INDIVIDUAL DIFFERENCES IN LEARNING STRATEGIES AND EXTERNAL REPRESENTATIONS

by

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Abstract

This thesis is about learning strategies that are specifically taught, presented in instruction booklets and then learned, in order to perform verbal recall tasks. It is also about how learning strategies that are not specifically taught and in this thesis called 'representations' are used by individuals to work out problems. There are two parts to the thesis. The first part used wordlists and learning strategies to assist subjects in learning lists of words. The second part of the thesis used problems and no taught or instructed learning strategies, but asked the subjects to show their 'workings out' in answering the various problems.

Four experiments are reported in the first part of the thesis. Subjects were aged 13 - 14 years in the first two experiments and 10 - 11 years in the latter two experiments. The Cognitive Styles Analysis was only used in the fourth experiment. The words chosen in all the four experiments were familiar nouns and adjectives and selected from common categories including: food, mode of transport, and animals. The results of these experiments show that either being taught or learning the strategies from written instructions does not greatly influence subjects' list learning performance. Also, it is unclear from the literature if the learning of learning strategies in learning lists of words, has a long lasting effect on the learner.

The second part of the thesis examined the 'workings out' of subjects after completing a variety of problems including : analytic reasoning, verbal reasoning, spatial, and mathematical word. This part of the thesis included two studies and in both the Cognitive Styles Analysis (Riding, 1991) was given. The subjects were postgraduates and undergraduates in experiments five and six, respectively. The data was analyzed in terms of not how many problems were correctly answered but how much representation and how many different types of representations were used in arriving at a solution to each problem. The representations were categorised according to the number of 'characters', 'lines', 'pictures' 'ideas' and 'letters' (number of characters used in total - the number of characters used in the answer) used in each problem. The results showed that most subjects used representations in solving problems. They also showed that such factors as age and cognitive style had an influence on the type of representation used.

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PREFACE

The introduction describes the broad aims of the thesis and the research project in which it was placed.

Chapter One provides definitions of the term 'learning strategies' as applied to list learning, and presents a wide overview of the history of learning strategies, human memory, gender and learning strategies, and cognitive styles and learning strategies.

Chapter Two presents four studies which reflect the areas of investigation outlined at the end of Chapter One.

Chapter Two (Study One) describes an investigation into the learning performance resulting from being taught seven learning strategies to recall four word lists (two concrete and two abstract) and also being given an instruction booklet to learn the strategies. There was one experimental group. Fifty secondary students were in the Study.

Chapter Two (Study Two) is again an investigation into the learning performance resulting from being given a modified instruction booklet on how to use one learning strategy and also being taught the same learning strategy. The learning strategies were reduced from seven to one. The experimental group was divided in four and each student was assigned a different learning strategy. The word lists were changed to all concrete nouns and single category. Fifty secondary students were in the Study.

Chapter Two (Study Three) is another investigation into the learning performance resulting from being given another modified instruction booklet on how to use one learning strategy to recall word lists and also being taught the same learning strategy. The learning strategy instructions were made simpler because the subjects were younger than those in Study Two. The experimental group was divided in four and each student was assigned a different learning strategy. The word lists were changed to all concrete nouns in three mixed categories such as 'food' and 'transport' and 'animals' and per list. Ninety - nine primary students were in the Study.

Chapter Two (Study Four) is another investigation into learning performance resulting from being given an instruction booklet on how to use a learning strategy to recall word lists and also being taugh the same learning strategy. The learning strategy instructions and words were the same used in Study Three. The experimental group was divided in four and each was assigned a different learning strategy. The Cognitive Styles Analysis (Riding, 1991) was introduced in this Study and given to all the subjects. There were 76 primary students in the Study.

Chapter Three provides definitions of the term 'external representation' as used in problem solving and presents a wide overview of the use of representations in problem solving. It discusses the history of problem solving, external representations, gender and the use of representation in problem solving, spatial ability and representations, mathematical problem solving and representations, and age and the use of representations in problem solving.

Chapter Four presents two studies which reflect the areas of investigation outlined at the end of Chapter Three.

Chapter Four (Study Five) describes an investigation into how external representations are used in solving three analytic reasoning problems. Seventy postgraduate education students were in the Study.

Chapter Four (Study Six) describes an investigation into how external representations are used in solving four much simpler problems (two verbal reasoning, one spatial and one mathematical word) than those in Study Five. There were 60 undergraduate education students in the Study.

Chapter Five outlines the conclusions of the thesis and discusses the implications for future studies.

INTRODUCTION

A mutual aim of teaching and learning is to help the student learn tasks more efficiently and hopefully be able to transfer this knowledge to new situations. Learning strategies have been used throughout time to make this aim achievable. There have been many definitions of the term and in this thesis Ally and Deshler (1979) offer the practical definition that learning strategies are the tools and techniques used by the learner in the understanding and learning of new materials or skills.

In educational and training situations individuals are faced with learning information as efficiently as possible because of the increasing amount of knowledge that is available. The teacher or instructor has to deliver more information in less time. In order to make this possible the teacher or instructor may decide to assist students by directly teaching them learning strategies. Alternatively, they might present them with written instructions and examples of learning strategies and let their students learn the strategies via a self-teaching method. The outcome may be that the student has found that learning the strategy has made his learning performance in a task better, unchanged or worse. It is hoped that the strategy has made his learning performance better.

Children differ in their learning ability and when they enter school they will encounter many new learning experiences and may experience difficulty in learning tasks in various degrees. They will be learning familiar or new words in their lessons and approach learning in different ways as individuals differ according to many characteristics including gender, age, and cognitive style. Cognitive style refers to the way a person processes information. It is a fixed characteristic and influences the way people approach learning tasks. Because children differ they obviously will learn at different rates and need different help in their learning. In learning to do a particular task, some will rely on being taught a learning strategy to do it, some will rely on written instructions about how to use a learning strategy to do a particular task, some will rely on both methods together and some will not need any assistance. Those not needing assistance may have learned various learning strategies over time and find they are using them in the solving of tasks. The purpose of this thesis will be to address these two different approaches to solving a task. The aim of the first part of this thesis is to compare performance on learning lists of words with or without the assistance of learning strategies. This might reveal whether teaching and instruction in 'learning strategies' are beneficial to students and it might also be revealed by the introduction in the fourth experiment of the Cognitive Styles Analysis (Riding, 1991) how cognitive styles affect the way an individual responds to being taught or instructed, to use learning strategies in learning lists of words. Four experiments were conducted in the first part of the thesis using children from primary and secondary school. The following research questions in Part One of this thesis were considered:

1) Does the teaching of learning strategies and giving instructions to learn the strategies have an influence on list learning performance?

1a) Does cognitive style and teaching learning strategies and giving instructions to learn the strategies have an influence on list learning performance?

The aim of the second part of this thesis, which contained two experiments, was to observe the use of external representations in the solution to problems, without teaching or instruction. This might reveal the amount and types of external representations being used by students to solve problems. It might also show how individual differences such as cognitive style affect the use of external representations in solving problems. The following research questions in Part Two of this thesis were considered:

1) Do individuals use external representations in the solution to problems?
2) Does cognitive style have an effect on the external representations used in problem solving?

The following terms will be used throughout this study:

Learning Strategy -
A learning strategy is an organised approach to a task and can be a way of facilitating learning, aiding problem solving, or accomplishing any task undertaken by the learner. This is the more general term and includes the term mnemonic but not vice versa.

Mnemonics -

Mnemonics are mental devices to improve one's memory, mainly long-term memory.

Initial Letter Strategy and First Letter Strategy -These terms will be used interchangeably.

External Representations (ERs) -

External representations stand for something in the absence of that thing, representing something about the world. They take many forms including pictures, diagrams, and words. Cox and Brna (1995) found external representations (ERs) are effective in reasoning due to their cognitive and semantic properties.

Research Views of the Study

Learning Strategies and the Learner

The manner in which to describe what occurs when an individual perceives and retains information from the external environment has been investigated by many researchers Eysenck (1977) .To distinguish what happens between short-term and long-term memory when an individual tries to recall a word is very complex. According to Atkinson et al. (1993) recalling the name of a person two seconds after being told it is an example of short-term memory, but recalling the same name a few hours later it is more difficult and is an example of long-term memory. Learning strategies have been developed to make the retrieval of information from long-term memory easier. Our means of learning is through language, which is essentially a symbolic medium for aiding the expression of thought, and it does so with varying degrees of accuracy. Word lists were studied in the first part of this thesis and as words are minor thought processes and it is possible (as symbolic logicians have done) to use them or their abstracted equivalents to study the nature of thinking (Eysenck, 1977).

Teaching Learning Strategies

In school, perhaps there should be time set aside for children to reflect upon how they remember words and this might give us clues to the learning strategies they use. The teacher might see the opportunity to teach a strategy where it was needed. For example, if a child could not remember the names of the children in his reading group he might use the story strategy (Crovitz, 1979) in which a person creates a story using all the names he wants to remember in a way that is meaningful to him. This strategy might be helpful in different subjects in the National Curriculum such as history where for example, a story could be created to learn the order of the Kings of England. Mnemonic techniques, such as the story strategy, have been successful even with relatively artificial materials (nonsense syllables and unrelated words (Yuille and Catchpole, 1974 and Weinstein, 1975). However, research indicates that time has to be devoted to learning and practicing strategies with the learning materials such as real and nonsense words.

Learning Materials, Instruction and Cognitive Style

A child learning the colours of the rainbow may be presented with materials in different ways by his teacher. For example, to instruct a child in how to learn the colours of the rainbow, the acronym 'ROYGBIV' (representing - red, orange, yellow, green, blue, indigo, and violet) might be taught. Or in contrast, each colour of the rainbow might be displayed on a piece of card and taught to the child. However, the teacher is not first finding out in which way the child learns best. The teacher is observing what the child knows or does not know. The learning strategy chosen by the teacher to aid the learner might not assist him in the learning of a particular task. The teacher would be at a greater advantage if he knew the cognitive style of the child he was teaching and then a learning strategy could be adapted to that child's cognitive style in a particular learning situation.

External Representations and the Learner

It is known that individuals use external representations in the solving of problems by examining their notebooks, homework, and exam papers. Serious examination of these visual representations e.g. a diagram, is not usually done by teachers or instructors, but has recently become an object of focused research and has been used by people since unknown time (Kulpa, 1997). External representations as defined by Zhang and Norman (1994) are in the world as physical symbols (e.g. written symbols) or as external rules, constraints, or relations embedded in physical configurations (e.g. spatial relations of written digits and visual and spatial layouts of diagrams). In this thesis external representations will be known as 'ERs'. How they are used in the solution to analytic reasoning, verbal reasoning problems, spatial and mathematical word problems and if the cognitive style of a person has an influence on the type of external representation used in the solution of the aforementioned problems is the focus of the second part of this thesis.

External representations have been influential in science and literacy. According to Kulpa (1997) much of the progress in science involved finding new representations of various phenomena or formal constructs for example, the diagrams of Euclid. Studies on literacy show the important functions of external representations. The classical view on writing, originally developed by Aristotle and presently restated by Bloomfield (1993) and Sassure (1983) is that writing merely transcribes or re-represents speech from one external representation in auditory form to another external representation in visual form.

Pemberton and Sharples (1996) support the view that external representations are the markings that writers make, singly, or in collaboration, on some external medium such as paper or a computer screen. They include notes, topic lists, written plans, idea maps, outlines, tables, concept maps, argument structures and annotations on the draft document as well as the draft in all its stages.

According to Pemberton and Sharples external representations can be short lived or idiosyncratic. They give the example of a simple *adhoc* sketch (or a shape described in the air or via a trace with a finger on a desktop) indicating intentions that are too amorphous to express easily in words.

External Representations in Graphical and Linguistic Formats

Knowing that external representations are used by people in solving problems necessitates further categorisation of the different graphical and linguistic representations that are used.

Stenning and Oberlander (1995) in studies of logical reasoning with diagrams argued that diagrammatic representations such as Euler's circles limit abstraction and by that means assist processibility. In other words, graphical representations can make some information interpretable and transparent in a particular form at the expense of limiting abstraction in general forms.

Cox and Brna (1995) reported that external representations referred to a wide variety of representations in both the linguistic and graphical modalities. Lohse et al. (1994) in their analysis of visual representations identified 11 basic categories: Graphs, tables, graphical tables, time charts, networks, structure diagrams, process diagrams maps, cartograms, icons and pictures. The term ER (external representation) as discussed by Cox and Brna also included sentences of natural language, sentences of formal languages (e.g., first order language logic), tables, lists, graphs, maps, plans, and set diagrams. Cox and Brna (1995) examined self-generated external representations used in solving analytic reasoning problems.

External Representations and Cognitive Styles

There have not been any studies to this author's knowledge of using the Cognitive Styles Analysis (Riding, 1991) first and then seeing the effect it had on the external representations that students used in their solution to analytic reasoning, verbal reasoning, spatial and mathematical word problems.

In a study by Cox and Brna (1995) about the use of external representations in the solution of analytic reasoning problems the authors report it is evident from the results of the workscratchings, for any given analytical reasoning problem, there is a large variation between subjects in the types and modalities of ER that individual subjects use on different problems. One source of the variation may be individual differences in cognitive style.

There are two parts to this thesis and the first part endeavoured to investigate the effects of teaching and instruction in the use of learning strategies on list learning performance. In the fourth experiment the Cognitive Styles Analysis (1991) was included. In the second part the investigation changed to whether individuals use external representation(s) in the solution to problems and the influence of cognitive style on these external representations.

The Chapters of the Thesis

Chapter One of this thesis examines the research that has been done in Learning Strategies from the time of the Greeks to the present and takes into account the following topics:

The Learning Process and Memory, Learning Strategies and their Historical Development in Verbal Learning and Individual Difference Variables. Chapter Two considers four experiments on 'list learning' conducted with children. Chapter Three is concerned with the smaller body of research as compared to the research on learning strategies that has emerged historically since the Greeks but more modernly in fields such as artificial intelligence known as 'external representations'. This chapter is divided into three main sections including External Representations, Problem Solving and Individual Difference Variables. In Chapter Four two experiments were conducted, one with postgraduates and one with undergraduates on 'problem solving'. The fifth experiment focuses on more difficult problems than the sixth experiment. These difficult problems are analytic reasoning problems. The simpler problems are verbal reasoning, spatial and mathematical word problems. Chapter Five discusses the results and implications of the six experiments and offers suggestions for further study.

CHAPTER ONE

MEMORY AND THE USE OF STRATEGIES IN LIST LEARNING PROBLEMS

INTRODUCTION

This brief introduction describes the background that initiated the research in this thesis. Starting from a teaching perspective of how to help students learn more effectively, it was thought that teaching them 'learning strategies' might produce a difference in learning.

The research to be reported in this part of the thesis is about learning strategies and their influence on verbal learning. From the time children enter school they are required to learn words in their lessons. Recall of the words is testing an individual's acquisition, storage and retrieval of words. The young child might use a learning strategy like 'rehearsal' (acoustically encoding, for example, a digit or word and then trying to recall it) in remembering the words but not be aware of the learning strategy he is using to remember them. In a given reading lesson, a teacher might present a child with a list of words taken from the child's reading book and ask him to learn the words. Teaching children learning strategies to remember words might be advantageous at the time a child is learning to read, because he might be able to use the strategies in other subjects. For example, in learning a set of words associated with transportation in a History lesson it would not be appropriate for a child to use the 'Initial Letter Strategy' in learning the following words e.g. motorcycle, tractor, truck and car. This is because a suitable acronym could not be formed from the initial letters of those words. It might be suitable to use the 'grouping strategy' (Bousefield, 1953) in learning these words, in which the child would be told that words associated with a particular topic (in this case, transportation) can be grouped together.

To assist the student in his learning it was thought that various learning strategies should be explored in the area of verbal learning. Individuals differ in their learning and these differences might influence their use of learning strategies and some of these variables are learning ability, gender and cognitive style (habitual way of processing information).

This first part of the thesis aims to find out how learning can possibly be made easier for the learner. It looks at how memory works, the learning strategies that have helped in the learning of verbal tasks and how individuals differ in their learning taking into account such variables as gender, age, learning ability and cognitive style. The following three main areas and corresponding main subheadings form Chapter One.

The Learning Process and Memory (how the individual interprets information)
learning and memory
coding and representation
remembering and memory

Learning Strategies (their historical development in Verbal Learning)
learning strategies
mnemonics

Individual Difference Variables and Learning Performance
verbal ability, spatial ability, and gender
cognitive style

THE LEARNING PROCESS AND MEMORY

This section describes the components of the learning process and includes the following: attention and memory, short-term memory, working memory and long-term memory and metacognition.

LEARNING AND MEMORY

Attention and Memory

A child in school may be presented with information to learn by his teacher, for example, a list of concrete nouns. In order to encode this information into short-term memory the child must attend to it by selecting it e.g. if a student borrowed some library books and was asked
to state the colour of the librarian's hair, he might not know because of not paying attention to it in the first place.

According to Hebb (1949) Aristotle's belief that learning is not possible without intention to learn and no memory of a sensory event was possible unless it was attended at the time of its occurrence required further explanation. Hebb maintained an event may be peripheral to the focus of attention and remembered, but usually attention enhances learning and memory. Attention and memory are distinct yet associated cognitive processes. Attention facilitates the process of encoding information before it has been recorded in memory and later accessed or retrieved. Broadbent (1958) reported that attention was necessary for such tasks as monitoring a radar screen or inspecting items on an industrial production line and attention came under the general title of 'vigilance'.

Short-Term Memory and Long-Term Memory

Galton (1883) was concerned with conscious attention and the concept of short-term memory is related to consciousness but it is not the same thing. Galton believed ideas were stored in something called an ante-chamber of consciousness and in today's terms this ante-chamber is known as short-term memory according to Baddeley (1990).

In contrast, storage sites for long-term memory are in cortical networks that are distributed throughout the cortex, probably in cortical networks that initially processed the information (Squire 1987). Information can be retrieved from long-term memory based on the principles of organisation and use of retrieval cues. It is possible to facilitate retrieval by storing information in an organised way. The more carefully organised the information is, when it is stored, the more easily it is retrieved provided a cue or place to begin is identified (Tulving and Pearlstone, 1966).

Working Memory

Baddeley (1986) described 'Working Memory' as active because it focuses on the active interpretation of newly presented information and also on integration of previously stored information. The model of working memory contains three major parts: the phonological (articulatory) loop, the visuo-spatial sketch pad and the central executive.

Gathercole and Baddeley (1989) found that phonological memory skills in four and five year olds were directly related to vocabulary learning. Working memory allows for temporary storage of information in the phonological (articulatory) loop or in the visuo-spatial sketch pad and both are overseen by a central executive function. The visuo-spatial sketchpad stores visual and/or spatial information. The phonological loop is used for the storage of verbal information. This loop consists of two related but independent subcomponents, a phonological store and an articulatory loop. The phonological store can receive information from either the auditory system or from visually presented text information recoded into a speech based form. Information in the store decays rapidly unless it is recycled, which is the process carried out by the articulatory loop. This is thought to be an active rehearsal based process, possibly involving subvocal articulation. This system is believed to have a limited capacity, which is time-based and it stores approximately two seconds worth of verbal material.

The phonological loop mechanism accounts for several standard findings from tasks involving the short-term storage and recall of verbal information. One is the word length effect, which is the poorer recall for lists of long words than lists of short words. This appears to be the result of the time limited nature of the rehearsal process; it takes longer to articulate words with more syllables therefore, fewer can be placed in the loop (Baddeley, Thomson and Buchanan, 1975). On the other hand, in the acoustic similarity effect the poorer recall of lists of phonologically similar items than lists of dissimilar items is due to the coding of information in the phonological store. Poorer recall results from the difficulty of discriminating between decaying memory traces, which are similar. Since the items are presented verbally the coding must be based on speech sounds (Salame and Baddeley, 1987). Neisser, 1967 viewed the central executive system as monitoring and co-ordinating the functioning of the memory systems and deciding the order in which processes would be performed.

The development of short-term memory capability has had considerable research attention over recent years. Children’s verbal memory span, tested with either digits or words, increases from approximately two to three items at four years of age to seven to eight items at fourteen years of age (Chi, 1978). The explanation for this change from a working memory perspective is that the younger children have slower rates of articulation, which means slower and less efficient subvocal rehearsal therefore, fewer items can be retained in the articulatory loop, resulting in shorter spans. As the child gets older, articulation improves, allowing more efficient and faster subvocal rehearsal, so that more items can be maintained in the loop.

When a child learns a new word they need to learn the meaning of the word, so the word becomes linked with a representation of its meaning in the long-term memory system. The child also needs to learn the sound structure of the word and a programme for reproducing the articulatory movements necessary to speak the words themselves. There has to be an adequate temporary memory trace in the phonological loop for the pattern of the word's sound structure to be successfully transferred. The more substantial the memory trace in the loop, then the more successful the transfer of the new word to long-term memory will be. Baddeley (1986) has shown there is a significant relationship between memory capacity and the ability to learn new words. Those with better working memories will learn more new words.

Metacognition

The term 'metacognition' refers to knowledge in two ways, knowing about one's own memory ability and limitations (an individual might know for example, that for him or her, names are difficult to remember) and knowing that tasks require different strategies according to the situation. There have been several studies concentrating on these two types of metacognitive abilities. The former type was examined by Brown (1978) in considering secondary ignorance (not knowing that one does not know). He maintained a mature learner evades secondary ignorance by knowing what task and relevant information is available and whether knowledge gaps can be filled via making inferences from this knowledge or whether knowledge must be acquired from an external source. In another study, Miyake and Norman (1979) showed that in order to ask a question it is essential the learner must know that he or she does not know something, but most importantly have an idea about what that something is. An individual might know for example that recognition tests are on the whole easier than recall tests.

Several studies on gifted children considered the second type of metacognitive ability, knowing that tasks require different strategies according to the situation. Studies will be discussed by the following authors: Swanson (1989), Kurt and Weinert (1989), Anderson (1985), Borowski and Peck (1986), and Bjorklund and Bernholtz (1992).

Swanson (1989) asserted that high verbal ability groups appeared to utilise qualitatively different monitoring strategies than non-gifted children. There were some conditions under which the gifted children were more adept in their use of monitoring strategies but exactly what triggered the efficient use of monitoring strategies was ambiguous. Swanson further argued that there was no hint that ability differences in cognitive monitoring diminish or accelerate with age. A contrasting view was held by Flavell (1971) in maintaining that the development of encoding and retrieval strategies are age related, as are increases in monitoring and knowledge about these encoding and retrieval operations.

Studies on 'strategy' use by gifted students showed on the whole, that they used strategies more effectively than their non-gifted peers did. In a German study Kurt and Weinert (1989) reported that ten to twelve year old gifted children were more likely to use study and recall strategies for a sort-recall task than their nongifted contemporaries. Furthermore, twelve- year-olds were more likely to use these strategies than ten year-olds. Anderson (1985) stated that gifted ten-year-olds used strategies for reading more efficaciously than non-gifted children. Borowski and Peck (1986) maintained that gifted eight-year-olds were more capable of adopting a clustering-rehearsal strategy during a maintenance task than their non-gifted peers when given only a brief verbal explanation of the strategy. The gifted subjects pre-existing metacognitive knowledge filled in the gaps in minimal training (Borowski and Peck, 1986). However the ability to monitor one's own strategy use was examined by Bjorkland and Bernholtz (1992) in asking children six, eight and ten years of age to name the strategy that they had used to remember classmates' names. Those whose reported strategy was similar to their observed strategy were labelled as 'consistent'. Those who could not name a strategy or who named a strategy dissimilar to their observed strategy were labelled as 'inconsistent'.

It was interesting that subjects of high and low intelligence were just as likely to be labelled as consistent as high intelligence subjects were.

In addition, Cavanaugh and Perlmutter (1982) maintained the knowledge about how to use mnemonic strategies differs among individuals. An individual might know that rehearsing a phone number just found in a directory would assist in ensuring its retention. An individual may also know that he or she is quite adept at remembering names (person variable) and also know that the task to learn the names of 20 new students is a laborious (task variable) and therefore, may need some strategy like imagery (strategy variable).

This section encompasses the coding and representation of information including: spatial memory, verbal memory, imagery and memory concrete and abstract words and sentences,
and arguments against the dual coding system of Paivio.

CODING AND REPRESENTATION

Spatial Memory

Spatial and verbal ability were the major variables of cognition according to Bannatyne (1971). In discussing spatial ability, Walter (1953), Pribram (1962) and Gregory (1966) maintained that visual perception was neurologically a scanning and matching process. According to Bannatyne (1971) spatial perception and spatial memory of objects and scenes, etc. was static or constant. When one sees a moving object it is tracked with one' s eyes to keep it relatively static in the line of vision. All visual mechanisms appear to concentrate on holding an image steady at the focus of the gaze long enough for one to recognise it by matching it against one's previous experiences. It is known that this occurs in reading (Lesevre, 1966).

Stewart (1965) compared subjects of high and low spatial ability on several memory tasks. The two groups were of similar intelligence. In a paired-associate task, picture-digit and word-digit pairs were used. It was found that the picture-digit pairs were learned faster by those with higher spatial ability. In a study of recognition memory for words and pictures the results were replicated. High spatial ability subjects were superior to low ability subjects on picture recognition and the opposite outcome was obtained for word recognition. The high spatial ability subjects found it easier to code a word as a picture than the low spatial ability subjects and the low spatial ability subjects were more able to code a picture as a word.

Verbal Memory

The study of language as psychological phenomenon has often been approached through other strata of subject matter. According to Bannatyne (1971) for example, those psychologists who have been studying intelligence have investigated verbal ability as one factor of something known as 'g' {Spearman's general intelligence (1946)}. In contrast, some psychologists have placed emphasis on motivational and emotional aspects of language. Neurologists have approached the problem of language by citing the functional areas of the brain, which are involved. A question to educationalists is why individuals differ in their ability to learn words.

Vernon (1961) pointed out that verbal ability was an inherent part of intelligence and as such must have an inherited basis. Bannatyne (1971) stated it is the potential for language acquisition, the genotype pattern of maturational development and perhaps the cognitive style, which is inherited rather than the data content of information on which intelligence operates.

Hunt, Lunneborg & Lewis (1975) compared high and low verbal ability subjects on several tasks. High verbal ability subjects had advantages over low verbal ability subjects. For example, on the Posner paradigm (involving a name-matching task) they were able to extract meaning more quickly from a physical representation. In the Brown-Peterson paradigm (involving retaining a consonant trigram over a period of a few seconds filled with counting backwards) high verbal ability subjects were superior to low verbal ability subjects. Operationally, verbal ability was measured by an individual's knowledge of the meaning of words, syntactical rules and semantic relations among the concepts indicated by words, in contrast, memory were tasks devised so that extra-experimental knowledge will not systematically affect performance. Performance depended only on information known to all the subjects. According to Eysenck (1998) intelligence tests measure a static ability to display relevant knowledge and memory tasks are involved with more active processes.

In examining the verbal ability of those with limited linguistic skills (e.g. young children) and even with articulate subjects, Cavanaugh and Perlmutter (1982) maintained all kinds of knowledge were not equally verbalisable. Indeed, Wellman (1977c, 1978) and Yussen and Bird (1979) established a nonverbal technique for assessing memory knowledge. Pictures were substituted for words in the presentation of memory problems. Thus, those of limited language skills could use this nonverbal technique.

Imagery and Memory

Baddeley noted in the 1960s a revised interest in visual imagery was based on evidence that both the judged imageability of words and instructions to use imagery had powerful effects on the rate of learning lists of words and prose passages. Baddeley ascribed most of the interest in imagery to the work of Paivio (1969).

Paivio (1969, 1971) advocated that there were two basic ways of representing information in memory. One (verbal or linguistic) and the other was non-verbal (imaginal, including different types of visual images). The dual coding system as it was known was strongly connected and it was possible to determine an image from a verbal label and a verbal label from an image. Paivio believed dual coded information could be accessed by either a verbal or non-verbal retrieval process. There is however twice as much information about a twice coded item than about an item that existed only in one coded form.

The basis for the dual coding system came from experiments by Begg and Paivio (1969, cited in Ernest & Paivio, 1971) in which the main variable being manipulated was the classification of words into ‘concrete’ or ‘abstract’. Paivio (1971) posited that images play an important role in language comprehension. An image is not an effective way to store the meaning of an abstract sentence; a verbal representation is more effective. One knows linguistic material contains a high percentage of concrete words. The evidence stated provides support in favour of picture-like representations found in long-term memory.

Evidence for Paivio's Dual Coding System

Concrete and Abstract Words

A number of studies investigating the processing of concrete and abstract words and sentences have been done based on Paivio's representation of information (verbally and non-verbally). Jones (1988) maintained that concrete and imageable items were easier to remember because they were more elaborately represented within the long-term semantic memory system. According to Begg and Paivio (1969) when subjects were provided instructions to make imagery connections for concrete and abstract words they made these connections faster for concrete than abstract words. Ernest and Paivio (1971) discovered spatial ability had no effect on the speed with which subjects formed images to concrete words. However, high imagery subjects formed images to abstract words significantly quicker than low imagery subjects did.

Paivio (1966) reported that concrete nouns gave rise to more imagery than abstract nouns. Pictures were even more efficient in producing imagery than concrete nouns, Paivio (1969). Accordingly, mnemonic systems in learning and recall producing superior results may be due to the fact that they give rise to more imagery. The better performance with concrete words than abstract words was due to the fact that pictorial representations of concrete words is easier than for abstract words. In effect (a) images of concrete objects are already stored in long-term memory and (b) recall of concrete words is facilitated because subjects can use the information available in two forms (imaginal and verbal) to aid during the learning phase. Schwanenflugel and Shoben (1983) posed an interesting argument, that more time was required to perform lexical decisions for abstract than concrete words when they were presented out of context but the difference was cancelled out when these words were preceded by relevant sentences. Therefore, verbal memory and most auditory memory to be effective must be inflexible and its content fixed in memory.

Sentences

Sachs (1967) found that memory for a sentence's meaning and memory for wording decay differently. He showed that subjects did not notice whether a sentence had been changed from active to passive as much as they noticed a change in meaning i.e. positive to negative.

Begg and Paivio found in the work of Sachs (1967) that memory for a sentence's meaning and memory for wording, decay differently, held for concrete sentences but not for abstract sentences. For concrete sentences, subjects recognised changes in meaning better than changes in wording alone. For abstract sentences, word changes were recognised better than meaning changes. Paivio interpreted these findings in terms of the dual coding system. The meaning of concrete sentences was stored more by images than by words. Changing the wording in such a sentence but leaving the meaning intact won't affect the image representation of the sentence and the change will not be noticed.

Sachs' work was extended by Begg and Paivio. They stated that typically concrete sentences contain concrete nouns. In concrete sentences, semantic changes were better detected than lexical changes that do not effect the original meaning. Lexical changes were detected best in abstract sentences. The meaning of a concrete sentence was separated from the specific words, which composed it. Concrete sentences were stored in the form of images constructed on the basis of their semantic analysis. The exact wording of these sentences may be forgotten rapidly but the images these sentences elicit tended to resist decay. The meaning of abstract sentences was more dependent on the constituent words and the memory for their meaning was more closely associated to their wording. Davis and Proctor (1976) indicated that recall of abstract sentences was impaired by a significantly greater extent through verbal rather than visual interference and the reverse was true for recall of concrete sentences.

Arguments against the Dual Coding System of Paivio

Arguments against the dual coding system of Paivio question, what pictorial representations in long-term memory were like and whether they were like perceptions of the outside world. Pylyshyn (1973) doubted Paivio's system because in considering the volume of storage necessary to store detailed copies of everything we see would render human memory capacity to be unlimited. In addition, he questioned how one would use such stored scenes. The images would have to be retrieved and this would require re-perceiving and analysing them to see what was there. This would be an entirely inefficient system because the stored pictures would have to be perceived before they could be used. Pylyshyn claimed that the stored pictures might as well be stored as already perceived entities in contrast to exact copies of visual events. The main challenge was how to gain access to a picture via a word. A word usually corresponds to several pictures and selection is difficult. The word 'rose' for example, corresponds to many possible pictures: large, small, button, red, pink, yellow, etc. Knowing which of these pictures is correct to select for the word 'rose' is the problem. Pylshyn maintained that images or pictures must exist in memory as 'analysed entities' that is, in the form of general descriptions in contrast to 'raw sensory materials' or pictures of the outside world. Individuals were able to construct images in their own heads and subjective experiences were associated with mental images. He does not deny that individuals experienced mental images, but they were a separate issue from the notion about whether one stores picture-like codes in long-term memory. Having a subjective impression of forming images does not imply that one does this because one has the actual pictures stored as one should and on the same basis was able to reconstruct these pictures from stored abstract, general descriptions. He believed representation of pictorial knowledge about the world does not differ from the type of representation achieved through language and it was a unitary theory of imagery and verbal processes.

Recognition, by the subjects was based on that integration. The greater the number of initial simple ideas a sentence had (resembling the integrated form), the more it was likely to be recognised as one of the originally presented sentences. Pylshyn's study was based on concrete sentences and according to Begg and Paivio (1969) it should not extend to abstract sentences. Begg and Paivio believed that abstract sentences were stored verbally implying that changes in wording should be more recognisable and changes in meaning less apparent. However, abstract sentences, according to Franks and Bransford (1972) should make subjects more precise with their recognition judgements as they could discover changes in the wording of the test sentences. They demonstrated their initial results in subsequent experiments, whether abstract or concrete sentences were used. The implication of their finding was that concrete and abstract sentences undergo the same process in memory.

REMEMBERING AND MEMORY

Recall - Serial Learning

In serial learning, the subject listens to or reads a list of words (or other verbal material) which are presented one at a time. The list is repeated in the same order until some criterion is reached such as the subject learning all the words and being able to recite them without error. Ebbinghaus claimed the distinguishing characteristic of serial learning was that subjects must learn a chain of verbal stimuli in order and each time a list is repeated items are given in the same order. An example is memorising the order of the Prime Ministers of England.

Free Recall and Recognition

In 'free recall' the distinction between 'recall' and 'recognition' is made more indistinct when definite cues or other materials are used to facilitate recall. If words are learned in pairs and one of the pair (the stimulus) is presented to cue the recall of the other (the response) the reproduction of the response would seem to be easier to achieve than if the cue word was not supplied. The difference is that the cue word is recognised and this very recognition of the cued word in paired-associate learning very probably introduces recognition pathways, which would not be used in pure recall. If the cue 'car' has to recall the criterion response 'night' one could use a mediator, the word 'star'. The letters 'ar' would be the recognition bridge. Although recall and recognition may be separate neurological and psychological processes (not scientifically resolved) in the laboratory they may be closely interwoven. In list learning subjects listen to or read a list of words or verbal items, which are presented one at a time and then try to recall them in any order. If more than one learning trial is used the list is often given a different randomised order on each subsequent trial. It differs from serial learning because order of recall is not important for the recall. An example of free recall is to memorise all 'league' football teams in any order.

According to Baddeley (1990) the relationship between recall and recognition was one of the oldest in the study of memory. Simply to say that recognition is easier than recall is questionable and he points out that comparing them is difficult. A subject in categorising every item he saw as ‘old’ in an experiment in the recognition condition, and scoring 100% would not show evidence of achieving this score through having a good memory. There have been some interesting experiments done on ‘recall’ and ‘recognition’. In the former Fabricus and Cavalier (1989) examined the aspect of how memory strategies work to improve recall, and used a labelling strategy. The results were that children who gave mental explanations said labelling worked because it helped them keep thinking about the pictures that they saw in the experiment after they had said the names. This study was supported by several authors including, Baker-Ward, et al. (1984) who maintained that young children will label or name items that they are instructed to remember. In experiments on ‘recognition’ Noble (1954) maintained that in ‘familiarity’ the more often one sees an object the more rapidly one becomes familiar with it even if one does not know its meaning (purpose). Gorman (1961) and Shepard (1967) claimed the opposite happened for word recognition familiarity. Words which occurred most frequently in the language tended to be less well recognised than unfamiliar words as there was less interference between rare (but understood) words than between frequently used words.

