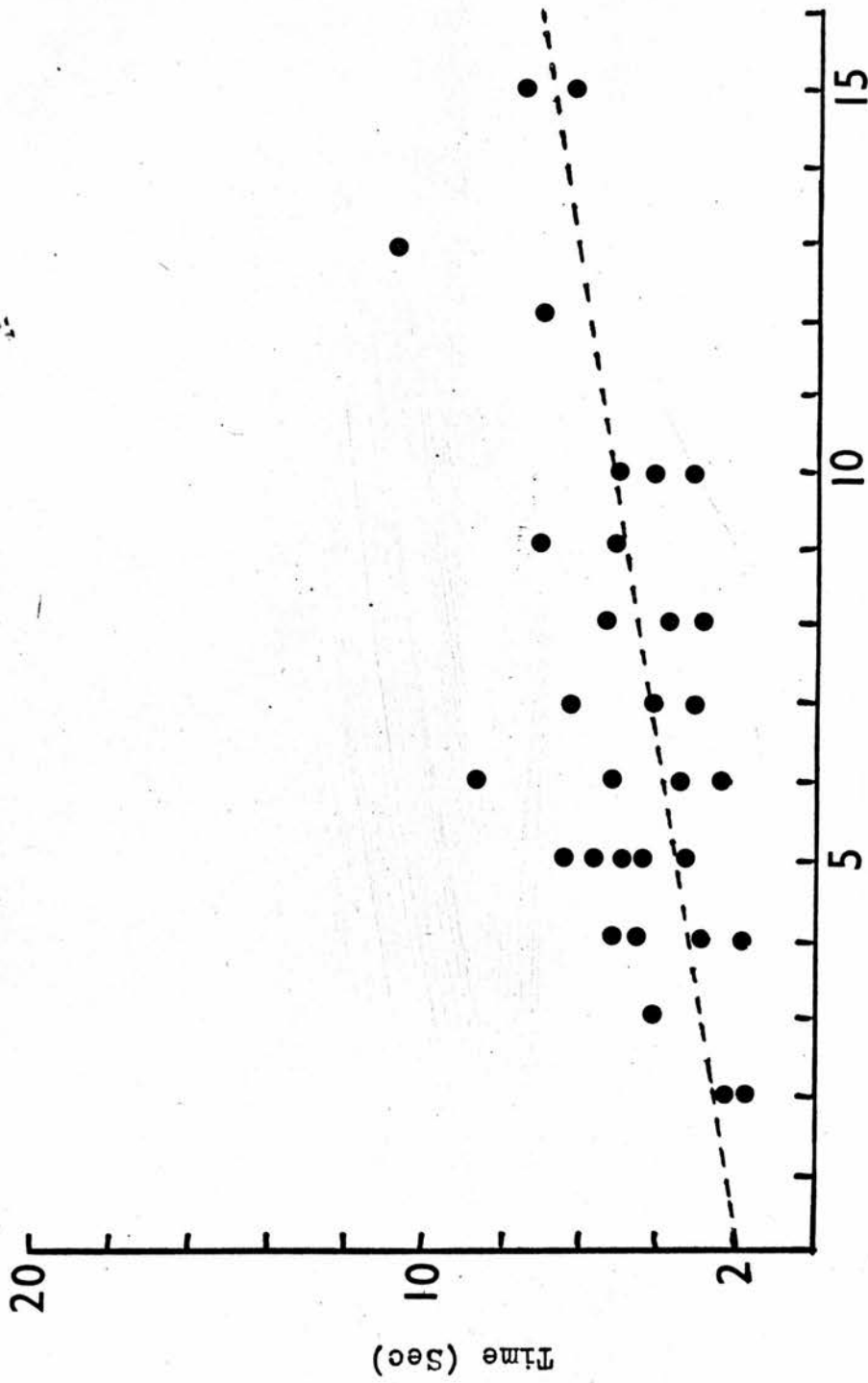


Fig. 11: Pairs of Shoes Reported

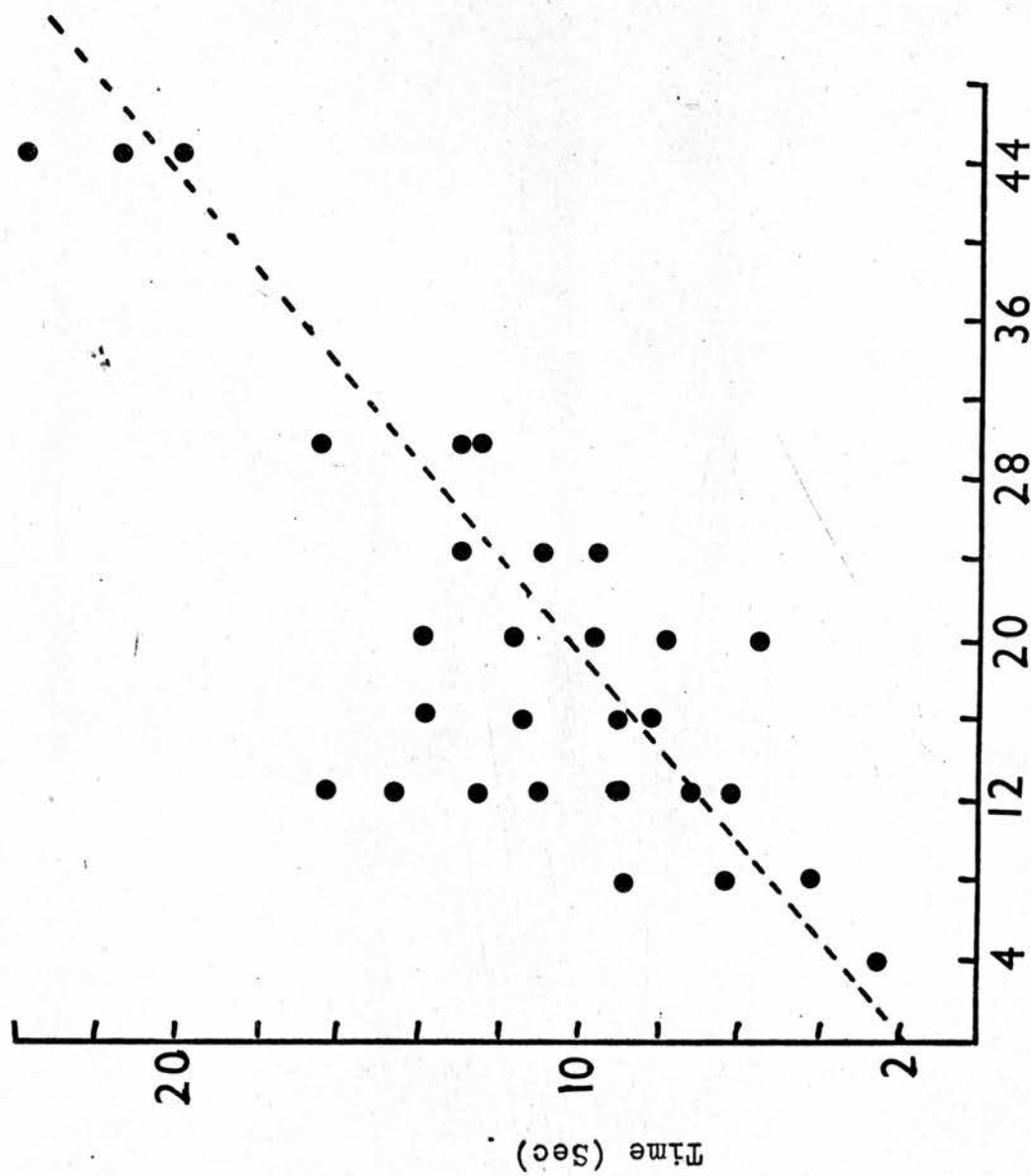


Fig. 12: Light Bulbs Reported

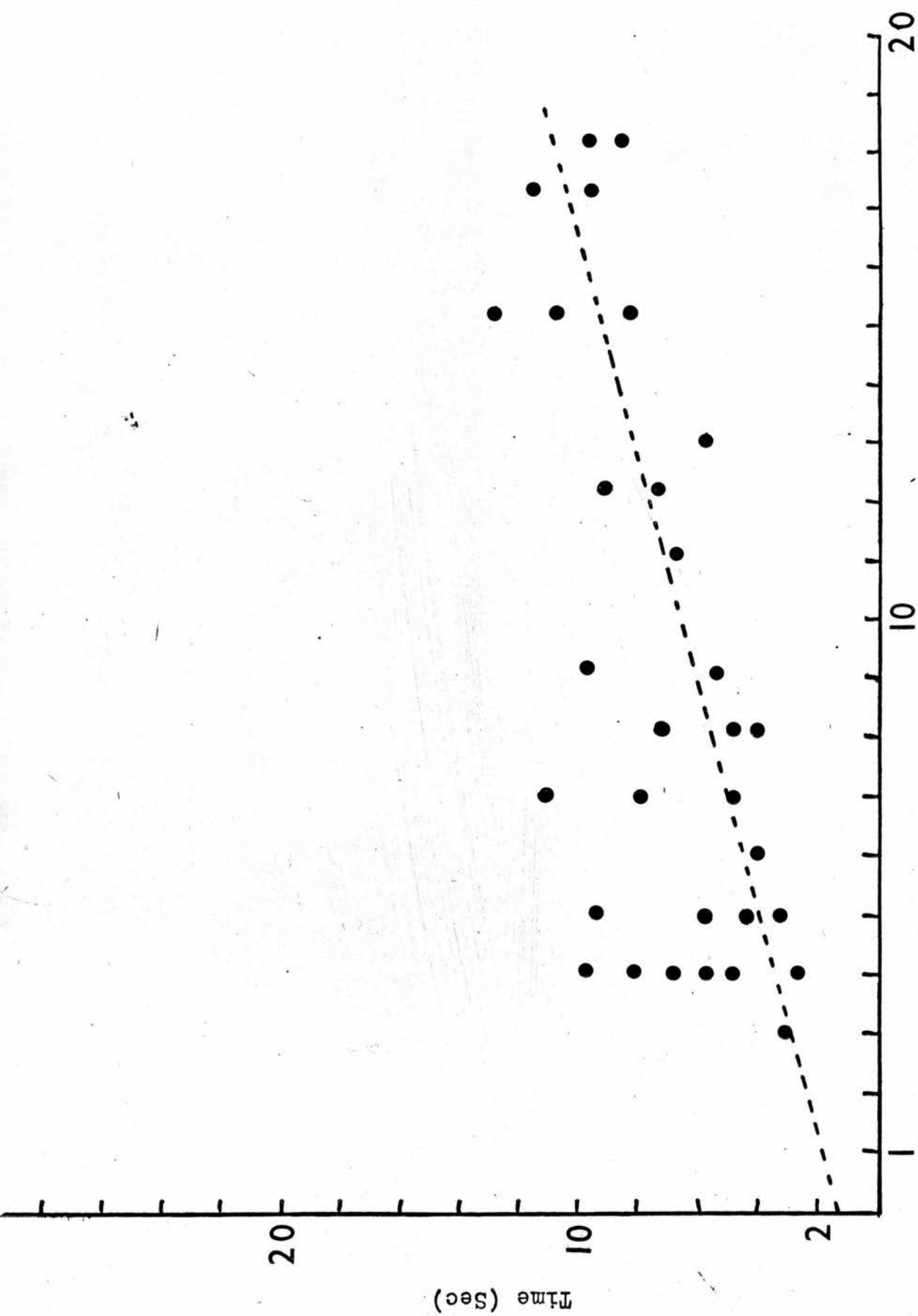


Fig. 13: Letters Reported

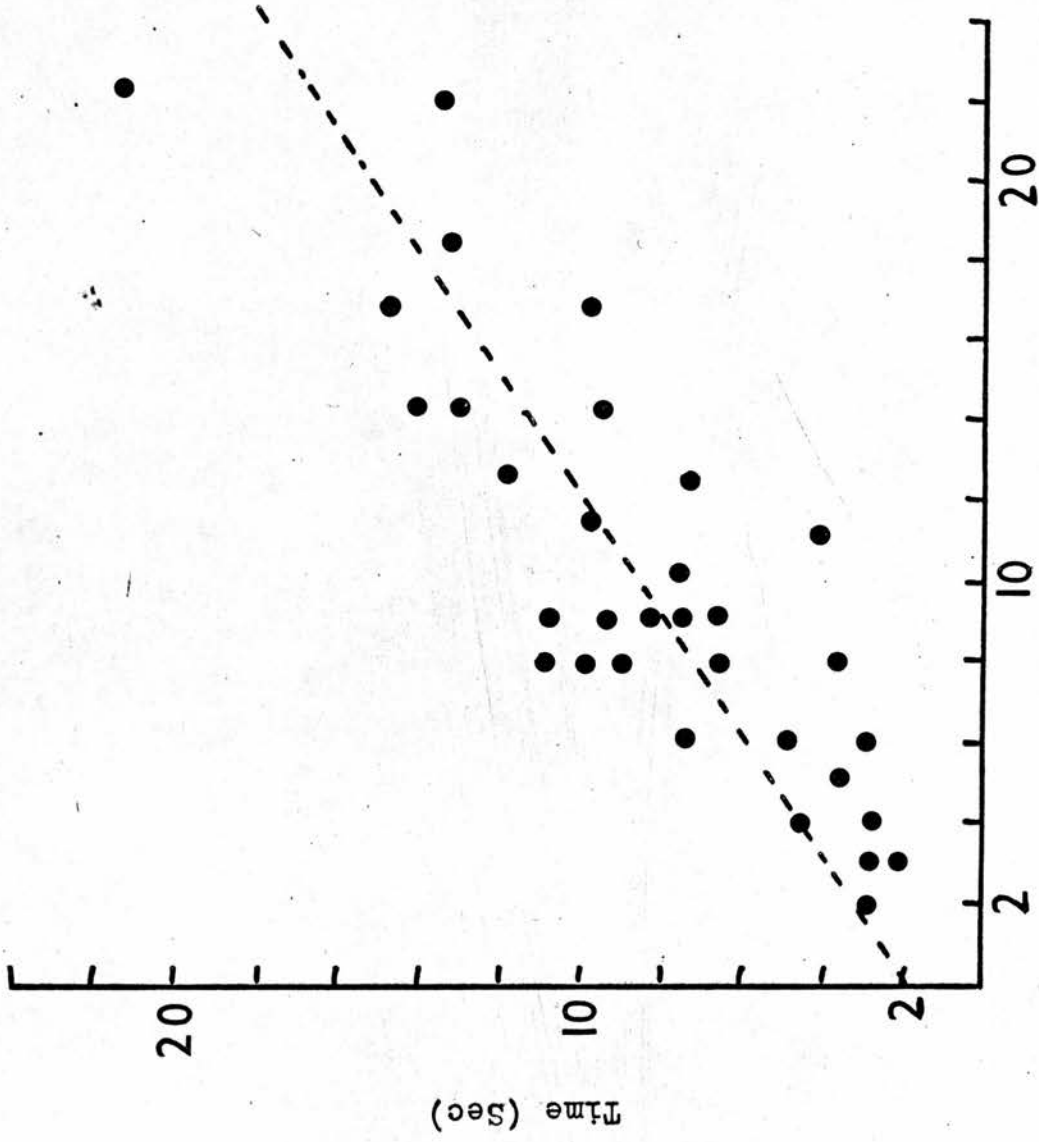


Fig. 14: Doors Reported

TABLE IV

	Correlation Coefficient between latency and counted units	Intercept (minimum reaction time in sec)	Slope (rate of counting in sec)	% of errors
CONDITION A				
Wooden Objects	0.614***	1.26	0.867	-
Shoes	0.281**	1.81	0.347	-
Doors	0.496***	1.99	0.413	-
Surname	0.369***	1.14	0.509	-
Light bulbs	0.650***	1.94	0.412	-
CONDITION B				
Closed counting (letters and words)	0.857***	3.17	0.607	0.08
CONDITION C				
Open Counting (letters and words)	0.896***	0.24	0.442	0.05
CONDITION D				
Open Counting (Figures)	0.737***	2.89	0.402	0.04
* P < 0.01				
** P < 0.005				
*** P < 0.001				

Discussion

Condition A: It is difficult to interpret the results obtained in this condition since there is no way of checking if the answer is correct. However, the results show a linear monotonic increase in the reaction time as a function of the number of elements reported. This

result could be taken as support for the suggestion that subjects constructed a representation of the corresponding set of objects prior to giving their answer. Perhaps, the subjects deal with the items individually, counting one by one as if the elements were actually externally available for inspection.