Several experiments have been conducted on recognition and multiple choice tests. Postman (1950) and Davis (1961) found subjects performed poorly when there were too many alternatives from which to choose. Interference in either proactive or retroactive inhibition does not seem a very important factor in recognition experiments but as a concomitant to the number of choice alternatives (Adams 1967). Little has been done on similarity as an interfering variable in the recognition process. The more similar the multiple-choice items are the greater would be the difficulty in determining which item was the original stimulus, Bannatyne (1969). He said it was probable that letters of similar shape being scanned at speed would be more often confused than dissimilar letters.

List Learning

The British empiricist Locke believed that the mind at birth was like a 'tabula rasa' (blank slate). The basic learning unit was an association of ideas and sensations. Ideas were transmitted through the senses i.e. sight, hearing, taste, smell and feeling. To describe the learning process Associationists, in particular David Hartley (1705 -1757) created laws for the cohesion between sensations and ideas. Hence, a sensation evoked a corresponding idea and when several sensations recurred together, the later presence of any one sensation could arouse the memory of all the ideas.

Although the study of 'list learning' is a very complex cognitive process the method to explore this is in many cases easy to understand. The subject hears a list of words or nonsense syllables read aloud at a constant rate. The list is heard in its entirety and the subject will be asked to state the first word. He is then told the correct one by the experimenter and tries to recall the second word, receives feedback and so on. This process will end when the subject can correctly anticipate each word in the list without error. The subject goes through the list each time and this is called the 'trial'. It took Ebbinghaus, the German psychologist, five trials to learn a list like TOR, NIS, XAB, DIL, SEV, PAQ, CEW and BOF. Ebbinghaus invented experimental design and was the theoretician for explaining the results. He invented the three-letter nonsense syllable because he wanted to study 'pure' learning untouched by previous experience. Unfortunately, not all nonsense syllables are equally meaningless. He also wanted to devise a method for serial learning. He made up all his lists and selected one and memorised it. He then read the list over, one syllable at a time at a constant rate continuing for a predetermined number of trials or until he reached the point of errorless recall of all the words.

In the late 1950s there was a shift in the study of verbal learning. The conceptions of the stimulus changed and it was found for example, that when a particular verbal unit was presented as a stimulus in a paired-associate task, the learner might use the first letter or the first syllable as a cue. According to Underwood (1963), the student could select only part of the stimulus provided by the experimenter and that would be known as stimulus selection. In addition, whilst in the learning process the verbal response provided by the experimenter might be changed by the student. In order to learn VIP as a response, the learner might code it as ' 'very important person' ' and mentally rotate the first letter of each word only. The association between the stimulus and the response was thought to be more complicated and less direct than previously believed.

In 'list learning' Rundus (1971) and Baddeley (1996) concur that presenting a single item on two occasions was remembered better if the two presentations were spaced. When subjects learn word lists with the repeated words far apart from each other in the list (high lag) or next to each other (zero lag), repeated words with high lag (many intervening words) are better remembered than words with zero lag (no intervening words). One possibility is that the serial position effect is playing a part, so lag effect experiments must take special care to counterbalance for serial position. For example in a list of twelve words there are twelve positions: 1, 2 -12; one word might occur in place 4 and place 5; this is an example of a lag of 0 intervening words. If a word occurs in place 3 and place 9 there is a lag of 5 intervening words. Rundus noticed the behaviour of the students when there was a high lag, because the students rehearsed the word more than when there was zero lag. The amount of rehearsal aids in the transfer of information from short-term memory into long-term memory. The spacing effect may be explained by saying that it encourages more self-initiated rehearsal. In this author's Experiments (One to Four) the subjects were told to learn lists of words, but not told how to use rehearsal. The subjects ranged in age from ten through thirteen. Research shows that in serial recall nine year olds rehearse only the most recently presented to-be recalled list items (single item rehearsal) but as age increases gradually more use cumulative rehearsal Cermak (1983) and Douglas (1981).

Transfer

A transfer study concerns itself mainly with the effect of learning A on the acquisition of B (as compared to having learned something else, X, or nothing else). First, there might be positive transfer if the experimental group learns B faster than the controls. Positive transfer - e.g. taking a course 'Introduction to Psychology' will help students to learn material for the course 'Psychology of Learning' more than 'Introduction to Cooking'. In contrast, negative transfer occurs when the experimental group learns B more slowly than the control e.g. learning to drive on the right hand side of the road in the U.S. makes it harder to learn to drive on the left in England. Zero transfer occurs if the experimental group learns at the same rate as the control as previous learning has no effect on new learning.

A study by Best (1993) suggested children's strategy transfer was influenced by prior experience. Eight year olds induced to use organisational strategies through exposure to categorical materials demonstrated better recall and organisation both immediately and three - five days later than children not shown how to use organisational strategies. In this author's Experiments (One - Four) the strategy 'grouping' was taught to the subjects and the subjects were given a booklet instructing them how to use this strategy. In experiment four
the 'grouping' strategy was used equally effectively by boys and girls in learning the four lists they were required to learn.

Forgetting

The two different traditions in verbal learning as suggested by Cofer (1976) are the Ebbinghaus and Bartlett. The Ebbinghaus tradition is based on the question of how much is learned, transferred or forgotten. The central issues involved determine the behavioural effects such as the fact that the rate of presentation influences the amount learned, or that the time elapsed since learning influences the amount forgotten. Stimulus materials refer to nonsense syllables or the number of items recognised. In the Bartlett tradition the question asked is 'what kind?' Typical research investigates organisation of memory or different ways people relate new knowledge to old.

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Ebbinghaus's main theoretical approach was a refinement of the older Associationist philosophy, i.e. if sensations ABC were presented together a requisite number of times each giving rise to ideas a, b, c, respectively, the subsequent presentation of only one sensation, B, would elicit all of the associated ideas - a, b, c. (Hartley 1705-1757).

To summarise, Ebbinghaus's contributions were:

1. That it is possible to study higher level cognitive processes using a rigorous experimental. method so going against the dogma of the 19th century that such a study was impossible.
2. Developing nonsense syllables and methods such as serial learning.
3. The findings such as learning and forgetting curves.
4. Establishing a tradition of rigorous systematic experimentation and quantitative analysis.

According to Bannatyne (1971) new material being memorised interferes in some way with previously learned material and causes forgetting. Nelson (1993) presented a classic explanation of forgetting. It was caused by interference related to what had been learned during the retention interval. This learning interferes with the subject's ability to recover information after the initial experiment, either because the initial encoding has been suppressed (Postman et al.1968), unlearned (Postman and Underwood 1973) or because of response competition (McGeoch 1932).

<u>LEARNING STRATEGIES - HISTORICAL DEVELOPMENT IN VERBAL LEARNING</u>

LEARNING STRATEGIES

Learning Strategies and the learner

The definition of a strategy is an organised approach to a task and it can be called a method, plan, tool or technique that facilitates learning, aids problem solving, or accomplishes any task undertaken by the learner. According to Naour and Torello, 1991, strategies provide a carefully sequenced plan of student behaviours designed to effect successful task completion and learning. Ally and Deshler (1979) view 'learning strategies' as techniques that assist in the acquisition, manipulation, integration, storage and retrieval of information across situations and settings. In simpler terms strategies are the tools and techniques used by the learner in the understanding and learning of new material or skills. A 'mnemonic' is a technique that aids memory. In this thesis the term 'learning strategy' and 'mnemonic' will be used to describe the assisting of the learner in his learning. An example of a learning strategy would be to restate instructions in one's own words. An illustration of a mnemonic would be 'The Method of Loci' or the ability to remember locations and assign faces to each. Learning Strategy is the more general term and 'mnemonic' comes under its umbrella but the reverse is not true. In this thesis the terms 'Initial Letter Strategy' and 'First Letter Mnemonic' will be used interchangeably.

The Study of Learning Strategies

Mnemonics are essentially mental devices to improve one's memory, mainly long-term memory. Learning strategies may also assist in improving one's memory but they take into account such things as the characteristics, of the learner and the learning materials. A thorough description of the study of learning strategies as a three-part process and the two main classes of strategy under the heading of learning strategy as described by Dansereau, Long, McDonald, and Actkinson (1975) follow.

The Three-Step Process

Dansereau et al. (1975) described the study of learning strategies as a three-step process. First, the learner's characteristics are defined; second, instructional materials and procedures are designed, and third, the learner's performance data is analysed. The second step (designing instructional materials) is the main part of the entire process. The instructional materials are devised to address the shortcomings of the learner's characteristics or to make the most of a particular learner's characteristic. 'Instructional Procedure' is the term, which describes how the materials are to be presented. The student involved with the instructional materials must be properly controlled so the effectiveness of the learning strategy can be known. The important issue is not which learning strategy is the best but which one is best for which particular learner. For example, in a list learning task a child learning the colours of the rainbow may be presented with materials in different ways by his teacher. Instructing an individual in how to learn the colours of the rainbow, the acronym 'ROYGBIV' (representing - red, orange, yellow, green, blue, indigo, and violet) might be taught. Or in contrast, each colour of the rainbow might be displayed on a piece of card and taught to the child. However, the teacher is not first finding out in which way the child learns best. The teacher is observing what the child knows or does not know. The learning strategy chosen by the teacher to aid the learner might not help in the learning of a particular task. Indeed, Hunt (1971) stated that individual characteristics are talked about and yet educational planners work from models for the student in general. The teacher would be at a greater advantage if he knew the cognitive style of the child he was teaching and then a learning strategy could be adapted to that child's cognitive style in a particular learning situation.

Incorporating the teaching and learning of learning strategies as a separate subject into the National Curriculum would need considerable empirical evidence to support its inclusion but has the potential of making children more efficient in their learning. For example, being aware that people tend to group things together (Baddeley, 1990) children might become more aware of how they are categorising new information. This might result in their work being more organised and hopefully improved. Testing the effectiveness of a learning strategy is achievable according to Gagne (1973) as the accomplishment of a task can be measured which can then provide evidence of a learning strategy's effectiveness. The important issue for the learner is not which learning strategy is the best but which one is most effective for him in a given task. .

Primary and Support Strategies

According to Dansereau et al.1975, the two main classes of strategy under the heading of learning strategies are those, which operate directly on the materials and those operating on the individual. The first set of strategies are known as primary strategies and they aid the individual faced with having to learn material in identifying the vital, difficult and unfamiliar parts of the material, use techniques to understand and retain this material, and then later recall and use the knowledge gained in suitable situations. To study a manual on oscilloscope operation for example, students must be able to point out the main characteristics of operation that are unknown to them and once this material is selected (e.g. operation of the vertical-hold knob) the student has to decode the author's words and pictures in a comprehensible manner to himself. The student when using the vertical-hold knob for example, may better understand what to do by converting the statement 'Rotate the vertical-hold dial counterclockwise' into 'Turn the knob in the upper right-hand corner to the left'. The student is faced with how to commit this comprehended material to memory (retention). In addition, when faced with a task, the student must be able to recall the correct information and act accordingly (retrieval and utilisation).

Support strategies, the second category of strategies, allow primary strategies to flow effectively. They include techniques to form an appropriate learning attitude, methods to assist with loss of concentration due to fatigue and frustration, etc., and techniques for monitoring and correcting the ongoing primary strategies. Responses to a learning strategy inventory (Dansereau,1978) indicate that students could be helped from more effective strategies in both areas: primary and support. Most of the prior research on learning strategies were studies addressing specific components (primarily via instructions to the students) and those assessing more generalised training as in a, 'Learning Skills Course'. The studies concentrated on four primary strategy areas; identification, comprehension, retention and retrieval; and one support strategy area: concentration.

The student should make learning time efficient and in dealing with material has to identify its difficulty. In the past the research in this area tended toward manipulating the identification and selection of stimulus material by varying anticipated recall requirements (Butterfield, Belmont, and Peltzman,1971) or monetary payoff conditions (McConkie, Rayner, and Wilson,1973). The students could be flexible in processing of incoming information but the studies showed the manipulations were so task-specific that on the face of it they had little applicability to strategy enhancement in general.

Comprehension and Support Strategies

The area of comprehension and retention in relation to improving students' skills has involved stimulating students to change their comprehension and retention activities with experimenter-generated, pre-, post- and interspersed questions (e.g. Rothkopf and Bisbicos, 1967), pre- and post-supplementary organising materials (e.g. Scandura and Wells, 1967), and varying payoff conditions (McConkie and Meyer, 1974;). These approaches required experimenter manipulations and although the findings of these studies, in the main, indicated that the procedures had positively influenced the comprehension and retention strategies of the students, they were not directly transferable to less controlled students.

In order to improve students' ability on a specific technique more direct manipulations of comprehension and retention strategies have been based on the act of instructing (generally without training). Instructions to form mental images (pictures) of verbal materials (Anderson and Hidde, 1971), instructions to state the material in the student's own words (DelGiorno, Jenkins, and Bausell, 1974) and instructions to reorganise the incoming material (DiVesta, Schultz, and Dangel, 1973). Therefore, according to Dansereau et al. 1975 if instructional manipulations were effective they might be improved by actual training and by integration with training on other facets of the learning process.

Mnemonics

The main problem faced by the learner is not what is going to be learnt but how it is going to be learnt. Children and adults may acquire the necessary skills based on their experiences to learn information, but there is little emphasis on teaching them general learning strategies, which once learned might be transferred to the gamut of subjects. According to Weinstein (1975) learning strategies are derived from an extension of classical verbal-learning research traditions. It is the intention of mnemonics and other memory techniques to assist the learner in remembering.

Mnemonics are used as a means of improving recall of unrelated items by adding meaningful connections between them at the instance of encoding and these connections will at another time enhance retrieval. The other conceptual bases underlying research in mnemonics other than encoding are elaboration and mediation. Mnemonic techniques usually affect incoming material by interrelating the items to be learned or by associating the items of a set of peg words or images (mental pictures) previously learned. They are mental devices to improve one's memory, mainly long-term memory. They are known to speed up learning (Loftus, 1980). The study of mnemonics dates form the Greek goddess Mnemosyne, around 500 B.C. The term, 'mental images' (imagery) a main feature in many mnemonics, is very effective for connecting pairs of unrelated items. Classical mnemonics relied primarily on visual imagery. A modern study on imagery-based mnemonics by Wang and Thomas (1992), in comparing imagery based instruction and rote learning on long-term recall of English translations of Chinese ideographs, found there was not any indication that imagery-based mnemonics conferred an advantage beyond immediate test recall. However, Riefer and Rouder (1992) in their experiments exploring cognitive processes showed that bizarre or unusual imagery is recalled better than common imagery. The results showed that bizarre sentences benefited the retrieval of noun pairs.

In contrast, Peter Ramus in the sixteenth century devised a system in which information was represented in a hierarchical tree, with abstract concepts branching into progressively more concrete instances, Baddeley (1996). His was a system of verbal mnemonics and it was viewed as having the advantage of not requiring the learner to remember as much additional information as the location and pegword systems. Mnemonics as a useful method for improving retention gained popularity in the 1970s. In the 1990s mnemonics are still used as aids in studying for examinations and also introduced in courses such as 'law' where a large number of cases have to be remembered.

Some popular mnemonic techniques:

1. First Letter or Initial Letter Mnemonic - In order to learn the order of the nine planets the following phrase is commonly used 'My very earnest mother just said use nine planets'. The first letter of each of the words is also the order of the planets.

2. Story Mnemonic - Make up a story to help an individual remember words.

3. Retrieval mnemonics - Go through the letters of the alphabet to cue a forgotten name or retrace mentally, one's action during that day.

4. Peg Word - Miller, Gallant and Pribram (1960) suggested the standard rhyming pegword list first introduced by Sambrook in the late 19th century in England:

one is a bun
two is a shoe, etc.

In this method a person first learns a rhymed pegword list like ‘one is a bun’, two is a shoe, etc. and then learns to associate imaginatively each of these words with the members
of the list to be learned, e.g. in learning a list such as:
ashtray
firewood, etc.

Memory is then assisted by attaching each new word to its respective position,
for example,
one-bun-ashtray
two-shoe-firewood.

Peg Word Mnemonic

The Peg Word Technique featured in experiments by several authors. Paivio (1968) used the ‘Peg Word’ technique in an experiment in which subjects learned a list of ten nouns presented one at a time and were then tested for recall. A second list was presented and the subjects were instructed to use either the ‘one-is-a-bun’ list as a peg list or an abstract list such as: ‘one is fun’, ‘two is true’, etc. The Peg Word technique assists the learner by providing a kind of internal imagery. The subjects in the experiment by Paivio (1968) were divided in half, with one half instructed to form images connecting each peg word with its associate from the new list of ten words, and the other half instructed to repeat the number, peg word and new word over and over again. The result showed more words in the second list were recalled when a peg list was given as compared to a control group not given a peg list. The subjects who were told to form images improved their performance considerably over those who were not.

In a current study, Krinsky and Krinsky (1994) reported immediate and long-term serial list learning effects for common nouns with ten-year olds. Children receiving mnemonic training with the peg word (one-is-a-bun) technique showed superior immediate recall effects during post-test compared to pre-test. However, pre-test versus post-test differences were not detected with a test for long-term retention in two days following acquisition.

Again concerning the peg word mnemonic a classic study by Wood (1967) of five experiments investigated several dimensions of mnemonic systems and three questions resulted:

1. Under what circumstances, if any, do mnemonic systems facilitate learning?
2. What are the elements of the mnemonic device responsible for this facilitation?
3. What are the relationships between mnemonic devices and several variables that have been demonstrated to affect learning, such as transfer paradigm, type of list, and list abstractness in free recall?

In the first experiment mnemonic peg lists were received by some of the students and they were divided into groups and asked to use the following: bizarre imagery, common imagery, and a form of verbal mediation. Of the groups told to use bizarre imagery one group was told not to use rehearsal. Of the groups not given peg words, one group was told to make an image of each response word with a bizarre image. The final group was a control receiving free-recall instructions.

The second experiment investigated whether there was an optimal presentation rate for learners using mnemonics by comparing a two-second and a five-second presentation rate.

The final three experiments compared a bizarre imagery group and a verbal mediation group to find out whether these groups would perform differently on a negative transfer paradigm, a high interference or a mediation list, and word tests of varying degrees of abstractness.

The results presented many interesting findings including: the group given peg words and the group told to link successive items of the list with a bizarre image did better than the control group using just free-recall instructions. Rehearsal and instructions to use bizarre images had no increased effect on performance in comparison to unrehearsed common images.

Groups receiving instructions to link the peg and response words by either verbal mediation or by bizarre imagery were compared and no differences in recall scores were found in any of the experimental conditions in Experiments Three - Five. A significant interaction was obtained between instructions and presentation rate (Experiment Two). The group using peg words and bizarre imagery performed significantly better than the control group using free-recall at a five-second presentation rate than at a two-second presentation rate. Most of the experimental conditions involved only one trial and in those studies involved in more than one trial, students given peg words were showing an improvement with practice and those who were not given peg words did not. Stoff and Engle (1971) argued that learning skills require training over time not simple exposure.

Method of loci

This is a classic mnemonic and the Greek poet Simonides is regarded as the inventor giving this method its most detailed description. Cicero in the first century B.C. was a follower of rhetorical sophism and believed in the joint ideal of philosopy and rhetoric. Quintilian lived in the period following Cicero and was born in 35 A.D. Both Cicero and Qunitilian expanded upon Simonides work and the rules governing the method were given in the Ad Herennium (Yates, 1966). The 'method of loci'or the ability to remember locations and assign faces to each, led Simonides to the inventing of a mental tool for remembering long strings of words. The individual mentally placed items in distinct locations in a room or a known route (e.g. the route from the individual's front door to the kitchen) and in order to recall the information, the individual imagines travelling back through the route obtaining items as they occur.

Studies done on mnemonic techniques have usually compared the recall of students instructed to learn a list of items by using a mnemonic method, e.g. method of loci, to the recall of students who are told to learn the items and not given any instructions. In a study college students were asked to study a group of 40-item lists (nouns) using as loci 40 locations throughout the college campus (Ross and Lawrence, 1968). Students were tested for their immediate recall after studying the list and 24 hours later, prior to learning a new list. Immediate recall results were significantly higher when compared to those usually obtained in rote-learning experiments (Bower and Winzenz, 1970). In a recent study by Cornoldi and Debeni (1991) loci mnemonics facilitated the memory passages of a text, the increase being greater for oral presentation than after private study.

Rhyming Mnemonic

The rhyming mnemonic was introduced by Higbee (1994) in a study with college aged students. They were instructed to learn twelve sayings e.g. 'curiosity killed the cat'. The students in the mnemonic condition rated the task as being easier than the controls that learned the sayings without mnemonics.

Picture Mnemonic

Ehri et al. (1984) in two experiments evaluated whether picture mnemonics helped prereaders learn letter-sound associations. Pictures integrating the associates were compared with disassociated pictures and with a no-picture control condition. Children in the integrated group learned five letter sound associations, each represented by a picture whose shape included the letter (e.g. the letter 'f'' drawn as the stem of a flower) and whose name (flower) began with the letter's sound. Children in the disassociation picture, picture group, learned letter-sound associations with pictures having the same names as the integrated pictures but drawn differently (without letter shapes). Children in the control group learned associations with picture names but no pictures. The results were that children taught with integrated mnemonics learned more letter-associations and letter-pictures were effective because they linked two unconnected items in memory. The shapes of letters found in pictures reminded the learner of previously seen pictures with those shapes whose names began with the correct letter sound.

In another interesting study about shape, Liu and Kennedy (1994) explained how form symbolism using squares and circles aided recall. Their study found that 20 words like *soft* and *mother* presented in a circle called the 'congruent' condition were likely to be better recalled than those in a square (the 'incongruent' condition).

External and Internal Mnemonics

A study on mnemonics by Lovelace and Twohig (1990) differentiated between external and internal mnemonics. Some examples of the former are: make shopping list, written memos to self, put in a noticeable place, and calendar. Examples of the latter are: mental retracing, get visual image, go through alphabet, make up rhymes, number of items shopping for, acronym of first letters, make up story. It was made clear from the study done on articulate older adults, median = 68 years that subjects used the external mnemonics much more frequently than internal ones. This concurred with the findings by Intons-Peterson and Fournier (1986) for college students and by Harris (1980) for housewives with a mean age of 46 years. The subjects in the study by Lovelace and Twohig, also were more likely to use retrieval mnemonics, which are employed when something is forgotten, than encoding mnemonics, which are constructed during initial encoding and storage of the experience.

The external mnemonics used in the study by Lovelace and Twohig such as writing lists for example provided maximum likelihood of success with a minimum of cognitive effort. They are given to prevent prospective memory failures (forgetting to do something intended). The internal mnemonics are focused on reducing retrospective memory failures (losing the content of a memory).

Mnemonics or No Mnemonics

Sometimes an individual does not know he is using a mnemonic in solving a task. According to Bellezza (1981) there is support that indicates research participants frequently use some form of mnemonics whether instructed to do so or not. Mnemonic instruction in many studies has been shown to be a positive technique in helping to remember information. It may be possible to improve recall ability by finding out which mnemonics an individual uses without instruction and reinforcing this in subject areas where the individual might be having difficulty. For example, using the Initial Letter Mnemonic in the periodic chart of the elements in chemistry.

In a series of experiments by Camp et al. (1983) undergraduates were given a fifteen-word list and were asked to predict the number of words they could recall. They were not given any mnemonic strategies. The result was untrained subjects used sophisticated strategies. This study revealed that students might benefit by being told the sorts of strategies they are using without being taught them and perhaps they could use these strategies in different learning situations.

Studies by Baltes (1991) in Berlin found that when older and younger subjects were taught mnemonic strategies for learning word lists both groups improved greatly when given mnemonic techniques.   Also, older trained subjects outperformed untrained younger subjects.   More studies need to be done in teaching mnemonics to younger and older age groups in order compare their ability to learn word lists.

Recitation

Recitation is the act of reading or repeating aloud information and differs from rehearsal inasmuch as the latter is a more thorough process.   For example, one might be told to recite a stanza of a poem, but rehearse (from beginning to end) the poem for a presentation before an audience. Gates (1917), Honeck (1973) and Mayer (1975) used 'recitation' in an experiment with nonsense syllables, proverbs and paired-associate learning, respectively.   Gates found that subjects retained more than twice as much when they recited for 80 percent of the time as compared to a group that just read the list of sixteen nonsense syllables over and over again.   Self-recitation helped to organise and assimilate the material for the student.

Honeck (1973) found that self-recitation in the restating of new material in a way consistent with general past experience improved memory performance. He read proverbs aloud to college students, for example, 'Great weights hang on small wires'.   The subjects heard either a repetition of the same proverb or a meaningful paraphrase like, 'Many important things are dependent for their outcome on details, small wires that is' after each proverb.   In this paraphrase condition memory for the proverbs was better considering the subjects heard each proverb only once rather than twice.   The learner through this memory technique was helped to connect new, unfamiliar words with existing, meaningful knowledge.

Mayer (1975) in a study suggested that recitation has different effects when a clear organising format is available.   In a set of interlocking paired-associates such as: 1.) C to N; 2.) H to L; etc; some subjects were told before memorising that the paths symbolised airline flights between Chicago, Houston etc., and others were given the same information after memorisation of the paths. The tests required that subjects integrate long chains of paths, e.g. ‘How many legs from S to L?’ The Before group performed much faster than the After group. It was suggested that good integration of recited information into long-term memory necessitated that existing assimilatory sets exist in long-term memory at the time of memorising.

Rehearsal

The definition of ‘rehearsal’ given by Atkinson et al. (1993) is that it incorporates the conscious repetition of information in short-term memory, usually involving speech. The process facilitates the short-term recall of information and its transfer to long-term memory. They pointed out that short-term memory has a limited capacity and long-term memory an almost unlimited one. Rehearsal is a strategy used when the information consists of verbal items such as digits, letters or words. The authors gave the example that in trying to remember a phone number, we most likely encode the number as the sounds of the digit names and rehearsed these sounds to ourselves until we dialed the number.

Paired - Associate Learning

This learning involves stimulus-response pairs. The first component of a pair (the stimulus) is presented and the subject is supposed to give the second component (the response). It is a technique used often in the learning of a foreign language.

In the area of paired-associate learning Rohwer et al. (1967) and Bower and Winzenz (1970) investigated the use of verbal and pictorial elaborators in the former and different learning strategies in the latter. Rower et al. (1967) gave primary school children 24 pictures of pairs of objects by a pairing-test method. There were three types of pictorial representations: coincidental, locational, or actional, and three types of verbalisations: naming control, conjunction string, and verb string. Both visual and verbal elaborators resulted in performance being equally achieved as compared to a naming-only control group. The addition of an elaborator was seen by the experimenters to increase learning efficiency.

Bower and Winzenz (1970) told subjects they had to construct either sentences or images to connect a pair of associated words in order to facilitate improved recall. The image and sentence mediation instructions compelled the subjects to search for and encode meaningful relationships between the word pairs, according to the authors. They noted that it is the creation of semantic relationships that initiates the recall of the paired associates in contrast to the construction of a mental picture.

Mediational Skills

There has been limited investigation of the training and transfer effects of mediational skills. Miller (1956) maintained that the number of units or chunks one was able to retain was about 'seven'. This was again cited by Postman (1965). The aim of mediational skills is to group or categorise the content of chunks in mediational ways allowing the ultimate capacity of short-term memory to be extended. This process is best explained by the following example: by grouping letters into syllables or numbers in threes, which are viewed as chunks, several basic items (letters or numbers) can be remembered.

Groninger (1966) posited if subjects could add their own language mediation associations to the inherent meaningfulness of the stimuli, for example a paired-word association, an increase in short-term recall will occur. The term 'Natural Language Mediators' is used when a subject creates his own verbal mediators to aid in recalling stimulus material in both short-term and long-term memory. Adams and Montague (1967) found that Natural Language Mediators used in paired-word associates assisted recall as follows:

1. Sentence association - the two words are used together meaningfully in one sentence.
2. The two words are associated by a single link word of a generic or similar nature.
3. The two words are joined by a sound association; a common rhyme between the sounds in the two words is found.
4. The initial letters are associated and remembered.

There are other Natural Language Mediators that exist in paired word associates and in other types of association between words. However, it was (Adams 1967) that cited the important skill 'transfer-of-training' that viewed the subject as having the ability to understand the relationship between elements of a pair of words and integrated sequences in one's own language repertoire and employ these sequences in the learning of the pair of words. The learning of lists of unrelated words and word pairs in many studies has shown that brief instruction on mnemonic techniques improves retention (Yuille and Catchpole, 1974 and Weinstein, 1975). These mnemonic techniques have been successful with relatively artificial materials (nonsense syllables and unrelated words).

Mediation Skills and the Mentally Handicapped

According to Bannatyne (1971) if one wants to know a great deal about normal functioning in any aspect of life, it is extremely rewarding to examine the abnormal preferably in parallel. This applies to the following according to Gregory (1966): medicine, studies of perception, emotional and cognitive development as well as the complex developmental studies, which underlie language.

It has been suggested in the literature that children with learning disabilities when shown how to use mediation skills may find an improvement in their learning. Mediational skills assist one in recalling short-term memory and long-term memory items. Bannatyne (1971) stated that by grouping or categorising the contents of chunks in mediational ways the maximum capacity of short-term memory could be considerably extended. For example, by grouping letters into syllables, which are seen as chunks, many more basic items (letters) can be remembered.

There have been several studies on mentally handicapped children, adolescents and adults and the use of mediational skills. Studies on 'paired-associate' learning with mentally handicapped children revealed that little or no transfer of newly acquired mediational skills of the learning of new paired-associate lists occurred in studies by Jensen and Rohwer (1963) and Milgram (1967). Ross (1971) found in his experiment that mentally handicapped children were able to transfer mediational skills in the learning of a paired-associate task. Ross, Ross and Downing (1973) in a study based on the above mentioned experiment tried to determine whether mildly mentally handicapped children could acquire skill in devising elaborative mediational links through observational learning instead of direct instruction. The result in this experiment based on stories and related strategies showed that students in the two experimental groups, (intentional learning and observation) performed equally well when compared to each other and significantly better than the control group. In another study Turnure and Thurlow (1973) presented mildly mentally handicapped children with one, two or no elaboration experiences and then presented them with a standard paired-associate task. The children receiving one elaboration training experience did not perform significantly differently to those receiving no elaboration experience. However, children receiving two training sessions did show significant positive transfer on test lists with experimenter-provided mediators. These studies would seem to indicate that mildly mentally handicapped children in receiving training in mediational skills in repeated trials improve in their word acquisition and retention.

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Scruggs et al. (1992) using twelve and thirteen-year old students with learning disabilities, found those students in the mnemonic condition, who received a map with pictures accompanying place names representing reconstructed keywords of those names, out-performing controls on measures of spatial relocation and a correct place/name matching task. During this study a training session was followed by a 90-second filler activity.

In the second part of their study, which was about science, Scruggs et al. (1992) found students successfully learned to generate “class” mnemonic strategies for science learning. Kingsears et al. (1992) focused on mildly mentally handicapped students and their use of keyword mnemonics in instructional procedures. The results were favourable for imposed and induced keyword methodology in the learning of unfamiliar science terms.

In another study, Scruggs (1993) found that children who were mildly mentally handicapped did better under two conditions (elaborative interrogation and mnemonic elaborative) than in the direct teaching condition. The mnemonic elaborative condition, which provided students with mnemonic peg words to facilitate recall, resulted in recall of ordered reasons to be higher than in the elaborative interrogation condition. Students in both 'elaborative' conditions linked reasons with explanations for those reasons.

The literature on learning disabled adults and mediational skills training was small. The following study is a good example of the use of such training. Disabled adults were given mnemonic strategies on face-name learning. In this study Gruneberg (1993) showed that providing an actual mnemonic link resulted in superior performance to merely instructing subjects on the use of visual imagery.

To help those with mental handicaps mnemonic training has been shown in the literature to improve short-term memory. Teachers of children and adults with mental handicaps might benefit from being trained in mnemonic techniques. Future studies would be interesting in comparing the recall ability of those mentally handicapped individuals taught mnemonic techniques and those who were not taught these techniques, in various verbal learning tasks.
The main problem faced by the learner is not what is going to be learnt but how it is going to be learnt. Children and adults may acquire the necessary skills based on their experiences to learn information, but there is little emphasis on teaching them general learning strategies, which once learned might be transferred to the gamut of subjects.

Grouping

Baddeley (1990) maintained that the learner actively organises material. Bousefield (1953), in an experiment presented a list of sixty nouns made up of fifteen-item categories: animals, names, professions and vegetables, to subjects at a constant rate and then subjects were given ten minutes to list all the words they could recall. The tendency was to place items in groups that contained members of the same general category. Bousfield after many experiments claimed that students showed a definite tendency to place items in groups and called this 'clustering'. Tulving and Pearlstone (1966) found that giving the names of categories at the time of testing enhances recall and this study according to Baddeley was important in linking categorisation and organisation to retrieval.

<u>INDIVIDUAL DIFFERENCE VARIABLES AND LEARNING PERFORMANCE</u>

INDIVIDUAL DIFFERENCE VARIABLES

Verbal Ability and Gender

Vernon (1961) classified 'verbal ability' into four main areas: verbal reasoning, verbal fluency, vocabulary and clerical ability. Other authors such as Maccoby (1966) included several other measures and excluded clerical ability. According to Maccoby, throughout the pre-school years and in early years girls exceed boys in most aspects of verbal performance. They say their first word sooner, articulate more clearly and at an earlier age than boys using longer sentences. They are also more fluent in their speech than boys. At the time of starting school there are no longer any consistent differences in vocabulary between boys and girls. Girls learn to read sooner and there are more boys than girls who require special training in remedial reading. It would be interesting to empirically investigate whether more female than males (adults) with learning difficulties are better in the various aspects of verbal performance.

Maccoby in 22 studies on research in sex differences involving children three years old and under found in 18 of these girls showed superiority over boys. In the other four studies there was no sex difference, that is boys were not superior there either. The areas of study were the age of first speech, articulation, verbosity, verbal fluency, lengths of statement, vocabulary, grammar, reasoning, reasoning (verbal) and general verbal skills. It is difficult to believe that environmental influences in the first three years of life could have such an overwhelming bias in favour of females particularly as in some of these areas boys attain superiority later on (which is more in reasoning or thinking ability, than verbal skills). Maccoby and Jacklin (1974) again focused on an analysis of gender differences in verbal ability in 85 studies. They found during the time from pre-school to early adolescence the sexes were very similar in their verbal abilities. Anastassi (1958) and Maccoby (1966) agree that at around age eleven divergence occurred where female superiority increased until high school and possibly into adulthood. The size of the female advantage varied but was usually about one quarter of a standard deviation. In studies by Anastassi it was argued that there were gender differences for simpler verbal tasks, but Maccoby and Jacklin reported that female superiority was apparent in both high-level and low-level verbal tasks.

Maccoby also noted that throughout the school years girls' do better than boys on tests in grammar, spelling and word fluency. According to Maccoby, in number ability girls count earlier than boys but boys excel at arithmetic reasoning at secondary school age and at university level and adulthood. Vernon (1961) and Smith (1964) stated spatial abilities in males were superior. Maccoby (1966) in agreement further reported that while young boys and girls do not differ on spatial tasks such as form boards and block designs, by early school years boys consistently do better on spatial tasks and this difference continues through secondary school and university. It is obvious that many sex differences are caused by nurturance, social and other environmental influences and even though research attempts to support this point of view, it is not precisely defined. The biological differences between the sexes should have their counterpart in the neurology and psychology of the human being. Phylogenetically the sexual character of organisms is so basic that it can be exhibited by bacteria (Wollman and Jacob, 1956).