The mean latency of the reaction time for each question taken individually, indicates that the time taken to answer correctly depends largely on the nature of the items considered. For instance, the estimated rate of counting for question 1 was slower than for the other questions (Table IV). It is reasonable to suppose that perhaps the subjects had to judge whether or not the objects were made of wood, taking therefore more time to give the answer. In contrast deciding the number of shoes they own yields the quickest response, with the fastest estimated rate of counting. The time taken to report the number of letters in the father's surname was very similar to that reported by Weber and Buck (1969).

Condition B: The results in this condition which is better controlled, are more precise. Unlike condition A, in this case the answers could be checked by the experimenter. Once more the correlations between the mean reaction time and the number of items reported was very high, (Table IV).

Conditions C and D: Highly significant correlations between the mean reaction times and the number of items reported were also found. Once more the mean reaction

times were also found to vary in relation to the nature of the items to be counted. The major point of interest arises from the comparison of the results for 'open' and 'closed' counting; the remarkable similarity of salient features of the data strongly indicates that the processes underlying both tasks are fundamentally alike. In closed counting conditions where the stimuli were not physically present it is reasonable to suppose that the subjects were using stored information about the particular items in question in order to generate an image of them; then proceeding to count the items in the image as if they were actually available for direct inspection. Efforts were made to choose questions which were essentially novel to the subjects, so that they did not know the correct answers in advance; but of course the unlikely event that a subject, on some past occasion enumerated to himself the number of wooden objects in his room, can not be ruled out.

In general the results give support to the suggestion that the reaction time increases linearly as a function of the number of correct responses increase. This linear increase in reaction time occurs in both open and closed counting and the estimated rate of counting varies as a function of the number of items counted.

The general aim of this study was to examine and extend by means of a different experimental paradigm one of the most important aspects of Bartlett's theory. The reconstructive part. One of the major implications of the results obtained in this study is that for simple or

highly familiar stimuli, the corresponding internal representations are quite rich in detail. Questions such as how many wooden objects are in your room, involve the retrieval of information about highly familiar objects as well as the specific key attributes which define them. In order to answer such questions, not normally posed, it seemed as if the subjects were making strategic use of the stored information in order to arrive at a novel and correct response. The characteristics of this process fit with Bartlett's initial notion of reconstruction in memory.

According to the introspections of the subjects, about how they arrived at their answers, it is reasonable to suppose that a process of reconstruction is involved. In order to be able to count the various elements in a set the subjects claimed to be making use of a sort of "mental picture" which included these items. If this is so, it could be proposed that special features of the various items must have been represented as well, otherwise it is difficult to appreciate how closed counting would have taken place. It appears, therefore, that the subjects were indeed making use of internal representations or images of the items in question.

In a previous reaction time study (Figueroa, 1974), in which essentially the same stimuli and paradigms as in condition A were used, the same positive correlation between the reaction time and imagery resulted. Also, other reaction time studies of internal representation

give evidence suggesting that subjects can generate and manipulate internal representations of external objects in order to make certain decisions about them (Shepard, 1975).

Very little is known about the mechanisms involved in the internal representation. Alternative forms of representation may also be involved such as propositional information (Pylyshin, 1973). Other processes than internal representation can also be involved in these tasks. Some of these could be the control processes postulated by Atkinson and Shiffrin (1968) which enable the access, transfer and selective analysis of salient features of information from memory. It is also possible that other processes such as the "mental eye" proposed by Paivio (1971) play an important role in such tasks. Reconstructive aspects of memory have been observed in linguistic tasks, which may not involve imagery (Smith, 1973). Reconstruction in memory can be proposed in a large variety of tasks involving the active retrieval and manipulation of information from memory. The scope and application of this concept may well include such phenomena as mental transformation of various shapes (Shepard, 1975), internal psychophysics (Moyer, 1973; Paivio, 1971) and abstraction (Bransford and Franks, 1971). In this sense, the notion of reconstruction may prove heuristically more fruitful than alternative systems such as those postulated by Craik and Lockhart (1972). G. Bower (1977) and others, since these theoretical systems cannot fully account for the wide variety of phenomena. Bartlett's notion of reconstruction

has remained a less precise and specified system which, in turn, gives rise to its general and appealing applicability. However, there is need for specification in greater detail of the process and nature of the internal representations which enable and guide the process of reconstruction.

III - ON THE LEVELS AND LIMITS OF REPRESENTATION

Abstract

Experiment IV

Introduction

Method

Subjects

Stimuli

Procedure

Results

Discussion

ABSTRACT

Subjects made timed decisions concerning the size of a visually presented circle relative to another one shown five seconds earlier. The reaction time function for correct LARGER/SMALLER responses was found to decrease rapidly and linearly when the relative difference in size between the circles increased from 17% to 45%. This function then became asymptotic for any greater difference in size between the stimuli. The results are related to an existing theory of visual memory involving the comparison of visual images in memory (Shepard, 1975). It is concluded that the use of imagery in these tasks may be restricted to discrimination involving fine grained analysis of visual features of the stimuli. The implications of this methodology to the study of the representational resolution, or fidelity, of visual images are discussed.

EXPERIMENT IV

Introduction

Possibly one of the most active and representative areas of research in cognitive psychology is the one referring to how information is represented in memory. The implications and results in this area promise to alter radically the way that psychological research is conducted. One of the most wellknown forms of this problem is the discussion about how information is coded. There are two main positions. One is the position involving imagery which argues that visual imagery is the way in which the information is codified and that this codification is special and modality specific. The other position states that codification is an abstract propositional format. Between the two is a series of alternatives (e.g. Pylyshyn, 1973; Paivic, 1971; Reed, 1974; For a review see Anderson, 1978).

It would be interesting to develop more knowledge concerning the difficult problem of how information is coded without having to play the game of taking up one position and treating the other as if it were completely wrong. The History of Psychology is full of such sterile approaches which lend in most cases to the conclusion that both are partially true (e.g. Restle, 1965). This is perhaps the consequence of the rather limited logic employed (Kvale, 1975).

Anderson (1978), has clearly described the limits of such an approach when applied to the problem of the

codification of information. He says that language limitations play a very important part as a source of argument. For instance, the concept of image has been used in one way or another as similar to a picture. This metaphor, however does not say much about the process. Another concept which causes confusion according to Anderson, is the one of propositional format, (which in some cases is equivalent to a verbal format). This concept has not been clearly defined and is different from the concept of proposition used in logic, which implies that it is abstract, has a truth value and rules of formation. Anderson (1978) also suggests that the validity of any of these positions (or one stating that both are true), depends on the postulated processes which are going to take place for manipulating representations. He considers that a representation must be considered to be an operative system, or as he puts it: "... We cannot test representations but representation-process pairs". He suggests that representations are strongly influenced by the task demands and that it is possible to find certain tasks which involve the translation from one code to another (e.g. Paivio, 1975). Anderson states that it is not possible to distinguish imaginal and propositional representations strictly on the basis of behavioural data. The experimental support for imaginal propositions is full of indirect data such as introspective reports and the imagery value of words. These imagery values of words serve to predict performance accurately, (e.g. Paivio, 1971). The scarce

direct evidence in favour of imaginal propositions comes from Shepard et al (1978) who are mentioned later on. An interesting conclusion that Anderson (1978) draws from his study is that "... barring decisive physiological data, it will not be possible to establish whether an internal representation is pictorial or propositional". The reaction to this conclusion, and the data presented by the author is going to be determined by what emphasis we attach to the study of the physiological (biological?) basis of the processes. This should not be confused with reductionism where the explanation given is at a different level.

It is important to examine more closely an important point made in Anderson's paper, viz. that "... There are a number of reactions to the possibility that we may not be able to identify the nature of the information representation. Frequent among my colleagues are disbelief and dismay - this would imply that cognitive psychology is not possible. However, I think the implication of this possibility is not that cognitive psychology should be abandoned; rather it should undergo a slight change. Our goal should be to develop some model capable of accounting for human intelligence, that is, predicting behaviour in a wide variety of situations where human intelligence is manifested. The fact that the model may be indistinguishable scientifically from other quite different models need not be a source of unhappiness. In fact, it is possible to take comfort in such equivalences. If a particular model is equivalent to many other models, we can be more confident in its basic truth". As can be appreciated, Anderson suggests that the problem is not in the discussion "per se" but in the problem of representation. Nowadays, this problem and mainly the possibility of representation, is based on the metaphor of "Images", which is not a very well defined concept.

If somebody really wants to contribute to the solution of the problem of representation, he can follow one of two groups of alternatives. The first consists in extending the problem and including more phenomena and different experiments. The second consists in analysing the limits of the interpretations about codification of information and representation, such as images, or propositional formats, not taking too much into account.

A concrete example of the first option is given by the studies of cross-modal functions, (For a review see Freides 1973 and Marks 1975). In these, evidence is given about the interaction of information coming from different senses for animals as well as for children and adults.

The work presented below emphasises the second approach. We examine the limitations of the image metaphor and study how images interact with other processes.

Let us accept that an objective study of imager is possible. The effects due to imagery may take the form of facilitation, disruption or delay in the execution of a particular behaviour. One, or several, of these effects can be a regular feature of the data and their study can enable useful inferences about internal representation.

Influential studies such as those of Bower (1972) and Paivio (1971) have demonstrated the functional significance of imagery. In a typical experiment of this kind subjects are asked to give their ratings from 1-10 to indicate the extent to which words read to them produced an image. Afterwards their ratings were used to predict

their performance in an experiment on memory. It was found that the higher the ratings of imagery the better the subjects performed on the memory task.

Some evidence concerning the modality of coded form of internal representations in memory is now available. In these experiments the subjects are asked to use in one way or another an image, which they have to compare to a picture presented by the experimenter (Segal and Fusella, 1970; Segal and Gordon, 1969). In some cases the task consists in saying if the image is the same or different (Posner, 1969; Posner et al, 1969), in other cases the subjects have to indicate if the image has certain characteristics (Brooks 1968).

In a recent series of reaction time studies, Shepard and his collaborators have obtained evidence concerning not only the internal structure inherent in visual images of various shapes, but also provided insight into the nature of the mental operations that subjects carry out on these representations in order to reduce uncertainty about them (Cooper, 1975; Cooper, 1973; Cooper and Shepard, 1973; Shepard, 1975 and Shepard and Metzler, 1971). The origin of internal psychophysics, a subject to which Fechner (1860) gave much emphasis. Accordingly the work of Shepard and his colleagues can be regarded as directly related to that of Fechner. Anderson (1978) states that Shepard's works are "... one of the most influential phenomena uncovered in recent research in cognitive psychology". Moyer, (1973) another author who has worked on this problem also uses the concept of internal psychophysics.

One of the most representative studies of this kind of work is that of Shepard and Metzler (1971). Subjects were shown pairs of drawings of perspective three-dimensional shapes and had to decide as quickly as possible whether the shapes were the same or mirror images of each other. The reaction time for correct decisions was found to increase linearly as a function of the angular difference in orientation between the shapes. This linear relationship has been obtained with sequential presentation of normal and backward (mirror image) versions of alphanumeric stimuli (Cooper and Shepard, 1973; Corballis, Zbrodoff and Roldan 1976), and random outline shapes (Cooper 1975; Cooper 1976).

Shepard (1975) and Cooper (Cooper and Shepard, 1973) have carefully examined some theoretical implications of this linear relationship between the reaction time and angular difference in portrayed stimulus orientation. In agreement with their subject's introspective accounts of how they performed the task, they proposed that the visual discrimination of shapes involves the mental comparison of internal representations corresponding to the external stimuli. This process is thought to be a rapid, parallel, point-to-point, template-like comparison. The greater angular difference in relative orientation, the longer it takes the subject to mentally transform (rotate) one of the shapes into congruence with the others. The process of visual discrimination in this kind of experiment is thought

to be due therefore, to an internal analogue of the external process of template-like comparison (Sekuler and Abrams, 1968).

It is possible that the linear relationship between reaction-time and relative stimulus orientation is not tied exclusively to orientation manipulations such as those reported by Shepard and Metzler (1971), and Cooper and Shepard (1973), but may also be found to vary as a function of the relative size between stimuli. Corcoran and Besner (1975), reported that in a letter-matching task, the reaction time to two physically identical letters could be selectively increased by varying the relative difference in size between the letters. Timed decisions concerning the relative size of objects in memory have also been found to vary linearly with size. For example, Moyer (1973) asked subjects to judge as quickly as possible the larger of two named objects and found that the larger the difference in the actual size of the objects the more quickly the judgement was made. Later, Paivio (1975) extended Moyer's finding using visually portrayed representations of the objects. Again, it seemed as if the subjects in these tasks were mentally comparing internal representations of the stimuli and responding on the basis of a match-mismatch between these representations.

One of the major implications of an account of visual discrimination which appeals to the mental comparison of images corresponding to the external stimuli, is that

analogue transformation and template-like comparisons may be the 'modus-operandi' of the brain in such discrimination. The studies of Cooper and Shepard give evidence regarding this issue. And Cooper (1975), arguing against alternative interpretations of the result, has argued only indirectly that mental rotation and comparison was the rule, at least in the kind of task he examined. Likewise, the data given by Moyer (1973) does not provide sufficient evidence to conclude that this is so. From his results, it would appear that subjects were indeed making strategic use of internal representations. Nevertheless, since these reaction-time studies of imagery were not aimed directly at investigating whether imagery is a necessary stage in visual comparison, the issue remains unresolved. Given the importance of the idea of images as a form of internal representation, or as in experiment III where metaphor of internal representation is used as a tool in the generation of responses; it is necessary to extend the analysis and the studies of Shepard et al (op.cit.) in conditions in which the experiment does not have a ceiling effect (that is limiting the possibilities of rotations of images), in which possibly other strategies could be found for the generation of responses.

In an attempt to determine whether visual imagery alone is involved in discrimination of visually presented shapes, an experiment was conducted in which subjects made timed decisions concerning the relative size of sequentially presented circles. A related aim of the experiment was

to investigate a hitherto unexplored implication of visual imagery in visual discrimination. This implication concerns the assumed representational accuracy or fidelity of visual images. Accordingly, discrimination must depend on the fidelity or resolution of the image compared. An index of such fidelity in representation may then be ascertained from the minimal difference in the relative size of the stimuli at which discrimination performance does not differ from chance.

Method

Subjects: seven volunteer students of the University without visual defects or glasses.

Stimuli: Seventeen outline circles varying from 1.6-22.2 cm. in diameter in equal increments of 1.6 cm.

Procedure: The subject sat facing a 50 x 60 cm screen at a distance of 2.5 metres. On a table in front of him were two telegraph keys. The subject's task was to press one of the keys if the second of two sequentially presented outline circles was larger than the first of these, or the other key if it was smaller in size. The larger of the two circles could appear as the first or second stimulus with equal probability.

The subjects initiated each trial by pressing a microswitch provided for this purpose. Each trial began with a 5 second exposure of a circle followed by the exposure of the illuminated screen for another 5 seconds and finally, the second circle was presented for the same

period of time. Simultaneously with the onset of the second stimulus an electronic timer was activated. The timer was stopped and a measure of the time elapsed was given when the subject pressed one of the two response keys (see Fig.15). The reaction time (msec) as well as the accuracy of the response were recorded. From the set of 17 circles generated, 7 different groups of circle pairs were chosen. In each of these groups the difference in diameter between the pair of circles was always the same. There were 6 such pairs in each group. For the 7 groups the difference in diameter between the circles in each pair was 1.6, 3.2, 4.8, 6.4, 8.0, 9.6 and 11.2 cm. respectively. Each subject received a different series of 10 block replications.

Results

Whenever the subjects responded "larger" when they should have responded "smaller", the response was considered an error and the reaction time was not included in the analysis.

The mean of the reaction times for each group was computed and subjected to analysis of variance. The reaction time was found to decrease significantly as a function of the difference in size between circles, ($F = 5.16$ $P < 0.05$). Closer post-hoc comparisons using the Newman-Keules test revealed that this difference in the mean reaction time was restricted to differences in diameter size of 1.6, 3.2 and 4.8 cm. (See Fig.16). The mean reaction time as a function of the difference in diameter is shown in Fig. 16 . The actual values of the mean reaction time for each diameter are given in Table V.

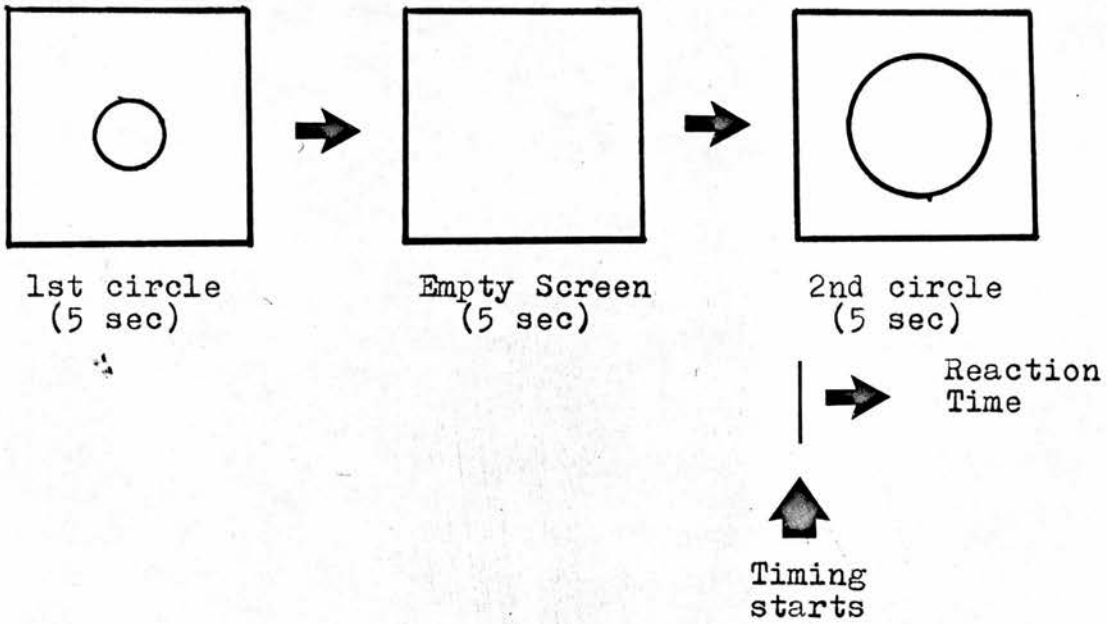


Fig. 15: Sequence of events during the experiment.

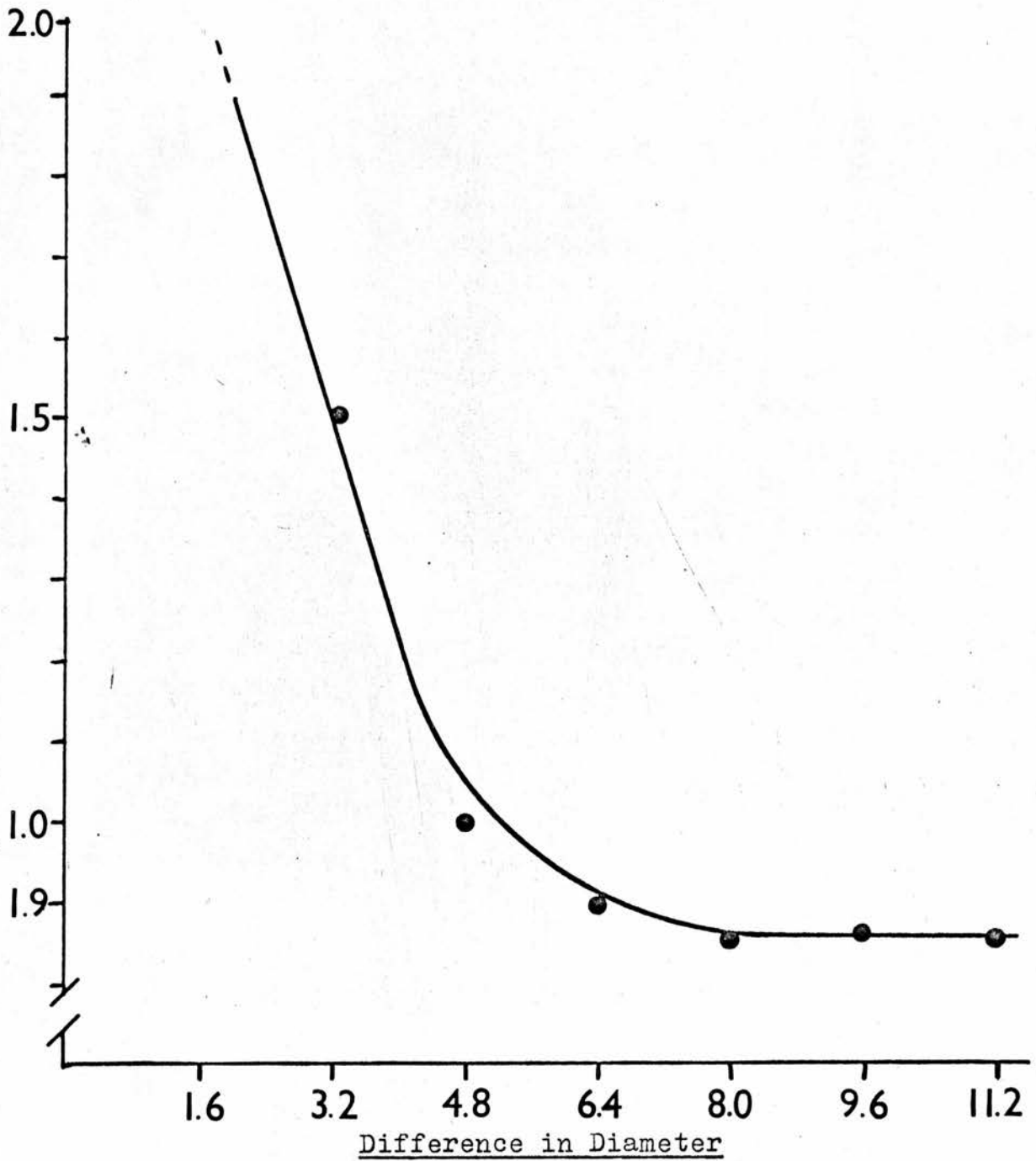


Fig. 16: Relation Between the Mean Reaction Time and the Difference in Diameter Between the Circles.

TABLE V:

Difference in Circle Diameter (cm)	Mean reaction time (msec)
1.6	random responses
3.2	1.70
4.8	1.19
6.4	0.94
8.0	0.93
9.6	0.96
11.2	0.95

Discussion

The results of this experiment indicate that reaction time does not maintain a linear relation with the difference in diameter of the circles. Where the difference in size between circles was small (1.6 cm), the subjects' reaction time was very long and the accuracy of the response was no different from chance. This result would indicate that subjects were slow in responding because they were unable to come to an appropriate decision concerning the relative size between the circles. Simultaneous presentation of the two circles at the end of the experiment revealed that the subjects could distinguish their difference in size, whereas they could not do so in the experiment when the interval between the presentation of the circles was five seconds. This in turn suggests that over a five second interval, the resolution of the internal representation of the externally presented test circle. When the difference in size between the circles

was greater than 4.4 cm the relative difference in size did not seem to affect the subjects response latencies. This finding argues strongly against the notion that the subjects in performing the task were comparing internal representations of the circles, or internal estimates of circle size. Rather, a comparison not implicating visual imagery is indicated. For intermediate differences in size of 1.6, 3.2 and 4.8 cm the ensuing reaction time function can best be fitted by a straight line.

The results of this experiment could indicate that perhaps the use of imagery in visual discrimination is invoked by the requirements of discrimination. Where discrimination entails a fine-grained analysis of the stimuli the best strategy available to the subjects is to generate visual images representing the stimuli and to operate on these images as if they were internally available for superimposition or point-to-point comparison.

Where discrimination can be achieved without detailed analysis an appropriate decision seems to be reached on a different kind of comparison process, perhaps not involving directly the conscious visualization of the shapes. It may be that the fine-grained or coarse level of analysis distinction made here can be experimentally manipulated and proved of great heuristic value in studying not only the limited uses of imagery but also in providing evidence concerning the fidelity of such representation of external objects and events in memory.

It could be proposed that the brain decides selectively which type of representation system to use in visual comparison. If the analogy between imagery and the "mind's eye" is to hold, we could perhaps consider both its "acuity" and when it is best for the brain to keep it closed.

B. GENERAL DISCUSSION OF THE EXPERIMENTAL SECTION

"If the Lord Almighty Had
consulted me before embarking
upon the Creation; I should
have recommended something
simpler"

King Alphonso X (The Wise)
of Castilla.

The main purpose of this discussion is to emphasize which are the following steps which can be taken after these experiments presented in this section. And at the same time, study their possible conclusions and generalizations.

The first important point that has to be indicated is that the methodology used in the experiments is not in any way special. On the contrary, it is standard and easily found in any journal such as the Journal of Experimental Psychology. It has all the defects and qualities of any other method used nowadays. This methodological point is important if it is considered in relation to some of the problems studied, mainly about Bartlett's ideas and the ideas of human information processing.

As has been mentioned in the section devoted to reconstructive memory, this approach represents a different alternative to standard memory research. This alternative has had an important influence. However, some of its more important aspects have been denied due to lack of experimental support. The experiments in support of this approach did not fulfil all the characteristics of control which nowadays are required. However, when the experiments are done in the appropriate way, the results indicate that some of the most important aspects of this approach are valid.

On the other hand, when strict methodologies are used to study other phenomena which seem to have a misleading assumption the results question traditional ideas. In the experiments of iconic memory it is assumed that letters are novel stimuli and it is assumed that with them, the characteristics of memory and its trace can be elucidated. According to the results reported here letters are not novel stimuli and the classic conception of iconic memory, of trace, and flow of information should be revised.

From the results obtained in the experiment on representation it can be appreciated that the results are not as simple as they should be according to the proposal that all the basic form of representation, and current proposal concerning the information (e.g. Paivio 1973; Shepard, 1978).

From a methodological and experimental point of view it seems interesting to repeat these experiments and study the effect of certain variables. Since these experiments are about what in general terms can be called imagery, it seems interesting to study this variable in more detail. Mainly, in relation to the experiments III and IV (as in Figueroa, et al 1974).

The effect of the time of presentation of the stimuli in experiment should be studied in more detail. A parametric study could give some interesting results about the fidelity of the images.

The difference in the reaction times in the experiment as a function of the stimuli used, suggest an interesting

area of work. It should be possible to plan a series of experiments since it seems that the methodological tools are enough to produce more results.

As can be appreciated the "modern" methodologies are flexible enough to allow the study and to enrich (or distort) our knowledge about memory phenomena, either using "old" or "new" ideas.

At a different level of analysis, the implications of these experiments can be studied in a more general way and some indications about what to do next can be analysed. With this broader aim in mind let us recapitulate the conclusions of each experiment:

From experiments I and II we may conclude that novel stimuli alter the characteristics of the trace. These results suggest that experiments on iconic memory have succumbed to a misleading assumption using known stimuli in situations where it is assumed that the information is yet to be learned. It is important to point out that the results do not deny the existence of a trace, but suggest that with letters it is possible to find iconic memory whereas with novel stimuli the situation is different. If the memory trace is to be studied (which is different from the trace left by the light or visual persistence) it is important to make sure that the information is "novel", since it is not possible to study information acquisition processes with information which is already in the system. It is in this spirit that the findings from studies of iconic memory should be interpreted (Dick,

1974) not as the first step in the flow of information, but in terms of a comparison between the input and what is stored. These studies could be suggested that are referred to the way in which the information is 'activated', which has complex relations with the time of presentation of the cues.

If it is true that the processes of manipulation of information are a function of novelty of the stimuli, a great deal of the ideas used nowadays have to be reformulated, (e.g. G. Bower, 1977, Shiffrin, 1977; Murdock, 1977 and Glanzer, 1977). Mainly, in relation to the idea of trace and stages of information processing. One of the most important implications of this study is the need to study the processes of acquisition of information and to distinguish between acquisition of information and reorganisation of what has already been acquired. With this in mind it would be interesting to study the acquisition of information in babies and children. But in those studies using adults, it should be kept in mind that novel stimuli may be an important variable to consider. It is possible to consider that in adults there are sophisticated forms by which the information is used and manipulated, and that in a certain way this information is based on a series of basic components. Maybe one of the most important aspects is the acquisition and regulation of new combinations of elements inside the total information already acquired. An illustrative example of this problem is the automatic translation from one language to another.

It is assumed that the problem consists in having something similar to a dictionary of relation between words and some grammatical rules. However, it seems that translating from one language to another requires something more general which can only be described as knowledge of the language. This situation can be paraphrased in the following form: in order to translate (analyse) from one language to another (stimuli) it is necessary to know the whole language (information).

A great deal of research has put more emphasis on forgetting and its different characteristics. In these situations it is also possible to suggest that what has been forgotten is only part of the information given to the subject. For instance, in the curves presented by Ebbinghaus, (1885) it can be observed that subjects forgot the combinations of letters which had been read to them, but not the letters themselves. This is important to analyse carefully since it may be relevant for a theory of memory.

From experiment III it is possible to conclude that if some of Bartlett's ideas are formulated in a more specific way, it is possible to develop experimental hypotheses which can be examined in detail. It is possible to see that the subjects can bring past information to the present and can generate something which could be called an "image" in order to give an answer. It is possible to suggest that this process is the process of reconstruction.

mentioned by Bartlett, that is different to the simple memorization or to the process of abstraction. The suggestion that this is an active process is based on a comparison between the control and the experimental conditions. In the control condition, subjects had to count the elements of the stimuli presented. This counting took a certain time which was correlated with the number of events. In a similar way comparing times it could be said that in the experimental condition the subjects do something similar to direct counting, but using representation of events, possibly in the form of an image.

This experimental situation suggests something similar to what other verbal reports suggest. Artists and scientists when giving accounts of how they solved a particular problem "in their minds", point towards a similar situation of reconstruction (e.g. Koestler, 1964). As has already been pointed out, reconstruction does not necessarily have to be visual, it can also be verbal (e.g. Smith, 1973).

If it is true that a process of reconstruction exists, it is possible to suggest that subjects in an active way manipulate information and generate "new" information which in turn can be stored. This aspect of generation of information is very important since it is possible to suggest a relation between this process and what in general terms is called problem solving. An extension to the problem of reconstruction refers then to the alteration of the information which the subjects can do, which can be

conscious that is the subjects can be aware of the changes. The direction and form of this change can be determined by different factors. Some data and experiments in this direction are found in Kvale's work (1974). The origins of this problem can be found in the ideas of the gestaltist psychologists (e.g. Koffka, 1935) about the reorganisation of the perceptual field. The study of the subjects' knowledge (memory bank) is an interesting problem, mainly in relation to how this knowledge is altered, without the direct participation of learning (in the sense of acquisition). This point of view leads us to the question to what extent is memory permanent? This poses an experimental problem since, in order to obtain an answer, a great deal of technical and experimental developments have to take place. Some of the elements to examine this question are available maybe more than any thing else, what is needed is a special interest in posing this kind of problem and attempting to search for an answer by experiment. Maybe the task is not as difficult as it seems at first since the "methodology" is there and there are some ideas which can serve as a guide, such as the ideas of schemata, reconstructive memory, processes of motive modification of information, and so on.

In the experiment IV reference was made to the problem of representation in general and in particular to the limits of the manipulation of information with images. If in the experiment III images were mentioned in relation to reconstructive memory, this does not imply that the metaphor is accepted as such in an absolute way. The idea of an

internal picture and one "internal eye" (e.g. Paivio, 1975; Shepard, 1978) is maybe too wide as a simple explanation.