Vernon (1960) in a survey of intelligence tests and in particular, in the area of reading disabilities found boys predominate (Maccoby 1966). He found in particular that informational items show sex differences in favour of males whereas more purely linguistic ones tend to favour females. Females were relatively superior in spelling (a sequential fluency process) and inferior in arithmetic. Females did better on verbal fluency than males and males were superior on spatial and mechanical tests. Vernon is therefore, in agreement with Maccoby on gender differences in verbal ability, arithmetic ability, and spatial ability.

Beard (1965) in a factorial study of structure and perception found girls were superior in verbal fluency and Ballard (1920) in standardising his reading tests found girls scored above boys in their rate of reading. In agreement with Beard (1965) is Thackray (1965) in finding that girls were superior to boys in reading readiness and readiness skill tests involving auditory discrimination at the (1% level) using context and auditory cues at the (5% level). Also in this study, the Kelvin Measurement of Ability Test (Bannatyne, 1971) showed girls did better than boys on the vocabulary profile and two reading achievement tests.

Arguments supporting a slight Gender difference in Verbal Ability

Denno (1983) in contrast to Maccoby indicated that females were superior in verbal ability, with a slight advantage starting in the pre-school years and after age 10 or 11 the difference became more reliable. In a study by Halpern (1989) it was also stated that females had better verbal abilities than males. This consensus that females are superior to males in verbal ability does not in the review of the literature discuss the nature of the differences in enough depth. The two categories to be examined are: (a) which types of verbal ability show gender differences and which do not, and (b) developmental timing and its influence on the inclusion and exclusion of the differences.

Shibley Hyde and Linn (1988), examined the global statement that females have superior verbal ability to males because very little was known about the nature of the gender differences in verbal ability, both in the types of abilities showing gender differences or the developmental timing of possible differences. They chose meta-analysis (quantitative methods to combining evidence from different studies). Hedges and Olkin (1985, cited in Shibley, Hyde and Linn, 1988) also provided evidence about the gender difference in verbal ability and it was small. In their review of 65 studies Shibley, Hyde and Linn (1988) reported data on gender differences in verbal ability. They tested such areas as reading comprehension, vocabulary and general verbal ability. The weighted mean effect size (d) was +0.11, indicating a slight female superiority in verbal performance. The authors indicated since the differences were so small it could be argued that gender differences in verbal ability no longer existed. They maintained that gender differences in verbal ability for different measures were also small. Analysis of tests requiring different cognitive processes involved in verbal ability indicated no evidence of substantial gender differences in any form of processing. In the analysis by age there were no changes in the magnitude of gender differences at different ages, contradicting Maccoby and Jacklin's (1974) finding that gender differences in verbal ability emerge at about age eleven. Studies published in 1973 or earlier, d= 0.23 and studies published after 1973, d=0.10, showed a decline in the size of the gender differences in recent years. Again in contrast to Maccoby, Lynn (1994) pointed out that males have larger brains than females and that brain size was positively correlated with intelligence. Based on this evolutionary information Lynn pointed out that males should have higher average levels of intelligence than females. This goes against the consensus view that there is no sex difference in general intelligence. In the survey of the literature according to Lynn it was found that among adults, males have slightly higher verbal and reasoning abilities and superior spatial abilities and if these three abilities together form general intelligence, the mean for males is four IQ points higher than the mean for females.

In the area of emotional disturbance, school failure, delinquency, autism, social immaturity and defects of speech, hearing and vision, boys invariably outnumber girls (Bentzen, 1966). A study by Nass (1993) stated that boys more often than girls were affected by all the cognitive developmental disorders of childhood. In addition, it was noted that differences in the aetiology of learning disabilities, general sex differences in learning styles in boys versus girls revealed the male tendency in learning disabilities. By the age of ten Nass reported that studies have shown boys have caught up with girls regarding reading skills. In summary, the following authors support girls' superiority to boys in verbal ability: Ballard (1920), Vernon (1960), Beard (1965), Thackray (1965), Maccoby (1966), Maccoby and Jacklin (1974) and Halpern (1989).

Auditory and Speech Ability and Gender

According to Bannatyne (1971) when children enter school at age five, six or seven to learn to read and write, the majority of them have a substantial store of spoken and auditory language rich in meaning. Speech ability is the ability to articulate without difficulty and understand spoken language. In noting the differences in girls and boys several studies on auditory and speech ability will be discussed.

Studies on auditory discrimination by Dykstra (1966), Templin (1957) and Burt (1950) found gender differences. Dykstra in a study using a large structured representative sample illustrated significant sex differences in performance on three auditory discrimination tests and on two reading tests. All such differences favoured girls. Templin found indications that girls were more proficient in discriminating speech sounds during the developmental period than boys. Burt in studying London children revealed boys outnumbered girls 2:1 in reading backwardness and defective auditory perception.

Morley (1965), contrary to what had been expected said there was little difference in the age in which girls and boys first began to speak. Boys experienced greater difficulty than girls did in their use of oral symbols of speech with defective articulation or unintelligible speech occurring more frequently and persisting at a later age. Defects of articulation were found in twice as many boys as girls at five years of age and in proportion to 3:2 at 6.5 years of age. Unintelligible speech at five years of age was three times as frequent in boys as girls who had a transient period of stammering. Girls were verbally superior to boys in general and sometimes into adulthood. Rogers (1952) showed females were superior to males in spelling and articulatory flow. The automatic recognition or recall of auditorally registered sequences of sounds as well as superior vocal-motor fluency was also reported as higher for females.

If auditory input was excellent and speech organs efficient, then output should be fast and fluent. This hypothesis supported by various studies reported females were superior to males in auditory discrimination. According to Luria (1966) the auditory analyser is more efficient in females than in males. In output males stutter more than females. Reports on sex differences by Bachrach (1964) show whereas males tend to stutter under conditions of delayed auditory feedback, females do not. An investigation of variations in cerebral venous drainage suggest the right vein of trolard is larger than the left in girls and not in boys. This is often the major vein in the hemisphere opposite to that used in speech, and it may be possible that differences in venous drainage are related to the superiority of girls over boys in certain verbal skills.

According to Bannatyne, however, spoken language is learned by very young children quite spontaneously, without the need for formal instruction. Most human characteristics, which are learned spontaneously, are universally and innately characteristic of the species.
whether the stuttering is permanent or temporarily and artificially produced. It is the automatic associative linkage aspects, which may be superior and not the quality of the concept, perceived objects, or reasoning processes, which are being associated to. For analysis it is necessary to separate skills of speaking, listening and reading from the conceptual context of the word or passage which is being spoken, heard or read. This separation is most obvious when a child or adult correctly articulates a lengthy passage

read from a complicated textbook but does not have any idea of what it all means. Therefore, an individual has acquired ability skills to recognise and automatically associate sound to a printed word using the everyday conventions of language, both phonetic and syntactical. Bannatyne in summary stated that females were superior to males in various automatic language skills but as confirmed by Maccoby (1966) are not superior in the conceptualising aspects of linguistic content. In other words, they were superior in spelling and fluency during their schooling but not in vocabulary.

Spatial Ability and Gender

Koussy (1955), Maccoby (1966) and Banatyne (1971) maintain that boys from the age of five exhibit greater spatial ability than girls and it is more pronounced in three-dimensional tasks than in two-dimensional tasks. In reviewing spatial ability Vernon (1961) and Smith (1964) both said it was a masculine trait. Smith points out that verbal ability and spatial ability may be a bipolar factor. In other words, there was a generalised tendency within a population for an individual having a leaning towards one type of ability and less towards another. Girls and women tended to be verbally superior particularly in terms of automatic fluency whereas boys and men would be superior in spatial, mathematical, and abstract reasoning, especially visuospatially.

In a modern study by Birenbaum et al. (1994) sex differences in spatial abilities using a standard two-dimensional paper and pencil test of mental rotation were found. Some features of the mental rotation test stimuli (e.g. long trajectories, multilined and multispotted) proved difficult for males and females, but more difficult for females. Males completed more items than females.

Visuo-spatial ability and Gender

Visuo-spatial ability was defined by Bannatyne (1971) as the ability to manipulate objects and their interrelationships intelligently (psychologically) both directly e.g. engineering, surgery and symbolically or abstractly e.g. geometry in two, three or multidimensional space.

In visuo-spatial abilities the largest gender differences are found on selected tests of visuo-spatial abilities. According to Halpern (1986b) visuo-spatial abilities are not a singular factor. Linn and Petersen (1985) stated that reliable gender differences are found at about the age of seven or eight (when they can first be measured) increasing at age eighteen and continuing throughout adulthood where males outperform females. The effect size for tasks involving the rapid mental rotation of figures is the largest of any of the gender differences. Tasks that involve spatial perceptions (e.g. the rod and frame) and spatial visualisation (e.g. embedded figures) produce smaller effect sizes, also favouring males.

Gender differences in tasks involving mental rotation reported men were faster than women, Kail (1979) and women were more sensitive to rotation in angles. Schecter (1991) found men utilise shape information in a motion stimulus to a greater extent than women do and women were more receptive than men to distance disparity information and the introduction of shape information to the motion stimuli decreased their sensitivity to distance.

According to Kail men being better at utilising shape information and more skilled at shape-comparison tasks may originate from men's use of a holistic strategy, in visual-spatial tasks. Women showed greater sensitivity to distance changes resulting from their use of an analytic feature-by-feature strategy. Reduction of women's sensitivity to distance in the presence of a shape cue may be due to their use of an analytic strategy. Shape is processed in a 'form' pathway related to the infer-temporal cortex while distance is processed by 'motion and spatial relations' in the posterior parietal cortex, Mishkin (1983). There may be gender related variations in the functioning of these processing streams and/or in their separation.

Memory and Gender

Recent studies on 'gender and memory' reveal a difference in the functional organisation of the brain. Marosi (1993) found that in children aged 7.6 to 13.3 an E.E.G. revealed differences in brain organisation. The results were that girls had higher right intrahemispheric coherence values than boys in all bands. These sex differences were numerous in the theta band. The interhemispheric differences were slight and girls had higher coherence values in all bands except for the alpha band where boys had higher interhemispheric coherence than girls did.

Shaywitz (1995) in citing the common view held that language functions were more likely to be highly lateralised in males and found in both cerebral hemispheres in females revealed, attempts to prove this have been inconclusive. However, it was found that during phonological tasks brain activation in males is lateralised to the left inferior frontal gyrus regions and in females the pattern of activation engages more diffuse neural systems involving both the left and right inferior frontal gyrus. Furthermore a study by Volf (1994) found sex differences in strategies of memorising imply a wider participation of the right-hemispheric ways of information processing in providing some forms of verbal activity in women.

Two studies in which short-term memory and gender were tested presented interesting results. Vitulli (1991) gave undergraduates short-term memory tests under varying types of presentation (auditory, visual and visual-auditory combined). Subjects in this study were told to 'chunk' or ‘rote’ memorise twenty-five computer-randomised digits. Men did better on the three-second rate than women, but at the one-second rate women had higher short-term memory scores than men. Hart (1992) in a study supported the view that verbal ability of women was greater than that of men where total word recall and the ability to cluster related words at recall were related significantly. Female subjects recalled more words than males.

Crawford et al. (1992) stated that people hold beliefs about how well others perform memory tasks according to another’s sex i.e. learning a shopping list (a stereotypically female task) and learning directions (a stereotypically male task). In the first experiment female and male subjects showed consistency in performing tasks according to their gender. The second experiment investigated whether memory performance would be influenced by changes in the label of the materials in memory tasks to be biased toward male or female gender background. Therefore, the labelling of a shopping list as pertaining to ‘groceries’ or to ‘hardware store’ and a set of directions to ‘make a shirt’ or to ‘make a workbench’ was carried out by the experimenter. The results indicated memory performance varied in ways consistent with gender.

Foreign Language Learning and Gender

In the literature on learning strategies in the area of list learning, studies have used learning strategies to enhance the learning of the list and though having been successful in some cases, list learning is not typical of a school-learning task. In contrast, research indicates that learning strategies are used by language learners at all levels in school (Ehrman and Oxford 1990).

The subject area known as ‘foreign language learning’ lends itself to the use of learning strategies and the different ways individuals learn languages. These two areas will be discussed.

The process of learning words uses association, by associating a collection of meaningless syllables with a word in a language that one understands. This association has been done by repetition in the past - saying the word in one’s own language and in the foreign language time and time again. The other methods of learning a foreign language include mnemonic techniques such as the ‘method of loci’ where a student is asked to choose a town he is familiar with and use objects within that place as the cues to recall the images that link to foreign words. Another technique is the Link Word Technique (Gruneborg, 1995) in which the student uses an image to link a word in one language with a word in another language for example -

English: French vocabulary

rug/carpet - tapis	image of an ornate oriental carpet with a tap as the central design woven in chrome thread

In the literature about learning a language other than one’s native language, studies by Ehrman and Oxford (1990) showed that in learning a foreign language there were no significant differences between sexes in language performance but females used learning strategies more than males. The number and kind of learning strategies reported by women were similar to those used by men who shared their psychological type.

Language learning strategies are techniques used by learners to improve any part of their language development (Oxford, 1990). The number of strategies may be less important than the learners' organisation and use of them. Unsuccessful language learners use a large number of strategies but in an unorganised manner. Cognitive and metacognitive learning strategies such as language practice or hypothesis formation (cognitive) and metacognitive learning strategies such as planning and evaluating one's study take priority in the literature over affective (emotional and motivational) strategies like rewarding oneself or social strategies such as studying with others (Oxford and Cohen, 1992).

Ehrman and Oxford (1995) showed that effective foreign language learners use a variety of learning strategies appropriate to the nature of the task, to the learning material, and to the individual's personality, goals, and stage of learning (Ehrman and Oxford, 1990b). They maintained that unsuccessful language learners used a great number of strategies but in a random way (Vann and Abraham, 1989). The authors also found that females more than males used conscious language learning strategies i.e. metacognitve (planning), affective (emotional) and social.

Language learning styles used by students in which Schmeck's (1983) distinction of 'analytic' and 'global' was examined (Oxford, Ehrman and Lavine, 1991) found that analytic students preferred working within categories and to analyse components of language. Global students tended to prefer conversation to rule-learning and practice.

Females in contrast to males in foreign language learning may use conscious language learning strategies, a finding in current studies of language learning strategies in several areas of the world (Oxford, 1993). Females especially use metacognitive (planning, evaluating, and organising) strategies, affective (emotional and motivational) strategies and social strategies, on the whole more than males. It is also suggested in the literature that females are better in listening skills than males (Larsen-Freeman and Long, 1991). It is apparent from the research in foreign language learning that the way females use learning strategies is more efficient than males and supports the natural tendency to actively organise materials (Baddeley, 1990).

Introduction to Cognitive Styles

Many theorists have used the term, ‘cognitive style’ and classified it according to their own specification. Many models and their assessments have evolved since 1937 when Allport defined ‘cognitive style' as a person’s habitual mode of thinking. Messick (1976) defines cognitive style as a general, habitual mode of processing information and individuals’ learning styles are simply the cognitive styles they exhibit when confronted with a learning task.

Riding and Cheema (1991) pointed out that cognitive and learning style differed in one main way in the number of style elements taken into account. Therefore, cognitive style as a bipolar dimension differs from learning style, which encompasses many elements and are usually not ‘either-or’ extremes. Some theorists define the two terms as having the same meaning e.g. Entwistle (1981), whilst Das (1988) believed the two to be different and tried to define them as separate concepts.

Cognitive Styles and Learning Strategies

Curry’s Onion Model

In the literature there is a difference between ‘style’ and ‘strategy’. The style an individual adopts is thought to be a more permanent dimension of that individual whereas strategies are the means utilised to perform in various circumstances and with various work. Styles are stationary and remain an indigenous characteristic of an individual. Strategies, on the other hand, are not fixed and may be learned and developed to deal with various circumstances and may be ways of using styles to make the most of a situation for which they are ideally appropriate. The term, ‘ learning style’ in the literature sometimes refers to the term, ‘strategy’. Curry (1983) discussed this differentiation and stated that there may be three main divisions into which all cognitive learning style measures may be grouped. The organised learning style divides into the following: learning behaviour is fundamentally controlled by the central personality dimension, translated through the middle strata information processing dimension and given a final twist by interaction with environmental factors encountered in the outer strata.

Curry described the outermost layer as the most observable style and called it the 'Instructional Preference'. The Learning Preference Inventory (Rezler and Reznovic, 1981); and Grasha, Reichmann Students' and Learning Styles Scales (Reichmann and Grasha, 1974) are examples of measures of this style. The instructional preference layer applies to one's choice of environment in which to learn. It also refers to the learner's and teacher's expectations and may also refer to unexpected occurrences and how they affect the learner. It is the level of measurement in the learning styles area that is on the one hand the most easily influenced and on the other hand the least stable.

Curry's second layer of the onion is known as the 'Information Processing Style' and it concerns one's intellectual approach to taking in information. This processing does not directly involve the environment in contrast to Curry's Instructional Preference. Measures of this style are more stable measures of the individual. The Information Processing Style however, is influenced by learning strategies. It is thought to be associated with the 'Learning Style Inventory' (Kolb, 1976); 'Cognitive Preference Inventory' (Tamir and Cohen, 1980) and 'Inventory of Learning Processes' (Schmeck et al.1977). It intersects between basic personality level individual differences and the availability of learning format choices.

The third layer of Curry's learning style onion is the innermost layer she referred to as the Cognitive Personality Style. The definition of this style is an individual's approach to adapting and assimilating information, which does not interact directly with the environment but is, an underlying and relatively permanent personality dimension that is expressed indirectly and is apparent only when an individual's behaviour is observed across many learning instances. The 'Embedded Figures Test' (Witkin, 1962); 'Myers-Briggs Type Indicator' (Myers, 1962) and 'Matching Familiar Figures Test' (Kagan, 1965) are all examples of measures which Curry suggested assess this third type of learning style. The Cognitive Styles Analysis (Riding, 1991) would be situated in the third (innermost) level of Curry's Onion Model.

Over 30 labels assigned to cognitive/learning styles have been cited by Riding and Cheema (1991). They may be grouped into two main cognitive styles and several learning strategies. Under the Wholist-Analytic Cognitive Style Family, field dependence-independence (Witkin, 1962), holist-serialist (Pask, 1972) and leveller-sharpener (Holzman and Klein, 1954) have been chosen for further discussion. Under the Verbal-Imager Style Family, verbal-imagery (Riding and Buckle, 1990) will be discussed and under learning strategies Kolb's (1977) categories (diverger, assimilator, converger, and accommodator) will be discussed. Under Learning Styles, the 'Inventory of Learning Processes' by Schmeck et al. (1977) will be discussed.

Field-Dependence-Independence

The distinction represented by field dependence-independence described by Witkin (Witkin 1962, 1978) contrasts the ways in which individuals process information. Witkin and Goodenough (1981) claimed that those who are field dependent tend to rely on external referents as guides in information processing, while field independent individuals place greater weight on internal referents.

Field independent individuals have an analytical style and focused attention, noticing and remembering details. They are interested in operations and procedures and tend to follow step-by-step, sequential organisational schemes. They are known as critical and logical thinkers. They are astute at observing differences between apparently different experiences.
Field dependent individuals tend to lean their attention toward scanning, resulting in the formation of global impressions rather than specific. In contrast to linear and sequential organisational skills of the field independents, field dependents' organisational skills involve random or multiple accessibility of components, allowing numerous and varied associations between specific experiences. There is also a distance relationship between perception and field dependence/independence.

Gottschaldt (1926, cited in Witkin, 1962) devised the method of assessing field dependence-independence by formulating rules of how to conceal a simple shape within a complex one. Based on this work Witkin (1962) designed a method of assessment involving ‘disembedding’ a presented simple shape from a complex one. This is known as the Embedded Figures Test. Witkin found that field independents impose structure upon the learning material and field dependents do not. Field dependent individuals when presented with unstructured learning material are at a disadvantage to field independent individuals.

Differences not only in cognitive functioning but in social orientation also exist. Field dependent individuals are interested in other persons while field independent individuals are more concerned with ideas and abstract principles. Witkin’s longitudinal analysis followed 1,422 students through their college careers and found students favoured study domains that were consistent as judged by the researchers with their cognitive styles as assessed on the field-dependent/field-independent dimension. The further findings were that students whose choices were incongruent with their styles tended to shift to more compatible domains, whereas those whose initial choice was suited to their styles tended to remain with their choices.

Holists-Serialist

Pask labelled this cognitive style dimension in 1972. In all his studies the subjects are instructed to understand and not memorise the material. In a study by Pask and Scott (1972) students had to learn principles of classification underlying the division of two species of Martian animals (Clobbits and Gandlemullers). They had to overtly request specific pieces of information and give reasons for each request. They had to ‘teach-back’ the classification systems after they learned them. This teach-back method was Pask’s hallmark.

In several studies Pask (1976a, 1976b) Pask and Scott (1972) identified two different learning strategies and the associated learning styles demonstrated by subjects in the teach -back paradigm. Pask (1976b) said that two pathologies resulted from overuse or misuse of either of these two strategies. One strategy was labelled ‘holist’ and the person showing cross-situational consistency in the use of this strategy was exhibiting the style called ‘comprehension learning’. The associated pathology resulting from rigid adherence to this style was labelled ‘globetrotting’. Comprehension learners (who use a holist strategy) take a global approach to the task, liberally using anecdotes to arrive at an overall description. They look further ahead than other subjects when working through a hierarchy of topics, have a wider focus of attention, try to first build up the big picture before determining where any of the details fit. The pathology in this case, globetrotting, involves jumping to conclusions on the basis of too little evidence, using inappropriate analogies and overgeneralising.

The contrasting learning strategy was labelled 'serialist' and the accompanying style was 'operation learning'. The pathology associated with overuse or misuse of the strategy was improvidence. Operational learners who use the serialist strategy progress linearly from one topic to the next. They are routinely concerned with operational details and procedures, working step by step through a series of topics attending carefully to sequential details. The pathology to which an operational learner is most subject (improvidence) involves a failure to use analogies and to build up overall maps. Such an individual 'sees the trees but misses the forest'. Avoiding pathologies, both comprehension and operation learners can arrive at comparable levels of understanding.

Pask (1976b) stated that very consistent operation or comprehension learners were likely to fall into pathologies of either improvidence or globetrotting. The most competent student has a versatile learning style, according to Pask. He uses a higher order metacognitive strategy based on both the serialist and holist strategies, alternatively employing analogy to get an overall model and then testing its applicability by examining details. Using his metacognitive skills the versatile student might be using different strategies according to the situation in which he finds himself. Pask maintained that the versatile learning style led to a very high level of understanding.

Leveller-Sharpener

This cognitive style dimension was proposed by Holzman and Klein (1954) but it might have been put forward first by Wulf (1922). 'Levellers' assimilate new events with those previously stored whereas ' 'sharpeners' ' treat new events in isolation from those already stored. The Schematising Test (Holzman and Klein, 1954) is based on individuals judging the size of squares of light in a darkened room. New squares of increasing size are added. Individuals who make greater underestimates are ‘ ‘levellers’ and those making less errors are 'sharpeners'. In story recall it was found that levellers tended to condense information, and have a loss of overall organisation and to be fragmented in terms of the overall structure of the story. Sharpeners in contrast, were able to relate the story with greater clarity and tended to exaggerate specific parts of the story (e.g. Gardner, Jackson, & Messick, 1960). In Experiments One through Four of this thesis one of the learning strategies, ‘Make into a Story’ was taught to students and they were given instruction in its use. It was based on Crovitz’s (1979) work with people who had suffered memory loss. It entailed creating a story to remember specific words, and in Experiments One through Four there were word lists to remember. In a future experiments it might be interesting to test students on ‘The Schematising Test’ as well as teaching and giving them instructions to learn the story strategy, ‘Make into a Story’. In this way the result on this test could be compared to the story they created after learning the story strategy.

Verbaliser-Imager Style

The way individuals differ in their imagery ability, has been studied since Galton’s 1883 ‘breakfast table questionnaire’, examining the quality of images reported by individuals when visualising certain scenes (e.g. the breakfast they ate in the morning).

More measures exist for assessing imagery whilst only three main measures exist for assessing the verbaliser-visualiser cognitive dimension (i.e. Paivio 1971; Richardson 1977; Riding and Taylor, 1976; Riding and Calvey, 1981, and Riding and Buckle, 1990). Imagers are those individuals who think in terms of mental pictures and verbalisers are those who think in terms of words.

Riding, Buckle, Thompson and Hagger (1989) devised a computer presented test of the verbaliser-imager cognitive style. The test comprises the computer presentation of pairs of words. The task is to decide whether the relationship between the first word presented and the second word belongs to the same category. These two categories are (1) same group, (2) same colour. There are 24 pairs of words in each category, half of which are true whilst the others are false in each category. The outcome should be that imagers are quicker on the same colour category because they can more easily generate images for the objects in question. The response time for verbalisers will be less for the same group category because of its verbal associations and which would not be easy to visualise.

The personality dimension of introversion-extraversion was examined by Riding and Dyer (1980). The description of introverts as being able to utilise their long-term memory better than extraverts was based on Eysenck's work in 1967. Riding and Dyer associate introverts with experiencing a large amount of spontaneous imagery when they think about information, but these mental images are not easily controlled and are likely to be replaced by new images as thinking proceeds. Extraverts, however, experience much less imagery but are able to voluntarily generate and control an image if they have to. In verbal associations with extraverts, they experience greater fluency, but less control and introverts experience less fluency and more control.

Cognitive Styles Analysis

The Cognitive Styles Analysis was used in the fourth, fifth and sixth experiments in this thesis. The Cognitive Styles Analysis (Riding, 1991) is a computer presented instrument measuring two basic cognitive styles; the Wholist-Analytic style (WA) and the Verbal-Imagery style (VI). It consists of three sub-tests. The first assesses the verbal-imagery dimension by statements being presented one at a time to be decided by the subject true or false. Half the statements contain information about conceptual categories and the remainder, appearance of items. Half the statements of each type were true and the remainder false. It was believed that the Imagers would respond more quickly to the appearance statements, since the objects could be easily thought of as mental pictures and the information for the comparison could be derived quickly from these images. It was thought that the conceptual category items would be responded to in a shorter time by the Verbalisers, since the semantic conceptual category membership is characteristically verbally abstract and can't be represented in visual form. The response time to each statement is recorded by the computer and a Verbal-Imagery Ratio is calculated. A ratio of less than one corresponds to a Verbaliser and a ratio of more than one corresponds to an Imager. It is interesting to note that individuals have to read both the verbal and the imagery items and it is not a test of reading ability or speed.

The second two subtests assess the Wholist-Analytic dimension. The first of these presents upon the computer screen pairs of complex geometrical figures and the subject must decide whether they are the same or different. Wholists should respond more quickly to this task because it involves judgements about the overall similarity of the two figures. The second subtest presents pairs of items; a simple geometrical shape (e.g. a square or a triangle) and a complex geometrical figure. The subject has to decide whether or not the simple shape is contained within the complex one. This task involves some disembedding of the simple shape within the complex geometrical figure in order to find that it is the same as the simple shape. It would be likely that Analytics {defined by Riding and Buckle (1990) corresponding to Witkin's field independents} may perform quicker than Wholists (corresponding to field dependents) on this task. The latency of the responses (twenty per assessment) is computed. The Wholist-Analytic Ratio is found for each assessment via a median latency time being calculated. A ratio of less than one corresponds to a Wholist and a ratio of more than one to an Analytic.

The test in comparison to the Embedded Figures Test differs in three ways. First, it positively measures the Wholist tendency and does not assume that if an individual does not do well on a disembedding task that they are field dependent. Secondly, an individual's relative performance on the two halves of the continuum are compared. Thirdly, the computer presentation of the CSA allows for accurate timing of the task.

Learning Styles

Talmadge and Shearer (1971) believed that 'learning style' would be a more useful concept than traditional personality and cognitive style constructs in accounting for variance in academic performance. They stressed the need to assess learning style from a behavioural-process orientation. From the theoretical perspective of Schmeck on learning style, it is a predisposition on the part of some students to adopt a particular learning strategy regardless of the specific demands of the learning task. According to Schmeck (1983,1988), a style is simply a strategy that is used with some cross-situational consistency. Schmeck defines learning strategy as a pattern of information-processing activities used to prepare for an anticipated test of memory. In Chapter Two of this thesis the students were taught and given instructions to use learning strategies such as, 'Imagine a Picture' or in other words use the strategy 'imagery' to help them remember a lists of words.

Schmeck noted that in learning to measure individual differences the predisposition to use certain learning strategies may be explained by more basic theories of personality and cognitive style (e.g. Kogan, 1976) and by very basic theories of neurological functioning (e.g. Ornstein, 1977). Schmeck stated that we all seek to identify and delineate basic behavioural processes.

Schmeck (1983,1988) through his work with self-report questionnaires derived strategies, through factor analysis of students' responses to the survey questions. Schmeck, Ribich and Ramanaiah (1977) wrote questionnaire items, each asking the students about a learning tactic (e.g. using imagery to remember the definition of a word). Factor analysis of students' answers to these questions led to clusters of tactics, which became clusters of questions and finally combined to form inventory scales. It followed that the instructions to the questionnaires were worded in a way as to ask students to answer the scales as they learn, in general rather than in a particular course. The scores according to Schmeck could serve as measures of what he called 'learning styles'.

Schmeck argued that individuals' learning styles were simply the cognitive styles that they exhibit when faced with a learning task. Lewis (1976) stated that one should always study the most basic individual differences that underlie more easily observable differences. Supposing, personality and cognitive-style differences underlie learning style, then Lewis would call for studies relating personality and cognitive style to learning. Schmeck pointed out that attempts have not been very informative in this area. Schmeck being most interested in learning chose to develop a measure of individual differences in the predisposition to use specific learning strategies. He believed that the differences he would observe would in the end be explained by more fundamental theories of personality and cognitive style (e.g. Kogan, 1976) and by basic theories of neurological functioning (e.g. Ornstein, 1977).

A learning style may become a learning disability according to Schmeck if nurtured at the expense of other methods of learning. According to Schmeck the disadvantage in the application of learning style theory is that students would be acquiring self-limiting views based on the result of being told of their learning style assessment. For example, a student informed that he is a left-brained learner {primarily concerned with verbal, analytical, abstract, temporal and digital operations} (Ornstein, 1972) and shown corresponding learning behaviours, may believe he is incapable of learning in right-brain ways {primarily concerned with non-verbal, holistic, concrete, spatial, analogical, creative, intuitive, and aesthetic operations} (Ornstein, 1972). This approach is especially unsuitable for the development of creative thinking. Creative thinking of a high quality involves the whole brain and requires a variety of learning styles and learning strategies.

One of the most interesting accounts of a learning style was that of Kolb (1979). Kolb defined perceiving and processing as two facets of a learning style. Learning style also encompassed decision-making and problem solving. Kolb used the model of the learning cycles as the framework against which to posit the existence of different learning styles. As people deal with and try to learn from situations, they are faced with the task of resolving the dialectical tensions between the alternative ways of grasping and transforming their experience. Over time, each individual tries to resolve the conflict between taking a reflective or active approach and between immersion or detachment from experience.

Each individual develops a learning style. According to Kolb's model (1971, 1981) the learning process is both active and passive, concrete and abstract. It can be viewed as a four-stage cycle: (1) concrete experience; (2) observation and reflection; (3) the formation of abstract concepts and generalisations; and (4) hypotheses to be tested by active experimentation which may end in new concrete experiences.

Kolb's Learning Style Inventory assesses how a learner emphasises the importance of each of the four stages in relation to the others. According to Kolb there are four types of people based on their learning styles: divergers, assimilators, convergers and accommodators. Divergers take in information concretely and process it reflectively.

They generalise from what they see. Assimilators, according to Kolb, start with an idea or abstraction and process it reflectively. They think and observe. The convergers take in experience abstractly and process it actively. They begin with an idea and then test it experimentally. Accommodators perceive experience concretely and process it actively. They are sensor feelers and doers.

Cognitive Strategies, Memory Strategies, and Metacognitive Strategies

In learning any task the learner might ask himself the following: (1) What knowledge do I have about a specific strategy I use? (2) When do I use this strategy? (3) How do I monitor the use of this strategy? and (4) How do I reconcile the complex interaction of the three? Pressley and Levin (1987, cited in mindtools 1995). The ability to use the right strategies at the right time is more important than just knowing a large number of learning strategies. It seems that there are many learning styles and using strategies related to one's preferred style may be advantageous to the learner as through trial and error he adapts strategies to situations. There are many learning strategies available. Some of the most versatile are the memory strategies (grouping, associating, elaborating, placing new words into a context, using imagery, semantic mapping, using keywords, representing sound in memory, structured reviewing, using physical response or sensation, and using mechanical techniques) and cognitive strategies (analysing and reasoning, creating structure for input and output).

According to Rigney (1976) cognitive strategies are thought to be based on two dimensions: (a) a cognitive orienting task and (b) one or more representational, selectional or self-directed capabilities. The term 'orienting task' refers to methods for inducing the student to perform particular kinds of operations and is used in the same way by Frase (1969), via his term 'orienting directions'. Cognitive strategies are used to indicate operations and procedures that an individual may use or acquire. The individual may retain and retrieve various kinds of knowledge and performing these operations and procedures might take the form of cognitive information processing as found in mental imagery. These operations also may be cognitively controlled (skimming a textbook and citing major points). The representational capabilities of an individual (reading, imagery, speech, writing and drawing) and selectional capabilities (attention or intention) and self-directional capabilities (self-programming and self-monitoring) are the basis of cognitive strategies. An individual's processing of an operation's performance constitutes a cognitive strategy that either one is aware of or not. An individual in learning something may be in a situation of a haphazard reinforcement of which they are not aware. Accordingly, an instructional system can be designed to teach an individual some cognitive strategies and not make one aware that the operations one is performing are cognitive strategies.

Rigney maintains there is a further classification of cognitive strategy, a detached and embedded cognitive strategy. The former is independent of the subject matter i.e. instructions to use mental imagery or instructions to think of analogies. The latter is not specifically defined independent of the subject matter. The instructional system requires the individual to use particular processing resources to achieve the orienting tasks in the subject matter. An example would be questions, as many times they are used to compel the individual into deeper semantic processing in long-tern memory. A further example would require an individual to multiply three-digit numbers in one's head, leading one into mental imagery to be followed intermediately by 'products' and 'carries'.

Memory strategies known under the general heading 'learning strategies' refer to such strategies as the following: initial letter mnemonic, story mnemonic, grouping and using imagery. The first three strategies (initial letter mnemonic, story mnemonic and grouping) are described in this thesis in the learning strategies section and the fourth strategy (imagery) is described in the coding and representation section. In the area of verbal learning these four strategies have historically been used to improve language acquisition. In foreign language learning verbal and imagery based mnemonics continue to feature in many experiments as very useful aids to learners.

Again Rigney states in addition to memory strategies and cognitive strategies, there are metacognitive strategies (centering one's learning, arranging and planning one' s learning and evaluating one's learning). For example, Brown (1978) reported that skilled readers use a variety of metacognitive processes during reading such as clarifying the purposes of reading and allocating attention to relevant information. These metacognitive processes are actually strategies and they act as an aid to comprehension and individuals failing to employ these strategies are known to have difficulties in reading. There are also affective strategies (lowering one's anxiety, thinking positively, and keeping in touch with one's emotional stability). The individual learner in any learning task is perhaps only thinking at one level of information processing at any given time. Hence, the learner being taught to be aware of several learning strategies at any given time might improve his capacity for learning.

CONCLUSION

In summary, the literature found on the learning of learning strategies to improve the learning of word lists was not large. There were no studies found in which subjects were followed over long periods of time to test the efficacy of the learning of various learning strategies and mnemonics. There were also no studies found in which subjects were taught learning strategies and given the Cognitive Styles Analysis (Riding, 1991) so the effect of the strategies could be shown to be influenced by cognitive style.