The most important result from this experiment is the no linearity between the stimuli and the reaction time. This can suggest the participation of another process in the generation of responses when the difference between the stimuli is big, (automatic response). In the same way when the difference between the stimuli is very small, the reaction time and the amount of mistakes are very big (limits in the image). As was mentioned in the introduction to this experiment, one of the best strategies at the moment, is to study this representation in combination with other processes. For instance, it could be proposed that a process of comparison takes place in imagery in which it is important to emphasise that images seem to have a limit in their existence as a representation of stimuli. It seems that images (in this experiment) are analogues of the external event, but do not have very good fidelity, since subjects are capable of distinguishing between the two stimuli when presented together, but are unable to do so if the stimuli are presented with a short interval in between each other. The possibility that the subjects had used two or more different processes during this task suggests the importance of studying these processes. Already other authors have pointed out the limits of the images in a point to point relation (e.g. Anderson 1978). These reports agree with the results obtained in this experiment.

Each of the experiments reported in this section are directed towards solving a hypothesis and are related to different processes and operations in memory. Each experiment (and related hypothesis) has independent life and forms part of a series of a wide theoretical and experimental study. In chapter II several problems facing the psychology of memory were analysed. In this experimental section an example has been given of how to tackle some of these problems, with the intention of searching for an experimental solution. It could be said that if any other problem in the study of memory is analysed in this way, in one way or another interesting data is going to be obtained. This task of tackling problems in an experimental way is very important and must not stop, since it is the one that gives life to research.

However, it is important to point out that together with research there must be an effort directed towards trying to put some order and give meaning to the data obtained, mainly if the experiments are considered as symptomatic of the need to widen and strengthen our ideas about memory. For this reason, in the next chapter, an effort will be made to present, in a unified way, suggestions which can be derived from the experiments reported in the experimental section.

Obviously from a few experiments a new explanation of memory cannot be derived nor to say the conclusion that the present explanations are wrong or limited. However, it is possible to try to give some general conclusions.

The first possible suggestion refers to the way in which information processing takes place. The idea of flow of information from iconic memory to short-term memory and then to long-term memory, cannot be taken in a literal sense. It is necessary to study this problem of how does iconic memory work. To do an intensive study with new information, with non-familiar stimuli. It is necessary to analyse carefully which are the interactions between what is stored and what is entering the system. If this interaction is to hold, (as has been supposed for many years), then it is necessary to give a more active roll to the stored information and not only to regard it as a box full of material.

It is also possible to suggest that the ideas of Bartlett, instead of being regarded as "classic" can be used and extended with modern techniques. It is possible to do experiments with the most creative and active aspects of memory. This does not imply that one approach should be substituted by the other. Unfortunately, Bartlett's point of view has not had the developments of other approaches. What can be done is to try to expand and develop the point of view of the active memory together with the great deal of knowledge accumulated, considering it from the passive point of view.

Another aspect which can be suggested from the experiments presented in this experimental section, intimately related to the previous one is that if memory is considered as having reconstructive aspects, it could be related to

intelligence and creativity. As it is indicated in some isolated experiments, and in a great deal of other every day life situations, the idea of reconstructions does not seem to be mistaken, therefore, it could be suggested that it could serve as a powerful tool in the development of our knowledge about intelligence and creativity.

If memory is something more than a phenomenon observed in the laboratory it could possibly be related to more important material than nonsense syllable or associated pairs and is really related to humans in a real world. If this is true, the functions of memory are something more than a store of information.

An important aspect is that in all these experiments, and in many others reported in the literature, there are indications of processes which are altering, moving, and modifying information, which should be incorporated in a more direct way in the models of memory. The processes that can be used or postulated must be very important characteristics, must not be considered as fixed mechanisms, but as mechanisms dependent on the information as well as on the task to be performed. Possibly, several mechanisms are activated at the same time.

Another fundamental aspect is the need of taking the problem of internal representation with all the possible means and not to try prematurely to give the simplest explanation. If somebody tried to collect what is known at the moment about representation using data dispersed in the psychological literature, it would possibly present a

similar report to the one given recently by Defeudis and Defeudis, (1977), when reviewing neurophysiological literature about codification and representation of information in the brain. The authors described a great deal of variables affecting the state of the neurophysiological system of codification and derive different levels in which several behavioural aspects may be partially codified. In short they give a review which describes multiple types of codes whose value is undeniable and avoid premature discussions.

The problem of representation as an explicit problem to be solved, has been in existence for relatively few years and the possible difficulties in trying to give some answer are only beginning to appear. This is why it is necessary to be careful when proposing solutions or models of representation.

In conclusion, the experiments reported in this section, give data which are of interest to memory research. These experiments no doubt need to be expanded and related to other significant variables. At the same time these experiments give some indication of the limitations of the possibilities of the present models of memory.

Without denying the need for more experiments, it could be considered that the next step should be to try to study which are the theoretical aspects which need to be developed in order to give direction by research. There are no rules to say which should be the next step; actually

to suggest which of two alternatives should be followed, is a problem of personal choice. Following the theoretical approach, with an emphasis on the integration of knowledge, some of the possible ways of developing and improving the ideas of memory research will be studied in the following chapter.

CHAPTER IV

CONCEPTUAL FRAMEWORK OF MEMORY RESEARCH

"..... There is no 'scientific method';
There is no single procedure, or set of
Rules that underlies every piece of
Research and guarantees that it is
'Scientific' and therefore, trustworthy.
Every project, every theory, every
Procedure has to be judged on its own
Merits and by standards adapted to the
Processes with which it deals."

P. Feyerabend
1978

"Round, like a circle in a spiral
Like a wheel within a wheel
Never ending or beginning
On an ever spinning reel as images unwind"

Jose Feliciano

A. INTRODUCTION

In previous chapters evidence was given concerning the limits of some memory models, as well as data which suggests modification of current ideas about the way in which memory operates. The reasons for suggesting a modification or extension of models of memory is not restricted to the experimental data presented here. For example there is a large amount of data about different phenomena, which simply repeats or modifies older experiments such as data contained in Baddley (1976). The impression obtained from reading this book is that the search for new data is not systematic and not directed by models or theories; it seems like a random behaviour. As its author points out "... we lose track of what we have already accomplished and simply go round in circles discovering and rediscovering the same phenomena."

Another reason for suggesting a change in current models of memory is that in contemporary research there is clear evidence of certain processes of manipulation of information which however have not been incorporated into the models of memory. Such processes are for example the high speed-scanning described by Stenberg (1975) or the phenomena of visual matching studied by Posner (1973). On the other hand there are other very important phenomena that were studied many years ago which, possibly because they suggested another model of memory, have not been studied in more detail. Representative phenomena of this kind are the ones involving reminiscence studied by

Ballard (1913), which have been replicated and extended by Erdelyi and Kleinbard (1978). The main idea of these studies is that, after learning there is a period in which performance is increased and then forgetfulness takes place. Since this idea is different from others proposed which do not mention forgetfulness, it has not been incorporated into the present models of memory.

An interesting situation is that these present models, (e.g. G. Bower, 1977) in most cases are too restricted and cannot interpret or describe the richness of the problems of memory. Even more importantly, if everyday life situations are taken into account, or if classic philosophical problems are emphasized, these models become very limited.

Given the present state of research, it is better to propose general views instead of precise, specific theories. A way of supporting this point of view is to use what is called "cognitive psychology", which is the alternative to behavioural psychology. It should be possible to study the research of memory as a particular case of cognitive psychology and try to process characteristics of a cognitivist conceptual structure of this area of research.

As was described in chapter II, some of the works which have been considered part of cognitive psychology are influenced by methodologies, concepts and explanations used in behavioural psychology. A concrete case is given by Anderson and Bower, (1973) who deny the importance of Bartlett-Neisser reconstructive hypothesis is a workable idea: "But why should anyone favour it over the reappearing trace hypothesis?"

It should be possible to propose a cognitivist conceptual structure, which could be applied and used in memory research. This task is not easy. For one thing this new structure or framework will have to be compared to the structure of the behavioural psychology which is very well elaborated and developed. Unfortunately, there is a lack of a clear statement of the cognitive point of view. The specific suggestion herein is that instead of patching together a theory of memory, it is better to suggest a general conceptual structure which can serve as a guide to research. Instead of giving a definition of a conceptual structure it is best to give an example and in this way demonstrate which are the most important characteristics of this kind of methodological tool.

1. Example of a Conceptual Framework: Ebbinghaus' Work

Let us take an example, Ebbinghaus' work (1885) and describe the structural framework which he used in his research on memory. It is possible that the conceptual structure used in research has great importance nowadays, as has been pointed out by Crowder (1976).

The first important aspect in Ebbinghaus' work is the supposition that "all" aspects of memory are being studied, as he put it: "... The term memory is to be taken here in its broadest sense including learning, retention, association and reproduction." He considered that all mental states such as ideas, sensations, or feelings which at a certain time are in the conscious and later disappear, have not ceased to exist or have been destroyed but in a

certain manner they continue existing, stored up, so to speak, in memory, and can appear or disappear either voluntarily or unvoluntarily. Large individual differences were proposed, in the way in which memory contents are reproduced as well as how the process takes place. Several factors affected retention and reproduction, according to Ebbinghaus, like attention and interest; but the most important factor in forgetting was time. One of the most important aspects in his studies on memory was the use of methods from natural sciences and the description of the results in numerical form. This methodology opposed introspective and qualitative analysis. On this approach to memory, the stimuli had to be simple and constant. This is why for some of his experiments Ebbinghaus used and developed nonsense syllables. The most important method he used was counting how many times it was necessary to read the stimuli in order to obtain complete learning, that is, the generation of responses without mistakes. A particular form of this method consisted in counting how many repetitions were necessary to obtain the same performance after a certain period of time had elapsed after the original learning, (saving method, "ersparnismethode"). Besides the detailed methodological considerations of constant rhythm in reading, rest periods and forms of pronunciation, it was considered that the most important variable to control, because of its negative effects, was the meaning of the material and to avoid all kinds of

mnemotechniques. The most important variables to study were rapidity or learning of syllables as function of their length or as a function of repetition.

As a result of his studies, Ebbinghaus described curves of forgetting and attempted an explanation of forgetting. He postulated that it was due to either interference of new learning, or due to decay with time. His results discussed the concepts of association and found some data related to remote associations.

This conceptual structure includes methodological restrictions, recommendations of the kind of analysis required (mathematical), kind of data to be collected, variables which are necessary to study (although he did not study all of them), clear recommendations about how to avoid the influence of external variables (meaning and mnemotechniques) as well as concrete results and some explanations. A conceptual structure contains some methodological aspects, some implications and some data. It is distinguished from a theory because a theory does not contain methodological recommendations and supportive data is not part of a theory proper. The conceptual structure used by Ebbinghaus (1885) is not described in an explicit form in his book, but his data and conceptual structure were used, extended and criticised for many years after the book's appearance.

Boring (1950) described the impact of Ebbinghaus' ideas on experimental psychology and pointed out something very important; that the conceptual structure of the (1885)

book of memory is different from the one given later by Ebbinghaus in 1905. This latter account was an intermediate step between the atomism of his book of memory and the future Gestalt psychology. This aspect of change and evolution of a conceptual structure in the study of memory is interesting since, as Brow and Deffenbacher (1975) remark, Muller and other researchers of the time greatly developed Ebbinghaus' approach, but their work has not been evaluated, and is rarely appreciated nowadays.

This example indicates the most important characteristics of a conceptual structure: the interest in general problems, methodological suggestions, emphasis on the important variables to study, interpretations of some phenomena, indication of which are the variables to control in order to avoid misleading interpretations, and so on. One of the most important aspects in an evaluation of this kind of theoretical structure, is how useful it is as a guide of research. It is difficult to deny that in this particular case, Ebbinghaus' ideas are still in use.

Nowadays there are other theoretical structures, such as the ones presented by Neisser (1967) or in G. Bower (1977), which are used more than Ebbinghaus' and which represent new alternatives. This does not prove, however, that Ebbinghaus' theoretical structure is wrong or that it should be supplanted by another one. This would be an overly simplistic way of seeing and developing research. What actually seems to happen is that other general forms of

studying certain problems develop without necessarily considering the other approaches to be mistaken. Deciding between theoretical structures is a very important scientific task, and must not be confused with the experimental test of the theory itself.

B. PROPOSITION OF A CONCEPTUAL STRUCTURE

Before describing a conceptual structure for the study of certain memory phenomena, some forms and problems of evaluation of this conceptual structure will be analysed.

1. The Problem of Evaluation

The first way to evaluate a conceptual structure is at a limited level, mainly related to experimental data. Referring to the conceptual framework of the experimental section presented here, the data suggests that there should be some changes in the present models, mainly to theories such as the one proposed by Atkinson (1974) described in chapter I. In particular changes should be made in the way in which iconic memory and phenomena of reconstruction are interpreted.

Another way to evaluate this conceptual structure is to interpret and study the problems and data discussed in Chapter III. Atkinson's theory does not seem to have the necessary power to explain most of the set problems. This in no way indicates that his theory is wrong, but suggests that it is limited in the range of phenomena it can encompass.

Independently of how much knowledge one has about the problems mentioned, their simple specification serves as a guide for evaluating theories. For it is possible to take two or three problems and examine the explanations given to them by certain theories. Of course, in some cases a theory will be limited and not cover such problems simultaneously. This would motivate further theoretical development, and, perhaps if it were done more often, there would be more attempts to develop and expand theories.

There is another way to evaluate a conceptual framework, which is to see if it is useful as a tool to generate experiments and hypotheses. This is perhaps the most attractive form of evaluation, but has a number of dangers and difficulties. The first danger is to consider the conceptual framework as recipes that indicate step by step what an experimenter should do. This problem applies not only to the case of conceptual frameworks, but to theories of all kinds, from specific and restricted to general and powerful. Conceptual frameworks are not algorithms but heuristic tools.

The problem of considering a conceptual framework only as a tool to generate experiments is illustrated in the theory of Hull (1943). As Hilgard and Bower (1975) stated, it was the most influential of the theories between 1930 and 1950, judging from the experimental and theoretical studies engendered by it, whether in its defence, its amendment or its refutation. However, the evaluation by Koch (1954) of the work and research of Hull concluded that

all that effort was sterile and a complete waste of time. In this example, the amount of research done within the general conceptual framework cannot be considered as a useful criterion in the evaluation of the theory. Therefore, the evaluation based on the generation of experiments has to be used very carefully.

Another form of evaluating a conceptual structure would be to study how clear it is, making the "zeitgeist" explicit, mainly when it is changing. It might then be possible to evaluate how much a conceptual structure can help in the specification of elements of future theories.

Taking into account these difficulties in the way of evaluating the conceptual structure, let us describe a conceptual structure for the study of certain memory phenomena. The first aspect that will be stressed are the assumptions, then the methodological recommendations and finally the most important aspects of a possible conceptual structure, will be described.

2. Assumptions

(1) The first and most important of all assumptions is that only if the range of problems that the conceptual structure covers is wide, along with its explanation, will there be comprehensive theories in the future. In talking about extensions of the range, general situations of research should be emphasized, mainly the formulation of problems directly related to everyday life. For this reason, the need to study, e.g. the participation of memory in dreams seem important, as has already been mentioned.

Or the involvement of memory in solving problems, and so on. Some authors call this characteristic of research, ecological validity, (e.g. Neisser, 1976). When everyday life situations are used it is necessary to be careful not to confuse the experimental situation with the experimental problem. For instance, the study of reading, is a general problem, which should not be confused with a situation of reading a certain language. This is a clear example of how many authors have postulated mechanisms and explanations (e.g. about reading) which are not general hypotheses, but specific to the experimental situations used. And when the same explanations are used in other experimental situations the results are different and the explanations do not apply, (e.g. Tzeng et al, 1977). For this reason, posing a problem for investigation has to be done with care.

If the stimuli used by the subjects is analysed the concept of extension of range becomes clear to illustrate. Every time "more complex" material is given to the subjects to memorize, different results are obtained which cannot be explained with the explanations given to the results obtained with "less complex" material, (e.g. Flores et al 1970; Jenkins, 1963, 1977).

Summarizing, the concept of extension of the range has to be used in different contexts referring to: (A) the material or stimuli used, (B) the methodologies and (C) the problems. On the other hand the extension of the conceptual range of theories increases the possibility of explaining more phenomena. This concept will become clearer

in the discussion below of the functions of memory, where it will be employed.