Mnemonics are visually or verbally based techniques and come under the heading of learning strategies. Several studies did show that after learning a mnemonic learning performance improved in the recall of words. The mnemonics that were effective were Method of Loci (Ross and Lawrence, 1968) The Peg Word Technique (Krinsky and Krinsky, 1994), and The Rhyming Mnemonic (Higbee, 1994). Some learning strategies that were effective were Recitation (Gates, 1917), (Honeck, 1973), Rehearsal in List Learning (Rundus, 1971) (Baddeley, 1996) and Paired-Associate Learning (Bower and Winzenz, 1970). Two verbal mnemonics (initial letter mnemonic and story mnemonic) and two learning strategies (grouping and imagery) were found to be helpful in verbal learning and it was decided to test their effect in learning lists of words.

The following techniques were chosen:

<u>Initial Letter Mnemonic</u> - the first letter of each of the words to be retrieved acts as a cue and is remembered in the form of an acronym e.g. ROYGBIV for the colours of the rainbow (Baddeley, 1996).

(2) The Story Mnemonic - placing words to be remembered in the form of a story, (Crovitz, 1979)

(3) Grouping - placing words of a similar category together (Bousefield, 1953)

(4) Imagery - Describing what is seen in the mind's eye (Galton, 1883)

It was decided to do four experiments in the area of verbal learning and more specifically in the learning of 'word lists'. In order to assist the learner in the learning of lists of words, it was decided to teach the following learning strategies: (1) initial letter, (2) creating a story (3) grouping and (4) imagery. Individuals differ in the way they learn and indeed in ability according to gender, age and cognitive style. These differences were addressed in the following four experiments but, The Cognitive Styles Analysis (Riding, 1991) was only introduced in the fourth experiment.

CHAPTER TWO

STUDIES OF WORD LIST LEARNING

SUMMARY - Experiments One - Four

Four experiments on learning lists of words and learning strategies to assist in the learning of the words, were conducted in Chapter Two. Words were chosen in Experiments One - Four over non-words. Hulme, Maughan and Brown (1991) measured memory span for words and non-words of differing spoken durations. The results were that memory span for words was better than for non-words in view of equating the two sets of materials for how quickly they could be spoken. The argument was that the poorer recall of the non-words was attributable to the absence of long-term memory representations for these items. Words were chosen over such stimulus materials as prose or letters and nonsense syllables because strategies such as 'imagery' might not be as effective in trying to remember the nonsense syllable *XAB* as in remembering a word like *TRACTOR*. Word lists rather than lists of numbers were chosen for the experiments. This is because turning numbers into words in order to make them more meaningful is a strategy in itself. Baddeley (1996) discussed the use of this method to remember the value of 'pi' to the first 20 decimal places. In this method each number is converted into a word with the number of letters in each word representing the number itself. Word lists were chosen to test the efficacy of learning strategies in Experiments One to Four.

Children and adults need to remember words in various school and work situations. To assist them they may be taught learning strategies depending on the particular task posed. There are two kinds of internal memory strategies and they are those that are learned naturally and those that can be defined as 'artificial mnemonics'. The former may be illustrated by the free recall of a word list and concentrating on items not recalled previously, in which adults tend to recall the last few items first, known as the recency effect (Baddeley, 1990). The reason for this may be that adults do not want to waste time remembering things they had learned previously. In contrast, children show a recency effect but do not use the strategy of devoting more time to previously failed items until they are aged seven to nine (Masur, Mcintyre and Flavell, 1973).

Mnemonics (verbal and visual) are learning strategies, and they artificially act as aids for teaching individuals to learn information. It is also hoped that they can be applied to new situations out of the initial context in which they are taught. They were chosen to help children learn lists of words in Experiments One to Four. In a study on mnemonics Lovelace and Twohig (1990) differentiated between external and internal mnemonics. Some examples of the former are: make shopping list, written memos to self, put in a noticeable place, and calendar. Examples of the latter are: mental retracing, get visual image, go through alphabet, make up rhymes, number of items shopping for, acronym of first letters and make up a story.

The *initial letter mnemonic* (acronym of first letters) helps one remember information deemed important for example, the first letters of each colour of the rainbow; 'red, yellow, orange, green, blue, violet and indigo' which form the acronym ROYGBIV. This is one of the most widely used internal strategies by students (Gruneburg, 1993). Another popular strategy is *placing words to be remembered in the form of a story* (Crovitz, 1979). Baddeley, maintained that the learner actively organises material and Bousefield (1953) after many experiments claimed students showed a definite tendency to place items in groups and called this 'clustering' and in this is thesis known as '*grouping*'. The use of '*imagery*' gained popularity in the 1960s as both the judged imageability of words, and instructions to use imagery had strong effects on the rate of learning lists of words, or passages of prose Baddeley (1990). Visual mnemonics have been used for many centuries. One that is used frequently involves turning a word or name into a picture. For example, 'Neil Kinnock' can be drawn as a kneeling king knocking. The above mentioned learning strategies correspond to initial letter, make into a story, grouping and imagery and were used in Experiments One, Two, Three and Four.

Children were chosen as subjects in Experiments One to Four because it was thought that they would not be as fixed in their learning as adults and learning strategies might have more of an effect on them. It is hoped that the teaching of learning strategies to children can be generalisable to subjects they learn in school. For example, the initial letter strategy should be applicable to English, history, geography, science and foreign languages.

In the junior schools, children have to learn many word lists in order to initiate attainment of concepts. For example they may have to learn the names of the continents or oceans and then match them to images of continents or oceans to develop higher order concepts such as the world map. Children may already be applying learning strategies to their work such as rehearsal (acoustically encoding for example, digits or words and then trying to recall them) and not even know they are doing this. In order to assist the learner, learning strategies could be taught such as the 'initial letter strategy' but also the learner should be told at the same time that the aim of learning the strategy is to improve memory, so they are more aware of its importance. According to Fabricus and Cavalier (1989) the aspect of children's knowledge about memory strategies that has been generally overlooked in the metamemory literature concerns children's notions about how memory strategies work to improve recall. In the four experiments subjects were instructed to write down how they remembered the words on the lists.

The second chapter is about the learning of word lists. Experiment One contains four lists of words (two lists are abstract words and two lists are concrete words). There are seven learning strategies, which are taught to the subjects before they begin the experiment. In Experiment Two there are four lists of words (all four lists are concrete words grouped by category) for example, list one contains all words associated with the category known as 'transport' and four written learning strategies. In Experiment Two, the subjects in the experimental group are presented with written instructions to learn one learning strategy and also taught the same learning strategy by the experimenter. In Experiment Three there are four lists of words (all four lists are concrete words grouped by mixed category) for example; list four contains words from the categories of furniture, animals and clothing. The experimental group is given written instructions to learn one learning strategy and also taught the same learning strategy by the experimenter. In Experiment Four the same words and learning strategies used in Experiment Three are replicated. In Experiment Four, the computer presented CSA (1991) is introduced.

Analysis of Variance

Analysis of variance using the computer programme SPSS (MANOVA) was used in the six experiments in this thesis since it enables comparison of the differences in means in more than two samples. ANOVA is a function of the variance of the set of group means, the overall means of all observations, and the variances in each group weighted for group sample size. The ANOVA table is interpreted through the significance of the F ratio, indicating the significance of each main effect and interaction effect. When a dependent variable is measured for independent groups of sample members, where each group is exposed to a different condition, the set of conditions is called a between-subjects factor (Schweigert, 1994). In the experimental mode the conditions are assigned randomly to subjects by the researcher and for example, in Experiments One through Four the subjects were randomly assigned to the independent variable 'strategy'. When a dependent variable is measured repeatedly at different time points for all members across a set of conditions (the categories of the independent variable), this is known as a within-subjects factor and the design is called within-groups or repeated measures ANOVA. In the within-groups or repeated measures design, there is one group of subjects. In each of the Experiments One through Four the same subjects were given four lists of words (the words in the lists differed in Experiments One and Two but were the same in Experiments Three and Four) to learn and the score on each list was known as the dependent variable. The object of a repeated measures design is to test the same group of subjects at each category of the independent variable. Because each subject is his or her own control the different groups are really the same people tested at different levels of the independent variable. In Experiment One the experimental group was taught seven learning strategies and in Experiments Two, Three and Four the experimental groups were taught one learning strategy. In Experiment Five the same subjects were given the same three analytic reasoning problems to solve and the score on the use of the variables known as 'character', 'line' and 'idea' were the dependent measures. Separate analyses of variance (ANOVA'S) were performed on the data in Experiment Six and there were four problems (one spatial, two verbal reasoning and one mathematical word). The score on the use of variables known as 'picture', 'letters', 'lines' and 'ideas' were the dependent measures. The significance level was set at $p<0.10$ in this thesis at the time of the first experiment as this was a pilot study. As an exploratory experiment it included

learning a large number of learning strategies which made it a complicated. In hypothesis testing we are making a decision which is either to reject or accept the null hypothesis. Once the decision is made we are susceptible to one of two types of error, namely type I error and type II error. The former occurring when the null hypothesis is true but rejected and the latter occurring when the null hypothesis is false but is retained. A type I error is determined by the significance level we choose for the experiment. A possible way of controlling for a type II error indirectly is to increase the rejection region for example to $p<0.10$ instead of $p<0.05$ and by enlarging the rejection area we automatically decrease the type II error and increase power.
The aims of the second chapter of this thesis is to find out whether being taught learning strategies and given written instructions to learn them improves one's ability to remember word lists. The second aim is to find out whether cognitive style has an influence on being taught learning strategies and given written instructions to remember word lists.

EXPERIMENT ONE: LEARNING STRATEGIES AND WORD LISTS CONCRETE AND ABSTRACT WORDS AND LEARNING PERFORMANCE

INTRODUCTION

The students in Experiment One were taken from the age range of 13 - 14 year olds. In this experiment the subjects were given instructions by the experimenter about how to learn seven learning strategies. These instructions were read aloud to the subjects by the experimenter. The lists included concrete and abstract words.

AIM

The aim of this study (Experiment One) was to find whether presentation of learning strategies before giving word lists improves the recall of the lists.

METHOD

Sample

The sample in the first experiment consisted of 59 year 10 students, (13 -14 year old, 29 male and 30 female) in an urban secondary school. They were randomly assigned to 29 in the control group and 30 in the experimental group. The control group was not given strategies and the experimental group was given seven strategies.

Materials

The learning material was a booklet consisting of instructions, four lists and learning strategies. There were ten words in each list. Two lists contained concrete nouns and the other two contained abstract words including adjectives and verbs. The words used in the first concrete list (concrete/easy) were the names of food all in the same category, food. The words in the second concrete list (concrete/difficult) were concrete nouns not capable of being grouped into a single category. The words in the first abstract list (abstract/easy) were nouns, adjectives and verbs and they were not in any single category. The words in the second abstract list (abstract/difficult) were not categorisable and consisted mainly of nouns. In this list there was one preposition (with) and one conditional verb (could), both which would not be possible to image.

<u>The seven learning strategies were</u>:
Initial Letter, Make Sentences using Initial Letter, Make into an Image, Conceptual Grouping, Make into a Story, Image each Item on a List and Appearance Grouping.

Booklet One

Instructions -

You will hear me say some words.
I want to see how many items you remember on each list in any order.
The lists are numbered 1 - 4.
You will be given one minute to learn the lists and one minute to write them down.

I will now teach you 7 methods of remembering words. Think about each method and ask questions if you do not understand them. You will be given four minutes to learn seven methods.

Write the number of the list you are referring to and the method or methods you used in remembering the list e.g. list 4 - methods 1,4,6.

Write down 'no methods used' if you did not use any of the methods.
Write down in words your own method if you used one in remembering any of the lists.

List Learning - Verbal and Picture Strategies

1. INITIAL LETTER e.g. ROYGBIV
   (The first letter of each colour of the rainbow)
2. MAKE SENTENCES USING INITIAL LETTERS TO MAKE A WORD OR STORY e.g.
   Letters were posted.
   Articles appeared in the journal.
   Water is a necessity to sustain life.

3 MAKE INTO AN IMAGE e.g. nonsense imagery 'A lettuce with a face'
4 CONCEPTUAL GROUPING e.g. all vegetables
5 MAKE INTO A STORY e.g. I gathered lettuces, artichokes and watercress as part of my ingredients for a recipe.
6 IMAGE EACH ITEM ON A LIST e.g. Imagine a crisp, fresh, green lettuce.
7 APPEARANCE GROUPING e.g. Picture several items in the same picture consisting of all green vegetables.

C1 (Concrete/Easy)	A1 (Abstract/Easy)
treacle	usable
sugar	construction
oats	grow
currants	thaw
eggs	protection
butter	bribe
raisins	absorption
icing	soft
prunes	sad
chocolate	imagination

C2 (Concrete/Difficult)	A2 (Abstract/Difficult)
holly	vanity
wood	opinion
mud	east
wrist	moment
chocolate	worth
clarinet	melt
twig	portion
calendar	with
ink	could
apple	insertion

Procedure

The booklets were presented to the students. Each contained general instructions on how to complete it and four lists of words. The students in both the experimental and control groups were told to look at each list for one minute. The control group was then told to rewrite the words in the list in any order that they could remember them. They were given a total of eight minutes to complete the booklet. The students in the experimental group were first taught seven learning strategies. They were also given these strategies in the booklet and were told what each meant and an example of how they were to be used. The students in the experimental group were given four minutes to learn the seven strategies and one minute to learn each of the lists and one minute to rewrite the lists. The total time allowed was twelve minutes.

RESULTS

The means and standard deviations for concrete/abstract lists with or without strategies are given in Table 1.1

Table 1.1

Means and standard deviations for boys and girls using or not using strategies and concrete/abstract lists

Variable		Mean	Std. Dev.	N
Concrete Easy Words	Male			
	no strategies	9.14	1.29	14
	strategies	9.80	0.41	15
	Female			
	no strategies	9.80	0.41	15
	strategies	9.33	1.45	15
For Entire	Sample	9.53	1.02	59
Concrete Difficult Words	Male			
	no strategies	9.43	1.16	14
	Strategies	10.0	.00	15
	Female			
	no strategies	9.47	1.06	15
	strategies	9.47	1.46	15
For Entire	Sample	9.59	1.07	59
Abstract Easy Words	Male			
	no strategies	7.93	2.06	14
	strategies	9.60	.74	15
	Female			
	no strategies	8.53	1.41	15
	strategies	7.80	2.48	15
	Sample	8.48	1.88	59
Abstract Difficult Words	Male			
	no strategies	7.43	2.10	14
	strategies	9.40	1.60	15
	Female			
	no strategies	8.27	1.98	15
	strategies	8.80	2.30	15
For Entire	Sample	8.49	2.09	59

Analysis of variance of Sex (2) and Treatment (2) with repeated measures on List type (Concrete/Abstract) and List difficulty (Easy/Difficult) was performed on the data. The summary table of the statistics is given in Table 1.2, Table 1.2a and Table 1.2b

Table 1.2

Summary of repeated measures ANOVA for Sex and Treatment by List

Test of Between-Subjects Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	55	4.61		
SEX	1	1.47	0.32	0.575
TREAT	1	16.28	3.53	0.065
SEX BY TREAT	1	28.25	6.13	0.016*

Table 1.2a

Summary of repeated measures ANOVA for Treatment by Concrete/Abstract List

Tests Involving Within-Subjects Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	55	1.81		
CONCABS	1	69.41	38.28	.000
SEX BY CONCABS	1	.39	.22	.644
TREAT BY CONCABS	1	6.62	3.65	.061*
SEX BY TREAT BY CONCABS	1	4.25	2.34	.132

Table 1.2b

Summary of repeated measures ANOVA for Treatment by Easy/Difficult Lists

Tests Involving Within-Subjects Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	55	1.14		
DIFF	1	.09	.08	.776
SEX BY DIFF	1	.51	.45	.505
TREAT BY DIFF	1	3.49	3.05	.086*
SEX BY TREAT BY DIFF	1	2.13	1.86	.178

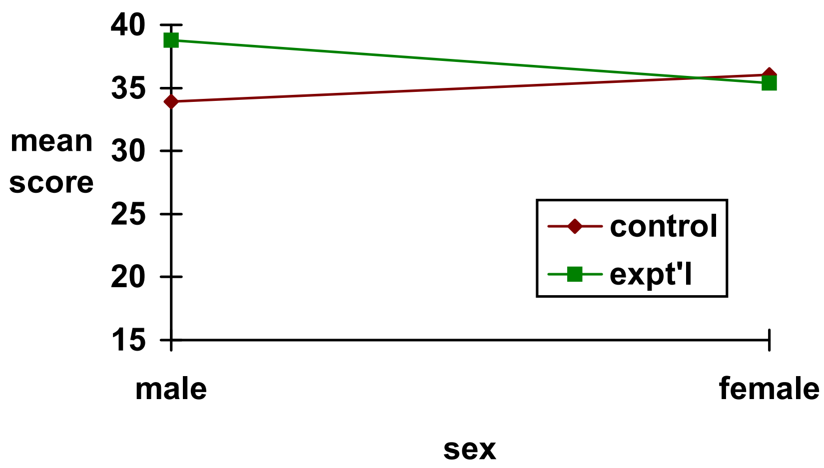
Analysis of variance showed one significant between-subject effect and two almost significant within-subjects effect. The former was an interaction of sex and treatment ($F=6.13$; d.f. = 1,55; $p=0.016$). The two latter almost significant within-subjects effects were (1) treatment by concrete/abstract list ($F=3.65$; d.f.=1,55; $p=0.061$) nearly reaching

the .05 level of significance and (2) treatment by easy/ difficult list (F=3.05; d.f. = 1,55; p=0.086).
These three effects will be discussed in turn:

Analysis of variance showed one significant between-subjects effect. This was an interaction of sex and treatment (F=6.13; d.f.=1,55; p=0.016)

Figure 1.1 indicates that boys do better after learning the strategies in the experimental condition than the girls.

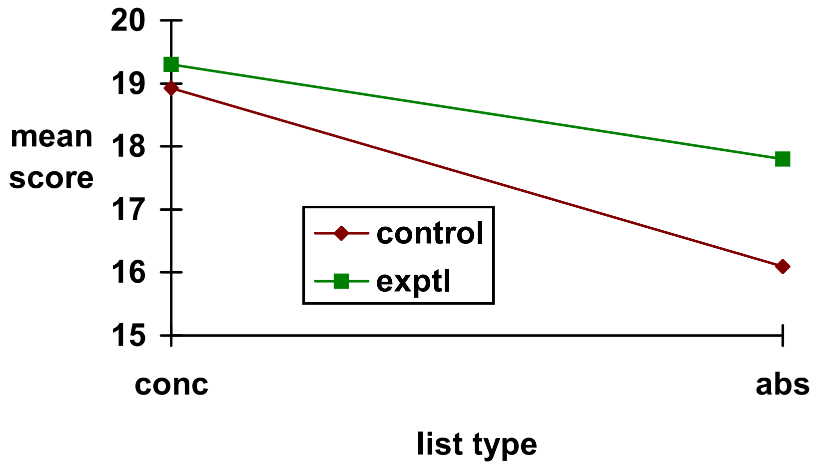
Figure 1.1 Female and male mean scores with or without strategies



Analysis of variance showed an almost significant effect. This was an interaction of Treatment by Concrete/Abstract List (F=3.65; d.f.=1,55; p=0.061).

Figure 1.2 shows mean scores for the entire population against concrete/abstract list scores. There was a greater decline in the mean scores for the control group than the experimental group from concrete to abstract words.

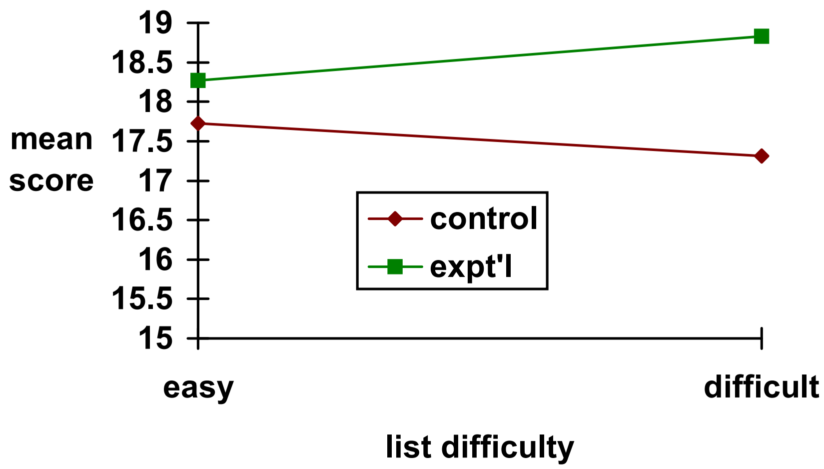
Figure 1.2 Mean scores of the entire population against concrete/abstract lists



Analysis of variance showed an almost significant effect. This was an interaction of Treatment by Easy/Difficult List ($F=3.05$; d.f. = 1,55; $p=0.086$).

In the graph, Figure 1.3 it is indicated that the recall of difficult abstract and concrete words was better than the recall of easy abstract and concrete words in the experimental condition.

Figure 1.3 Mean scores with or without strategies against easy and difficult lists



DISCUSSION

Sex by Treatment

The data showed one significant between-subjects effect. This was an interaction of sex by treatment. The girls did better than the boys in the control group and the boys did better than the girls in the experimental group.

Girls' Performance in the Control Group

The girls outperforming the boys in the control group might be as according to Maccoby (1966) in 22 studies on research in sex differences involving children three years old and under, that in 18 of these girls were superior to boys in verbal ability. In the other four studies there were no differences between boys and girls, so boys were not superior there either. Again Maccoby points out that throughout the pre-school years and early years girls exceed boys in verbal performance. Girls say their first words sooner; articulate more clearly and at an earlier age use longer sentences than boys do. At the start of school there are no longer any consistent differences in vocabulary between girls and boys, but girls learn to read sooner and do better on tests in grammar, spelling and word fluency. Research has found that more boys need remedial help in reading than girls and dyslexic boys outnumber dyslexic girls.

Other studies supporting the idea that girls have superior verbal ability include: Ballard (1920), reporting a study in which standardised reading tests were given and girls scored higher than boys in their rate of reading readiness. Rogers (1952) found that females were superior to males in spelling and articulatory flow, automatic recognition or recall of audibly registered sequences of sounds and superior in vocal-motor fluency. Thackray (1965), in a study on reading readiness skill tests involving auditory discrimination at the 1% level and using context and auditory cues at the 5% level, concluded that girls were superior to boys and also in this study the Kelvin Measurement of Ability Test showed girls did better than boys on the vocabulary profile and two reading achievement tests.

The fact that girls outperform boys on reading tests might have influenced their superiority in remembering the words on the lists in the control group in Experiment One. If they were superior in reading they might have had a more well-developed visual representation of a large number of small and common words such as 'she' and used phonological analysis for comparatively longer or new words (McCusker, Hilinger and Bias, 1981). Encountering a particular long or new word, i.e. 'respiration' regularly in a passage of reading, would be transferred to them through visual analysis as an addition to phonological analysis. In Experiment One the learning of the lists possibly introduced the subjects to new and long words, but as it was not involving the regular reading of a passage but of reading word lists, the subjects would not have been introduced to the same word more than once. It might also be that if girls are superior to boys in reading that it takes boys longer to identify words and this would affect how many words the boys remembered.

Anastasi (1958), Maccoby (1966), and Maccoby and Jacklin (19974) stated that female superiority in verbal ability emerged at age 11. In studies by Anastassi it was argued that there were gender differences for simpler verbal tasks, but Maccoby and Jacklin reported that female superiority was apparent in both high-level and low-level verbal tasks. The children in the present study were 13 and 14 year olds again possibly accounting for the girls superiority in the control group.

In a study by Vitulli (1991) it was found that females had higher short-term memory recall than males. The females in the control group did not have to learn strategies and they would only have the lists of words to store in their short-term memory, possibly giving them higher scores than the boys would. Baddeley (1996) supported by, Daneman and Carpenter (1980) has shown that memory span has a reliable association with reading skill. Accordingly, the combination of higher short-term memory and higher reading ability in girls, in studies by Ballard (1920) and Thackray (1965) might account for girls doing better in the control group than the boys in learning the word lists.

Boys Performance in the Experimental Group

In contrast to the girls doing better in the control grouped the boys did better than the girls in the experimental group. This may have been because after learning the strategies this enabled the boys to keep thinking about the lists and keep them active in their mind. Fabricus and Cavalier (1989) found that teaching children to learn the strategy 'labelling' (label or name items that one is instructed to remember) helped subjects remember because the children remarked they could hear the names of items they were told to learn in their heads. The children in Fabricus and Cavalier's study included some who knew that labelling improved recall, but had no conception of how it worked, and others who were not aware that labelling improved recall. Only those aware that the labelling strategy was capable of aiding an individual in his learning in the subsequent processing of information, were able to adapt it to the demands of a separate memory task a week later. The boys in Experiment One were instructed to learn 'learning strategies'. The learning strategies did improve their recall ability. They were not told however, that learning the strategies is known to improve recall ability. It would be interesting in further experiments to describe to subjects how learning strategies work, the fact that researchers have found that in some cases they do improve recall, and that they can be used in tasks other than learning a set of words in a word list. For example, the 'initial letter strategy' can be used to remember the order of the planets in their distance from the sun. The strategy of learning the first letter in each of the words in the following sentence ‘My very earnest mother just said use nine planets’, could be taught to children in science lessons at the same time as they were introduced to the study of the planets.

The boys doing better than the girls in the experimental group might be due to them having better spatial ability than girls. Maccoby (1966) in twelve studies found that boys were superior to girls in spatial ability. Imagery is not purely spatial nor visual, but may be both, Baddeley (1990). In the 1960s studies on imageability of words, and instructions to use imagery had a major effect on the rate of learning lists of words and prose passages according to Baddeley. The boys used strategies in Experiment One more effectively than girls did. There were seven strategies to learn in Experiment One and three were imagery strategies. In Experiment One ‘ Make into an Image’, ‘Image each Item’ and ‘Appearance Grouping’ were referred to as strategies three, six and seven, respectively. It is unclear which strategy or combination of strategies the boys used but if they used any or all of the imagery strategies this might have helped them remember the lists based on their superiority over girls in spatial ability (Maccoby). Also, the boys might have been high imagers and formed images to the abstract words in the lists faster than the girls (Ernest and Paivio, 1971). Ernest and Paivio discovered spatial ability had no effect on the speed with which subjects formed images to concrete words. However, high imagery subjects formed images to abstract words significantly quicker than low imagery subjects.

‘Make into a Story’, was one of the strategies to be learned by the subjects in Experiment One. It would be interesting in a further experiment to ask subjects to hand in their written story and sentences, and those abstract and concrete in theme could be identified. Begg and Paivio (1969) in comparing abstract and concrete sentences stated that a typical concrete sentence involves concrete nouns. An example of a concrete sentence was, ‘The spirited leader slapped a mournful host.’ An example of an abstract sentence was, ‘The arbitrary regulation provoked a civil complaint’. The experimenter would then be able to see whether concrete or abstract sentences were more effective in helping a subject in recall and which was used more by boys or girls.

Treatment by Concrete/Abstract List

There was an almost significant effect of treatment by concrete/abstract list. It was found the control and experimental groups did better in learning concrete words in contrast to abstract words. Paivio (1966) referred to word concreteness as the extent to which a word denotes an object that one is capable of experiencing through the senses. In comparison to abstract words, concrete words maintain an advantage over abstract words in paired associate learning, recognition, and free recall (Paivio, 1971), comprehension (Moeser, 1974), lexical decision (Bleasdale, 1987), (Schwanenflugel and Shoben, 1983), and pronunciation (de Groot, 1989).

According to Begg and Paivio (1969) words are classified into 'concrete' or 'abstract' and when subjects were provided instructions to make imagery connections for concrete and abstract words they made these connections faster for concrete words. This was due to the fact that pictorial representations of concrete words were easier to access than for abstract words based on the Dual Coding Theory of Paivio (1969). Paivio maintained that images of concrete objects were already stored in long-term memory and recall of concrete words could be facilitated because subjects could use information in two forms (imaginal and verbal) to assist them during the learning phase. The Dual Coded Theory enables one to derive an image from a verbal label and a verbal label from an image. Dual coded information could be accessed by either a verbal or non-verbal retrieval process. There is twice as much information about a twice-coded item than about an item that exists only in one coded form according to Paivio.

The case for learning concrete words better than abstract words was further extended by Sachs (1967b), and Begg and Paivio (1969). It was also shown by Sachs that memory for a sentence's meaning and memory for wording decay differently. Subjects do not notice whether a sentence has been changed from active to passive as much as they notice a change in meaning, e.g. positive to negative. Begg and Paivio extended this work to concrete and abstract sentences. In concrete sentences, semantic changes were better detected than lexical changes that did not effect the original meaning. Lexical changes were detected best in abstract sentences. The meaning of a concrete sentence was separated from the specific words, which composed it. Concrete sentences were stored in the form of images constructed on the basis of their semantic analysis. The exact wording of these sentences may be forgotten rapidly but the images they elicit tended to resist decay. The meaning of abstract sentences was more dependent on the constituent words and the memory for their meaning was more closely associated to their wording.

It was shown in a study by Stewart (1965) comparing high and low spatial ability subjects on several memory tasks that high spatial ability subjects were superior to low spatial ability subjects on picture recognition and the high spatial ability subjects found it easier to code a word as a picture than the low spatial ability subjects. In Experiment One if the subjects were known to be either high or low spatial ability subjects this could have accounted for their performance in learning the words but this was not known.

Treatment by Difficult/Easy List

There was almost a significant within-subject effect of treatment by difficulty of list, indicating that strategies may be more effective in the recall of difficult abstract and concrete words rather than easy abstract and concrete words. In the case of difficult concrete words this might be because these words were not all related to one another, as were the easy concrete words. Therefore, a strategy like ‘conceptual grouping’ might not have been as necessary in remembering easy concrete words, since the items were all foods. In contrast the indication that strategies might have been more effective in the recall of difficult abstract words, is difficult to explain if the boys were using imagery strategies - three, six and seven. This is because the words ‘with’ and ‘could’ contained in the abstract difficult list were not possible to image.

Schwanenflugel and Shoben (1983) support the view that more time is required to perform lexical decisions for abstract than concrete words presented out of context but the difference is cancelled out when these words are preceded by relevant sentences. Therefore, if ‘treatment by difficulty’ had been significant it might have shown that the abstract words used in it were easier to remember using strategies that put the abstract words into a context for example, using sentences to make a story (Strategy Five - Make Into a Story).

Davis and Proctor (1976) stated that the recall of abstract sentences was impaired more through verbal than visual interference and the opposite was true for recall of concrete sentences. In 'treatment by difficulty' if treatment had been significant it might have meant that subjects could have been forming sentences using Strategy Five and that impaired the learning of easy abstract words. A subject might have become confused in recalling sentences from a story he had made up and then not recalled the correct 'easy abstract' word he had to remember.

Procedural Problems

The seven learning strategies in this first experiment were too numerous to learn in the time that was allocated, as commented by the children in the experimental group. They were cut down to four strategies in Experiment Two.

EXPERIMENT TWO: LEARNING STRATEGIES AND WORD LISTS CONCRETE WORDS GROUPED BY CATEGORY AND LEARNING PERFORMANCE

INTRODUCTION

The students in Experiment Two were taken from the same age range as experiment one (13 - 14) year olds. The second experiment differed from the first because it was thought that seven learning strategies were too numerous to learn and it was decided to change to four learning strategies (one for each experimental group). The instructions for learning the strategies were adjusted, accordingly. The instructions for learning the strategies were not read aloud to the subjects by the experimenter. The lists were also changed to all concrete nouns as they were thought to be easier to recall than abstract words.

AIM

The aim of the second experiment was to find whether one taught learning strategy improves recall of revised word lists.

METHOD

Sample

The sample in the second experiment consisted of 50 year ten students (13 - 14 year-old) 23 boys and 27 girls. They were divided into groups of 10. The 10 in the control group were not given any strategy and the other 4 sets of 10 students, called the experimental group, were given one strategy each.

Materials

The learning material was a booklet consisting of instructions, four lists of concrete nouns and each list containing words from one familiar category such as 'transport' and one learning strategy. There were four learning strategies in total and they were Initial Letter, Make into a Story, Group in the same Family and Imagine a Picture. The dividing of the experimental group and assigning of learning strategies is described in the Procedure section.

Booklet Two

Read the word list instructions. There are examples showing you how to learn them. There will then follow four lists with nine words in each. You will be given one minute to learn each list and one minute to rewrite it. Write each list without looking at the instructions. Then write down any of the word list instructions that you used to remember the list.

WORD LIST INSTRUCTIONS

Initial Letter

Make into a Story

Grouping in the same Family

Imagine a Picture

Word list Instruction

(A) Initial Letter - Instructions

1. Use the first letter of each word in a list of words to make a word or words. This new word or words can be a nonsense word e.g. ROYGBIV (The first letter of every colour of the rainbow) - Red, Orange, Yellow, Green, Blue, Indigo and Violet.

2. Use the first letter of each word in a list of words to make a word or words. This new word or words can be a real word. e.g. DETECTORS (the first letter of each of the words) - <u>d</u>og, <u>e</u>el, <u>t</u>iger, <u>e</u>mu, <u>c</u>at, <u>t</u>oad, <u>o</u>wl, <u>r</u>at and <u>s</u>nake.

Word list Instruction

(B) Make into a Story - Instructions

1. Create a story to remember specific words in a list. The words (dog, eel, tiger, emu, cat, toad, owl, rat, snake) can be used in the following story -

The Australian farmer had seen an emu, owl, rat, toad and snake outside. He had a dog, cat and an eel in his house. However, he had to visit a zoo to see a tiger.

Word list Instruction

(C) Grouping Things In the Same Family - Instructions

(1) Make a list of all things in one group, e.g. all animals -
dog, eel, tiger, emu, cat, toad, owl, rat, and snake.

Word list Instruction

(D) Imagine a Picture - Instructions

1. Make a list of all things in one group which are the same colour by picturing several animals a all brown in the same picture

e.g. brown dogs, brown eels, brown tigers, brown emus, brown cats, brown toads, brown owls, brown rats and brown snakes.

2. Make a list of all things in one group by picturing each one separately,

e.g.

a brown dog
a brown eel
a brown tiger
a brown emu
a brown cat
a brown toad
a brown owl
a brown rat
a brown snake

3. Make a list of nonsense pictures,

e.g.

A brown emu with some brown eels stuck to its head acting as a hat.

A brown dog with a brown snake twisted around its neck looking like a scarf.

LIST 1	LIST 2
album	isle
atlas	county
autobiography	island
dictionary	continent
encyclopaedia	parish
handbook	estate
paperback	territory
textbook	district
thriller	region

LIST 3	LIST 4
submarine	orange
canoe	apple
aeroplane	apricot
escalator	bananas
tractor	dates
helicopter	lemons
motorcycle	strawberries
automobile	pears
spaceship	tangerines

Procedure

The students were presented with a booklet that contained general instructions and four lists of words. There was one control group (1x10 subjects) and four experimental groups (4x10 subjects). The students in the control group and the experimental groups were told to look at each list for one minute and rewriting time was one minute per list. The students in the control group were told to rewrite the lists in any order that they remembered them. They were given eight minutes to complete the task. The students in the experimental group were divided into four groups of ten and told to learn one strategy each chosen by the presenter. The strategy was explained in the same booklet that contained the general instructions and each group of ten students was taught how to use the assigned strategy. They were given one minute to learn the strategy. The total time allowed to complete the booklet including the learning of the strategy was nine minutes.