(2) A second assumption refers to the relations between a psychological and a neuropsychological view of memory research. The problem here is that there are two disciplines studying the same subject from different points of view, which produces a conflict that can not be solved by one approach triumphing over the other, but only by co-operation between both disciplines. A possible way in which this co-operation could take place could be trying to relate the processes and phenomena studies in the two disciplines by a bridge theory. An example of this is found in Hull's theory of learning which tries to relate learning to the theory of personality of Freud, (e.g. Dollard and Miller 1950). However, the present possibilities of this kind of relation are scarce, basically due to the limits of knowledge in both disciplines. However something that must be done is to emphasize and recognize this situation and to be alert to any possibility of relating these areas of knowledge, in order to avoid the temptations of giving explanations based on physical processes of doubtful nature as with some of the explanations given in artificial intelligence.

Relating this point to the present work, if experiments I and II suggest limits to the concept of trace. This does not mean that the whole idea of trace is wrong. The problem lies in that the idea of trace used is simple and it will be necessary to give a more sophisticated version

in order to understand the biological basis of memory. As was suggested by Defeudis and Defeudis, (1977) the "codes" represent information in the brain are varied and span a whole range: from changes that could take place in the size of the neurons to possible changes in the molecular structure of the transmitters. These kind of ideas about the memory trace are only the beginning of the systematic study of representations from a neurophysiological point of view, and differ from the simple classical idea of trace.

(3) A third assumption presents certain problems, in relation to the kind of concepts used, and how are they used in memory theory. Since psychology constantly uses concepts from other disciplines, it is necessary to assume that these concepts are taken in a wide and general sense and not in a strict and specific sense. For instance, the concepts of "information", "process", "code" and so on, have exact definitions in the disciplines where they originate, but in psychology are only tools. For instance the concept of "code" depends on the physical characteristics of the code mentioned in particular, as well as on the process of codification and decodification. At the moment, in psychology, it can only be supposed that there are codes in the brain. However, the nature of the processes involved are not known. Their existence is postulated as a possible metaphor.

One of the healthiest affects of cognitive psychology is the liberation from the operationlism which attempted

to define all the concepts used. It is possible to suppose that more flexibility in the use of concepts can facilitate the construction of models and theories. For example, nowadays, the concept of information is used with great flexibility, not relating it to the mathematical formalism involved (e.g. Baddley, 1976; Bjork, 1970; Fodor, 1975).

(4) An assumption which it should not be necessary to make clear is the relevance of the developmental psychology of memory capacities. But it seems that with the exception of Piaget and Inhelder, (1973) most models do not pay attention to development as an important factor, (e.g. Norman, 1978; Postman, 1973; Shiffrin and Atkinson, 1969; Wickelgren, 1977). There are many forms of development, as illustrated in the experimental work of T. Bower (1977). This author found that certain abilities appear and then disappear in development, or that a process has an affect on lateral processes and not linearly. He also observed that the transition from one stage to the other is sometimes gradual and some times very quick. In a few words, the concept of development is very important, complex interactions between different processes including memory have been demonstrated in children. Perhaps the lack of a clear idea about the development of memory processes, is due to the lack of a general theory of development.

If the models of memory available at the moment, are taken in a general sense, for instance the ones described

in G. Bower (1977) or Norman, (1970), it could be considered that from the moment of birth, humans are equipped with different mechanisms, and, that memory processes have only tenuous relations with biological phenomena. This is a clear example of non-attempted dualism, possibly due to a lack of clear description of the assumptions of the theory. Of course, most authors would deny that their models can be interpreted as dualistic.

On the other hand Kvale, (1974), Reigal, (1972) and Rose and Rose, (1974) have indicated that a static point of view about many different psychological phenomena is due to the ideological structure of Anglo-American research that emphasizes isolated problems and the existence of immutable elements, which have to be studied separately. These authors are especially critical about the study of development and change of memory.

In summarising, the most important assumptions necessary for the elaboration of a conceptual structure to guide research in memory are:

- (1) Only if one tries to expand the range of problems covered by the conceptual structure, will future theories be general enough to explain a significant variety of phenomena, including those of everyday life. That is, it is necessary to have a tendency towards generalization of methods, procedures and explanations.
- (2) Because there are other disciplines trying to explain the same phenomena studied in the psychology

of memory it is useful to recommend, whenever possible, to give compatible explanations between areas of knowledge, mainly in relation to neurophysiology. Besides, a number of phenomena (not all) have biological bases, and it is necessary to be careful in order to avoid dualist explanations. Perhaps in the future a more direct relation with neuropsychology will be possible.

(3) More flexibility in the use of the concepts is needed, since a number of them originate in other disciplines and when used in psychology only part of their original meaning is maintained. Therefore it cannot be expected that a concept has to be defined in psychology in the same way as in the area from which it originates. On the other hand not all concepts have to be borrowed from other areas, completely new concepts can be created in psychology.

(4) Memory phenomena develop in different ways, and therefore it is necessary to pay attention to phenomena of change. Without restricting the changes to those of a biological nature.

The limits and difficulties of the present theories lay precisely in their assumptions, and especially in those which are not explicit.

3. Methodological Considerations

One of the forms in which a conceptual structure can be very useful is in the methodological sense, since it

gives some explanations of "how" to obtain information. Ebbinghaus' conceptual structure gives some indication of the methods to be used in this area of research. It is important to remember the difficulties described by Ebbinghaus, (1885); he stated that:

"1 - The constant flux and caprice of mental events do not admit of the establishment of stable experimental conditions.

2 - Psychological processes offer no means for measurement or enumeration."

Ebbinghaus suggested also that only in a partial way is it possible to solve these problems in memory research.

A researcher in the field of memory, has to bear in mind these difficulties, since his task is to overcome the difficulties and not as had happened in the past, to continue using the methods of Ebbinghaus, without considering their limitations and with only a very few changes, (e.g. Kausler, 1974). It is important to emphasize the limits described by Ebbinghaus himself, and it is necessary to improve the methodology available.

The first methodological problem refers to how much is it really possible to study the acquisition or learning in a "pure" form without the interference of biological variables and phenomena of development and previous learning. A possible solution was the one given by the behavioural school on one hand, and on the other by Pavlov, who reached the conclusion that only if learning is studied in animals

will it be possible to "discover" the principles and laws governing learning without the influence of certain complications, such as language. A clear example is Hull (1943) who tried to study learning laws and other phenomena in animals. Nowadays it is considered that even this alternative is limited since the phenomena considered as prototype of learning, classical and instrumental learning, are themselves influenced by biological factors.

One of the best methodological alternatives for studying "pure" memory is to investigate the development of memory. For example, T. Bower (1977) found clear examples of complexity of memory in infants. However, it has often been thought that the "most important" variable in the acquisition of new material is the information already present in the system. This proposition was made explicit by Ebbinghaus and part of his methodology emphasized the control of the effects of meaning and past information. Even nowadays, this is considered the most important variable that has to be controlled. Experimental evidence in support of this proposition is given in the works of Wallace et al (1957) who instructed the subjects to use as much past information as possible, in a paired associated task. His results were different from those obtained in conditions where past information was controlled as much as possible.

A change in the way in which memory phenomena are conceived, giving emphasis to the use of acquired information, can lead to a number of new and interesting results.

This change in the interpretation of memory, from a conception of a passive system which only receives information and stores it, to the notion of a system which receives, searches, relates, and modifies information as the result of comparison with stored information, is a theoretical and methodological step that it is necessary to take.

Besides enquiring about the speed, amount or characteristics of the stimuli presented, one should ask (and control) what information does the subject already have, which will facilitate or limit the acquisition of the information or stimuli being used in an experimental situation. There are ways of studying past information which can be found using "new" stimuli, comparing the results with those obtained in experiments using nonsense syllables or another kind of verbal material familiar to the subject. Examples of novel material are found in the figures designed by Vanderplas and Garvin (1959) and in the stimuli used by Garner (1974), who demonstrated that patterns of stimuli used in experiments have an internal relation which has significant effects on performance. The effect of past information cannot be limited to its direct effects, for there are a number of indirect factors which influence the acquisition of information, as for example the effect of attitudes on perception and attention (e.g. Erdelyi, 1974).

Often subjects manipulate a certain physical dimension, of a stimulus in a different way than it is manipulated by the experimenter. This idea is expressed in the results of psychophysics experiments, (e.g. Stevens, 1975; 1966),

especially when extreme values are used. There are a number of implications which can be derived from this fact. For instance, in experiment IV above, it was observed that the relation between the physical dimension and the reaction time is not linear, Shepard, (1978) in his experiments used reaction time as a direct criteria of the relation between the physical and "mental" dimension; but in his experiments the limit in the manipulation of information was imposed by the task (in which rotation was restricted). In the experiments described in Chapter III the manipulation of information was less limited and it was observed that there are not such linear relations in the representation. This difference in results has repercussions for the interpretation of memory phenomena.

A number of experiments in memory at the moment are still using the conceptual structure of Ebbinghaus. In a few cases there are attempts at new experimental designs, some of which are quite sophisticated (for instance, multi-factorial experiments). Batting (1968) stated about the experiments on paired associates that there should be more research "involving the simultaneous orthogonal manipulation of all known tasks and procedural variables known or suspected to have any effect whatever within any kind of paired-associated learning". Although Batting referred only to paired associates, his comments can be applied to all memory research. This kind of approach requires the "co-operation of a large number of researchers", but possibly one of the ways to increase our knowledge of

memory consists in "using an I.C.B.M. Inter-Continental Batting Method" such as the one proposed by Tulving and Madigan, (1970).

One extension of the classical form of memory experiment consists in giving as little information as possible to the subject and make him use the information which he already has. This approach can give some results about manipulation of old information in order to produce "new" responses (see experiment III, Chapter III). This approach can also give an idea of how the information is stored, mainly in relation to semantics (e.g. Figueroa et al 1976; Brachman, 1977; Collins and Loftus, 1975).

Summarizing, the experimental results as well as the study of the forms in which the experiments are done, suggests the need, in the area of memory research, for a change in the kind of material used as well as the use of sophisticated experimental designs in order to surpass the forms of research proposed by Ebbinghaus (1885) which are still used nowadays.

C. THE CENTRAL ASPECTS OF THE CONCEPTUAL STRUCTURE OF MEMORY RESEARCH

The criticisms of various authors about the present state of memory research have already been discussed, (Chapter I). It was suggested that one way of improving the situation is to study the most relevant and significant problems in memory. A series of problems, concerning memory were then given. Special attention was given to

those problems relating to everyday life situations. If the list of problems in itself is interesting and significant, the detailed research into characteristics and relations of the problems has to be guided by a conceptual structure, at the beginning and later by a general theory, which ideally should be more explicit and complete than the ones already proposed.

Any conceptual structure is only a transitory step in the development of research, which has to be directed towards this approach is to propose conceptual structures which serve as general guides for interpreting experiments.

An example of a simple conceptual structure is the one presented by Tulving (1972) which refers to the distinction between episodic and semantic memory, as follows:

"Let us think of episodic and semantic memory as two information processing systems that (a) selectively receive information from perceptual systems (Gibson, 1966) or other cognitive systems, (b) retain various aspects of this information, and (c) upon instructions transmit specific retained information to other systems, including those responsible for translating it into behaviour and conscious awareness. The two systems differ from one another in terms of (a) the nature of stored information, (b) autobiographical versus cognitive reference, (c) conditions and consequences of retrieval, and probably also in terms of (d) their vulnerability to interference resulting in transformation and erasure of stored information, and (e) their dependence upon each other. In addition, psychological research on episodic memory differs from that on semantic memory in several respects.

Episodic memory receives and stores information about temporally dated episodes or events, and temporal-spatial relations among these events. A perceptual event can be stored in the episodic system solely in terms of its perceptible properties or attributes, and it is always stored in terms of its autobiographical reference to the already existing contents of the episodic memory store. The act of retrieval of information from the episodic memory store, in addition

to making the retrieved contents accessible to inspection, also serves as a special type of input into episodic memory and thus changes the contents of the episodic memory store. While the specific form in which perceptual input is registered into the episodic memory can at times be strongly influenced by information in semantic memory - we refer to the phenomenon as encoding - it is also possible for the episodic memory to operate relatively independently of the semantic system.

Semantic memory is the memory necessary for the use of language. It is a mental thesaurus, the organized knowledge a person possesses about words and other verbal symbols, their meaning and reference, about relations among them, and about rules, formulas, and algorithms for the manipulation of symbols, concepts, and relations. Semantic memory does not register perceptible properties of inputs, but rather cognitive reference of input signals. The semantic system permits the retrieval of information from the system, leaves the contents unchanged, although any act of retrieval constitutes an input into episodic memory. The semantic system is probably much less susceptible to involuntary transformation and loss of information than the episodic system. Finally, the semantic memory may be quite independent of the episodic system in recording and maintaining information since identical storage consequences may be brought about by a great variety of input signals."

Although this distinction does not say anything about how to obtain more information about memory (there are no methodological indications), it is a powerful tool which has clarified research. In a certain way, perhaps more relevant, it has also influenced certain kinds of research in giving meaning to aspects of transformation and utilization of information with special emphasis on meaning. Thus, this conceptual structure of Tulving, is different from the conceptual structure of Ebbinghaus and his followers who avoided the use and study of meaning. Tulving (1972) introduced in a more explicit form the idea of memory as an active phenomena. However this conceptual

structure is not rich enough to give an idea of the way in which memory functions, specially if the phenomena already mentioned in the list of problems (Chapter II) are included.

Analysing the limits of the present models of memory such as the ones proposed by Norman (1969), Atkinson and Wescourt (1975) and in G. Bower (1977), and also the results of the experiments done and the list of important problems in memory, it becomes clear that there is a need to propose a conceptual structure of research, that conceives memory as an active phenomenon. "Active" can be understood, in the context of the memory concepts of Bartlett, (1932) and Tulving (1972) who, emphasized the use and transformation of meaning in memory. In other words, they gave emphasis to the function of memory. It is in this direction that our ideas about memory should be expanded. Additionally the operations and transformations should be studied and a way found of analysing the problem of representation.

Summarizing, three of the most important aspects of a conceptual structure are:

1. The description of the most important functions of memory.
2. The description of the most important processes for the realization of these functions of memory.
3. The description of the representation or states of information.

As these aspects are intimately related and in constant interaction, it is difficult to study them separately. Consequently every attempt of research has to take into account the whole memory system. This is true for other systems, for instance, the perceptual one is equally as difficult to decompose into separate units. This does not mean of course that experiments cannot be done on even the most specific aspects of the system of memory; what it does mean is that we cannot forget that the whole system is involved.

1. THE FUNCTIONS OF MEMORY

The belief that memory is only a store of data or information is a relic of a former stage in the development of research. Nowadays, experimental data has forced us to abandon it. The view of memory as a simple store goes back to Plato thus:

"There exists in the mind of man a block of wax of different sizes and qualities in different men. This tablet is a gift of memory, the mother of the muses, and when we wish to remember anything which we have seen or heard or thought, we hold the wax to it and the material receives its impression as the seal of a ring. We remember and know what is imprinted as long as the images last; but when it is affected or cannot be taken, then we forget and do not know." (Taken from Jowett, 1931).

Some contemporary models sustain this static conception of memory, changing only the concept of wax for that of a store, (or box like short and long term memory). However, after Plato, Aristotle considered the functions of memory to be much more complex, active and internally related to

thinking and to intellectual processes, (e.g. Sorabji, 1972). The idea of memory as a complex system is ancient; however, the model used in psychology so far have been more Platonic than Aristotelian. If, on the other hand, we pay attention to the Aristotelian model and bear in mind current findings, we can define the functions of memory more completely and, what is more, in relation to the conception of men as intelligent and active beings. If one wants to explain memory, we must abandon the simplistic idea of memory as a store or simple trace, (e.g. Gomulicki, 1953) and substitute for it the idea of memory as a complex system composed of different functions, processes and states of information. Accordingly, let us point out some of the functions which could be considered as most relevant:

FUNCTION I: The Construction of a Model of the World

The interaction of human beings with their environment leads to the development of a model of the world, wherein many events and constant factors are ordered as a whole. As time goes by, this model becomes more articulated and interaction with the environment becomes easier. As the model is articulated, every "new" experience becomes assimilated into it and slowly brings about a series of regularities which facilitate behaviour. Memory is a system which organises constants in this model which are the active results of different processes elaborating received information. In that sense, memory does not only receive information and store it passively.