RESULTS

The means and standard deviations for List1, List2, List3 and List 4 are shown in Table 2.1

Table 2.1

Means and standard deviations for L1 - L4

Variable		Mean	Std.Dev.	N
List 1				
	Male	8.09	1.28	23
	Female	7.89	1.15	27
For Entire	Sample	7.98	1.20	50
List 2				
	Male	6.70	2.40	23
	Female	7.22	2.10	27
For Entire	Sample	6.98	2.24	50
List 3				
	Male	6.39	2.19	23
	Female	7.41	1.67	27
For Entire	Sample	6.94	1.97	50
List 4				
	Male	6.65	2.59	23
	Female	8.41	1.01	27
For Entire	Sample	7.60	2.08	50

Analysis of variance of Sex (2) and Strategy (4) with repeated measures on List (4) was performed on the data. The summary table of the statistics is given in Table 2.2

Table 2.2

Summary of Repeated Measures ANOVA for Sex and Strategy by List

Test of Between-Subjects Effects

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	40	7.36		
Sex	1	23.32	3.17	.083
Strategy	4	14.69	1.99	.114
Sex By Strategy	4	8.71	1.18	.333

Test of Within-Subject effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	120	1.99		
List	3	12.96	6.50	.000*
Sex by List	3	7.01	3.52	.017*
Strat by List	12	2.60	1.30	.225
Sex By Strategy By List	12	.46	.23	.997

There were two significant within-subject effects. There was a significant interaction of sex by list (F=3.52; d.f. =3,120; p=0.017). Girls did better than boys in the experimental condition in lists 2,3, and 4 and boys did better than girls in list 1. There was also a significant main effect of 'List' (F=6.5; d.f. =3,120; p= .000). Some lists were easier to learn than others.

Figure 2.1 shows the mean scores for girls (F) and for boys (M) plotted separately against
list number. It shows increasing divergence of girls' above boys' mean scores.

Figure 2.1 Female and male mean scores against list number

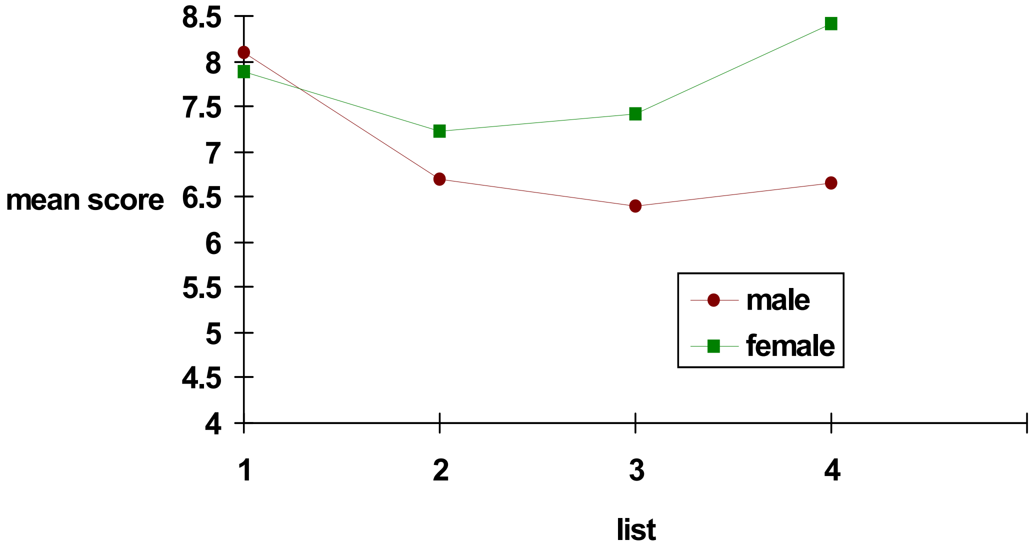
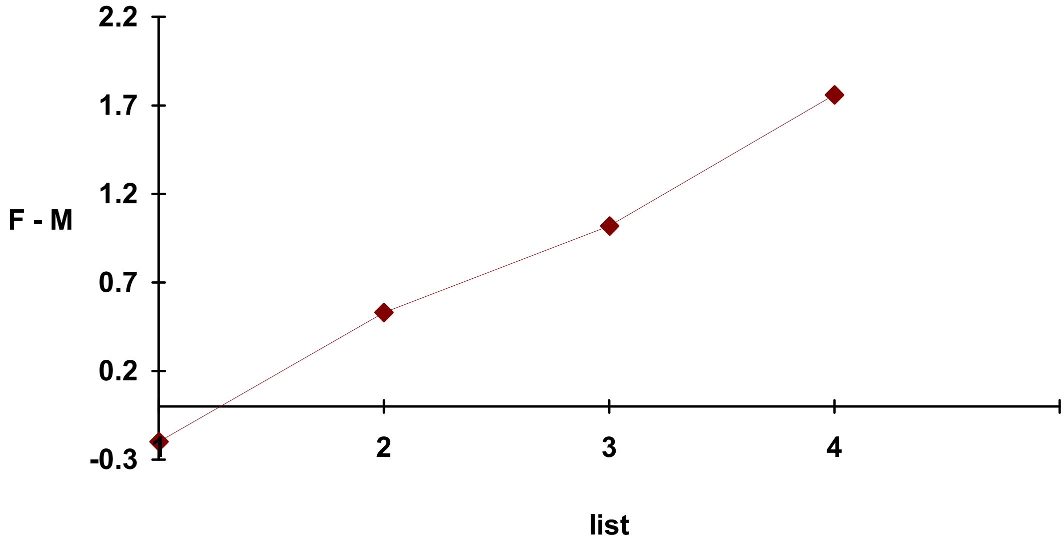


Figure 2.2 shows the trend in the mean difference between girls and boys (F-M) with list number as being almost linear. The control group was excluded because it was too small (1x10) subjects.

Figure 2.2 Difference between female and male scores against list number



DISCUSSION

Sex by List

There was one significant within-subject effect. This was an interaction of sex by list. There was also a significant within-subject effect. This was a main effect of list in which some lists were easier to learn than others. These two effects will be discussed in turn.

Boys' performance on the lists

The boys doing worse than the girls on lists two, three and four might have been because with repetition boys were worse than girls in remembering lists. It may be that boys were not as studious as girls, or they were getting more tired after each list, or they were bored, or they had poorer motivation than the girls. Adams (1967) noted that one's performance in a trial could be decreased by lack of motivation or work inhibition. In contrast, Goran - Nilsson (1987) conducted an experiment in which subjects were either given the standard instructions for free recall learning, or were given a substantial

financial reward for good performance. This information was given before the experiment began or between learning and recall, so it could influence both learning and retrieval. There was no difference in the performance of the group offered a reward and the group not offered a reward. Goran - Nilsson's experiment did not imply that motivation is not relevant, because if the students in his experiment were totally unmotivated they might not have participated in the experiment.
According to Baddeley, the subjects in memory experiments are usually highly motivated. This may be due to the fact that they feel that we are dependent on memory for learning. The incentive of reward in Baddeley's view had little effect on the performance of subjects in his experiments on memory.

In a study by Chan (1994) it was found that motivational variables such as self-perception of competence, was not particularly important for students in the primary and lower secondary years. In Experiment Two the age range was 13 - 14 and corresponds to the lower secondary years. The boys in this experiment might not have been expected to be highly motivated because of their age.

The words used in each of the four lists were arranged so that each list contained words of a specific category, e.g. tractor, helicopter and canoe represented the category, transport (List Three). An interesting study by Tulving (1962) found that giving names of categories at the time of testing enhances recall. In Experiment Two the students were not told the category names before nor after they were given the lists. This might be why the boys did not do as well as the girls in recalling the words on the lists.
Tulving and Pearlstone (1966) investigated this effect in an experiment where subjects learnt 12 or 48 words consisting of one, two or four words in each category. The results were that subjects who were given the category names recalled many more words than those tested by free recall. Their study linked categorisation and organisation to the process of retrieval.

It may also be that the boys in Experiment Two experienced an interference effect of learning a new list and getting confused with what they had previously learned.
Retention might have decreased by learning previous similar lists. Accordingly, in 'retroactive inhibition' material previously learned is interfered with or forgotten by

material which has been subsequently learned and in ‘proactive inhibition’ newly learned material can not be remembered when the subject is tested because material (usually of similar type) which has been learned on an earlier test interferes with the new material, from being retained. In Experiment Two the lists were of similar type e.g. books and it might be that proactive inhibition took place.

Girls Performance on the Lists

The better performance of the girls after learning each list might be because they were getting faster at articulating the lists to themselves and rehearsing and recalling the lists. According to Hulme (1984) in his experiment relating recall to speech rate for words of different lengths over a wide variety of ages in children and adults, it was found that subjects of different ages recalled, on average, as much as they could say in roughly 1.5 seconds. In serial recall nine year olds rehearse only the most recently presented to-be-recalled list items (single item rehearsal) but as age increases more cumulative rehearsal takes place Cermak (1983). The girls in this experiment were 13 - 14 years old and might have become better at rehearsal. The girls not doing better than the boys on list one but then doing better than the boys on lists two, three, and four and also performing better after each list might be due to the practice effect. The girls were getting more skilful at recall of the words on the lists as they kept doing them.

According to Flavell (1971) the development of encoding and retrieval strategies is age related, as are increases in monitoring and knowledge about these encoding and retrieval operations. Cavanaugh and Perlmutter (1982) noted knowledge about memory should be referred to as ‘metamemory’. Flavell (1978) described two chief types of memory knowledge ‘sensitivity and variables’. The former term referred to knowledge about the necessity to use memory strategies for a specific task, that is knowledge that some tasks required mnemonics and others did not. The latter term referred to an individual’s knowledge about specific facets of memory situations. ‘Person variables’ apply to knowledge about one’s own and other’s characteristics, limitations and abilities as a memoriser. An individual might know that for him or her, names are difficult to remember. In Experiment Two the boys not outperforming the girls on lists two, three, and four may have been due to the fact that they were not as good as girls in memorising lists of words.

A study by Brown (1978) examined another facet of 'person variables' in her treatment of secondary ignorance (not knowing that one does not know). According to Brown a mature learner evades secondary ignorance by knowing what task and relevant information is available and whether knowledge gaps can be filled via making inferences from this knowledge or whether knowledge must be acquired from an external source. Miyake and Norman (1979) showed that in order to ask a question it is essential the learner must know that he or she does not know something, but most importantly have an idea about what that something is. Task variables encompass all of the characteristics about the materials and task demands, that an individual comes to know affects performance. An individual might for example know that recognition tests are on the whole easier than recall tests.

Strong (1912) found that performance declines as the number of events to be learned increases. The result is called the 'list-length effect' and is a touchstone for any model of recognition memory. In Experiment Two the word lists were all the same length. Experiment Two used four lists in the testing of recall. Recall tests are considered to be more difficult than recognition tests according to Miyake and Norman (1979). This could account for the boys not performing as well as the girls in the experimental group in Experiment Two. It might also be that the boys did not know that recall tests are usually more difficult than recognition tests or that Experiment Two involved the testing of recall. The boys were 13 - 14 years old and at that age not considered mature learners.

Cavanaugh and Perlmutter (1982) maintained the knowledge about how to use mnemonic strategies differs among individuals. An individual might know that rehearsing a phone number just found in a directory will assist in ensuring its retention. An individual may also know that he or she is quite adept at remembering names (person variable) and also know that the task to learn the names of 20 new students is laborious (task variable) and therefore, may need some strategy like imagery (strategy variable). The types of variables are important and also various combinations of them are interesting. In Experiment Two 'strategy' was not significant. Each subject was told to learn a specific strategy and would not have been instructed to explore various combinations of strategies. In a further experiment it would be interesting to focus on the learning of various combinations of strategies, for example instructing subjects to learn two strategies at a time (make into a story, and imagery) and using the same lists of words to test learning performance.

According to Cavanaugh and Perlmutter (1982) in examining verbal ability, those with limited linguistic skills (e.g. young children) and even with more articulate subjects, all kinds of knowledge are not equally verbalisable. In Experiment Two words needed to be remembered and they would be equally verbalisable depending upon the how well the subject could read and pronounce the words. In contrast Wellman (1977c, 1978) and Yussen and Bird (1979) established a nonverbal technique for assessing memory knowledge. Pictures were substituted for words in the presentation of memory problems. Therefore, those of limited language skills could use this nonverbal technique. It is not known whether pictures being used instead of wordlists in Experiment Two would have resulted in the boys outperforming the girls.

The ability to monitor one's own strategy use was examined by Bjorkland and Bernholtz (1992) in asking children aged six, eight, and ten years to name the strategy that they had used to remember classmates' names. Those whose reported strategy was similar to their observed strategy were labelled as 'consistent'. Those who could not name a strategy or who named a strategy dissimilar to their observed strategy were labelled as 'inconsistent'. It was interesting that subjects of high and low intelligence were just as likely to be labelled as 'consistent'. In Experiment Two strategy was not significant and it was not known whether knowing if the subjects were consistent or inconsistent in their ability to name a strategy would have had an influence on their performance on the word lists.

Gifted Children and Strategy Use

Swanson (1989) found that gifted sixth grade children (mean IQ = 127.72) regularly recalled more items than nongifted children (mean IQ = 105.20). In Experiment Two and in Experiments One, Three and Four it was not known whether any of the subjects were gifted and it was unknown whether this influenced their performance. Swanson also examined children's abilities to (1) prioritise effort on a primary and equally important secondary tasks; (2) distribute and allocate resources between tasks; and (3) cope with transfer or interference of information from the central to the secondary task as indicators of cognitive monitoring. He found in his first experiment, nongifted and gifted children were equally capable at the prioritising of tasks, at sharing resources between the two tasks, and were at equally low levels with interference of information between the two tasks. In the second experiment, which accommodated a high effort condition where the children were to choose which of two equally applicable words completed a sentence, gifted children made fewer intrusions and were less likely to be distracted by the secondary task. It was Swanson's belief that the high verbal ability group did not appear to utilise qualitatively different monitoring strategies than the nongifted children. There were some conditions under which the gifted children were more adept in their use of monitoring strategies but exactly what triggered the efficient use of monitoring strategies was ambiguous. Swanson further argued that there was no hint that ability differences in cognitive monitoring diminish or accelerate with age. In Experiment Two it was not known whether any of the children were gifted and therefore, if there were any gifted children in the sample this is a possible explanation of higher recall ability of one student over another.

Main Effect of List

The words used in each of the four lists were arranged so that each list contained words of a specific category, e.g. tractor, helicopter, and canoe represented the category, transport (List Three). Each word in the lists could be analysed in another experiment and its correlation with all the words in the lists as a whole, obtained to find out why some words were easier to recall than others. Also, the words in the four lists contained high associates such as 'apple' and 'pear' and this might have influenced subjects' ability to recall words. According to Jenkins and Russell (1952) when subjects are asked to recall lists with high associates e.g. *man woman*, and even if the words are split up during presentation, they are usually recalled as pairs.

A study in categorising by Bousefield (1953) presented subjects with 60 words, consisting of 15 animals, 15 boys' names 15 professions and 15 vegetables, not in order. The result was that recall was much higher than recall of a list of 60 unrelated words. It is notable that the lists in Experiment Two in which each contains related words, e.g. list four contains three fruits (orange, apple, apricot, etc.) Jenkins and Russell (1952) reported, should have been easier to recall than lists of unrelated words. The boys only did better than the girls on list one (which contained words pertaining to the category, 'books').

The girls doing better than the boys on lists two, three and four might be due to the practice effect in which a general improvement takes place in performance as subjects acquire skills associated with the task the experiment poses. In Experiment Two the girls would have to complete the task of learning four lists and after not learning list one as well as the boys, they did outperform the boys in learning the next three lists. Maccoby and Jacklin (1974) stated that girls were superior in tasks of high and low level verbal ability. Bannatyne (1971) also found that girls had superior verbal functioning in language skills compared to boys. Maccoby (1966) reported that girls were superior in vocabulary and this emerged at age 11 and continued through adulthood. In Experiment Two the girls were 13 - 14 year olds, the same age as the boys. According to Maccoby, girls might have been more familiar with the vocabulary used in the instructions to the word lists and perhaps even the words on the lists than the boys making the task of learning the words easier for them. Subjects were not tested on the strength of their vocabulary ability, but it would be interesting in a further experiment to test this ability and observe the differences in vocabulary used by males and females after learning Word List Strategy B (make into a story). Of particular interest would be the words (noting their level of difficulty) chosen to compose the story and if those with a superior vocabulary were better at learning lists of words.

The boys did better than the girls only on list one. This list contained words all relating to reading material, i.e. textbook. There would have to be further investigations as to why the boys did better on this list than the girls did. In Experiment Two the subjects that participated were not known to suffer from any language impairment. However, if any language impairment did exist to even a minor degree in any of the subjects, the literature points out that boys outnumber girls in language disabilities. According to Templin and Darley (1960) real deviations in language behaviour are more frequently found in boys as compared to girls. Bannatyne claims that most aphasic cases tend to be boys and this follows sex difference patterns in dyslexia, in other language disabilities and in other research on normal children. Also in the area of reading disabilities boys predominate according to Maccoby (1966). In the area of emotional disturbance, school failure, delinquency, autism, social immaturity and defects of speech, hearing and vision, boys invariably outnumber girls (Bentzen, 1966). In the four experiments the quality of the vision and the hearing of the subjects was not known to the experimenter, but it was assumed that none of the subjects suffered any of these anomalies to an extent, which would have impaired a subject's performance on learning the words on the lists.

'Strategy' was not significant in Experiment Two and if Strategy C (Grouping Things In the Same Family) had produced a significant effect this would have been unusual because the lists were already in categorised form.

To find which strategy helps which people the most, the following factors were proposed as important: 1 - gender, 2 - age, 3 - gender / age / time. The outcome was to do a study with younger children, and make the strategy instructions for each strategy simpler in order to hopefully reduce the time needed to learn it.

EXPERIMENT THREE: LEARNING STRATEGIES AND WORD LISTS CONTAINING CONCRETE WORDS OF MIXED CATEGORIES AND LEARNING PERFORMANCE

INTRODUCTION

The subjects in Experiment Three were younger than those in Experiments One and Two, and they were 10 - 11 year olds. It was decided in Experiment Three to alter the word lists again to all concrete nouns but the words in each list would be able to be grouped into three categories. For example in list one, the categories were animals, vehicles, and fruit. The strategy headings were the same as in experiment two but 'Initial Letter Instructions' was changed to 'First Letter Instructions'. The instructions for the four strategies (First Letter Instructions, Making into a Story, Grouping in the Same Family and Imagining a Picture) were changed.

AIM

The aim of the third experiment was to find whether one taught learning strategy improves recall with second-revision word lists.

METHOD

Sample

This sample consisted of 99, year 5 students, (10-11) year old, 55 male and 44 female from an urban primary school in Staffordshire. They were divided into groups and each was given a strategy as follows: 22 control, 24 strategy 1,17 strategy 2, 16 strategy 3, and 20 strategy 4.

Materials

A booklet was presented to the students, consisting of general instructions, four lists of concrete nouns belonging to three different categories and one learning strategy. There were four learning strategies in total and they were the same ones that were used in experiment two. The dividing of the experimental group and assigning of learning strategies is described in the Procedure section and follows the same pattern as experiment two.

Booklet Three

Instructions

You will be given a list of 12 words. Look at the lists for two minutes. Write down the list of words. At the end try to describe how you remembered the words.

(A) First Letter Instructions

Using the first letter of each word try to make a word. This can be a real word -

<u>s</u>houlder
<u>u</u>nderground
<u>p</u>alm
<u>e</u>ye
<u>r</u>ailway

(SUPER)

1. This can be more than one real word -

<u>p</u>alm
<u>u</u>nderground
<u>r</u>ailway
<u>s</u>houlder
<u>e</u>lephant
<u>m</u>otorway
<u>a</u>rm
<u>k</u>angaroo
<u>e</u>ye
<u>r</u>ailway

(PURSE MAKER)

(B) Making Into a Story

Write a story to help remember the 12 words in the list. The words are:

shoulder
underground
palm
eyes
railway
motorway
arm
runway
kangaroo
elephants
tigers
snakes

e.g. My shoulder and arm had been hurting so I decided not to drive on the motorway. I purchased a video that fitted into the palm of my hand and switched on the television. The screen needed adjusting so it did not hurt my eyes. The video, about travelling, began with a man entering an aeroplane on a runway in Britain and ended with this man boarding the underground in London. The man in the video travelled to Africa and Australia. In Africa he saw animals such as tigers and elephants and snakes and in Australia he spied a kangaroo in front of the railway.

(C) Grouping things in the Same Family

Make a list from a larger list of all things in one group e.g. List -

shoulder
underground
palm
elephant
runway
motorway
arm
railway
kangaroo
eye
tiger
snake

palm	railway	snake
eye	underground	elephant
arm	motorway	tiger
shoulder		

(D) Imagining a Picture

Make a list of all things in the list by picturing each one separately

a man's shoulder
a woman's arm
a man's eye
a baby's palm

(Body parts of a human being)

List 1	List 2
car	foot
tortoise	piano
banana	potato
tractor	ear
rat	harp
motorcycle	onion
lemon	saxophone
ape	tomato
orange	organ
truck	mouth
elephant	lettuce
apple	finger

List 3	List 4
bee	chair
orchid	rabbit
dragonfly	desk
stomach	coat
poppy	lion
elbow	table
marigold	trousers
teeth	ostrich
ant	hat
snapdragon	emu
wrist	shorts
spider	stool

Procedure

One learning strategy was assigned to each of four groups of students. The control group was not given any learning strategy. Instructions on how to complete a booklet containing the four lists of words were included in each one and given to the experimental and control groups. One of four different learning strategies was taught to its assigned group and in addition the same written instruction was in the booklet containing the four lists of words. The students were told to learn the lists for one minute and rewrite each list taking one minute. Students given a learning strategy to learn were given one minute to learn it.

RESULTS

The means and standard deviations for List1, List2, List3 and List 4 are shown in Table 3.1

Table 3.1

Means and standard deviations for Sex and Lists (1 - 4)

Variable		Mean	Std. Dev.	N
List 1	Male	9.29	1.96	55
	Female	9.93	2.03	44
For Entire	Sample	9.58	2.00	99
List 2	Male	9.13	2.49	55
	Female	10.09	2.24	44
For Entire	Sample	9.56	2.42	99
List 3	Male	8.58	2.31	55
	Female	9.70	1.65	44
For Entire	Sample	9.08	2.11	99
List 4	Male	9.49	2.19	55
	Female	10.48	2.09	44
For Entire	Sample	9.93	2.19	99

An analysis of variance of Sex (2) and Strategy (4) with repeated measures on List (4) was performed on the data. The summary of the statistics is given in Table 3.2

Table 3.2

Summary of Repeated Measures ANOVA of Sex and Strategy by List

Test of Between-Subjects Effects

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	89	12.56		
SEX	1	82.39	6.56	.012*
STRAT	4	14.50	1.15	.336
SEX BY STRAT	4	18.63	1.48	.214

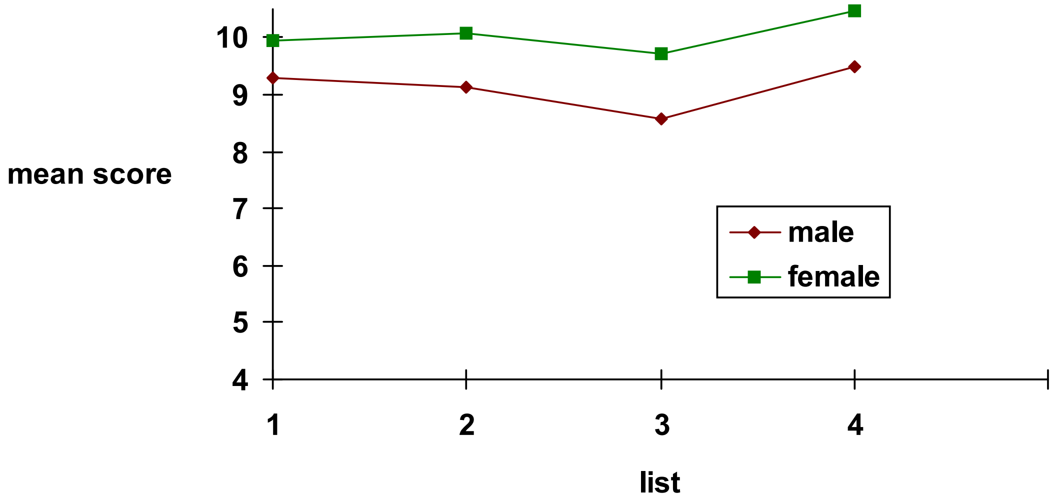
Tests Involving 'List' Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	267	1.88		
LIST	3	12.75	6.79	.000*
SEX BY LIST	3	1.24	.66	.577
STRAT BY LIST	12	.74	.39	.965
SEX BY STRAT BY LIST	12	1.16	.62	.827

There was a significant between-subject effect of sex ($F=6.56$; d.f. = 1,89; $p = .012$). This was a main effect of sex and it showed that the girls did better than the boys on all the lists. There was also a significant within-subject effect of list ($F= 6.79$; d.f. = 3,267; $p = 0.000$). This was a main effect of list. It showed that there was a difference between the four lists and some were easier to remember than others.

Figure 3.1 shows the mean scores for girls (F) and for boys (M) plotted separately against list number.

Figure 3.1 Female and male scores against list number



DISCUSSION

Main Effect of Sex and Main Effect of List

There was a significant between-subjects effect of sex and a significant within-subject effect of list . This was a main effect of sex and a main effect of list. The main effect of sex indicated that girls obtained higher mean scores than the boys in the control and experimental groups. The main effect of list indicated that some lists were easier to learn than others.

Main Effect of Sex

The girls outperforming the boys overall in this experiment may be due to being superior in verbal ability in comparison to boys, as according to Maccoby (1966) at about age 11 the sexes diverge, with females becoming increasingly better on tasks involving both receptive and productive language, and on 'high-level' verbal tasks (analogies, comprehension of difficult written material, creative writing) and lower-level measures (fluency).

Other studies have also shown that girls have higher verbal ability than boys do. Hunt (1975) compared subjects of high and low verbal ability on several tasks and found that girls outperformed boys. Vandenberg (1966) reported that females were superior in verbal fluency over males and this was reflected in their spelling, grammatical ability, articulation of surnames and talking earlier than boys. In Experiment Three the girls might have been able to articulate the words to themselves more clearly than the boys and this would have aided them in recall.

Beard (1965) found in a factorial study of structure and perception that girls were superior in verbal fluency. Ballard (1920) in standardising his reading tests found girls scored above boys in the rate of reading. Since time was important to learning the word lists, it might have been that the girls read the words faster than the boys did and this would have been influential in the number of words recalled. The boys in Experiment Three might not have been as adept at reading as the girls. If they encountered a word they did not know on the word list they might have employed global solutions including skipping the word or guessing or analytic solutions such as sounding the word out. They could not use contextual clues because the words were presented singularly.

As girls are purported to have better verbal ability than boys, (Maccoby 1966) then examining the rate of processing within the phonological loop which is provided by speech rate is useful. In Experiment Three the girls might have encoded and rehearsed words more quickly than the boys and in doing so remembered a longer sequence of words than the boys. In several studies it was shown there is a systematic relationship between the rate at which words may be spoken and there are increases in memory span with age Hulme (1984). Hulme and Tordoff (1989) compared the memory span of four, seven and ten year olds for one- two- and three-syllable words. The results were that there was a notable difference in memory span between groups and more significantly differences in memory span between age groups were closely paralleled by increasing speech rate.

The Brown - Peterson memory paradigm used by Hunt (1975) comparing high and low verbal ability subjects involved retaining a consonant trigram over a period of a few seconds filled with counting backwards. The Sternberg and arithmetical calculation data used in this experiment revealed that those with high verbal ability were quicker in the utilisation of information in short-term-memory. As girls are thought to have higher verbal ability than boys according to Maccoby (1966) then they should be quicker in learning words on a word list than the boys. In Experiment Three girls learned more words on the word lists than boys in the experimental and control conditions.

The girls in Experiment Three might have been better at learning word list strategies than the boys. In a study by Chan (1994) it was pointed out that strategic learning could be enhanced for primary and lower secondary students by combining strategy instruction with attributional training. In addition to teaching students the use of cognitive strategies for learning, teachers should also be able to advise students that their learning successes and failures are attributable to the use of effective or ineffective strategies. In Experiment Three the subjects were taught word list strategies. In Experiment Three 'strategy' was not significant. Discussion of attributional training was not done in any of the experiments. It is not known whether the students would have performed better or worse had they been instructed in this training

There might be a neurological reason that girls do better than boys on verbal tasks. Shaywitz (1995) put forward the view that the functional organisation of the brain for language showed during phonological tasks brain activation in males lateralised to the left inferior frontal gyrus region and in females the pattern of activation engages more diffuse neural systems involving the left and right inferior frontal gyrus. Accordingly, sex differences in the functional organisation of the brain for language indicated that these variations exist at the level of phonological processing. The words 'man' and 'mad' are phonologically similar and the words 'day' and 'bar' are not phonologically similar. The words on the lists in Experiment Three were intended to be phonologically dissimilar. Thus, in recalling the words the discrimination among memory traces would not be difficult, as is the case if the memory traces are similar i.e. in phonologically similar words.

Volf (1994) said there were sex differences in strategies of memorising implying wider participation of right hemispheric ways of information processing in providing some forms of verbal activity in females. The girls in the experiment would have an advantage over boys according to Volf if their brains were capable of a greater amount of information processing relating to verbal activity than boys. The boys not doing better than the girls in Experiment Three may be due to the learning of strategies interfering with the learning of the words on the word lists, as in ‘retroactive interference’. In the case of ‘retroactive interference’ the number of words forgotten from a list is directly related to the number of other lists inserted between the learning of the list and the recall of that list. The boys would have been told to learn their assigned strategy and then to learn all the lists by applying the strategy. After learning the strategy they would have been presented with lists one through four. It is unclear of course how well they learned their assigned strategy, but they might have been learning each successive list and trying to remember the strategy to remember the list before going on to the next list. Therefore, the strategy being recalled first and then a list might interfere with the learning of the list. In contrast, proactive inhibition might have taken place where the boys in learning the four similar lists of words (all concrete nouns) were remembering less words as they went along from list one to list four because of the similarity of the lists. In actual fact their score went down slightly on list two and then more dramatically on list three, however it improved on list four. The boys' and the girls' scores both went down on list three. This may be due to the confusion between the similarity of the words 'snapdragon' and ‘dragonfly’ in list three. Wicklegren (1965) stated that articulating items which sounded alike confused subjects. In list three the words ‘dragonfly’ and ‘snapdragon’ might have become confused because the suffix ‘fly’ and the prefix ‘snap’ might have not been articulated properly by the student and then forgotten, leaving only the word ‘dragon’. Those with higher verbal ability had the advantage over those with lower verbal ability in being able to extract meaning quickly from a physical representation. According to Maccoby (1966) girls have higher verbal ability than boys and this might explain why they outperformed the boys in the experimental and control groups in Experiment Three.

The development and use of memory strategies in children according to Schneider and Pressley, (1989) occur during the early elementary school years and children can be trained to use, maintain, and transfer strategies prior to entering school. Text comprehension strategies usually develop in later elementary school years (Brown and Smiley, 1978) after children learn basic reading skills such as decoding. In Experiment

Three the girls outperforming the boys in the experimental and control groups, may have been due to their ability to transfer strategies, being superior to boys (Schneider and Pressley, 1989).

In two studies on gifted children and learning strategies it was found that they were more likely to use a taught strategy than their non-gifted peers were in two different tasks. The German study by Kurtz and Weinert (1989) reported that ten - twelve year old gifted children were more likely to use study and recall strategies for a sort-recall task than their nongifted peers. Furthermore, twelve year olds were more likely to use these strategies than ten year olds were. Anderson (1985) stated that gifted ten year olds used strategies for reading more efficaciously than nongifted children. In Experiment Three 'strategy' was not significant and it is not known if any of the subjects were gifted. It would be interesting to replicate Experiment Three using the same age group (10-11) and experimental materials with gifted and nongifted subjects and compare recall performance.

Borowski and Peck (1986) found that gifted eight-year-olds were more capable of adopting a clustering-rehearsal strategy during a maintenance task than their nongifted peers when given only a brief verbal explanation of the strategy. The gifted subjects pre-existing metacognitive knowledge filled in the gaps in minimal training (Borowski and Peck, 1986). In a further experiment, the assessing of pre-existing knowledge about the use of strategies would be informative and useful in analysing subjects' recall performance.

Torgensen (1977) reported that because of ineffective learning strategies some children fail at their work. In Experiment Three 'strategy' was not significant and it might be that the strategy the subjects in each group had to learn was ineffective. This could be because the subjects did not understand the strategy, did not have enough time to learn the strategy or did not have enough practice in applying the strategy. In further experiments more time could be devoted to learning a 'learning strategy' and demonstrating this via a pre-test, testing the ability to use learning strategies.

According to Gaddes and Edgell (1995) children may fail at their work because of inattention, weak self-confidence, poor motivation and a lack of a strong intent to learn.

He also found that a mixture of perceptual deficits and motivational weaknesses might cause failure. The boys in Experiment Three might not have been giving their full attention to learning the word list strategies, because they may have thought they were unimportant. They possibly felt that learning the lists of words was not a meaningful task, because it did not relate to what they were currently learning in school.

In yet other cases, neither perceptual deficits nor motivational weaknesses may be involved and the student may perform at a mediocre level based on their creative imagination or originality. Gaddes (1983) noted that these students may perform satisfactorily on tests of highly structured material that they had mastery over. Faced with open-ended problems that entailed mental procedures of trial-and-error, independent choice and decision, and restructuring and reorganisation of present knowledge, some students may feel they are unable to cope. In Experiment Three the boys in not outperforming the girls in the experimental group, might not have been able to learn the word list strategies and apply them to a list because they had no previous experience of learning a list of words nor of learning a word list strategy. The boys may not have been able to reorganise any of the lists according to a word list strategy. For example, the third strategy (Grouping Things in the Same Family) would have required reorganisation of the lists in category order.

Also, Gaddes pointed out that students who performed well on tests of highly structured material they had gained mastery over, may be able to learn routinised number facts efficiently. Arithmetical problem solving that involves a flexible interaction of several conceptual processes operating simultaneously and sequentially may appear to some students as being too difficult and they might lack adequate adaptive intelligence to deal with problem solving. These students according to Gaddes may lack adaptive intelligence either through inheritance or unimaginative teaching. In Experiment Three the learning of number facts and arithmetical problem solving were not included and it would be interesting in a further study to see if there was any relationship between learning lists of words and lists of numbers.

In Experiment Three, the boys not outperforming the girls according to Craik (1973) may have been due to the strategies they had to learn, not being compatible with their existing knowledge structures. It may also be as maintained by Bransford et al. (1979) that one’s knowledge about retrieval influences one’s ability to encode. It is important that the encoding activity matches retrieval demands. Paris (1978) argued that memory is not an exact copy of experience and one is actively interpreting incoming stimuli. Furthermore, Cavanaugh and Perlmutter (1982) stated that one's previously acquired knowledge is applied to the information presented and retrieval is the reconstruction of accessible information from knowledge and the retrieval environment. However, these authors emphasised the context in which memory operates is a vital determinant of memory performance. In Experiment Three the boys may not have been able learn the word list strategies possibly because of not having prior knowledge about learning strategies. Any of the learning strategies assigned to them to learn such as 'grouping' might have seemed to be invented for the experiment at hand instead of having an extensive empirical history. Therefore, they might not have been able to relate the learning of the strategy to a knowledge base.

Alexander et al.(1995) maintained children are thought to be able to regulate and control strategy use when they independently use and transfer strategies in contrast to using strategies only when prompted or guided. Ashcroft (1990) stated that strategies can be derived automatically and not as some part of a conscious metacognitive evaluation of task needs. Fabricus and Cavalier, (1989) reported that the regulation of one's own strategy use is thought to be highly dependent on accompanying metacognitive knowledge about the strategy (variable knowledge). It was not known if the subjects in Experiment Three knew how to use strategies. They were instructed to learn word list strategies but a specific test to designate how well they understood how to use these strategies was not included. This type of test could be included in a further experiment.