The development of this model of the world is a process which uses certain skills of biological origin, which allow for instance, a neonate to exhibit the first forms of information seeking. One of these mechanisms is the ability of infants to orient their eyes in the direction of sounds (audio-visual co-ordination); as was originally studied by Aronson and Rosenblom (1971). Similarly, Fagan (1976) found evidence suggesting that 7 month old infants are capable of recognizing the invariant features of faces. From this it is possible to see that infants are capable of using classes of information, not only information relating to specific events. This ability of manipulating information can be considered as the basis for the development of the model of the world. As T. Bower (1977) commented, babies at this age, give the impression that they remember not only the experimental situation but what they have to do in it. The development of powerful forms of memory such as are involved in the recognition of invariant features is related to the general development of intelligence. The result of this is the development of adaptive forms of interaction with the environment.

Although it is in children where the most important features of the model of the world are developed, in adults the function of the model becomes clearer. The existence of such models is expressed in the way in which humans manipulate a large number of factors in their environment. For example, an intuitive idea of gravity

and its effects exists which is independent of culture. In a more restricted way, the model of the world can be observed for example in people's ideas about the functioning of society. Another case is observed in people with religious ideas, which organize, interpret and render "logical" a number of events, e.g. an earthquake or an illness can be considered as a "divine" punishment.

Another way of describing the model of the world, is to say that it represents values, traditions and customs which are all abstract entities and nets of information that the subjects acquire. The concept of a model of the world is a powerful tool in the study and explanation of complex behaviour. For a model of the world is conceived of as giving rules and pattern to behaviour. However, it is not possible in memory research to evaluate the contents of the model, the only thing that can be done is to study and observe the sophisticated effects that it has on human behaviour. It is possible that parts of the model of the world are common to all people, which is an interesting working hypothesis. On the other hand, it is possible that parts of the model are limited to nationalities, (e.g. Americans, French, English); or to certain groups (e.g. army, navy, boy-scouts) in which more specific information content is found and whose effects are dramatic, as in terrorist groups, who have a model of the world which gives reasons for bombing cities.

All these examples suggest that people have in "memory" a great deal of information which helps to direct behaviour

and to establish orderly interaction with the environment. On the other hand models of the world need not behave logically. In many ways they seem to be composed of totally independent different sub-models. Since the construction of this model of the world depends on behavioural confrontation with the environment, to some extent the model will vary according to the environment. However, as much of the environment is constant, several aspects of the world will be identically represented in different subjects' models. Using the terms in their Piagetian sense, it can be said that the accommodatory and assimilatory powers of the memory system are very great and highly flexible. The possession of models of the world is not an exclusively human trait; they are also found in animals, (Griffin 1976).

FUNCTION II: The Construction of an Internal Model for Action

Previous experience, especially of interaction with other people, creates a model of rules, plans, intentions and so on, which guide an individual's behaviour. This internal model is highly individualized, based on personal experiences and serves as a general guide to action. Some parts of this internal model form perfectly structured information nets for action. These are unique and are the product of specific training which organises and forms a knowledge net that helps to generate specific actions. The interaction of the model of the world with this internal model for action, creates a style of individual

activity whose purpose is to solve contradictions within or between models and between models and the environment. In the model of the world as well as in the internal model, the basic component is information, but this is integrated in sub-units which are not simply sums of elements. The models have an internal structure which is not the passive result of the accumulation of information; the contents are related in specific ways by processes of the memory system.

The idea of an internal model for action was suggested by Craik (1943). He postulated that one of the fundamental functions of brain is the creation of an individual model of the world. He referred specifically to individuals, their experiences and specific abilities.

Two examples of the importance of the internal model for action taken from everyday life are, first, the importance of biographies of great personalities, especially of the fidelity with which the ideas and psychology of the person is expressed. Other people try to learn from the ideas and actions of important people. A second example is the interview which is important for similar reasons: to obtain information about how much a person knows in order to be able to perform in a job for instance, or, in general to know more about a person to whom some responsibility will be given.

The development of the internal model for action develops gradually over time. It may be the product of formal or informal education, or the result of practice.

For instance, a person can have a detailed knowledge of the laws of mechanics and engineering, without being capable to repair a machine because of lack of practice. Similarly, in certain kinds of learning tasks the development of the internal model will be relatively slow and require much practice, as in the case of some forms of medical practice. The internal model for action is the result of continuous learning and experience in which not only the solution to a problem is stored, but also the way in which it was solved in order to use the same procedure in the future. Another important question is how an internal model for action facilitates or limits new learning situations. For this reason, it is important to try to know the quantities, qualities and relations of the information in the internal model for action in order to understand and predict behaviour.

An extension of the postulate of the internal model for action, is the supposition (of long history in philosophy and psychology), that the subjects not only have knowledge about something but are acquainted with what they know and possible know how to know. Some concrete steps in this direction were given in the experiments on memory-monitoring-processes by Hart (1967), but there is not much known about this phenomena.

There is some continuity between the model of the world and the internal model for action. Possibly, the contents of information in memory as a whole are organized in subsets which are to some degree independent and which can

generate actions that may even be contradictory. For instance, people might not be able to make a comprehensive analysis of all that is in their "memory" at a given time. All these possibilities suggest limits to the workings of the memory system.

The postulation of models of the world and models for action could be considered as a contradiction within psychological science which ordinarily consists in finding universal or constant aspects of behaviour. These models are influenced by individual idiosyncracies and personal experience; however, it has been known that in the study of human variability aspects in humans a number of kinds of behaviour find their explanation in several kinds of behaviours.

These models of the world and the internal model for action, are conceptual tools which allow us to entertain a wider point of view concerning memory function, this should be especially helpful in trying to understand people in realistic situations.

FUNCTION III: The Generation of Hypotheses

One of the great differences between S-R models of memory and cognitive ones, lies in the difference between conceiving of a human being as a reactive system and as a system capable of predicting change. A fundamental function of memory is the generation of hypotheses about the present and future behaviour both of the environment and the organism. The basis for the creation of hypotheses is the model of the world and the internal model, since

these store the experienced information which allows for the detection of regularities. It may be postulated that this information is formed into structures containing enough information to generate possible future outcomes.

In the beginning of the 1930's Krechevsky (1932) (nowadays David Kretch), experimentally demonstrated the existence of hypotheses in rats (e.g. Will 1974). This theoretical concept became an element of Tolman's cognitive theory, as well as that of Bruner et al (1956), who demonstrated the fundamental role of hypotheses in concept learning and thinking in humans. In spite of the importance of the concept of the hypothesis in modern cognitive psychology, there has not been much interest in its development. An exception is Levine (1975) who has demonstrated the use of hypotheses in rats, monkeys and humans by means of sophisticated experimental techniques. As Levine said:

"After two decades of subterranean existence, the hypothesis theory re-emerges victoriously, solving old problems with new insight and new techniques."

The mirror image of the generation of hypotheses is the generation of random responses. Interestingly, Wagenaar (1972) reviewing the literature on this topic, asserts that humans are incapable of generating random responses even though pressure is put on them to do so. In other words, humans are unable to produce random series of responses and instead always use a pattern. This supports the notion that the generation of hypotheses is as an important process in the manipulation of information.

Mental hypotheses can be considered from two points of view: the first is Krechevsky's (1932) which consists in the description of behaviour of rats in a maze, where it is found that the animals use a systematic pattern of responses. A tendency to respond in a particular manner was found where it was not expected, and where there were only two alternative behaviours possible. The second point of view from which hypotheses can be considered is in subjects' performance on more complicated tasks where behaviours take on a pattern, (e.g. Levine, 1975). Most importantly, here subjects report that they are using a "hypothesis" or prediction about the relations between the stimuli in the experiments. This second point of view is possibly the most interesting since there is a relation between performance and the verbal report of the subjects.

The study of hypotheses in human behaviour has developed in the last years, primarily in the study of concept formation. Bourne and Dominowski (1972) write "... It is probably fair to say that the use of a hypothesis theory has become the predominant theory today at least for behaviour in conceptual tasks." (See also Brown 1974). It is very interesting that it has not been possible to do experiments in which subjects do not use hypotheses in conceptual tasks, (e.g. Watson, 1960).

Although there is considerable evidence about hypothesis use there has not been any interest to relate this evidence to memory research, and even less interest in trying to see the importance of information as the basic

material for the construction of hypotheses. Thus, even though in studies on concept formation the most powerful explanation available is the hypothesis theory, the origin of hypotheses and the variables that participate in their construction are unknown.

A way of increasing our knowledge about the participation of hypothesis in memory function is to see how these hypotheses operate. Let us consider first an organism - X - without reflexes (biological reflexes) and incapable of learning. This kind of organism is going to survive only if its environment is completely stable, and it will not be able to reproduce itself. If one gives to this creature a mechanism for reflexes then it will react to its environment, it will be able to reproduce, and survive as a species, but it will not survive if there are changes in its environment. If the organism has the ability to learn and react to changes it will "learn" every time there is a change. However, if it not only learns but is capable of generating some learned behaviours at random, it is going to confront changes with these behaviours and it will not have to learn something new for every change in its environment. More effective would be if, instead of generating a learned behaviour at random, the organism were capable of matching the characteristics of the present situation with those of situations already learned, and thereby select an "appropriate" response. In this case the possibilities of survival are increased. If in addition to the matching process it is capable of

predicting the effects of a situation based on past information, then the organism will have an even greater chance of survival. The ability to predict events before they take place is a very important advantage for survival. The prerequisites for prediction are information and the ability to foresee an event before it fully takes place.

This situation can be described metaphorically: when a lion is pursuing a gazelle it is able to see the gazelle "with its internal eye", not in the place it is at the beginning of a jump but where it will be at some later time. Thus, it can catch its prey. If animals and people were merely reactive systems (that is stimulus-response) and not predictive ones, the biological order we know would be impossible.

The hypothesis theory can help interpret everyday life problems. For instance, Lindsay and Norman (1972) gave examples where subjects who have some information about stimuli find it easier to recognise the stimuli later on. Similarly, when Coltheart et al (1975), gave their subjects information about a class of stimuli which were presented, the reaction time decreased significantly. In these cases positive information facilitated performance, but in other cases negative information inhibited performance. For instance, in an experiment on discrimination, Levine (1972) presented evidence about how having information facilitates or inhibits performance in a certain task. A more concrete example of the effect that certain hypotheses or information can have on a task, can

be observed during reading or in the recognition of combinations of letters without meaning, (e.g. Estes, 1976). The effect of hypotheses can also be observed in memory for plans, where subjects organize a pattern of behaviour and modulate them before actually doing something. When somebody is playing the piano, for instance, he is not reading the notes being performed, but the ones that follow. In such cases, people have to organize a behavioural pattern before its performance. A related problem is driving a car; where a final target organizes the responses before their performance, and in this case often without a detailed knowledge of the particular steps to be done.

To summarize, the simple hypotheses are patterns of behaviour as opposed to the generation of random responses. More complex hypotheses are the employment of past behavioural patterns when the organism is confronted by similar situations. In this case there is a process of selective scanning for similarities between past and present situations. At a third level, subjects are capable of using part of previously acquired information and of manipulating it so that when they are confronted with their environment, they can produce an appropriate response. The response here may be a "new" one (as in experiment III, Chapter III). In this sense hypotheses are related to the processes which modify information. At another level subjects verbalize the relations between events to come. The constant use of hypotheses in humans can be seen when

a person is walking in the street. In this situation, the stimuli received help to predict the behaviour of other people around, and also the behaviour of the cars, traffic lights, and so on. At the same time the person is combining this information with his own particular plans of behaviour and with his internal model for action. Although this example is merely a personal report it gives an idea of the constant flow of past and present information that subjects use in a number of situations where information is used predictively.

The above ideas about the functions of memory can help to extend models of memory and to give a point of view which, while not new, is more powerful than the storage models of memory such as the one described in Chapter I. It cannot be denied that one of the functions of memory is to store information, but if we take into account that information is transformed and organized before it is stored, and that once it is stored it is constantly modified, the concept of a store in itself becomes less important, although it is necessary to analyse it.

FUNCTION IV: The Information Store

Information is not statistically stored, but is constantly used and altered. The construction of models of the world, of internal models, the generation of hypotheses and the use of processes manipulating information are all the product of stored information. The concept of a store, is a metaphor in psychology, which has to be considered very carefully in order to avoid making

errors such as relating it in an overly simple form with neurophysiological mechanisms. For instance, to try to find certain relations between short term memory and certain neurophysiological structures or processes, is very simplistic, since short term memory phenomena are not sufficiently understood. Yet discussions of this kind can be found in studies on animal memory which use the concepts of short and long term memory, (e.g. Medin, 1976). Also this kind of discussion can be found in studies concerned with neurophysiological processes in humans, such as the work of Shallice and Warrington, (1970).

The biggest difference between the models influenced stimulus-response psychology (such as those found in Kausler, 1974) and the cognitivist point of view, (such as Neisser, 1971; Neisser, 1976) is that this latter approach is interested in describing how information is stored and not only in describing functional relations in the acquisition of information. This interest in how information is stored is manifest in the attempts to speculate about representation, a concept which is at the centre of memory research and, as Anderson (1977) puts it, at the centre of cognitive psychology. But the interest in having a "scientific revolution" in psychology (Lipsey, 1974), has resulted in premature discussions concerning the nature of representation, such as the discussion between Paivio and Pylyshyn. This kind of activity is premature because concrete ways of representation are postulated (for instance propositional versus pictorial

representation), although the words are used only in a metaphorical sense. There has been a sudden effort to postulate how information is represented, without analysing the difficulties of this kind of theorizing.

Before trying to discover how representation processes take place it would be advisable if a more detailed analysis were done to distinguish the neurophysiological codes of memory from the psychological study of representation. If one asks how it is that humans represent information, the answer would seem to involve reference to a neurophysiological code. However, it might be that memory function and representation are something more than biochemical activity in the brain. If this is so, it would be necessary to maintain a psychological level of analysis without reducing it to processes at the neurophysiological level. This is why it is necessary to mention other processes of information manipulation when talking about representation, making reference to forms of representation different from the metaphor of pictorial or propositional representations. In the experiments presented in the experimental section (Chapter III), it was argued that considering information in conjunction with other processes sheds more light on function than only considering pictorial representation.

It is possible to propose other forms of representation based on the data already known concerning representation. Examples of this are representations in a dual pictorial-propositional system, (e.g. Paivio, 1974) or representation as a form of statistical manipulation of the redundant

aspects of information, (e.g. Pribram, 1971). There are speculative aspects of representation, such as the ones that use holography translating it to a psychological model, (e.g. Pribram, 1977 or Cavanagh 1972). Evans' (1967a, 1967b) experiments illustrate a study in which Bartlett's (1932) schemata concept is defined as a sort of statistical analysis of structural constancies, and as a form of representation. These examples demonstrate the need to obtain more information in order to understand the forms of representation, and also illustrate how other forms of representation can be proposed using the same data.

It is necessary to create working hypotheses and not to reduce theoretical activities to the study of two alternatives (pictorial and propositional). Examples of some working hypothesis of this kind are the ideas of Fodor, (1975) who proposed that in order to represent language, an "internal Language" must exist which is as rich as the language that is represented. In other words, it is proposed that it is not possible to conceive a representation as an "internal picture", and that also machine languages should not be confused with representation and interpretation.

Later on, this problem of store of information and representation will be discussed further.

As was previously remarked, to understand how human memory works, it is necessary to study memory as a complex system composed of different functions, processes and states of information. Having analysed some of the functions

which were considered most relevant, let us consider some of the processes which, according to the general conceptual structure proposed, should be emphasized.