According to Maccoby boys are better at spatial task than girls. Stewart (1965) maintained higher spatial ability subjects find it easier to code a word as picture than low spatial ability. In comparing subjects of high and low spatial ability in a paired-associate task of picture-digit and word-digit pairs Stewart (1965) found that picture-digit pairs were learned faster by those with higher spatial ability. In Experiment Three 'strategy' was not significant so it was not possible to know if boys were using strategy four (imagining a picture) which may be a strategy used by those with higher spatial ability, to remember the lists.

Main Effect of List

The main effect of 'list' in Experiment Three indicated that some of the lists were harder to learn than others. A further experiment would have to be conducted to analyse every word on the lists and see if certain words or word combinations were causing difficulty.

EXPERIMENT FOUR: COGNITIVE STYLES AND LEARNING STRATEGIES AND WORD LISTS CONTAINING CONCRETE WORDS OF MIXED CATEGORIES AND LEARNING PERFORMANCE

INTRODUCTION

In Experiment Four the subjects were the same age (10 - 11) as those used in Experiment Three and also from an urban primary school. The only difference from Experiment Three was introducing the Cognitive Styles Analysis (Riding, 1991).

AIM

The aim of the fourth experiment was to find whether one taught learning strategy improves recall with the word lists used in Experiment Three and also analyse the effect of cognitive style on learning performance by introducing the Cognitive Styles Analysis.

METHOD

Sample

This sample consisted of 76, year five students (10- to 11-year old), 41 boys and 35 girls from an urban primary school in Staffordshire. They were divided into groups and each was given a strategy (17 strategy 1, 17 strategy 2, 19 strategy 3, 16 strategy 4 and there were 7 subjects in the control group). They were all given the Cognitive Styles Analysis (CSA) except four students who were absent.

Materials

A booklet (identical to the one used in Experiment Three) was presented to the students, consisting of general instructions, four lists of concrete nouns belonging to three different categories and one learning strategy. There were four different learning strategies in total. The same procedure used in Experiments Two and Three were followed for assigning the learning strategies to the experimental group in its divisions. All the subjects were given the computer-presented CSA in Experiment Four determining their position on each of the cognitive style dimensions the Wholist - Analytic and Verbaliser - Imager (WA and VI).

Procedure

One learning strategy was assigned to each of four groups of students. The control group was not given any learning strategy. Instructions on how to complete a booklet containing the four lists of words were included in each one and given to the experimental and control groups. One of four different learning strategies was taught to its assigned group and in addition the same written instruction was in the booklet containing the four lists of words. The students were told to learn the lists for one minute and rewrite each list taking one minute. Those student given learning strategies were given one minute to learn each. The computer - presented CSA was given to each student prior to being given the word list booklet. The control group was excluded because it was too small. Those who made too many errors on the CSA were excluded. They were not included because they either did not take the CSA seriously or they did not understand how to do it and so their results were considered unreliable. Those scoring <60 on the Wholist-Analytic cognitive style dimension were excluded. The sample size was reduced to 53.

RESULTS

Characteristics of the Sample

On each cognitive style dimension the sample was divided on the basis of their style ratios, with almost equal numbers in each division. For the analyses, the Wholist-Analytic dimension was split into two divisions: Wholist 0.66 to 1.10 = 1 and Analytics 1.11 to 5.03 = 2 (mean = 1.30, median = 1.17). Similarly, the Verbal-Imagery dimension was split into two divisions: Verbalisers 0.67 to 1.12 = 1 and Imagers 1.13 to 1.93 = 2 (mean = 1.13, median = 1.13). The correlation between the two styles was 0.06, confirming the independence of the measures (see also Riding & Douglas, 1993; Riding & Mathias, 1991). There were three separate analyses of variance performed (1) Analysis of variance of Wholist-Analytic cognitive style, Verbal-Imagery cognitive style and Sex with repeated measures on list and position of list. (2) Analysis of variance of Wholist-Analytic cognitive style, Verbal- Imagery cognitive style and Strategy with repeated measures on list and position of list. (3) Analysis of variance of Wholist-Analytic cognitive style, Sex and Strategy with repeated measures on list and position of list.

The means and standard deviations for Wholist-Analytic Style and Verbal-Imagery Style are shown in Table 4.1

Table 4.1

Means and standard deviations for Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style by List Number

Variable			Mean	Std. Dev.	N
List 1		Wholist	8.54	1.98	26
		Wholist Verbaliser	8.64	2.31	14
		Wholist Imager	8.42	1.62	12
		Analytic	9.07	2.54	27
		Analytic Verbaliser	9.08	2.47	12
		Analytic Imager	9.07	2.69	15
	For Entire	Sample	8.81	2.28	53
List 2		Wholist	9.35	2.24	26
		Wholist Verbaliser	9.00	2.45	14
		Wholist Imager	9.75	2.00	12
		Analytic	8.93	2.42	27
		Analytic Verbaliser	9.25	2.45	12
		Analytic Imager	8.67	2.44	15
	For Entire	Sample	9.13	2.32	53
List 3		Wholist	8.35	2.21	26
		Wholist Verbaliser	7.64	2.10	14
		Wholist Imager	9.25	2.09	12
		Analytic	8.52	2.31	27
		Analytic Verbaliser	9.08	2.43	12
		Analytic Imager	8.07	2.19	15
	For Entire	Sample	8.45	2.24	53
List 4		Wholist	9.65	2.34	26
		Wholist Verbaliser	9.43	2.82	14
		Wholist Imager	9.92	1.88	12
		Analytic	9.93	1.98	27
		Analytic Verbaliser	9.75	2.09	12
		Analytic Imager	10.07	1.94	15
	For Entire	Sample	9.79	2.18	53

Analysis of variance of Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style and Sex with repeated measures on Position of List was performed on the data. The summary is given in Table 4.2.

Table 4.2

Summary of Repeated Measures ANOVA for Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style and Sex by List and Position

Tests of Between-Subjects Effects

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	45	4.92		
SEX	1	5.23	1.06	.308
WA	1	.89	.18	.673
VI	1	.61	.12	.726
SEX BY WA	1	.02	.00	.954
SEX BY VI	1	4.83	.98	.327
WA BY VI	1	2.66	.54	.466
SEX BY WA BY VI	1	15.38	3.13	.084

Tests Involving 'List' Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	135	.60		
LIST	3	5.09	8.45	.000
SEX BY LIST	3	2.48	4.12	.008*
WA BY LIST	3	.61	1.01	.391
VI BY LIST	3	.24	.39	.758
SEX BY WA BY LIST	3	.21	.34	.794
SEX BY VI BY LIST	3	.34	.56	.644
WA BY VI BY LIST	3	2.17	3.61	.015*
SEX BY WA BY VI BY LIST	3	.17	.28	.842

There was one significant within-subject effect. This was a three-way interaction of List and Wholist-Analytic cognitive style and Verbal Imagery cognitive style (F=3.61; d.f.=3,135; p= .015). The mean scores of the groups is given in Table 4.3. There was also a significant within-subject interaction of sex by list (F=4.12; d.f. =3,135; p=.008). Girls outperformed the boys on lists 1,2,4 and worst on list 3.

The mean scores of the groups is given in Table 4.3

Table 4.3

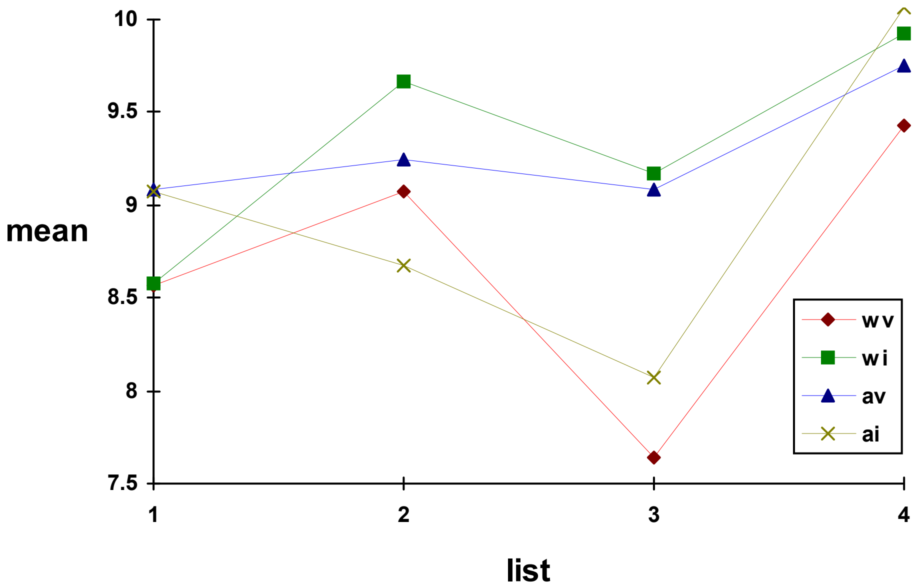
Comparison of means for cognitive styles and list

LIST	WV	WI	AV	AI	COMPARISON
1	8.64	8.42	9.08	9.07	WI<WV AV>AI AV>WV
2	9.00	9.75	9.25	8.67	WI>WV AV>AI WI>AV
3	7.64	9.25	9.08	8.07	WI>WV AV>AI WI>AV
4	9.43	9.92	9.75	10.07	WI>WV AV<AI AI>WI

Table 4.3 shows that in List 1 Analytic Verbalisers outperformed Wholist Verbalisers. In List 2 Wholist Imagers outperformed Analytic Verbalisers. In List 3 Wholist Imagers outperformed Analytic Verbalisers. In List 4 Analytic Imagers outperformed Wholist Imagers.

In the graph, Figure 4.1, it is indicated that Wholist Imagers, Wholist Verbalisers and Analytic Verbalisers are following the same trends in answering the lists, i.e. increase from List 1 to List 2, then decrease from list 2 to List 3, then increase from List 3 to List 4.

Figure 4.1 Mean scores for different cognitive styles against list number



The means and standard deviations for List 1first-last, List 2first-last, List 3first-last List 4first-last against Wholist-Analytic Style are shown in Table 4.4

Table 4.4

Means and standard deviations for List 1first-last, List 2first-last, List 3first-last, List 4first-last against Wholist-Analytic Cognitive Style

Variable		Mean	Std. Dev.	N
List 1first	Wholist	3.27	.87	26
	Analytic	3.11	.97	27
For Entire	Sample	3.19	.92	53
List 1middle	Wholist	3.00	1.02	26
	Analytic	2.96	1.09	27
For Entire	Sample	2.98	1.05	53
List 1last	Wholist	2.27	1.28	26
	Analytic	3.00	1.07	27
For Entire	Sample	2.64	1.23	53
List 2first	Wholist	3.42	.81	26
	Analytic	3.33	.73	27
For Entire	Sample	3.38	.77	53
List 2middle	Wholist	3.15	1.12	26
	Analytic	2.96	.94	27
For Entire	Sample	3.06	1.03	53
List 2last	Wholist	2.77	1.45	26
	Analytic	2.63	1.30	27
For Entire	Sample	2.70	1.37	53
List 3first	Wholist	3.00	.94	26
	Analytic	2.89	1.01	27
For Entire	Sample	2.94	.97	53
List 3middle	Wholist	2.46	1.21	26
	Analytic	2.78	1.05	27
For Entire	Sample	2.62	1.13	53
List 3last	Wholist	2.92	1.13	26
	Analytic	2.85	.95	27
For Entire	Sample	2.89	1.03	53
List 4first	Wholist	3.54	.71	26
	Analytic	3.59	.75	27
For Entire	Sample	3.57	.72	53
List 4middle	Wholist	3.00	1.17	26
	Analytic	3.11	.97	27
For Entire	Sample	3.06	1.06	53
List 4last	Wholist	3.12	1.21	26
	Analytic	3.22	.89	27
For Entire	Sample	3.17	1.05	53

lists 1(first,middle,last) - 4(first,middle,last) represents the lists divided into three positions with four words in each position of the list, for example list 1first has four words.

Analysis of variance of Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style and Strategy with repeated measures on List and Position was performed on the data. The summary of the statistics is given in Table 4.5

Table 4.5

Summary of repeated measures ANOVA for Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style and Strategy by List and Position of List

Tests Involving ‘ List By Position’

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	222	.62		
LIST BY POSITION	6	1.77	2.86	.011
WA BY LIST BY POSITION	6	1.32	2.14	.050*
VI BY LIST BY POSITION	6	.76	1.22	.295
STRAT BY LIST BY POSITION	18	1.14	1.84	.022
WA BY VI BY LIST BY POSITION	6	.62	1.00	.426
WA BY STRAT BY LIST BY POSITION	18	.66	1.07	.381
VI BY STRAT BY LIST BY POSITION	18	.58	.93	.539
WA BY STRAT BY LIST BY POSITION	18	.43	.70	.809

There was one significant within-subject effect (F=2.14; d.f.=6,222; p=0.050). This was an interaction of WA and List and Position. The interaction is illustrated in Figure 4.2. The mean scores of the groups is given in Table 4.6

Table 4.6 Comparison of mean scores for Wholists and Analytics against list position

LIST	W	A	Comparison
1 first	3.30	3.11	W>A
1 middle	3.00	2.96	W>A
1 last	2.30	3.00	A>W
2 first	3.40	3.33	W>A
2 middle	3.15	2.96	W>A
2 last	2.77	2.63	W>A
3 first	3.00	2.89	W>A
3 middle	2.46	2.77	A>W
3 last	2.92	2.85	W>A
4 first	3.53	3.59	A>W
4 middle	3.00	3.11	A>W
4 last	3.11	3.22	A>W

Table 4.6 illustrates the performance of Wholists and Analytics in each division of the lists.

In lists 1first and 1middle Wholists did better than Analytics.
In list 1last Analytics did better than Wholists.
In lists 2first, 2middle, and 2last Wholists did better than Analytics.
In list 3first Wholists did better than Analytics.
In list 3middle Analytics did better than Wholists.
In list 3last Wholists did better than Analytics.
In lists 4first, 4middle and 4last Analytics did better than Wholists.

Figure 4.2 shows an interaction of WA by List by Position (F=2.14; d.f. =6,222; p=0.050)

The graph illustrates that Analytics out performed Wholists on List 1last.

Figure 4.2 Mean scores of Wholists and Analytics against position for list 1

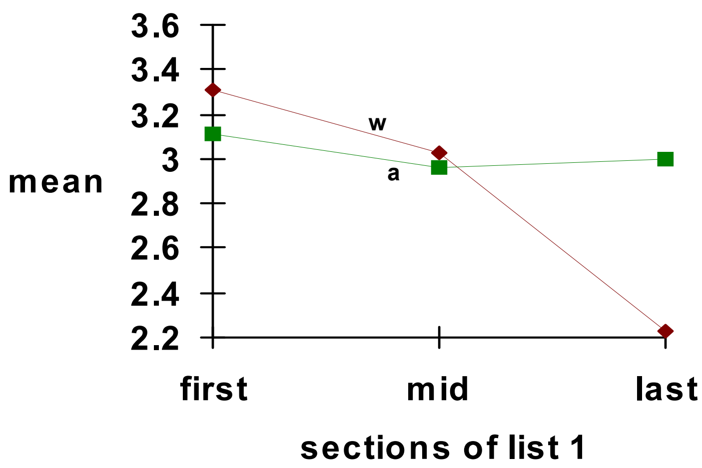


Figure 4.3 Mean scores of Wholists and Analytics against position for list 2

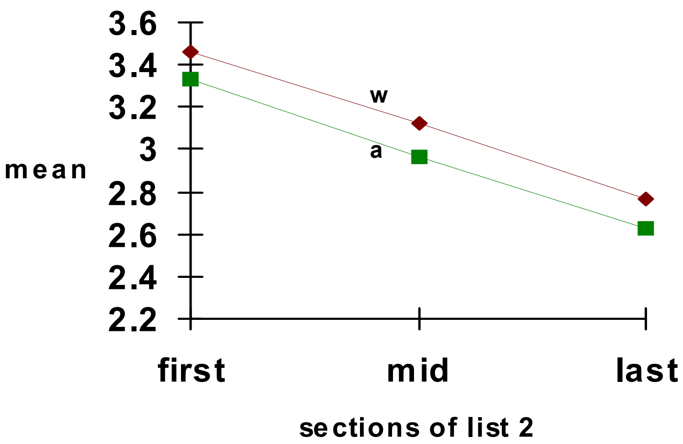


Figure 4.4 Mean scores of Wholists and Analytics against position for list 3

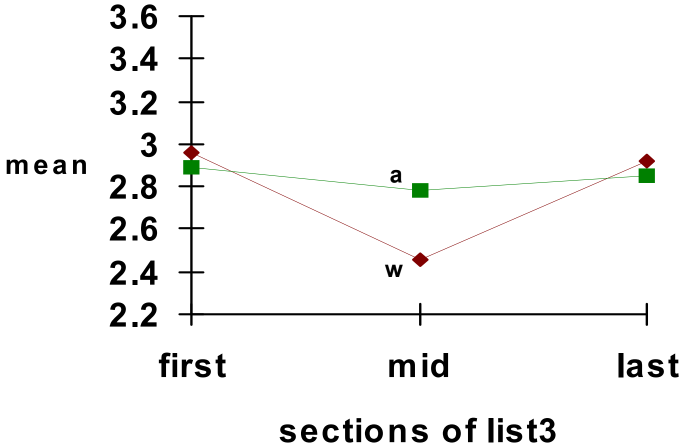
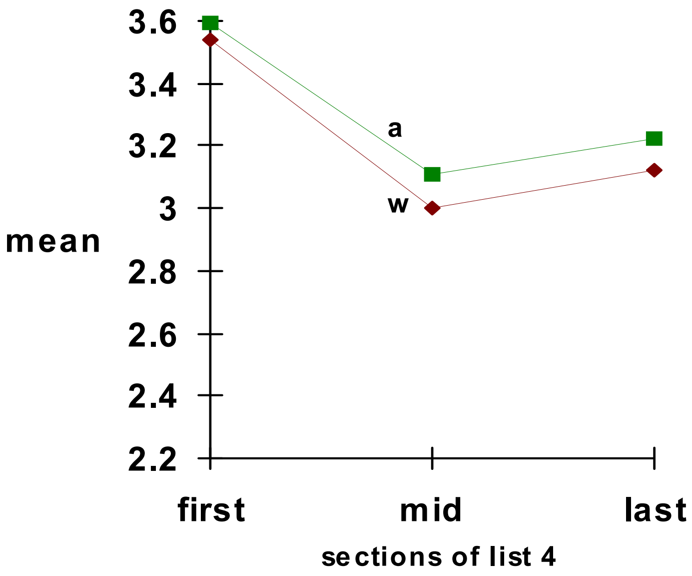


Figure 4.5 Mean scores of Wholists and Analytics against position for list 4



The means and standard deviations for List 1(first,middle,last), List 2(first,middle,last), List 3(first,middle,last) and List 4(first,middle,last) against sex and strategies 1-4 are shown in Table 4.7

Table 4.7

Means and standard deviations for Lists 1(first,middle,last) List 2(first,middle,last), List 3(first,middle,last), List 4(first,middle,last) and sex and strategies 1-4

Variable		Mean	Std. Dev.	N
List 1first	Male	2.89	.96	28
	Strategy 1	2.86	.90	7
	Strategy 2	2.00	.76	8
	Strategy 3	3.38	.52	8
	Strategy 4	3.60	.89	5
	Female	3.52	.77	25
	Strategy 1	3.67	.82	6
	Strategy 2	3.29	.95	7
	Strategy 3	3.83	.41	6
	Strategy 4	3.33	.82	6
For Entire	Sample	3.19	.92	53
List 1middle	Male	2.68	1.09	28
	Strategy 1	2.86	1.07	7
	Strategy 2	2.13	1.36	8
	Strategy 3	3.00	.53	8
	Strategy 4	2.80	1.30	5
	Female	3.32	.90	25
	Strategy 1	3.33	1.03	6
	Strategy 2	3.71	.49	7
	Strategy 3	3.00	.89	6
	Strategy 4	3.17	1.17	6
For Entire	Sample	2.98	1.05	53
List 1last	Male	2.68	2.31	28
	Strategy 1	2.43	.98	7
	Strategy 2	2.38	1.41	8
	Strategy 3	3.38	1.41	8
	Strategy 4	2.40	1.14	5
	Female	2.60	1.15	25
	Strategy 1	2.33	1.37	6
	Strategy 2	2.86	1.07	7
	Strategy 3	2.17	1.17	6
	Strategy 4	3.00	1.09	6
For Entire	Sample	2.64	1.23	53

List 2first	Male	3.32	.77	28
	Strategy 1	3.43	.98	7
	Strategy 2	2.75	.46	8
	Strategy 3	3.63	.52	8
	Strategy 4	3.60	.89	5
	Female	3.44	.77	25
	Strategy 1	3.83	.41	6
	Strategy 2	3.00	.82	7
	Strategy 3	3.83	. 41	6
	Strategy 4	3.17	.98	6
ForEntire	Sample	3.38	.77	53
List 2middle	Male	2.93	1.22	28
	Strategy 1	2.86	1.46	7
	Strategy 2	2.13	1.36	8
	Strategy 3	3.38	.74	8
	Strategy 4	3.60	.57	5
	Female	3.20	.76	25
	Strategy 1	3.33	.82	6
	Strategy 2	3.29	.49	7
	Strategy 3	3.00	.89	6
	Strategy 4	3.17	.98	6
For Entire	Sample	3.06	1.03	53
List 2last	Male	2.32	1.28	28
	Strategy 1	1.29	.76	7
	Strategy 2	2.25	1.04	8
	Strategy 3	3.00	1.41	8
	Strategy 4	2.80	1.30	5
	Female	3.12	1.36	25
	Strategy 1	2.33	1.86	6
	Strategy 2	3.43	1.13	7
	Strategy 3	3.67	.52	6
	Strategy 4	3.00	1.55	6
For Entire	Sample	2.70	1.37	53

List 3first	Male	2.89	1.03	28
	Strategy 1	2.71	1.11	7
	Strategy 2	2.38	1.06	8
	Strategy 3	3.88	.35	8
	Strategy 4	2.40	.55	5
	Female	3.00	.91	25
	Strategy 1	2.50	.84	6
	Strategy 2	3.57	.79	7
	Strategy 3	3.33	.82	6
	Strategy 4	2.50	.84	6
For Entire	Sample	2.94	.97	53
List 3middle	Male	2.71	1.15	28
	Strategy 1	2.71	1.11	7
	Strategy 2	2.25	1.28	8
	Strategy 3	3.00	1.31	8
	Strategy 4	3.00	.71	5
	Female	2.52	1.12	25
	Strategy 1	2.33	1.21	6
	Strategy 2	1.86	1.46	7
	Strategy 3	3.33	.52	6
	Strategy 4	2.67	.52	6
For Entire	Sample	2.62	1.13	53
List 3last	Male	2.96	1.00	28
	Strategy 1	3.00	1.00	7
	Strategy 2	2.38	.74	8
	Strategy 3	2.88	1.13	8
	Strategy 4	4.00	.00	5
	Female	2.80	1.08	25
	Strategy 1	1.83	1.33	6
	Strategy 2	3.14	.90	7
	Strategy 3	3.17	.41	6
	Strategy 4	3.00	1.10	6
For Entire	Sample	2.89	1.03	53

List 4first	Male	3.46	.79	28
	Strategy 1	3.57	.53	7
	Strategy 2	2.88	.99	8
	Strategy 3	3.88	.35	8
	Strategy 4	3.60	.89	5
	Female	3.68	.63	25
	Strategy 1	3.67	.82	6
	Strategy 2	3.71	.49	7
	Strategy 3	3.83	.41	6
	Strategy 4	3.50	.84	6
For Entire	Sample	3.57	.72	53
List 4middle	Male	2.82	1.25	28
	Strategy 1	2.29	1.25	7
	Strategy 2	2.13	1.25	8
	Strategy 3	3.63	1.06	8
	Strategy 4	3.40	.55	5
	Female	3.32	.75	25
	Strategy 1	3.00	.89	6
	Strategy 2	3.29	.49	7
	Strategy 3	3.67	.52	6
	Strategy 4	3.33	1.03	6
For Entire	Sample	3.06	1.06	53
List 4last	Male	3.21	1.03	28
	Strategy 1	3.00	.82	7
	Strategy 2	2.75	.89	8
	Strategy 3	3.38	1.41	8
	Strategy 4	4.00	.00	5
	Female	3.12	1.09	25
	Strategy 1	2.00	.89	6
	Strategy 2	3.52	.79	7
	Strategy 3	3.33	.82	6
	Strategy 4	3.50	1.22	6
For Entire	Sample	3.17	1.05	53

lists 1(first,middle,last) - 4(first,middle,last) represents the lists divided into three positions with four words in each position of the list, for example list 1first has four words.

Strategy 1 = Initial Letter
Strategy 2 = Story
Strategy 3 = Grouping
Strategy 4 = Imaging

Analysis of variance of Wholist-Analytic Cognitive Style and Sex and Strategy with repeated measures on List and Position was performed on the data. The summary of the statistics is given in Table 4.8

Table 4.8

Summary of repeated measures ANOVA for Wholist-Analytic Cognitive Style and Sex and Strategy by List and Position.

Tests involving 'List by Position'

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	222	.54		
LIST BY POSITION	6	1.19	2.19	.045
SEX BY LIST BY POSITION	6	.79	1.45	.197
WA BY LIST BY POSITION	6	.26	.48	.826
STRAT BY LIST BY POSITION	18	.80	1.47	.103
SEX BY WA BY LIST BY POSITION	6	.61	1.12	.350
SEX BY STRAT BY LIST BY POSITION	18	1.11	2.05	.009*
WA BY STRAT BY LIST BY POSITION	18	.70	1.30	.189
SEX BY WA BY STRAT BY LIST BY POSITION	18	.75	1.38	.144

There was one significant within-subject effect. This was an interaction of sex and strategy and list and position (F=2.05, d.f.=18,222, p=0.009). The mean scores of girls and boys is given in Table 4.15. Girls used strategies more effectively on the lists than the boys using strategy 1 and strategy 2, and equally with boys on strategy 3. Boys outperformed girls using strategy 4.

Table 4.9 Comparison of the Means of List against Strategy and Sex in Lists 1(first,middle,last) - 4(first,middle,last) for Boys and Girls

List	Strategy	Mean (Boys)	Mean (Girls)	Comparison
1first	1	2.86	3.67	G>B
	2	2.00	3.29	G>B
	3	3.38	3.83	G>B
	4	3.60	3.33	B>G
1middle	1	2.86	3.33	G>B
	2	2.13	3.71	G>B
	3	3.00	3.00	B=G
	4	2.80	3.17	G>B
1last	1	2.43	2.33	B>G
	2	2.38	2.86	G>B
	3	3.38	2.17	B>G
	4	2.40	3.00	G>B
2first	1	3.43	3.83	G>B
	2	2.75	3.00	G>B
	3	3.63	3.83	G>B
	4	3.60	3.17	B>G
2middle	1	2.86	3.33	G>B
	2	2.13	3.29	G>B
	3	3.38	3.00	B>G
	4	3.60	3.17	B>G
2last	1	1.29	2.33	G>B
	2	2.25	3.43	G>B
	3	3.00	3.67	G>B
	4	2.80	3.00	G>B
3first	1	2.71	2.50	B>G
	2	2.38	3.57	G>B
	3	3.88	3.33	B>G
	4	2.40	2.50	G>B
3middle	1	2.71	2.33	B>G
	2	2.25	1.86	B>G
	3	3.00	3.33	G>B
	4	3.00	2.67	B>G
3last	1	3.00	1.83	B>G
	2	2.38	3.14	G>B
	3	2.88	3.17	G>B
	4	4.00	3.00	B>G
4first	1	3.57	3.67	G>B
	2	2.88	3.71	G>B
	3	3.88	3.83	B>G
	4	3.60	3.50	B>G
4middle	1	2.29	3.00	G>B
	2	2.13	3.29	G>B
	3	3.63	3.67	G>B
	4	3.40	3.33	B>G
4last	1	3.00	2.00	B>G
	2	2.75	3.57	G>B
	3	3.38	3.33	B>G
	4	4.00	3.50	B>G

Table 4.9 illustrates that : -

1. The order of popularity for strategies 1-4 for girls is

Strategy 2
Strategy 1
Strategy 3
Strategy 4

2. The order of popularity for strategies 1-4 for boys is

Strategy 4
Strategy 3
Strategy 1
Strategy 2

The girls obtained higher means than the boys using Strategy 1, Strategy 2, and equally using strategy 3. Boys outperformed girls using Strategy 4. The order of popularity of strategies is exactly reversed for boys and girls.

Figures 4. 6 to 4.9 show mean scores of girls and boys plotted separately against strategies.

Figure 4.6 Mean scores against strategy for girls and boys in sections f, m and l of list 1

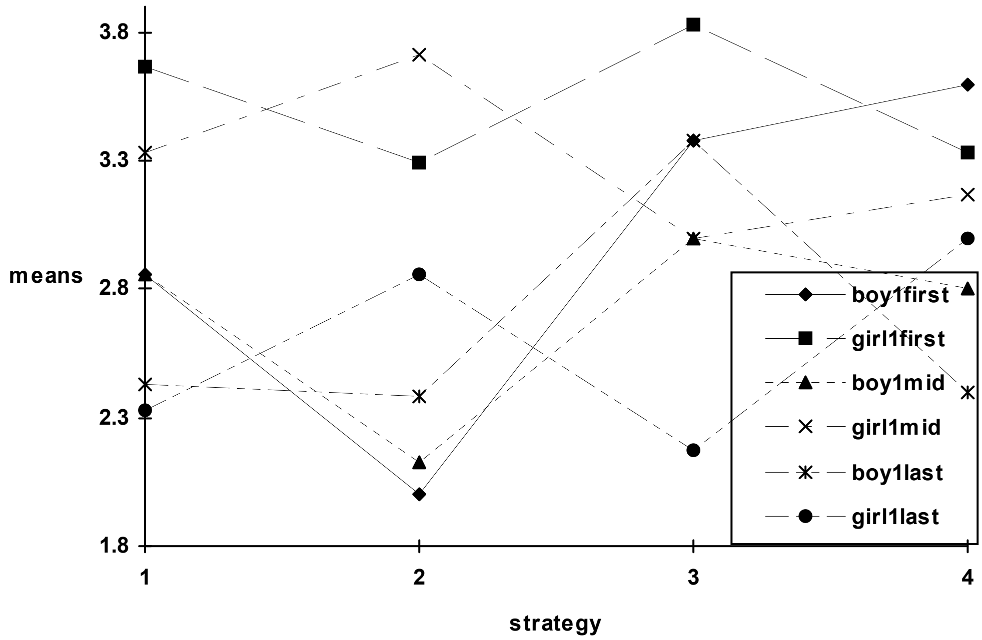


Figure 4.7 Mean scores against strategy for girls and boys in sections f, m and l of list 2

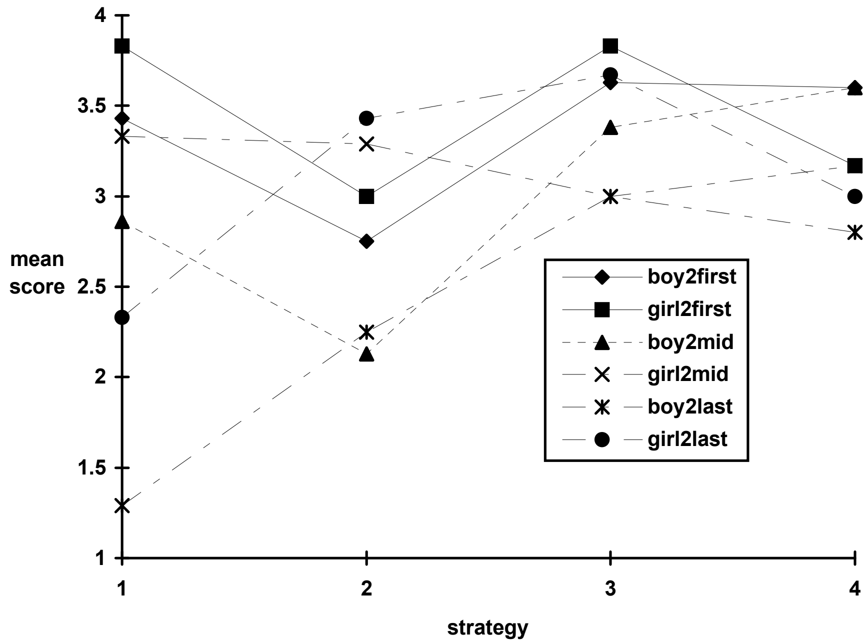


Figure 4.8 Mean scores against strategy for girls and boys in sections f, m and l of list 3

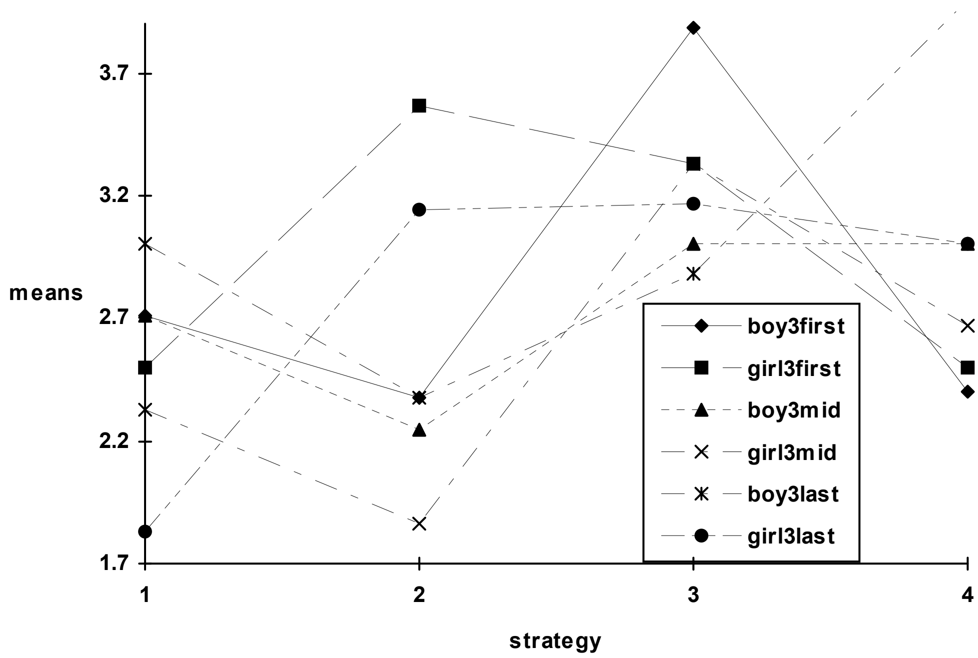
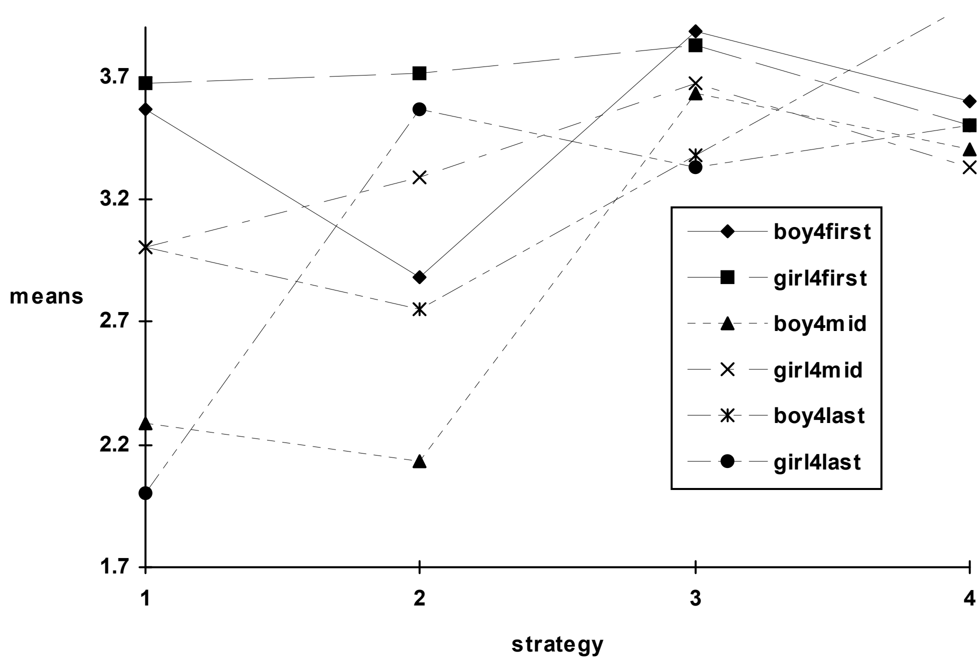


Figure 4.9 Mean scores against strategy for girls and boys in sections f, m and l of list 4



DISCUSSION

Sex by List

There was a significant within-subject interaction of sex by list. Girls outperformed the boys on lists 1, 2, and 4 and equally on list 3. According to Maccoby (1966) in 22 studies on research in sex differences involving children three years old and under, in 18 of these girls were superior to boys in verbal ability. In support of Maccoby concerning girls being superior to boys in verbal ability are Ballard (1920), Vernon (1960), Beard (1965), Thackray (1965), Maccoby and Jacklin (1974), and Halpern (1989).