2. PROCESSES OF MEMORY (FOR THE RECONSTRUCTION AND USE OF INFORMATION)

In order to perform its functions, a memory system needs a series of mechanisms to receive, alter, modify, store and use information. In most current models of memory, it is assumed that there are a series of "boxes" and that there are ways of transferring information from one "box" to another. A number of models related to and derived from Shiffrin and Atkinson (1969) lay some importance on the processes of control of information, (e.g. Atkinson et al 1974; Schneider and Shiffrin, 1977), and some evidence for different processes of information manipulation has been found. Typically these processes have been experimentally demonstrated, but not incorporated into a model. It seems necessary therefore, to introduce these processes of information control and, more importantly, their characteristics, into a conceptual structure. When these processes are seen as unified and working together, the advantages of the kind of conceptual structure which emphasizes mechanisms as opposed to stores, can be better appreciated.

Some, of the information control processes are of biological origin and others are the result of interactions between genetic and developmental processes. Examples

of these processes are those described as orienting reactions by Sokolov (1963). In working with human beings it is difficult to distinguish between a process and the information as such. This, among other things, suggests the dependency of certain processes on specific information. An example of this is found in the experiment II (Chapter IV) where the characteristics of the stimuli effected the speed of processing. Another example of this interaction between a process and the information is found in the relations between span of memory and the kind of material used in tasks of recognition, (Cavanagh, 1972).

It is important to mention the distinction between voluntary and automatic processes. In the first case the process is under partial control by the subject, (e.g. Schneider and Shiffrin, 1977) and Smirnov, 1973). Automatic processes are considered to be independent of the subject's control. An important factor in distinguishing between voluntary and automatic processes is that subjects are able to give some kind of report about voluntary processes. The current literature suggests that this ability is very limited, (e.g. Nisbett and Wilson, 1977).

Another characteristic of the memory process for which there is evidence is the use of two or more processes at the same time. This has been called parallel processing, (e.g. Cofer, 1976; Estes, 1975). An important implication of the function of two processes operating at the same time is that it shows the limits of artificial intelligence

simulations. Also by postulating parallel processing, it may be easier to elaborate a theory about how information is codified. Memory processes are limited in speed, capacity and in how they are used. These characteristics may have some relation with other cognitive processes.

A. The Most Important Processes

At the moment, there is knowledge about the nature of processes, but what is suggested below suffices to explain a great deal of data. Let us examine some well known processes.

1) The Process of Scanning

This is a clear example of a process which manipulates information. Usually what is meant by "scanning" is the selection of stimuli from a set, for example, this process takes place when a subject has to indicate whether or not a stimulus was present in a set of previously presented stimuli, (e.g. Sternberg, 1966, 1975). From this kind of experiment two complex types of scanning can be inferred. One involves the use of symbolic representation of stimuli, the other the search in memory for a series of events using only a single cue, (a part of the stimulus). Scanning may be general, for example, in response to a request to find the "similarities" between one stimulus and a past sample: in other cases, the selected stimulus or target event is general and the information the subject has to find is specific.

Sternberg (1966) presented a set with a variable number of letters to the subjects. Later on a single letter was presented, and the subjects had to indicate if the letter was part of the previous set or not. The results indicated that the larger the number of letters in the set, the greater the reaction time. These studies have been replicated and extended to a number of different conditions and have been interpreted in more than one way as Sternberg (1975) points it out. However, these results possibly indicate the existence of a process which is probably composed of a series of specific operations of information manipulation. It is possible that this is a process that can be applied in a variety of situations and is not only observed in a laboratory.

The original experiments on scanning, were restricted to situations involving short term memory, but Juola et al (1971), have observed that this process is more important in situations involving information contained in long term memory. Juola et al asked subjects to indicate if a word was part of a set composed of 16 to 64 words. It was reported that the reaction time was affected by many variables, but that there seemed to be a process of scanning for information. In most of these experiments, the kind of stimuli affects the speed of response, and this supports the idea of an intimate relation between information and processes of information manipulation. In experiment III (Chapter III) subjects used some sort of scanning in order to move the "image" of letters later on, used other processes in order to generate "new" information.

In everyday life situations, several examples of scanning can be found. For instance a person can be unable to give an answer to a question immediately, but when later involved in other activities, suddenly remembers the answer. In these cases it seems as if the response "jumped" from somewhere in memory when the person was no longer trying to remember. It may be proposed that scanning continued while the person involved himself in other tasks.

2) Process of Detection

In this case, the process involves finding a particular event from a whole array of information that the subject receives at one time. It may involve "simple" or automatic situations like detection of gradients of brightness. For example, Neisser, (1964), asked the subjects to indicate how many times specific letters appeared in a list of many letters presented. In simpler cases it is not easy to see the participation of memory, but in more complex cases it can be seen that, in order for the subject to detect "something" in the environment, he needs "to know" it in the first place. This process is the central part of attention, which was at one time thought to be independent of memory. There seems to be a complex relation between past information, strategies and attention, (e.g. Norman, 1969).

3) The Process of Codification

This consists in the transformation of information

into a code with which the memory system can operate.

The way in which information is codified seems to involve the following characteristics:

- (1) - It is unique.
- (2) - It has information about the sensory modality which received it.
- (3) - It has contextual information concerning other events already known in the same sensory modality as well as in others.
- (4) - There is a rapid change to an abstract code.
- (5) - Codes conserve many of the basic parameters of information, (in other words, codification is achieved without loss of information).

There are some indications as to how codification occurs:

- (1) - By the structure of the codifying system which codifies. For example, there is evidence that optical illusions are the product of the kinds of filters used in the perceptual system (e.g. Ginsburg, 1975).
- (2) - There is evidence that codification is categoric, although the elements are not necessarily fully differentiated (Batenson and Chantrey, 1972; Garner, 1974).
- (3) - There is evidence that cultural factors affect the codification of events.

For instance the work of Tzeng et al (1977) that demonstrates that codification of letters can be done in two ways. The first is as acoustic encoding and the other

as semantic encoding. In this last one phonological aspects do not seem to be important. These kinds of encoding change according to the characteristics of the language studied. For instance, English codification of words seems different than German codification of words. German speaking subjects the acoustic confusion of letters is much less common than in English speakers. If it is true that codification depends in this case on the language used, the researchers who emphasize encoding in short term memory (e.g. Baddley, 1978; Morton, 1978) will have to modify their theories since it seems that the form of encoding they propose is language dependent.

Differences in language not only affect the way in which information is codified, but using letters which are codified in a phonologic form or in a form of ideogram (Park and Arbuckle, 1977), seems to affect the memory performance. Additional data relating to the way in which language affects codification comes from the study of dyslexias, which is difficult to find in Japan, because Japanese is an ideographic language (Makita, 1968).

These examples of codification are interesting because they indicate the limits of the available models of memory. There is a confusion between the experimental variables (in this case phonetic variables) and the theoretical propositions of codification (in this case acoustic codification). If the models of memory in Norman (1970) or in G. Bower (1977) are analysed it can be observed that most models mention acoustic codification, but the experiments that give support to the models are done only with English speakers.

4) The Process of Labelling and Grouping

One of the factors which facilitates the acquisition of information, is the ability to form categories to handle new information. That is, to use old pre-stored information in the process of acquiring new information. This process is not exclusively verbal, there are many other forms. In a sense, every event that enters the system of memory is first related to what is already known. In this way the system does not need to "learn" the same event several times. Every stimulus which reaches the system is analysed using several processes and grouped in some information net.

The results of experiments I and II (Chapter III), imply that in most experiments of memory what has been done is to activate a process of labelling and grouping. In most experiments the subjects are receiving stimuli that consist in material already known, therefore what they probably do is to group it. Despite the vast number of experiments, knowledge concerning information grouping is scarce and is limited to the studies on clustering by Bousfield, (1953) who studied the organization of material into groups is determined by stimuli or by the subject (Cofer, 1976). Thus, the problem is still open, and this process needs to be studied more systematically.

5) The Process of Analysis

In cases in which information is not easily classified, a more detailed study of the information is initiated

by the memory system. This sort of study uses learned strategies to analyse information, for instance, it uses left to right procedures in the analysis of non-sense words, (e.g. Wickelgren 1977). A vast amount of past information is also used to detect similarities, (e.g. Katona, 1940; Posner, 1973). There is evidence that this analysis of stimuli does not work from the more specific to the more general aspects, but the reverse, from general categories to details, as suggested by Minsky, (1975). Likewise, the question of constancy does not only involve physically simple forms. There are examples of more "abstract" kinds of constancies, (e.g. Julesz, 1971).

6) The Process of Comparison

Posner (1973) demonstrated this process by asking subjects to indicate whether two stimuli presented were different or similar, (the similarities of the events varying from being physical to being semantic). By measuring the reaction time, he observed that the time it took the subject to give an answer is a function of the complexity of the comparison. Subjects had both to compare stimuli presented in the same sensory modality and ones presented in different modalities.

This process of comparison can be generalized to a great many situations, many of which have not yet been studied experimentally. For instance, it may be the basic process involved in decision making and may also be involved in the comparison between the "real" and the "ideal".

A situation which illustrates this point is where information given to the subject is incomplete and although the subject knows "something" is missing, he cannot specify what it is, (e.g. Flores, 1970). Many comparisons in the memory system may require "metrical systems" of which we have no knowledge at all, as it is shown in the experiment IV, (Chapter III).

As it was mentioned in the introduction of the experimental section, (Chapter III), the idea of mental comparison can be found in Fechner (1860). However, it is only now that representation is being considered, that it is possible to study the processes of comparison. Even in the case of "simple" comparisons such as the ones in psychophysical studies, (e.g. Stevens, 1957; 1966) it is necessary to postulate the participation of memory, since although the stimuli are "outside" the subject, the comparison is probably based on subjects' internal representation of events. However, there have been no suggestions about how comparisons take place, even though they are supposed to occur.

7) The Process of Decision

An extension of the previous process is the capacity to make decisions based on incomplete information. This process required the help of other processes. The process of decision is therefore, not perfect and predictable but influenced by knowledge and often even by "irrational information" structures.

8) The Process of Buffering

As there is so much information in the memory system, it is necessary to postulate a system of buffering, which consists in the retention of certain information for easy access and use. This process does not involve bestowing an intermediate status on the input of information, but rather, is a process of extracting old information in relation to what is entering the system at any given time. This process is an important and necessary part in the activity and results of other processes.

An example of this process can be observed in experiment II (Chapter III). In this experiment, subjects moved the information that was contained in the "buffer" (which in this particular case is called "imagery") and manipulated it, probably using other processes in order to generate an answer not previously known. Other examples of buffering as an active process of manipulation of information are found in the work of Baddley and Hitch (1974). There is in the literature, vast information about this process of buffering, (e.g. in G. Bower, 1977); it seems that researchers on memory consider short term memory as a phenomenon in which information enters and leaves from either the environment or long term memory. In other words, short term memory is used to explain this process of buffering, (e.g. Hitch, 1978). This shows how more sophisticated ways of understanding the storage systems are being proposed herein.

9) The Process of Change

This process allows the combination of two separate groupings of information and the production of new information which can be used in different ways from the original groupings. When two groupings of information are combined, they are not only "added"; rather, their internal relations are integrated to produce new relations. For instance, this process seems to operate when two words are combined to make a third one, with a different meaning and characteristic, (e.g. "epistemic-machine"; "dialectical-psychology"). This process of change works with real or ideal information, and its results are complex. The basis of this process may be found in the use of abstract characteristics of representation or internal codes and not simply in the manipulation of physical characteristics, (e.g. Kvale, 1974).

Possibly the biggest difference between present models of memory and the conceptual structure proposed here, is that herein it is supposed that information in memory changes. To suppose that the content of the information can be altered by memory processes implies that the memory system is capable of generating more information without the need for learning as such. If it is true that memory is reconstructive in this sense, (experiment III; Chapter III) then the kind of memory models available will have to be modified. This raises the possibility of explaining certain "intelligent or creative" processes by which humans generate new combinations of information. A simple case is that of artists who combine known elements (colour, words)

in new structures of information. Other cases are observed in the capacity of people (mainly children) to understand and generate combinations of new words (e.g. Clark and Clark, 1977). Although the example of language is well known in linguistics, it is absent in models of memory.

10) The Process of Transfer

A great deal of literature is directed to the problem of transfer of information, especially referring to the transfer of information from short term to long term memory, (e.g. Baddeley, 1976; Wickelgreen, 1977). However, even though in memory models some "boxes" (short term memory, long term memory, etc.) are presupposed from which "arrows" denote the movement of information from one "box" to the other, the process of transfer of information is rarely made explicit. Possibly it is thought that information flows in the same way as electricity or water. This idea of flow of information was probably taken from cybernetic models where electricity flows from one location to another.

The evidence of movement of information in the memory system does not imply that this movement takes place from one metaphorical box to another. In order to be able to understand this process it will be necessary to have more information about the internal codes and their characteristics. Nevertheless, the idea of transfer of information is a process that can help to explain several aspects of memory. For instance, in experiments I, II and III (Chapter III), it may be supposed that there was flow of information.

Transfer of information may also explain experiments where what seems to happen is that there is a problem of accessing information (not merely forgetting), (e.g. Shiffrin and Atkinson, 1969; Murdock, 1974). A specific example of the limits of this process of transfer of information is the "tip of the tongue" phenomenon studied by Brown and McNeill, (1969). In this case the subjects who have to give an answer cannot give it even though they report that they know it.

11) The Process of Response Generation

This process is complex, especially in relation to language. It could be proposed that a master control is necessary in order to classify and direct which information net should be used and in what order, as well as to determine the modifications necessary to the algorithms, for their adequate performance in different situations. Sometimes the generation of responses involves only the performance of skills already known, but in other cases, new patterns have to be produced. If the new patterns are effective they may be stored for use in future similar situations.

The processes described here are not an exhaustive list and only indicate examples of the kind of phenomena which are to be found in the literature. As was mentioned in the previous chapter, the supposition of a reconstructive memory necessarily requires the postulation of processes of manipulation of information; since reconstruction in

memory clearly indicates an active change in information. However, if memory research is to be used to explain other phenomena, it will also be necessary to postulate such active processes. For instance, the experiments of Baddley and Hitch, (1965) demonstrate that there is an interaction between short term memory and the solution to various intelligence tasks.

In conclusion, the utilization of various processes plays a significant part in memory functioning. Support for this suggestion is found in the fact that:

- (1) - The various processes of manipulation of information, are not only experimental, observed phenomena, but are necessary for the construction of memory theories.
- (2) - A number of phenomena and problems, such as the ones suggested in Chapter II, cannot be explained using only the available models, (Chapter I).
- (3) - The most important aspects of the present models of memory are, first, their dependence on the concept of static-trace, (experiments I and II, Chapter III) and, second, their lack of interest in the reconstructive aspects of memory, (experiment III, Chapter III). The introduction of these processes in future models of memory is important as a motivation for the designing of future experiments to come.

3. HOW IS INFORMATION STORED AND REPRESENTED?

Having described the functions and the processes of memory which according to the conceptual structure proposed here, are considered to be of most interest, a basic point

nevertheless remains to be analysed - namely, how is information stored. The answer to this question, is: - it is not known - a common answer in psychology and in science in general. The answers which have been attempted have only given us some analogies (or metaphors):

(1) Information is represented in humans in the form of images which are a point-to-point codification of events, represented as an "internal picture", (e.g. Paivio, 1971; Anderson, 1977).

(2) Information is stored as propositions that can be of different kinds: (A) As propositional representation where the events are translated into a system similar to the predicate-calculus, where the events are something like axioms or propositions. For instance, Clark, (1969), comments that in a logic system of the following kind: "A is smaller than B; B is smaller than C, etc." it is possible to manipulate information using logical tools similar to the ones used in theorem proving in mathematics. (B) Another propositional form in which information can be stored is as a network where the information is assumed to be based on units (which represent one thing or subject); properties, (which represent characteristics of the unit) and pointers, (associations of various types among units and properties). This model of Collins and Quillian (1969) describes some forms in which information can be represented, and makes several predictions. This model has been extended and modified by Anderson (1976) and Anderson and Bower (1973).

- (3) A third form of an interpretation of memory as a propositional form is as a set model in which it is assumed that information is represented as a series of features in which it is supposed that some features are essential and others are accidental. This work is represented by Smith et al (1974). These three versions of memory as a propositional representation were arbitrarily chosen and are only used to illustrate the active form of theorization about representation of this approach.
- (4) Another analogy found about how information is stored, is modelled on the statistical analysis of events (Evans, 1967).