Wholist-Analytic Cognitive Style by Verbal-Imagery Cognitive Style by List

There was a significant within-subject effect. This was a three-way interaction of List and Wholist-Analytic cognitive style and Verbal-Imagery cognitive style. Verbalisers find concrete and readily visualised information more diifficult than semantically and acoustically complex details with Imagers the reverse (Riding and Taylor, 1976; Riding and Calvey,1981; Riding and Dyer, 1980). Wholists, when faced with information see the whole 'picture' and 'Analytics' in a similar position tend to focus on only one aspect of the whole at a time, so making it more prominent.

The Analytic Verbalisers outperforming Wholist Verbalisers in List One might have been because they were able to remember the words by breaking them down into their parts due to their ability to process information in parts better than the Wholist Verbalisers. In List One eight out of the twelve words had more than one syllable. In List Two Wholist Imagers outperforming Analytic Verbalisers might be because that list included 'body parts' and they are concrete entities, easily visualised. In List Three Wholist Imagers outperforming Analytic Verbalisers might be again the inclusion in that list of body parts and for the same reasons given for List Two. In List Four Analyltic Imagers outperformed Wholist Imagers and this might be because Analytics tend to organise information into precise conceptual groups and the words in the list were concrete nouns that were easily visualised and could easily be grouped into the categories of furniture, animals and clothing.

Hulme and Mackenzie (1992) showed that recall of words that took less time to say was better than for those that took longer. Even when the number of syllables is the same, words with shorter articulation time are better recalled. The only words that contained the same amount of syllables (two) were in list 4middle. The articulation time of all the words in lists 1-4 would have to be known to make a comparison with the articulation time needed for the words in list 4middle and this would have to be done in a further experiment.

Wholist-Analytic Cognitive Style by List by Position

The four lists in experiment four were compiled by using concrete nouns and mixed categories e.g. transport, animals, and food in list one. There were four words in each of three categories per list. The four lists contained words with one syllable, two syllables, three syllables and four syllables. Serial recall of short, one syllable words is maintained by Baddeley, Thomson and Buchanan (1975) to be considerably better than that for long five syllable words. This word-length effect can be explained by the fact that long words take longer to articulate than short words. In Experiment Four since the lists were of mixed word length another study could be done to find out if specific long or short words were causing a problem in recall.

There was a significant within-subject effect and this was an interaction of Wholist-Analytic cognitive style and List and Position showing that Analytics significantly outperformed Wholists in list 1last. The words in this position of the list were (orange, truck, elephant, and apple). The words ‘apple’ and ‘orange’ could be broken down into two syllables and ‘elephant’ could be broken down into three syllables. The word ‘truck’ was monosyllabic. It might be that Analytics could recall the words on list 1 last better than Wholists through their ability to see things in parts. For example they may have only recalled ‘el’ and ‘e’ to remember the word ‘elephant’ but further studies would have to be done to see if Analytics do remember words of more than one syllable by their syllabic divisions better than Wholists.

Witkin and Goodenough (1981) identified three separate but related cognitive restructuring skills: (a) providing structure for an ambiguous stimulus complex, (b) breaking up an organised field into its basic elements and (c) providing a different organisation to a field other than that which is suggested from the inherent structure of the stimulus complex. Analytics are better at doing tasks that require restructuring skills. The four lists in Experiment Four were composed of words from ten different categories, for example, the categories in List One were vehicles, animals and fruit. The words in the lists did not appear in category order. The Analytics did not do as well as the Wholists in learning the lists and it would appear that they were not using their restructuring skills to learn the lists especially the 'grouping' strategy which might have helped in restructuring the lists.

Davis and Cochran (1989) found that research on the learning style 'Wholist - Analytic', had not identified what strategies if any were used by participants spontaneously, but only where specific instruction to use a specific strategy was employed. In a study by Frank and Keene (1993) using the Hidden Figures Test, classification of cognitive style was determined. It was also stated that the two most used strategies were 'categorisation' and 'rehearsal', where Analytics favoured the former and Wholists the latter. Rehearsal is a developmental process (Kail 1984). From an information processing approach rehearsal represents a global and passive strategy, as it does not need restructuring or elaboration of the material to be learned. This approach is characteristic of Wholists. In Experiment Four the learning of four lists was the task and this might account for Wholists doing better than Analytics in lists 1first,1middle,2first,2middle,2last,3first,3last,4first,4middle and 4last since they use rehearsal more effectively than Analytics. It is characteristic of Analytics to prefer categorisation to rehearsal and Wholists to prefer rehearsal to categorisation. 'Strategy' was not significant and therefore, it is not possible to know if Analytics used the 'grouping' strategy (a restructuring strategy) more effectively than Wholists. The strategy of rehearsal was not taught to the subjects in this experiment and it would not be possible to know from the results how effective it was in learning the words in the word lists. According to Frank and Keene (1991) Analytics also chose 'Making into a Story', ‘Imagery,’ and ‘Rehearsal’ as their next most used strategies. Wholists chose ‘Categorisation’, ‘Making into a Story’ and ‘Imagery’ as their next most used strategies.

Sex by Strategy by List by Position

There was one significant within-subject effect and this was an interaction of sex and strategy and list and position. According to Baddeley (1986) an individual may fail to recognise a word he has been shown but be able to recall the word given an appropriate cue. Mnemonics are cues to aid retrieval. The following literature supports the assertion that mnemonics are learning strategies that are effective aids to retrieval.

Krinsky (1994) supported the use of mnemonics in a study involving immediate and long - term serial list learning effects for common nouns with ten-year-olds. Mnemonic training with Peg Words e.g. (One is a Bun) showed superior immediate recall effects during the post-test compared to the pre-test. In Experiment Four there was no pre-test and it might be interesting to include a pre-test in another experiment to test the subjects on their understanding of each strategy used in Experiment Four and then give them the word lists.

Belleza (1981) confirmed that mnemonic strategies improve students’ ability to recall information indirectly by operating on their storage processes. The girls performed better than the boys using strategy two. This might be because girls, being thought of as superior in verbal ability, especially vocabulary, found the task required of them via strategy two (Make into a Story) not too demanding on working memory. In this case the material to be learned would have been designed by them making it meaningful and not easily forgotten as in contrast to a rote learning task. Fox (1964) points out that category names were effective cues for retrieving items from that category, even though the category name had not been explicitly presented. The four lists in Experiment Four did not have category titles but possibly by learning strategy three (Grouping) the small associated clusters of words in each list would be recognised as belonging to a distinct category. Category learning appears to be independent of explicit memory (Knowlton and Squire 1993). Category level knowledge may be acquired by abstracting information across encounters, with examples. Accordingly, instructing subjects on

using ‘grouping’ as a strategy and giving examples of its use should help them in learning lists. ‘Grouping’ was an equally effective strategy for boys and girls.
In a study by Matthews and Dorn (1995) it was pointed out that intelligence is more strongly related to free recall of lists if the words in the lists can be reorganised around semantic categories in contrast to lists where a reorganisation strategy is not found (Jensen and Frederiksen, 1973). In Experiment Four the ‘grouping strategy’ which teaches subjects to reorganise words in a list into categories did prove to be effective for boys and girls.

The four strategies (strategy one - initial letter, strategy two - story, strategy three - grouping and strategy four - imagery) had different effects on the boys and the girls. The effect of learning ‘strategy one’ was girls outperformed boys. The effect of learning ‘strategy two’ was girls outperformed boys. The effect of learning ‘strategy three’ was girls and boys did equally well. The effect of learning ‘strategy four’ was the boys outperformed the girls.

Strategy One (*Initial Letter Strategy*)
Strategy one in Experiment Four instructs the learner on the use of the ‘initial letter strategy’, (explained in the method section of Experiment Four) which is based on a mnemonic technique. Loftus (1980) reported that mnemonics speed up learning. Wilson maintained (1991) that the initial letter strategy aids the learner in improving recall. Lenz (1996) also stated that whenever presented with a list that is important to remember this should be a cue for using the First Letter Strategy (used interchangeably with the *initial letter strategy*). The girls outperformed boys using this strategy. In the literature girls are superior in verbal ability (Maccoby, 1966). In another experiment it would be interesting to test the effectiveness of the ‘initial letter strategy’ in answering comprehension questions about a prose passage. The aim would be to see if this strategy has an effect in using it to answer questions about a prose passage, in contrast to subjects who had not been taught the strategy.

Strategy Two (Making Into a Story)

Crovitz (1979) maintained strategy two (story) assists the learner in recall. The girls in Experiment Four used this strategy more effectively than the boys. This could be because girls are superior in verbal ability and vocabulary and composing a story depends on these abilities. In a future study this strategy might be applied to an experiment in which the subjects have to remember historical events for example, and construct a story incorporating all the them. A post-test could be devised to see if the strategy was effective.

Strategy Three (Grouping)

Strategy three (grouping) was equally effective for the girls and boys in Experiment Four. Baddeley maintained (1986) that the learner is an active organiser of information and performs the clustering of material naturally but he did not report gender differences in clustering. Grouping, clustering, and categorisation are principles that have been demonstrated in the experimental laboratory. According to Bousefield (1953) experimental subjects formed groups of the items they were trying to learn, by observing clustering in the words recalled by them.

Tulving (1962) examined the response strategies used by subjects learning lists of unrelated words. He found that subjects organised the words and that once formed these organisations tend to stick throughout the rest of the experiment. That is, once a subject puts together some of the words on the list the he is trying to learn, the tendency is always to recall them together, regardless of the way the words are scrambled up by the experimenter. Moreover, Tulving maintained that the learning of new words builds on the previously acquired structures.

The effectiveness of 'strategy three' in Experiment Four indicates that it would be interesting to use it in a further experiment, for example, in structuring one's answers to a prose passage. Subjects in the experimental group would be taught the grouping strategy and the control group would not. Subjects would be told to prepare their answers using only 12 words out a possible 20 for each question. Out of the 20 words 15 would be categorisable. Subjects' notes would be handed in and examined as well as the final answers to the questions. It would be interesting to examine how many words in the final answers were grouped by category as well as the way words used as answers were arranged in the rough notes.

Strategy Four (*Imaging a Picture*)

Strategy four was about the use of imagery in learning lists of words. Imagery is not purely spatial or visual, but may be both, (Baddeley, 1990). Yates (1966) maintained that visual strategies assist in recall. Jones (1988) reported that concrete and imageable items were easier to remember because they are more elaborately represented within the long-term semantic memory system. The boys outperformed the girls using this strategy as the literature suggests boys have greater spatial ability than girls do. The visual system of an individual may have two separable components, one concerned with pattern processing and detecting ‘what’ and the other concerned with location in space and conveying information about ‘where’. Tasks that involve spatial perceptions e.g. The Rod and Frame Test and spatial visualisation e.g. The Embedded Figures test favour males (Linn and Petersen, 1985).

A classic study by Wood (1967) found a group given peg words and a group told to link successive items of a list with a bizarre image did better than the control group just using free recall instructions. In Experiment Four the subjects were instructed to use imagery and the boys outperformed the girls using this strategy. It is also more difficult to recall common imagery as opposed to bizarre imagery, Riefer and Rouder (1992). It might be beneficial in a future experiment to teach subjects how to use the strategy ‘ bizarre imagery’ to remember lists of word.

Overall discussion for Experiments One, Two, Three and Four

The issue raised in the introduction was whether learning strategies are beneficial in remembering lists of words. It was decided to use words in all the experiments in favour of non-words, as memory span for words was better than for non-words (Maughan and Brown ,1991).

Remembering Words

Craik and Lockhart (1972) suggested that memory-trace is a by-product of information processing and the more deeply an item is processed, the better it will be remembered. In encoding information into short-term memory one must attend to it and the individual is selective about what is attended or not attended and information is entered in a certain code. The representation might be visual - a mental picture, acoustic - the sounds of the names of digits, or semantic - some meaningful association of digits. So in trying to learn a phone number the individual uses these possible ways of encoding information into short-term memory. In remembering a telephone number one is most likely to encode the number as the sounds of the digit names and rehearse these sounds to oneself until one has dialled the number. An acoustic code is favoured when one is trying to keep the information active by rehearsing it (Atkinson, 1993).

Learning Strategies and Cognitive Style

Rehearsal is an especially popular strategy when the information consists of verbal items such as digits, letters or words. Rehearsal is a process of keeping information active by rehearsing it (repeating it over and over again to oneself). Rehearsal was not taught to the subjects in Experiments One to Four but it was observed that some of the subjects were repeating the words to themselves and might have not been aware that they were. A 'learning strategy' is the processing that occurs when preparing for a test of memory and in learning how to use one effectively, the outcome in a learning experience might either be that the strategy was learned or not learned. A 'cognitive style' relates to the way an individual perceives and thinks about information. Therefore, if an individual is tested on both cognitive style and learning strategy, they can be made aware of how to develop strategies to enhance their style in various situations. Only the subjects in Experiment Four were given the Cognitve Styles Analysis (Riding, 1991). In Experiment Four there were no significant interactions of cognitive style and strategy. There were only significant interactions of cognitive style and list. A further experiment could be done in which a subject's cognitive style was assessed and then learning strategies that were suitable to the subject's cognitive style could be taught.

In the four experiments the learning strategies used were initial letter, making into a story, grouping and imagery. The four learning strategies used in the four experiments were chosen to help subjects remember lists of words. The strategies, 'grouping' and 'imagery' might be more generalisable to other learning tasks than 'initial letter' and 'make into a story' which are more suitable to verbal tasks such as learning a list of words.

Grouping

This strategy might be transferable to other tasks if it is learned and practiced. According to Baddeley (1986) when learning lists of unrelated words, on successive learning trials individuals tended to produce clusters of words in the same order again, suggesting they were organising words in some consistent manner.

Imagery

Paivio (1969) in describing visual memory believed the process involved a dual coding system in which it is possible to derive an image from a verbal label and a verbal label from an image. In contrast, Pylyshyn (1973) stated that representations of pictorial knowledge about the world do not differ from the type of representation achieved through language and a unitary theory of imagery and verbal processes exists. Experiment One was concerned with remembering concrete and abstract words. It seems that there should be no difference in the remembering of concrete and abstract words according to Pylyshyn and strategy three (make into an image) and strategy six (image each item on a list) when taught to subjects should enable them to learn both types of words effectively. The results in Experiment One showed that in a nearly significant finding (treatment by concrete/abstract words), concrete words were easier to remember than abstract words. This result would be in agreement with the findings of Paivio, that concrete words are easier to remember than abstract words. However, another nearly significant finding in experiment one (treatment by difficulty) revealed that the recall of difficult abstract and concrete words was better than the recall of easy abstract and concrete words. There needs to be more experiments done to find out why this happened.

The results in Experiment One indicate that strategies benefited the boys but not the girls. In Experiment Two 'strategy' was not significant. In Experiment Three 'strategy' was not significant. In Experiment Four there was a significant interaction of 'sex and strategy and list and position'. There were differences in the girls and the boys learning the strategies effectively (girls outperformed boys on learning the lists using strategies one and two equal on strategy three and worse using strategy four). The reasons why strategies might not have been effective in Experiments Two and Three could be because the subjects did not understand the strategies and were unable to apply them. It could also be that they did not see the usefulness of strategies and refused to learn them. Another possibility is that retroactive inhibition took place in which interference caused the extinction of the memory trace (Bannatyne, 1971). The interference effect of learning a new list and getting confused with the lists previously learned might have occurred.

It was also possible that unwanted factors (confounding variables) influenced the experiments. In Experiments One to Four the class teacher did not administer the experimental materials and the children might not have adjusted to receiving instructions from the experimenter. In addition, other unwanted factors might have influenced the subjects in the four experiments such as tiredness and boredom. It could also be that the students were not motivated to learn the lists, because they thought that they would not need to remember any of the words for a school based assignment and possibly saw no need for transferring these words to another task.

The literature on 'mnemonics' suggests that they aid in learning performance. The reason verbal and visual mnemonics were chosen as strategies to be learned in Experiments One to Four is because they are supported by many authors as assisting in recall. Rohwer et al. (1967) said that mnemonics aided in learning performance. Ross and Lawrence (1968) found that loci mnemonics benefited students. Bower and Winzenz (1970) in comparing mnemonics and rote learning cited the former as significantly better. Belleza (1981) stated that mnemonics increased learning performance. Krinsky and Krinsky (1994) found in immediate and long - term serial list recall mnemonics improved learning. Higbee (1994) found the use of a rhyming mnemonic improved recall.

The two mnemonics and two learning strategies used in Experiments One to Four (initial letter, make into a story, grouping and imagery) respectively, have been supported by several authors, for example the initial letter strategy aids the learner in improving recall, Wilson (1991). Crovitz (1979) asserted that the 'story' strategy also improves recall. Baddeley maintained (1986) that the learner is an active organiser of information and performs the clustering (grouping) of material naturally.

Gender Differences in Learning Performance

The results in Experiment One indicate that girls performed better than the boys in the control group and the boys performed better than the girls in the experimental group. The results in the second experiment indicate that the girls out-performed the boys on lists two, three and four in the experimental condition and boys out-performed the girls on list one in the experimental group. The girls out-performed the boys in the third experiment in both the control and experimental groups. The girls learned strategies one and two more effectively than the boys in the fourth experiment did. Girls and boys learned strategy three equally well and boys learned strategy four more effectively than girls did.

In summarising the four experiments the gender differences in Experiments Two, Three and Four showed that girls were better in learning more of the lists than boys using learning strategies. In Experiment One they outperformed the boys and they were the control group. The girls'overall performance in learning the words in the lists in the four experiments was better than the boys. Girls' superiority in verbal ability is supported in the literature by many authors. According to Maccoby (1966) throughout the pre-school years and in early years girls exceed boys in most aspects of verbal performance. Also in the area of reading disabilities boys predominate (Maccoby). Gonzalez and Adanez (1993) found that girls had a better verbal ability than boys did. A Russian study by Volf (1994) pointed out sex differences in strategies of memorising imply wider participation of the right hemispheric way of information processing in providing some form of verbal activity in women. In concurrence Shaywitz.(1995) reported females were found to have a functional organisation in their brain making them superior in language in which the left and right side were activated whereas in the males only the left side is affected.

Hart (1992) showed females recalled more words than males and clustered related words more than males. Birenbaum et al.(1994) found females demonstrated better associative memory than males. Vitulli (1991) again in the area of memory found females had better short-term memories at a one-second interval than males. In contrast, the reasons that the boys did not do as well as the girls in learning the lists might be that boys have better spatial ability and girls have better verbal ability, according to Vernon (1961), Smith (1964) and a recent study by Birenbaum, Kelly and Levikeren (1994). The learning of a word list is a verbal task. According to Maccoby (1966) the superiority of boys is in spatial ability and this is not apparent till the age of five. The boys in the experiments were either aged 10,11,13 or 14. Also Maccoby found that spatial ability depended more on logical operations than on automatic verbal functions.

Examining Other Learning Strategies

List learning strategies proved to be effective in learning some of the lists. It might be interesting to investigate the effectiveness of generalisable learning strategies as supported by Dansereau, Weinstein, & Pask 1975 (the application of knowledge to new problems in order to demonstrate understanding of learning material). The proposal might be to do a new study using different materials and different strategies. Instruments that diagnose a student's learning deficiencies have been designed by several authors including Svensson (1984) and Weinstein (1983). In examining these instruments one could focus on some of the generalisable learning strategies to be included in a further study and observe their effect on the learner.

Svensson (1977) emphasised the need to identify differences in how students learn that directly effects their learning achievement. He proposed that an instrument be developed for diagnosis that could facilitate the design of remedial learning strategies. He focused on covert or overt thoughts and behaviours that related to successful learning and that could be altered through educational intervention. Wenistein et al.(1983) resulting from analysis of study skills books, manuals and programme curriculum guides created a 90 item Inventory to diagnose strengths and weaknesses of students who were entering university. Some of the items on the inventory include selecting main idea; test strategies; information processing; and self-testing. The goal was to make the student responsible for his own learning. New experiments would need to be devised to investigate the effectiveness of some of these strategies.

CONCLUSION

In teaching learning strategies and giving written instructions to learn the strategies in the first part of this thesis it was found that learning strategies were effective in Experiment One and to a much lesser extent in Experiment Four in learning the word lists. They were not effective in Experiments Two and Three. The four studies mainly showed a gender difference in learning the word lists. Knowing the cognitive style of the students in Experiment Four did not reveal that one style was greatly influenced by learning the learning strategies over any of the other styles. Therefore, further insight into how a person solves a particular task when he is not taught learning strategies nor given instructions about how to use learning strategies posed the focus of the second part of this thesis. It switched from teaching and giving instructions to learn how to use learning strategies to the observing of what learning strategies a person uses in solving tasks. This meant that the learning strategies used by the students in further experiments in this thesis would have to be available externally. The manner in which to observe the way a student used a learning strategy might be to examine the things he notated when solving a problem. The ‘working out' used to solve a problem would not be affected if the student was given a problem in class and monitored by his teacher to see he was not given any help in doing the problem . In effect the ‘working out' produced by the student to solve the problem would be the learning strategy that the student used to solve the problem. In a case where there were no apparent external notations made by the student then it would be assumed that the learning strategy(ies) used to solve the problem would remain unknown to the teacher. Indeed in learning lists of words in Experiment One some subjects when asked how they arrived at a particular answer said, ‘I did it in my head.'

It was found that only in Experiment One and Experiment Four learning strategies improved the recall of words in the word lists and not in Experiments Two and Three. The reasons for this may be the following:

1.) Learning strategies might only be effective if taught to students for a longer period of time.

2.) Learning strategies might only be effective if the students had a longer period of practice in the use of the strategies and recall of the word lists.

3.) The learning of learning strategies to remember lists of words is an artificial process (Harris, 1992) and the learner might have difficulty in linking the strategy to the task, for example knowing how to use the 'grouping' strategy and after using it forgetting one or two words in a list that can't be grouped. Also, the learner might in trying to remember the words on the list not succeed because the words lacked in importance to him.

To carry on from this point would involve spending an extensive period of time with the same students used in Experiment Four, but training them in the use of learning strategies much more intensely. However, this was not possible because the students were not available for the amount of time required. An alternative and overlooked area of research that would not require teaching time, but give an interesting account of how students solve a learning task might be to examine the 'working out' (external representations) a student uses in their solutions to problems. It was decided by this author to examine the literature on external representations and how they are used in the solution to problems. A review of the literature in the use of 'external representations' was conducted in Chapter Three.

CHAPTER THREE

THE USE OF EXTERNAL REPRESENTATIONS AS A STRATEGY IN PROBLEM SOLVING

INTRODUCTION

The first part of this thesis was concerned with learning strategies and the chosen learning task was learning lists of words because of an interest in the function of memory in verbal learning. In education through the ages there have been various stages in which a particular type of learning has been favoured e.g. Discovery Learning in Science with its own learning strategies. Piaget believed that the primary aim of education was to create people who can do new things. Children should learn by doing and the role of the teacher is first to provide the appropriate environment and materials and then allow children to choose freely among them. In this way he thought they would experience the intrinsic satisfaction of discovering something new for themselves. However, in order to do new things it might be important to have previously been taught a set of learning strategies to enable a child to learn and remember. For example, if a child were learning about a new topic in History, such as the inventions in the Victorian Era, by knowing the learning strategy 'grouping' he might better remember the inventions according to the type of invention i.e. they all run on electricity (telephone, phonograph and light bulb but not the manual typewriter).

Historically, educators have been looking for a set of learning strategies that could be generalised to all subjects. According to Weinstein (1975), learning strategies are derived from an extension of classical verbal-learning research traditions. Weinstein devised a generalisable learning strategy programme to be situated in an educational or training environment. The learner would be given a set of strategies to maximise acquisition, retention and retrieval outcomes of a learning task. Resnick (1989) addressing learning strategies, confronted the proposal, whether, thinking could be taught in the form of general skills which operate across a range of knowledge, or only as domain specific in that each field of knowledge has its own distinctive style of knowledge. Resnick maintained that this was probably the single most important and theoretical issue in the field of learning research. Baron and Sternberg (1987) viewed that various approaches are compatible and deal with different aspects and methods of teaching thinking skills. Ultimately, the most profitable program of instruction in the opinion of the authors will be the one that combines the best elements of the various approaches.

In Chapter Two of this thesis four studies were conducted in which learning strategies were taught and instructions in their use were given to students to help them learn word lists. There were some interesting results pertaining to Gender Differences and Learning Strategies, and Cognitive Style and List Learning Performance. There were no interactions of Cognitive Style and Learning Strategies.

In the first four studies it was apparent that gender and learning strategies had an effect on the recall of words. In summarising the four experiments the gender differences in Experiments One showed that boys outperformed girls in learning the lists after learning the learning strategies, but girls outperformed boys in the control group. In Experiments Two and Three 'strategy' was not significant. In these two experiments it was found that overall, girls outperformed boys in remembering the words on the word lists. In Experiment Four there was only one significant interaction including 'strategy' and it showed that girls outperformed boys using the 'initial learning strategy', girls did better than boys using the strategy 'make into a story', girls and boys performed equally well using the 'grouping' strategy and boys outperformed girls using 'imagery' strategies. In Experiment Four girls outperformed boys in learning the lists. The girls' overall performance in learning the words in the lists in the four experiments was better than the boys. Girls' superiority in verbal ability is supported in the literature by many authors. According to Maccoby (1966) throughout the pre-school years and in early years girls exceed boys in most aspects of verbal performance. Also in the area of reading disabilities boys predominate (Maccoby). Gonzalez and Adanez (1993) found that girls had a better verbal ability than boys did. A Russian study by Volf (1994) pointed out sex differences in strategies of memorising imply wider participation of the right hemispheric way of information processing in providing some form of verbal activity in women. In concurrence Shaywitz (1995) reported females were found to have a functional organisation in their brain making them superior in language in which the left and right side were activated whereas in the males only the left side is affected.

In respect to the learning of learning strategies, boys outperformed girls in the experimental group in Experiment One. In Experiment One there were seven learning strategies to learn.
It is unclear which strategy or combination of strategies the boys used. However, the boys doing better than the girls in the experimental group might be due to them having better spatial ability than girls. Maccoby (1966) in twelve studies found that boys were superior to girls in spatial ability. According to Baddeley (1990) imagery may not be purely spatial nor visual, but may be both. Three strategies out of the seven in Experiment One were imagery strategies ‘ Make into an Image’, ‘Image each Item’ and ‘Appearance Grouping’ and were referred to as strategies three, six and seven in Experiment One. The boys might have found these strategies easier to learn than the other strategies because of their superior spatial ability. Further experiments would need to be done using these strategies to. In Experiments Two and Three ‘strategy’ was not significant.

In Experiment Four there was only one interaction including the variable ‘strategy’. This was a four-way interaction of ‘sex by strategy by list by position’. The four strategies (initial letter, make into a story, grouping and imagery) had different effects on the boys and the girls. The girls in learning the more verbal strategies {strategy one (initial letter) and strategy two (make into a story)} obtained higher mean scores than the boys. The boys in using strategy four (imagery) obtained higher mean scores than the girls. The effect of learning ‘strategy three’ was the mean scores of girls and boys were equal. In the literature studies on verbal ability, and spatial ability concur that females are superior in the former and males in the latter. The ‘grouping’ strategy did not reveal a gender difference and this might be because people naturally tend to categorise things (Bousefield, 1953).

There were two significant within-subject interactions in Experiment Four, which included Cognitive Style. They were ‘List by Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style’ and ‘Wholist-Analytic Cognitive Style by List by Position’. In the former interaction the Analytic-Verbalisers outperformed Wholist-Verbalisers in list one. In list two Wholist-Imagers outperformed Analytic-Verbalisers. In list three Wholist-Imagers outperformed Analytic-Verbalisers. In the interaction of

Wholist-Analytic Cognitive Style and List and Position, Analytics significantly outperformed Wholists in list 1c. The words in this position of the list were orange, truck, elephant, and apple. The words 'apple' and 'orange' could be broken down into two syllables and the word 'elephant' could be broken down into three syllables. The word 'truck' was monosyllabic. Further studies would have to be done to see if Analytics remember words of more than one syllable by their syllabic divisions better than Wholists.

The result of these four studies indicated that being taught and instructed to learn learning strategies to assist in the learning of lists of words were not as effective as was hoped. However, in several of the experiments 'strategy' did influence learning performance. In Experiment One strategies benefited the boys but not the girls. In Experiments Two and Three 'strategy' was not significant. In Experiment Four there was a significant interaction of 'sex and strategy and list and position'. There were differences in the girls and the boys learning the strategies effectively (girls outperformed boys after learning strategies one and two, equal on three, and worse after learning strategy four). So for further experiments, it was decided not to continue teaching learning strategies to assist in the learning of word lists. It was thought that there were three plausible reasons why the learning strategies were not more effective. They were the following:

(1) There might not have been enough time devoted to teaching the learning strategies.

(2) There might not have been enough time to practice the learning strategies, because of constraints of the schools' and students' timetables.

3) The students might have thought that learning the strategies was not a useful task.

Harris (1992) suggests that the learning of lists of words with the aid of learning strategies is an artificial process. Baddeley (1990) is in agreement and cites the example that people who take 'memory training courses' may learn various visual imagery mnemonics for remembering lists of words but according to Higbee (1994) do not put what they learn into practice.

It was decided to look at the way students approach a learning task by examining their 'working out' (external representations) when doing a problem. Zhang and Norman (1994) reported external representations are in the world as physical symbols e.g. written symbols. They can also be external rules, constraints, or relations embedded in physical configurations e.g. spatial layouts of diagrams. The written word, is itself an external representation used by most people for communication and in their working out of various problems such as analytic reasoning problems. This view is supported by Pemberton and Sharples (1996) in their belief that external representations are the markings that writers make, singly, or in collaboration, on some external medium such as paper or a computer screen including notes, written plans, tables, etc.

Chapter Three is concerned with the different external representations that have been used to solve problems. Children will be given problems to solve throughout their schooling into adulthood and they will range from simple verbal reasoning problems to the more complex analytic reasoning problems. As individuals differ in their ability to solve problems these differences as well as gender, age, and cognitive style will also be taken into account. The three main headings and main subheadings in Chapter Three include the following:

External Representations
external and internal representations
constructing representations

Problem Solving, Historical Implications And The Influence Of External Representations
different approaches used to solve problems
analytic reasoning, verbal reasoning, spatial and mathematical word problems

Individual Difference Variables And Problem Solving
gender differences in spatial and mathematical problems
age differences
cognitive styles and spatial and mathematical problems

EXTERNAL REPRESENTATIONS

External and Internal Representations

The definition of 'external representations' has been discussed in the literature and several definitions have emerged. According to Zhang and Norman (1994), internal and external representations are two indispensable parts of the representational system of any distributed cognitive task. The authors maintained that to study a distributed cognitive task, (i.e. The Tower of Hanoi Problem) it is necessary to separate the representations of the task into its internal and external components so that the different functions of internal and external representations can be identified.

External representations are in the world as physical symbols (e.g. written symbols, beads of abacuses, etc.) or as external rules, constraints, or relations embedded in physical configurations (e.g. spatial relations of written digits, visual and spatial layouts of diagrams, physical constraints in abacuses, etc.). Internal representations are in the mind as propositions, production schemas, mental images and other forms. According to Travers (1993) when one begins a problem-solving task one mentally visualises and arranges the givens, so all representation commences as internal. Cox and Brna (1995) maintained that concerning the nature of internal representations, popularly debated within cognitive science, advocates can be found for the position that internal imagery is merely epiphenomenal (concomitant to it). In an experiment by Zhang (1997) using 'Tic-Tac-Toe' as the problem and its isomorphs (line, number, shape, and colour) it was found that 'line' was the easiest isomorph to use. The external representations were ' line, shape and colour' and the internal representation was 'number'. According to Zhang, in 'number' the nine elements in the Tic-Tac-Toe problem are represented both externally and internally, externally because they can be perceptually separated and internally because the meanings (numerical values) of the nine digits have to be retrieved from memory. 'Line' was easy to work with because symmetry in 'line' could be directly perceived, which could reduce the size of the problem space. In Experiments Five and Six of this thesis on the use of external representations in problem

The Self-Explanation Effect

Zhang and Norman (1994) have outlined a theoretical framework for analysing the ways in which internal and external representations interact. The authors back the argument that external representations change the nature of the task. Their approach provides one starting point for an investigation underlying 'the self-explanation effect'.

Brna, Cox, and Good (1996) described 'the self-explanation effect' in its original presentation as being associated with good performance on problem solving through the use of example solutions (Chi et al. 1989). It appears that more successful problem solvers have three special characteristics. In contrast to the poorer students, they tend to: more frequently explain and justify actions to themselves; monitor their comprehension performance more accurately; and refer back to an example for a specific piece of information. This effect may elucidate the ways in which diagrams function in both problem solving and sense making. For example, Wertsch and Toma (1995) have argued that the use of external representations changes the nature of the task. However, Cox (1996b) points out that the use of diagrammatic representations might permit the self - explanation effect. He suggests that low expressivity of graphical external representations may assist, to a greater extent than sentential representations, a reflective, self-explaining student by confronting him/her with the need to consider more than one model of the information in question. On the other hand, low expressivity may lead the student into considering only that model. Cox further argues that there hasn't been enough work to determine the mechanisms that might lead to the effect, nor on the ways that diagrams play a part in this process.

Wilkin (1994) studied the interaction of self-generated diagrams in relation to the self-explanation effect. Poor learners, as defined by a median split, used self-generated diagrammatic representations in trying to understand motion along a curved path. Her results indicated that the adjacency of diagrammatic features would often lead to error, a result quite consistent with Lowe's detailed analysis of the interaction between domain expertise and accuracy in a study of ER usage (Lowe, 1996). The argument generally is that diagrams may mislead the novice diagram constructor without additional instructional support.

Brna et al. (1996) maintain the self-explanation effect has been replicated in physics and computer science, but its fundamental cognitive processes have not been fully investigated. ER construction may affect self-explanation but the issue has received little research attention. The modality in which an ER is constructed (i.e. linguistic or graphical) may affect the operation of the processes underlying the self-explanation effect. In the case of constructing a diagram for example, the semantic properties of graphics may confront the learner with his or her poor problem comprehension since unlike language, graphics force a determinate representation that is strictly limited in terms of the amount of abstraction that can be expressed (Stenning and Oberlander, 1995). Hall, Kibler, Wenger and Truxas (1989) have observed that much of a problem solver's activity is devoted to reaching an understanding of the problem. With language, learners may re-write or translate a problem in somewhat abstract terms and may even hide from themselves their incomplete comprehension.