All these attempts to give an answer to the problem of how information is stored are simplistic although for each of the alternatives there is some experimental support. However, it should be emphasized that these are attempts to give an answer to questions different from those posed about the problem of memory in-the-past when the problem of memory referred to its parametric characteristics. Then, the questions referred to how many repetitions are necessary in order to remember something; how big does the list have to be; what are the effects of the material or of different kind of presentation; how much is going to be stored; how many kinds of stores are available; and so on. It seems that the concept of internal representation, embodying how the information is stored, is a relatively new concept around which research in this area is developing.

The hypotheses discussed herein, are only a first attempt and will require more elaboration. These are hypotheses relating to a series of questions which are relatively new, and they will be useful only if this is kept in mind. To propose explanations between which a researcher must decide has led to premature discussions, as has already been mentioned, in the case of propositional versus pictorial representation. A symptom of how premature this discussion is, is the lack of elaboration of the different positions as well as the apparent disinterest in other possible alternatives, (e.g. Evans, 1967). Likewise it also seems that there is a lack of interest in a number of alternative models, judging from those which have not been taken into account (e.g. Pribram, 1977).

Before an answer can be given, it will be necessary to analyse in more detail the problem of how information is stored. One way of analysing this problem is to specify the characteristics of possible solutions. Instead of deciding on one of the hypotheses mentioned, (or several others found in the literature), criteria might be elaborated which could be useful in seeking a solution to the problem.

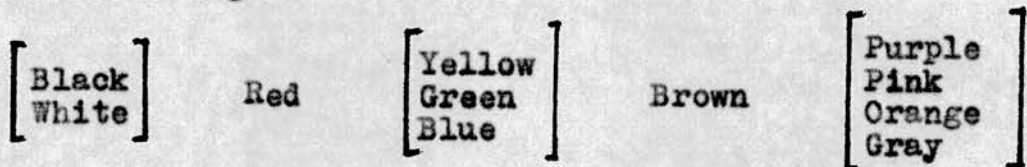
As was already mentioned, the problem of representation is relatively new. However, some of the terms and phenomena mentioned have a long history. For instance the metaphor of images, as presented by Hannay (1971) has ancient antecedents. Representation is mentioned nowadays as one of the most important aspects of cognitive psychology

(e.g. Anderson, 1977). As Pylyshyn (1973) comments: "Cognitive psychology is concerned with two types of questions: What do we know?, and How do we acquire and use this knowledge? The first type of question... concerns itself with what might be called the problem of cognitive representation". One of the ways to study how we represent information, is pointing out the difference between codes and abstract codes. The term "codes" refers to the neurophysiological approach to the study of memory. It has been observed that there are different forms of codification in the C.N.S., as well as different forms of processes participating at this level of study, (e.g. Defeudis and Defeudis, 1977). The term "abstract codes" refers to those used in psychology as "constructs". For instance, to talk about images, supposes an abstract code that represents information in the form of a grid of $m \times n$ elements, where the values assigned to these elements are continuous, that is, represented in a form of a picture. To refer to a model of images, does not specify concretely in which form the abstract code is presented in the brain. The same happens with the idea of propositional representation where it is only assumed as a possible analogy. Perhaps this form of abstract code is not so abstract, since examples and descriptions are being used, and the object represented is almost a copy of the real object. In one case the relation between representation and object seems direct, as in the case of images, but in the case of propositional representation, an analogy is given to

computer languages, (e.g. Anderson, 1976) or a metaphor of physical and semantic features is used, (e.g. Smith et al 1974). In short an abstract code, involves rules of correspondence between code and object. Specifying the nature of abstract code is difficult, mainly because of the lack of relevant data. This also indicates the limitations of the pictorial representation and propositional representation models. If it is not possible to specify the differences between neurophysiological and abstract codes, the concept of representation in a psychological sense will remain unclear. Some researchers, (e.g. Anderson, 1977; Shepard, 1978) have attempted to specify the characteristics a code at a psychological level should have, but they have not made a distinction between this and the neurophysiological code. The idea of an abstract code has been used in an axiomatic way, that is where proof of its validity is not necessary. Another simpler kind of code might be proposed; for instance, postulating a continuity between neurophysiological and abstract codes. But the results would be different, and the kind of theory that could be proposed would have a hybrid character. On the other hand, it might be supposed that codification does not always take place at one level, and that certain "events" are codified at one level while others are codified at more or less abstract levels, (Pribram, 1977 and Fodor, 1975).

Another criterion that may be useful for solving the problem of how information is stored involves the notion

of a genetic program. It has been suggested that a part of the abstract code is biologically determined. A clear example of this postulate is Chomsky's (1968) concept of "deep structure". He suggests that there is a "universal grammar" biologically determined. This postulation of a genetic program refers to two things: first, to the structure of the cognitive system, and second, to the way in which the system works. In both cases it is supposed that there is biological determination. An interesting example of this kind of programming is the study of basic colour terms done by Berlin and Kay, 1967 and Kay, 1975 who studied the number of terms used in different cultures to describe colours. These authors, observed that the amount of basic terms that different groups use range from 2 to 11. The terms are not produced at random but have a structure. For instance in the language using only two terms, these are black and white. They also observed that in languages with more terms, these are used in a systematic form, that is taking colours from the following hierarchy, from left to right:



It also was found that if persons from different groups are asked which is the most representative red colour from a set of tokens, of different colours, there is a high degree of consistency. An extension of these studies is the work of Bornstein et al, (1976) who demonstrated that

four month old babies respond in a categoric way to colours, that is, pay more attention to those colours considered by adults as best representative: blue, green, yellow and red. In other words, it seems that babies give a categorical response to a physically continuous dimension.

These results can be considered as examples of interactions between biological aspects of cognition and language development. Although the fact that children use a biological system to detect colours, formed by 3 or 4 basic colours, is not that significant, the development of names to indicate colours in a systematic form is relevant to how information is represented.

This criterion of biological programming leads us to the next criterion for the problem of how information is stored. This refers to internal representations due to psychological development. Any model attempting to explain representation has necessarily to describe the development of representation. The example just referred to, about the development of colour terms is a clear example of how it seems possible to find rules about some aspects of internal representation, and how the development of colour terms is a specific process and not the result of random activity. Another example of development of forms of representation is found in Piaget's idea (Piaget and Inhelder 1973) of stages of development, for instance in the use of images. The concept of memory development should not be limited to conceiving of processes which grow

in size or quantity of information, but extended to conceiving of the participation of new forms of manipulation of information.

Another important criterion for solutions to the problem of how information is stored involves specifying the processes of manipulation of information. This criterion has already been mentioned, but it is only when representation is considered that to postulate such processes produces a substantial difference between a "modern" theory or representation and the traditional models of memory. Processes help to give a more active sense to the models. This point was illustrated in the experiment III, (Chapter III), where the idea of reconstruction depends on the existence of processes capable of transferring information.

In conclusion, the problem of how the internal representation takes place, is one of the critical points in memory research before it will be possible to give a thorough explanation. If knowledge in this field is to develop, there is a need for new data (for example experiments III and IV, Chapter III) and new ideas (as the ones mentioned here). To decide in favour of one party, or one of the hypotheses, is a waste of time since the explanatory hypotheses now available are too limited. An example of how limited these hypotheses are is that they are not explicit about the criteria mentioned here, namely difference between code and abstract code, role of genetic

program, development of representation, and participation of processes. Changes in emphasis in the study of memory can be seen recently in work such as Fodor's (1975) on representation.

4) EVALUATION OF THE CONCEPTUAL STRUCTURE PROPOSED

As was mentioned at the beginning of this chapter, it is difficult to find criteria of evaluation of conceptual structures and not only that, it is difficult to define conceptual structure. However, it is necessary to evaluate the conceptual structure presented here.

Throughout the chapter, two conceptual structures have been illustrated with examples such as Ebbinghaus' (1885) or Tulving's (1972). An evaluation of Ebbinghaus' work indicates its theoretical and experimental influence, in the amount of research that it generated, as well as the generation of different kinds of theories and hypotheses in memory research. Likewise, the conceptual structure of Tulving, albeit more limited than Ebbinghaus', also seems to be as a valuable tool mainly for the understanding of semantic aspects of information. Tulving made explicit the distinction between learning with and without meaning, and suggested that learning with meaning was important, (even though the concept of meaning is not clear). The conceptual structure presented by Tulving is not the only one that can be found in the literature. For instance, there are others, such as the idea of levels of processing, proposed by Craik and Lockhart (1972) which has generated

some activity. However, it has not been very valuable as an instrument of work as demonstrated by Nelson (1977); Baddeley (1978); and Broadbent (1977), although it has also been modified by its authors, (e.g. Craik and Jacoby, 1975; Lockhart, Craik and Jacoby, 1975).

The conceptual structure presented here and especially the description of processes, is partially an evolution of certain ideas of Bartlett together with some results from more recent memory research. It has been suggested that the study of the possible functions of memory can give a new perspective to research, especially if the variety of important problems related to memory are taken into account, (Chapter II).

A special way to evaluate this conceptual structure, which may be useful for figure memory research, is to compare it with the theories of memory such as the ones represented by Shiffrin and Atkinson (1969) or the version proposed by Atkinson and Westcourt (1975), which was described in Chapter I. This comparison is partial and limited since the orthodox theory is elaborated in a precise way and the conceptual structure proposed herein is only a series of propositions and possible ideas for future use.

In order to evaluate the conceptual structure presented in this chapter, let us emphasise some points which are considered to be weak points in other theories (mainly the orthodox theory) and relate them to the possibilities offered by this conceptual structure. When

possible, the experimental data presented in Chapter III will be mentioned, as it is an expression of the conceptual structure proposed. The first limitation that the orthodox theory has is its dependence on the idea of trace exemplified in specific form in the idea of iconic memory. This limitation is demonstrated by the results of experiments I and II (Chapter III). This limitation is only the elaboration of a misleading assumption in memory research: To consider letters, nonsense syllable and related material as novel elements to be learned instead of as opportunities for the re-organization of old material, leads to many mistakes. The implications of this misleading assumption are many, one example of this problem is the fact that much of the evidence about short term memory and long term memory is based on experiments which make the same mistake.

Related to this misleading assumption is the idea of information received in a static way, either in short term memory or long term memory, where it is supposed that old information is not important and does not play any role in the collection of new information. Data supporting the notion that memory is not a static trace come from studies on reminiscence. These studies indicated that in some situations over time instead of forgetting, there is, on the contrary, an improvement in performance, and that this change in memory is not affected by interference or other experience after learning, (e.g. Ederlyi and Klienbard, 1978). Experiments such as these suggest the need for

totally different interpretations of memory. Experiment III (Chapter III) can be taken as evidence for Bartlett's idea, which is absent in the orthodox theory, that memory is a system capable of generating and changing information. However, Bartlett's ideas have not been elaborated in a more complete way and it is necessary to take some hypotheses from recent work, in order to postulate a possible way in which reconstructive memory might work.

Two important ideas for the development of the kind of approach in memory research as is proposed herein are, first, the experimental demonstration of different processes of manipulation of information (scanning, comparisons, etc.) and, second, the ideas of representation with images is not alone sufficient, (e.g. experiment IV, Chapter III), for it will be necessary to have more elaborate ideas in order to explain.

Another limitation of the orthodox theory is the specificity of its postulates, which do not allow the solution of the great number of problems in this area, as was described in Chapter III. This leads to one of the most important limits of the orthodox theory, that is, its lack of ecological validity. Specifically the orthodox theory, is related to and directed towards the explanation of "laboratory problems" and in many cases it is restricted to "old verbal material" and is not directed towards the phenomena involved in learning and memory in general.

One of the characteristics that would be desirable in a theory of representation, as well as in a theory of

memory in general, would be a description of the processes of development of the forms in which information is acquired, as well as the development of the processes involved in memory. If it is true that a number of learning situations are studied with familiar material, it will be necessary to describe which are the forms in which basic events are acquired, and this probably can only be achieved by studying infants. Therefore, it would be desirable for a new theory of memory to include studies on infants and emphasize how basic events are acquired and organised.

Another limit of the orthodox theory is that it is a passive system and not a system capable of predicting changes in the environment. One of the ways to analyse the capabilities of the cognitive system to predict events, is to propose a process of generating hypotheses for particular tasks which in turn leads to the concept of the model of the world and the model of action proposed in this chapter. These postulates are not an attempt to make more complex memory models, but to try to give a more realistic answer to specific phenomena found inside and outside a laboratory, such as the serial order of behaviour, or to try to explain the personal knowledge scientists and artists. Even in the most sophisticated forms of representation derived from the orthodox theory, such as the works of Smith et al (1974) and Collins and Loefstus, (1975), representation is considered as a store and not as a tool for the solution of problems. To some degree

these models of representation are only an extension of the associationist ideas as clearly presented by Anderson and Nower (1973) in their model of HAM.

Another limitation of the orthodox theory is that it is elaborated as an attempt to explain a series of specific experiments, (e.g. experiments of short term memory) and has grown with new results from other experiments (iconic memory, differences between short and long term memory), thus it is not the result of an attempt to make a theory of memory, and is therefore limited in scope and range of extension.

In conclusion, the orthodox theory of memory, which is representative of current theories of memory, has serious limitations, mainly in its dependence on the strict concept of trace and its basis in experiments using verbal material. Because of this, one of the characteristics that would be desirable in a future theory of memory is special emphasis on the reconstructive aspects of memory information use. However, some of the aspects of the orthodox theory, such as the postulation of processes of information manipulation, will certainly be useful in the explanation of memory. It appears that memory has a number of functions each of which has important influence on behaviour, only if all these functions are taken into account will it be possible to understand the cognitive processes. Although it is possible to develop some hypotheses about the functions, processes and reconstructive aspects in information use,

the specification of how information is represented is still an open problem. Perhaps at the moment to solve this problem will involve collecting more clear experimental data. This certainly will be necessary before we will be able to decide between possible interpretations of representation, memory and information use.

GENERAL CONCLUSIONS

**"Wir müssen wissen!
wir werden wissen!"**

**(We must know!
we shall know!)**

**D. Gilbert
(1930)**

This work has been an attempt to evaluate some experimental-theoretical relations in contemporary memory research. On one hand, some theories can be found like the theory of Shiffrin and Atkinson (1969) which is based on a series of ideas such as the concept of static trace and stages of processing. On the other hand, a great deal of phenomena and problems in memory research are open to investigation and cannot be integrated in a general view. This is due not only to a lack of interest in theoretical work but it is also possibly due to a limitation of some of the basic ideas, as it was suggested by the experimental results presented here, (Chapter III). Based on this evidence it is considered that there is a need for a change in the conception of memory. One of the possible alternatives consists in using the ideas of Bartlett (1932) and some of the ideas that can be characterized in a very general form as "cognitive psychology". These ideas could be used as a conceptual structure for the development of better theories in the future.

As it was suggested by the experimental evidence, the idea of reconstructive memory of Bartlett is a tool that together with the idea of processes of manipulation of information helps to see the phenomena of memory in a clearer way and related to other important cognitive processes.

In this work the possibility of change and active memory were emphasized, and experimental evidence was given

in its support, (Chapter III). This possibility can help to explain some of the phenomena of memory mainly if it is considered that humans are organisms moving in a changeable environment and are not abstract entities of laboratory. This idea of change must be taken carefully in order to avoid a violation of certain semantic limits connected with the concept of memory, mainly because the theory of memory is interested in constant aspects as well as memory processes and not in the specific changes in the contents of information of certain particular subjects.

The results of the experiments on iconic memory have important implications for the theory and research in memory and give some indications of the need for a critical analysis of the way in which work in this area is carried on, since this basic concept of iconic memory incorporated in most recent models of memory, does not seem to be constant for all experimental situations.

The experiments on reconstructive memory suggest the possibility of studying the contents and change of memory and not what the experimental situation or the experimenter puts inside the system.

In the same way these experiments allow the study of the power of resolution present when working with images, as well as the study of the limits of this kind of representation with a systematic technique.

One of the most important conclusions of this work is the need to develop new views in the form of theoretical work and to overcome the empiricism (positivism), in order

to take a step towards a new way of tackling the experimental and theoretical problems as it is done in other sciences.

The need for more theoretical work to guide and put order in research seems to be among the primary necessities in the area of the psychology of memory.

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