Writing

Studies on literacy show the important functions of external representations. The classical view on writing, originally developed by Aristotle and presently restated by Bloomfield (1993) and Sassure (1983) is that writing merely transcribes or re-represents speech from one external representation in auditory form to another external representation in visual form.

Pemberton and Sharples (1996) supported the view that external representations are the markings that writers make, singly, or in collaboration, on some external medium such as paper or a computer screen. They included notes, topic lists, written plans, idea maps, outlines, tables, concept maps, argument structures and annotations on the draft document as well as the draft in all its stages. The authors also stated that external representations could be short lived or idiosyncratic. They gave the example of a simple ad-hoc sketch (or even a shape described in the air or via a trace with a finger on a desktop) indicating intentions that are too amorphous to express easily in words. Wood (1992) in his studies of pairs of collaborating authors pointed out how one author drew a large funnel shape to represent the overall structure of the paper, and later both writers cited places in this shape when talking about parts of the paper. Pemberton and Sharples noted that external representations could in some cases, be too ambiguous and could be resolved by writing down a more precise form of words.

Graphical Representations

According to Cox (1996b) the cognitive effects of graphical ERs e.g. diagrams, are to reduce search and working memory load by organising information by location. Semi-graphical ERs, for example tables, make information explicit and can direct attention to unsolved parts of a problem (e.g. empty cells of a tabular representation). Graphical ERs can also help the problem solver by easing perceptual judgements and can act as aids to retrieval (Larkin & Simon, 1987). In 1772 Euler faced with the problem of teaching syllogistic reasoning used graphical teaching methods based on analogy between set membership and spatial containment. Stenning and Oberlander (1995) in their studies of logical reasoning with diagrams argued that diagrammatic representations such as Euler's circles limit abstraction and by that means assist processibility. In other words, graphical representations can make some information interpretable and transparent in a particular form at the expense of limiting abstraction in general forms. They argued that graphical representations were less expressive than sentential representations and they in effect, aid processibility and name that aspect of graphical representational systems 'specificity'. Therefore, graphical representations forced specification of classes of information in contrast to systems allowing arbitrary abstractions. According to Cox (1996a) unlike graphical ERs, linguistic ERs needed more active search, comprehension and inference.

Linguistic and Graphical Representations

Cox and Brna (1995) reported that external representations referred to a wide variety of representations in both the linguistic and graphical modalities. Lohse et al. (1994) in their analysis of visual representations identified 11 basic categories: Graphs, tables, graphical tables, time charts, networks, structure diagrams, process diagrams maps, cartograms, icons and pictures. The term ER (external representation) as discussed by

Cox and Brna also included sentences of natural language, sentences of formal languages (e.g., first order language logic), tables, lists, graphs, maps, plans, and set diagrams. Cox and Brna concentrated on external representations and maintained that mental representations could be external or internal.

Cox and Inder (1994) pointed out that one of the key things about diagrams is the fact that they usually represent a single state of affairs and represent at least some aspects of it completely. For example, one can say that the spoon is above and the knife is beside the plate, but one can not draw a diagram of this situation without saying whether the knife is to the right or left of the plate. Here the Theory of Mental Models, developed by Johnson-Laird and Byrne, 1991 predicts that a problem is more difficult to solve if more than one model has to be considered. Additional models put a strain on limited working memory.

External Representations (Workscratchings)

External representations stand for something in the absence of that thing, representing something about the world. They take many forms including pictures, diagrams, and words. Cox and Brna (1995) found external representations (ERs) are effective in reasoning due to their cognitive and semantic properties. Subjects' use of ERs in their solutions to analytical reasoning problems were investigated. The source of data consisted of a large body of ERs ('workscratchings') used by students in their solutions to problems delivered via paper and pencil tests.

The authors' results showed great diversity of ER across subjects, allowing the usefulness of various ERs under differing task conditions to be studied. The range of ERs used by subjects included plan, diagram, various tabular representations, directed graphs, set diagrams, logic, lists, and natural language. Subjects' prior knowledge of ER formulations was shown to be a major factor in the effectiveness of ER use. The authors focused mainly on external representations, stating mental representations may be external or internal. They directed their attention to subject-constructed representations of domain knowledge. Their work relates somewhat to the work of Kieras and Bovair (1984) but whereas those authors were concerned with the facilitating effect of an appropriate internal representation (mental model) upon learning to operate a device, Cox and Brna were concerned with the role of external representations in problem solving.

They also pointed out that supporting the use of external representations was not about graphic communication but about the spontaneous construction and use of a variety of external representational forms in a self-communicative manner as subjects develop and examine their own ideas.

ERs occur in everyday living. Graphical ERs such as freehand idea sketches are an invaluable aid to creativity in design disciplines such as architecture (Goldschmidt, 1991). Some examples of ERs given by Cox and Brna were, when buying new floor covering one takes along an annotated plan to the carpet store, communicating the directions to a party to friends which require the drawing of a map, and taking shopping lists to the supermarket. All these are examples of the use of ERs used in everyday problem solving or related activities. Cox and Brna also asserted, in addition to everyday examples, it is well known that ERs are effective aids to problem solving for a range of more formal problem types. These include analogical reasoning (Beveridge and Parkins, 1987), algebra word problems (Singley, 1989), logical and analytical reasoning (Barwise and Etchemendy, 1995) and more generally, in scientific and mathematical discovery (Davis and Hersh, 1981).

Brna, Cox and Good (1996) pointed out that diagrammatic reasoning in educational contexts (and in general ones too) can be described as depending on the nature of the task, the semantic properties of the diagram, and the person's prior knowledge, including skills, preferences, experiences, etc. A major difference between the educational and general contexts is the emphasis in the former on learning, and accordingly greater importance is placed on those characteristics, which are expected to promote learning. In both contexts an individual might want to solve a problem. The process of working through from an informal, ill-defined task to a solution has been described by Cox and Brna in terms of the stages of comprehension, selection of external representation systems, construction of external representations, and use (including reading-off results) Cox and Brna (1995). In noneducational, professional contexts, groups of colleagues work on a problem together using diagrams both as a vehicle for problem solving and as a means of performing a variety of communicative acts. Therefore, the diagram may be both an end product and a means to an end.

Hyperproof

In contrast to using self-generated diagrams (external representations) the Hyperproof program presents information to the user as a partial diagram. Cox and Inder (1994) found that on the basis of their performance on diagrammatic reasoning problems on pre-course tests, subjects were classified as either ‘diagrammatic’ or ‘non-diagrammatic’ reasoners. The post-course tests showed that the diagrammatic reasoners improved to a significantly greater extent when using Hyperproof. However, the diagrammatic reasoners in the syntactically (the way words are put together) taught group actually decreased in their performance relative to their non-diagrammatic counterparts.

The Hyperproof program allows the user to solve reasoning problems whose topic is a simple blocks world. Information is presented in the form of a partial diagram of a blocks world plus one or more sentences expressing additional information about the world. The inference system enables the user to modify both diagram and sentences in accord with rules that preserve the information content available from the two sources. Cox and Inder, also noted that Hyperproof findings raised some important educational questions for the teaching of logic. Some students, classified as diagrammatic reasoners, seem to benefit from graphical teaching methods more than others. In contrast, students whose cognitive style is more verbal seem to respond better to language-based teaching methods. An important question is whether the less graphical students can be taught to reason more graphically. The authors suggest if not, then perhaps students should be tested and assigned to classes that are taught in a way that matches their cognitive style preference. According to the authors if graphical reasoning can be successfully taught, then systems such as Hyperproof will serve to broaden the range of reasoning tools that students can use.

Cox and Inder maintained that language, with its syntactic structure, is just one of several different ways in which information can be expressed. Diagrams, maps, and other graphically based forms of representation can also be conveyors of the information used in reasoning. Valid inference is simply the general process of extracting new information from information gathered from a variety of sources and presented in a variety of forms, including (but not limited to) both the linguistic and the visual. This is a way to think about reasoning in most situations, even in cases that at first seem very symbolic, like mathematical reasoning.

Working with Diagrams

Brna, Cox and Good (1996) pointed out that in educational contexts, there's tension between 'making things easy' and helping students to learn. This tensions derives from the assumption that learning comes through doing rather than from some form of passive observation. If learning to utilise diagrams is to be effective, it is expected that practice in utilising diagrams will be important. For example, if one believes that Venn diagrams are an effective method for solving a certain class of problems, then providing a problem together with a range of possible diagrammatic solutions may make it easier for students to solve the problems but give the student no opportunity to practice diagram construction. Secondly, there is a tension between situated diagram systems and the desire to achieve a degree of generalisation so that the skills and knowledge gleaned from one learning system can more easily be transferred to a new system. Attempting to provide a stand-alone curriculum for education in the use of diagrams will be met with this sort of problem. Thirdly, there is a difficulty that arises in terms of meeting a new diagram system at the same time that new subject-based material is being learned. The tension exists between learning the diagram system versus learning the topic (Brna et al., 1996). The authors' organised their discussion along three lines:

1. the tension between making things easy and helping students to learn
2. the question of how to support the generalisation and transfer of diagrammatic skills
3. learning unfamiliar representational systems while learning conceptually new subject matter

Learning comes from doing rather than from some form of passive operation. The full range of problem solving skills do need practice to attain both competence in performance and comprehension of the (diagrammatic) representational system itself. The authors also accepted that it would be a mistake to assume that observation is inevitably passive: an observer may be highly active in constructing, for example, some interpretation of a diagram without necessarily manipulating the diagram in any way. Whatever the form of internal representations, students are actively processing information obtained from the external representation. It is also reasonable to assume a framework along the lines of

Rumelhart and Norman's 'Accretion, Tuning and Restructuring' (Rumelhart and Norman, 1978) that sometimes new information can lead to extensive internal restructuring (though the current belief is that such 'radical' change is quite rare).

Activation and Supplantation

Salomon (1994) discussed the concepts 'activation and supplantation' in relation to external representations. The former occurs when the preconditions of a previously learned skill are satisfied, while supplantation is the case where an external transformation has the same effect as the internal transformation that the learner would have applied. Therefore, supplanting both saves cognitive effort and models the transformation explicitly. These ideas appear to be productive for any analysis that seeks to explain different effects attributable to the external representation systems themselves. Saloman argued that activation of a cognitive skill is only of benefit if the basic skill is present, short circuiting is useful for saving mental effort but at the cost of failing to provide skill activation. Supplantation is seen as a way in which poor mastery of a skill can be compensated for. Saloman pointed out that we have no reason to assume that these outline hypotheses work either for all situations or for all students. Saloman was in agreement with Cronbach and Snow (1977) that the high-verbal learner who is weak in visualisation might be supplied with extensive diagrams and left to generate his own verbal representations (assuming that it is the process of diagram construction that is being supplanted).

Cox, Stenning and Oberlander (1994) pointed out that subjects classed as good diagrammatic reasoners performed better than poor diagrammatic reasoners following a graphically taught logic course. There was also evidence that syntactic teaching produced better outcomes for non-diagrammatic reasoners in a syntactically taught group, and the teaching approach matched to reasoning modality preference produced better learning outcomes. The authors remained unclear whether it is best to compensate for, or teach to cognitive style differences. Even if the identifying of relevant individual preferences/aptitudes was achieved, it is expected that it will not be possible to make a simple either/or decision.

Constructing Solutions

Constructing your own diagrammatic solutions may help the learner. Hall, Kibler, Wenger and Truxaw (1989) have observed that much of a problem solver's activity is devoted to reaching an understanding of the problem. With language, learners may re-write or translate a problem in somewhat abstract terms and may have even concealed from themselves their less than complete comprehension (Hall et al. 1989). It may be the interplay between problem descriptions in natural language and in diagrammatic form that assists the individual to understand the nature of the task in some deeper way.

Cox (1996) pointed out that in solving analytical reasoning problems under test conditions subjects produce ERs spontaneously, for totally private consumption and aren't intended for communication with another individual. The externalisation of representations allows subjects to examine and develop their own ideas (Reisberg, 1987). This externalisation of a representation is often associated with translation and usually analytical reasoning problems are presented linguistically and the information is translated or re-represented in a different modality, often diagrammatic or graphical. Some subjects, may want to represent the problem information in the same modality using natural language (re-writing the sentences, perhaps in abbreviated form) or using formal languages such as first-order logic. Concerning analytical reasoning problems, the ability of the chosen ER to capture the level of abstraction of the information contained in the problem is more important than the ER's modality per se (Cox, Stenning and Oberlander, 1995a, b).

ER construction is equivalent to building a model of the information in the problem. Semantically equivalent models may not be equally suited for all types of problem solving tasks (Day, 1988). Some representations facilitate the rapid comparison of values (e.g. histograms) whereas other representations facilitate read-off of precise values (e.g. tables). Effective ER use necessitates both an adequate representation of the information in the problem and a representation suited to the type of task posed by the problem. Representations also differ in their ability to convey what might be termed 'progress' through the 'problem 'information. Tables or spreadsheets are for example, very good at emphasising (via empty cells) missing or not-yet-represented information. In ER construction the individual is helped in problem solving by re-ordering the information in ways useful for solutions and by displaying the range of possible models of the information, making missing information explicit, and representing implicit information explicitly. It is essential ERs be constructed correctly to effectively perform these functions. Slips and more profound errors can occur at any of several stages in ER construction. In trying to construct a representation the problem solver must decide whether a single, unique model adequately expresses the information in the problem stem. If not, the individual may need to change to a more expressive representation in the same modality as the first attempt (e.g. from natural language to first-order logic) or to a different representation in a different modality (e.g. from a tabular representation to a set diagram). Individuals differ in the extent to which they externalise their reasoning. They differ in the extent of externalisation; some individuals reason with no ER, others use 'minimal' ER strategies and some use 'full blown' diagrammatic models. ERs probably serve different functions for different people. Individuals vary in the way in which they partition their internalised and externalised cognition. Individuals also differ in the extent to which they interact with or operate upon their graphical representations. For fully model-based (i e.diagrammatic) reasoners, the level of interaction and the amount of intertranslation of information is greater than for their less diagrammatically inclined counterparts (Oberlander, Monaghan, Cox, Stenning and Tobin, 1996).

Reisberg (1987) viewed the process of constructing an ER as a procedure for 'widening the context of understanding' and 'turning ones representations into stimuli'. ER selection and construction consisted of dynamic iterations and interactions between external and mental models. Some tasks could be carried out with internal representations but were very difficult. Hinton (1979) instructed subjects to imagine picking up a cube and holding it such that one corner was vertically above the other. He then asked the subjects about the location of the corners that they weren't 'holding'. Most subjects believed that the corners will form a square along the 'equator' of the cube. The middle edges of the cube, in fact, form a zig zag. Hinton contended that most subjects' mental images were not fully elaborated and that we mentally reconstruct the cube on the basis of an incorrect approximation of the transformation involved. We worked from some poorly elaborated, structural description. Externalising the representation by drawing a diagram of the cube assists greatly with determining the correct arrangement of corners. It helps to turn an individual's initial internal representation into an external stimulus which, upon reprocessing, assists with finding a solution. Simply, the process of externalisation helps to disambiguate ambiguous mental images. Similarly, the process of drawing an ER such as a diagram (i.e. externalising a mental model) can facilitate problem solving. One interpretation of Reisberg's view was that externalisation facilitates the transfer of information between cognitive subsystems in ways that were not possible according to the dual-coding hypothesis (e.g. Paivio, 1968).

One question in the debate concerned the extent to which, and at which level, communication occured between the various perceptual and cognitive subsystems. The question was, if there was an interlingua, a kind of internal mentalese, which mediated between linguistic and imagistic internal representation? Alternatively, was the only route between the subsystems via externalisation? Reisberg (1987) favoured the second position and it requires further research.

Children and the Construction of External Representations

Fletcher and Bray (1997) looked at young children's ability to formulate external representations (i.e.external representation strategies) in problem solving tasks and observed whether or not problem solving performance improved when they were instructed to either create or use external representations. Children's problem solving performance improved when children were instructed to create or use external representations such as models, drawings, or notes (DeLoache, 1989).

Fletcher and Bray pointed out that young children's ability to devise and then use external representations (i.e. external representation strategy) spontaneously has not been extensively explored. Children's external representation strategy use has been examined with hide and find tasks (e.g. the use of cues to mark hidden objects) and objects placement tasks (e.g., arranging objects to mark where to place objects). Using an object placement task, Bray, Saarnio, Borges, and Hawk (1994) found that when a verbal prompt was given (e.g. It's okay to move the objects) seven-year-old children used an effective object arrangement strategy. It was thus found that external representation strategy use is more likely to occur when children are provided with verbal prompts (Bray et al., 1997).

Practicing Representation

According to Greeno and Hall (1997) one interpretation of 'practicing representation' refers
to a type of exercise that is required of students, mainly in mathematics and science. They have to practice using the standard forms of representations, such as arithmetic expressions, tables, graphs, and equations. In another interpretation, 'practicing representation' may be part of a social practice done via conducting research on practices of representation in schools and in work settings. Learning to construct and interpret representations involves learning to participate in the intricate practices of communication and reasoning in which the representations are used. The authors maintained their research on practices of representations has implications for curriculum and instruction in school mathematics and science and they make the following three points:

1. Forms of representations can be thought of as useful tools for constructing understanding and communicating information. They do not have to be taught as ends in themselves. The situation at a point in time may determine how representations are constructed and adapted when representations are used as tools for understanding and communicating.

2. When representations are used as tools for understanding and communicating, they are constructed and adapted for the purposes at hand. Non-standard representations may serve these purposes better than a standard form and students should learn how to generate representations flexibly for their use.

3. For something to function as a representation, people must interpret it to give it meaning. Standard forms of representations are valuable and it is important to learn how to use them. Students can become actively involved in learning to construct and interpret representations through discussions of their characteristics including advantages and limitations. (Greeno and Hall, 1997, p. 362)

Greeno and Hall stated that representations were used to aid understanding when individuals were reflecting on an activity or working on a problem. As individuals or groups work on problems, they may make drawings, write notes, or construct tables or equations. These representations help them keep track of ideas and inferences they have made and also serve to organise their continuing work. Sometimes an analysis is constructed to be sure that a conclusion is valid or correct, and then the representation can also be used as an argument that supports the conclusion.

The authors reported that the representational work people do often uses nonstandard forms, which were constructed for the immediate purpose of developing their understanding. In most cases, individuals produce representational forms in ways that serve immediate local purposes. In addition to being representations of something, they were 'for something'. This contrasts with the general practice in school, finding students learning to construct representations of information without having a real purpose. It might be thought that the flexible construction of understanding using representations occurs only with problems that arise in such complex practices as engineering, but those working on school-like tasks also construct understanding in flexible, adaptive ways.

Research findings in this area are important for arguments about how representational forms might be made and used in new kinds of classroom practices. Representations are constructed for specific purposes during attempts to solve problems and communicate with others about these attempts. Additionally, the meanings of representations can also shift as problem-solving purposes and difficulties change. Under these conditions, representations often match the processes of solving the problem, providing a kind of model of the students' thinking as they work. This contrasts with common methods of teaching and assessment, in which students are instructed to represent problems with standard forms that depend on a classification of problem types, rather than on the processes of solution. Students often construct representations in forms that help them see patterns and perform calculations, taking advantage of the fact that different forms provide different supports for inference and calculation. Accordingly, solving a problem involves an interactive process in which students construct representations based on partial understanding and then can use the representations to improve their understanding, which leads to a more definitive representation, and so on.

In using and constructing conventions of interpretation in Peirce's (1893) view, with which Greeno and Hall agree, there are three things involved whenever there is a representation: something that is represented, the referent; the referring expression that represents the referent; and the interpretation that links the referring expression to the referent.

Sometimes there is an assumption that physical notations (texts, numerals, pictures, equations, and so on) on their own constitute representations and that information is somehow contained in the physical patterns that are written or drawn on paper or stored in computer files. This conception disregards the very fundamental principle, expressed decades ago by Peirce that for a notation to function as a representation, someone has to interpret it and thereby give it meaning. The person who produced a representation in the first place had an interpretation in mind, and the notation was a representation for that person. But if it is to be a representation for other people, they have to do the interpreting.

Greeno and Hall noted that standard forms -such as equations, Cartesian graphs, and tables – have extensively shared conventions of interpretation, and it is important for students to learn these so that they can understand these forms when they encounter them and construct them to communicate their ideas. Standard instructional practices in mathematics provide students with opportunities to learn the conventions of interpretation of standard representational forms at an operational level. According to the authors' understanding representations included knowing that there can be different interpretations of the same notation. It is important to know the conventional interpretations of standard forms, but it is often productive to construct nonstandard representations in working on problems and communicating about ideas. The Algebra Project 1989 involved students in constructing representations. They were engaged in processes of developing symbolic representations that expressed their understanding of mathematical concepts and principles in relation to their experience. Greeno and Hall described a teacher's fifth-grade mathematics' class in which part of a class period was spent working in groups on the problem: 'A car is travelling 40 miles per hour. How far will it go in 3 ½ hours? How long will it take to go 70 miles?' The class teacher led a discussion of the answer to the first part of the problem., and the students agreed that it should be 140 miles. This example was further analysed. The teacher found by walking around the room some students really did not understand this type of problem. She asked one student to explain it to the class and he said, 'it was just three times 40'. The teacher then asked what if an individual did not know why one was supposed to 'times' and how that could be explained. The student said he could explain that and drew a line in his notebook while the teacher drew a line at the board. The student went to the board and drew on the teacher's line the representation which he used (in his notebook) constructing the explanation of the multiplicative relation between the time and distance of a trip taken at a constant speed. By engaging students in these conversations the teacher arranged for them to participate in the construction of representations that they used to construct and communicate the meanings of mathematical symbols and operations. They reached understanding through representations that they and their classmates had constructed.

Greeno and Hall then discussed research that emphasised the expressive or inventive properties of representations in mathematics and science. The technical forms of representations, such as tables, graphs, and equations used in these subjects are often contrasted with representations in fields such as painting, sculpting and literature, which are adapted to particular uses of expression and communication, are flexibly constructed, and are open to multiple interpretations. The authors argued that representations in mathematics and science also have these properties. They maintained students benefit educationally if they were involved in activities in which they learned to construct versions of representations flexibly and to participate in discussions in which conventions of interpretation were developed. Such an approach enabled them to understand and appreciate that mathematical and scientific representations, like those in other domains, were adapted for particular uses.

According to Greeno and Hall fundamental differences exist in the forms and uses of representations in different domains. Eisner (1997) in agreement pointed out that if different forms of representations performed identical cognitive functions then there would be no difference between such disciplines as music, dance, and computing. Key differences do exist between the kind of learning and the representations students use in different disciplinary domains. Greeno and Hall maintained that every student's educational activities should include an abundant variety of experience and learning made possible through participation in multiple practices of representation. Crossing domains, these practices shared important features of use, adaptability, and interpretation that should be included in classroom learning.

PROBLEM SOLVING, HISTORICAL IMPLICATIONS AND THE INFLUENCE OF EXTERNAL REPRESENTATIONS

A brief history of Problem-Solving

According to Luria and Tzvetkova (1966) problem solving has existed as a school subject for several centuries and the methods of problem solving have formed a specific discipline. They believed every teacher knows that his pupils may face the following: occasional difficulty in memorising the question of a problem, decoding the logico-grammatical relationships of its statement, the inhibiting of impulsive guessing, and also the inadequate use of earlier developed stereotyped solution methods.

Maier (1970) maintained that research on problem solving before the 1930's still treated 'logic' as the basis for intelligent or rational behaviour. Psychology was an offshoot of the philosophy of mind 'thinking' and questions of consciousness, imageless thought, and concept formation were the subject matter of research in thinking (e.g. Woodworth, 1938). Maier found that a problem becomes difficult when its solution requires responses that deviate from the common ones or from previously learned ones. The creative person should be a good problem solver because he can solve not only routine problems but those that require more than a learning mechanism.

Historically, the philosophers had attributed reason and soul to man alone. Thorndike (1898) initiated an experimental approach to the analysis of problem-solving behaviour by developing the 'problem box' and observing how cats found their way to food. This led to a whole series of problem-box investigations, and Watson's text (1914) exhibited four pages of pictures of the various types of problem boxes used in animal studies. Watson described problem-box mastery as the development of motor habits and grouped it with maze learning. Thus, problem solving became classified with learning, and the reluctance to credit animals with a higher process was defended. The mechanism in this type of problem solving has been referred to as trial and error, and fitted nicely with learning, so that we now speak of trial and error learning. This method reduces initial success in problem solving to chance, and makes mastery of the problem-box as a matter of learning from successes and failures. Various types of puzzles have been used to study human problem solving, so that trial and error has become a generally accepted mechanism. Dewey (1913) adapted the concept, trial and error, to account for human problem solving by describing a process he called 'mental trial and error'. In this way, the problem-solving capacity of the trial-and-error process was expanded. At the same time, it gave man a kind of superiority over animals in that he could eliminate incorrect alternatives without trying them out behaviorally. Investigators of comparative behaviour questioned the existence of 'higher mental processes'. Adams (1929) found an element of selectivity and insightfulness in the behaviour expressed; but both recognised the characteristic of variability in the behaviour. A higher status was accorded to 'trial-and- error' behaviour when Dewey (1910) described problem solving as generalised to the thinking process of man. Dewey's model of thinking emphasised the point that the person, when confronted with a problem, goes from one idea to another is, of importance since variability emerges as the dominant characteristic of problem solving behaviour.

An individual in solving a problem is using his thinking and reasoning abilities (Bannatyne, 1971). In a classic experiment by Zeigarnik (1927) subjects recalled more of the interrupted than the completed task in a series of manual and mental assignments. It was thought that the interruption by the experimenter might have made the problems more memorable than the ones that the subjects were permitted to complete. This memory effect for problems is not well verified, and differences such as time spent on problems and the type of problem solving processes used may contribute to repeated failures to replicate the Zeigarnik effect (Seifert and Patalano, 1991).

In contrast Pachauri (1935) found that subjects had better memory for completed tasks than for interrupted ones on some manipulations of Zeigarnik's original experiment. He attributed these results to the fact that once finished a task becomes in a sense an entire or fixed form. This difference could explain the greater recall of the completed items. Bartlett (1932) illustrated that people are more likely to misremember story details that do not conform to a memory schema, while at the same time exhibiting accurate recall for details consistent with schematised knowledge.

Memorability effects attributed to Zeigarnik (interruption) effects may be more accurately described in terms of reaching impasses in some solution attempts. For example, in Yaniv and Meyer's (1987) studies, only one third of the word-definition trials resulted in a failed retrieval attempt, indicating that subjects more often solved the definition than met an impasse. Under these conditions, impasse memorability rather than Zeigarnik-like interruption appeared to be involved. In addition, although some theories have attempted to characterise the processing path in problem solving (Laird, Newell and Rosenbloom, 1987; Newell and Simon, 1972; VanLehn, 1989), there has been no connection found between processing characteristics and problem memorability. These results suggested that the nature of the processing occurring on each solution attempt may affect memorability and therefore, presumably, representational differences for problems based on the processing that occurs. They may provide an important constraint with which to assess performance of computational models of cognition (Newell, 1990).

Luria and Tzvetkova (1966) advised careful analysis of the wording of a statement, which often plays the decisive role in problem solving can either simplify or complicate the understanding of the problem. They concluded that the psychological analysis of different problem types and the development of their scientifically grounded classification were still a new subject requiring investigation. In the following section different types of problems will be discussed.

Different Approaches Used to Solve Problems

An individual approaches a problem e.g. a verbal reasoning problem, from a unique set of experiences. Knowing how to solve a problem involves breaking it down into steps in order to find a starting point that makes sense to the learner (Whimbley and Lochhead, 1991). It also concerns knowing how a problem was solved in the past including the speed of solving a problem, reading ability and vocabulary. Gaddes and Edgell (1995) noted that children may perform satisfactorily on tests of highly structured material that they had mastery over. Faced with open-ended problems that entailed mental procedures of trial-and-error, independent choice and decision, and restructuring and reorganisation of present knowledge, they may feel they are unable to cope.

To help the learner solve a problem, suggestions have been made by many authors. There are strategies that can teach one how to solve problems. The important point is that the learner understand the strategy and how to apply it, for example the use of ‘analogy’ (to supply the final term in a proportion, as to supply ‘darkness’ in the proportion day : light night : ……..).

According to Orton (1992) the aim to improve problem solving skills should be dealt with in school. Polya (1945-1962) led the way in establishing a routine for problem solving and how to train people to become better problem solvers. Wickelgren (1974) following in the tradition of Polya advised that some problems may be solved faster entirely in the head, but the majority of problems will be more quickly solved by representing information on paper early on in working on the problem. He gave four credible reasons:

First, writing down the components of a problem focuses your attention on the need to give names (symbols, diagrammatic representation) to each of the important concepts in the problem.

Second, it automatically draws your attention to the information stated in the problem as you attempt to represent that information on paper.

Third, as you derive inferences or get to intermediate stages in the solution of the problem, writing aids your memory for these inferences or intermediate stages at later stages in the solution of the problem. Having the information or inferences you drew from the given information written down allows you to use rapid visual scanning to jog your memory for prior concepts and facts that might usefully be combined with the concepts and facts to which you are currently paying attention.

Fourth, problems that involve tables or matrices of information are especially difficult to retain as a visual image purely in the mind. Such information is very efficiently represented by means of a table written on paper. Similar conclusions apply to graphs and other figures, which may be difficult to accurately imagine and remember purely mentally, without graphic aids.

The value of teaching problem-solving strategies was considered by Wickelgren (1974) in the following problem:

Tom either walks to work and rides his bicycle home or rides his bicycle to work and walks home. The round trip takes one hour. If he were to ride both ways, it would take 30 minutes. If Tom walked both ways, how long would a round trip take?

This problem illustrates a basic problem solving strategy of dividing the givens into subgoals. The problem could be examined in the following way:

What are the givens?

How long would it take to ride one way?

How long is a round trip?

How long does it take to walk one way?

How long is the round trip if Tom walked both ways?

A student in a school situation would be at an advantage if he knew how to use this type of problem solving strategy and that is what Wickelgren was advocating.

Orton (1990) considered at what point does a verbal problem become unsolvable? Is it when an individual does not understand what the problem is asking you to do or is it the point where you can't visualise what the problem is asking you to do? Is it just the vagueness of a word that hinders the individual? According to Anderson (1990) problem solving is another strategy to improve the student's ability to recall information.

Several authors have noted that there are important steps in solving problems.
Polya (1945) suggested four steps, Bransford (1985), offered five steps, Chisko and Davis (1986) developed five topic areas, Greeno and Riley (1987) designated three parts, and Whimbley and Lochhead (1991) illustrated five methods:

Polya (1945)

1. Understand the problem
2. Devise a plan-strategy
3. Carry out the plan
4. Look back

A modification of these steps was offered by Bransford. He suggested a five step process called IDEAL problem solving:

1. Identify the problem;
2. Define the problem through thinking about it and sorting out the relevant information;
3. Explores solutions through looking at alternatives, brainstorming, and checking out different points of view;
4. Act on the strategies;
5. Look back and evaluate the effects of your activity.

Chisko and Davis (1986) designated the following five topic areas around which lessons could be built to develop students' thinking skills.

1. Recognising and defining problems;
2. Organising information and using modeling techniques;
3. Analysing data, recognising trends, and making decisions;
4. Being flexible and thinking creatively
5. Generalising and consolidating

Greeno and Riley (1987) designated:

1. identifying what the problem is asking
2. explaining how one would set problem up
3. finding what needs to be done to calculate the solution

According to Whimbley and Lochhead (1991) the good problem solver possessed five characteristics:

1. positive attitude
2. concern for accuracy
3. breaking the problem into parts
4. avoiding guessing
5. activeness in problem solving

In each of these areas the heuristics (short cuts) of problem solving would be applied. Students become actively involved with the problem by being asked questions such as: What do you know? What do you want to know? What immediate information would be useful? What is a reasonable range for a solution? Have you ever seen anything like this before? Does your solution satisfy all requirements of the problem? Can you use the solution to this problem to draw general conclusions about similar problems?

The desire to help learners become better problem solvers, is the aim of education and not only mathematics education (Brown, 1978). Gagne (1970) stated that we probably couldn't teach people to become better problem solvers. This is because we can't teach thinking skills in a vacuum, as each problem involves its own content and context, if it doesn't we've moved toward routine exercises. Having solved a problem we have learned something but we have not become a better problemsolver per se. Ausubel (1963) too, whilst accepting that training in problem solving within a fairly narrow well defined subject discipline might achieve some success, painstakingly pointed out that there were transfer problems.

According to Whimbley and Lochhead (1991) the good problem solver possesses certain characteristics and one of the most important may be ‘activeness’. It is through doing more things as they try to understand and answer difficult questions that good problem solvers succeed in solving a problem. The good problem solver will try to create a mental picture of the ideas of a written description in order to ‘see’ the situation better. However, there are no clear rules of combinations or symbol types in assessing what is meant by a ‘picture’ according to Eysenck (1995).

Dealing with a verbose, confusing or vague presentation the good problem solver will attempt to pinpoint it with concrete examples and/or familiar experiences. The good problem solver as reported by Whimbley and Lochhead will also ask himself questions about a problem, answer the questions and also talk to himself as he crystallises his thoughts. Other aids include count on fingers, point to things with a pen, write on the problem, make diagrams or use other physical aids to thinking. Whimbley and Lochhead portray the ‘active’ problem solver as being active in various ways, which increases their accuracy and helps them achieve a clearer understanding of ideas and problems.

Perhaps the good problem solver is able to solve problems using his subconscious mind according to Orton (1992). He proposed that the successful solution of problems is dependent on the learner not only having knowledge and skills but also being able to tap into them and establish a network or structure. Sometimes a flash of insight occurs and this involves the realisation of some previously unacknowledged relationship within the knowledge structure. It depends on the richest possible knowledge base from which to draw. According to Whimbley and Lochhead, it is also known that it helps to turn the problem over in the mind thoroughly to try out avenues of approach and bring to the forefront a whole range of techniques and methods, which might be appropriate. Perhaps the solutions might still not come, but might come subsequently after a period of time away form the problem as if the subconscious mind, freed the constraints of conscious attempts to solve the problem, continues to experiment with combinations of elements from the knowledge base.

Analytic Reasoning and Verbal Reasoning Problems

In Experiments Five and Six of this thesis three analytic reasoning problems were used in the former and two verbal reasoning, one spatial and one mathematical word problem were used in the latter. Problem solving in areas such as verbal reasoning implores the learner to not only examine the problem at hand but also one's own thinking ability. Using one's reading and reasoning ability is essential to solving verbal reasoning problems. According to Baddeley (1996) these problems look at grammar and the way in which syntax is processed. For example, the active sentence, 'The boy kicked the ball' is more rapidly processed than the passive sentence, The ball was kicked by the boy', or the negative sentence, 'The boy did not kick the ball'. Similarly, 'analytic reasoning problems' also requires using one's reading and reasoning ability and these problems are posed in the form of logical puzzles and games. As Martinson (1993) pointed out students doing analytic reasoning problems devise their own record keeping system. This system would include notational devices and diagramming techniques invented by the student or adapted from other sources. The main consideration was that the student creates a system he understands and can use. Children are given problems to solve throughout their schooling. Exposure to various problem-solving representations, for example, 'diagrams' might assist the learner inasmuch as he will be continually presented with problems (varying in difficulty).

SPATIAL PROBLEMS

Introduction to Spatial Problems and External Representations

Thurstone (1938) in his theory of 'intelligence'asserted that spatial abilty was one of the seven factors known as 'primary mental abilities.' Smith (1964) maintained that spatial problems involved abstract thought and reasoning. However, Bannatyne (1971) found that spatial ability can be used in a concrete manner (involving abstract spatial principles) as when an architect designs a building or a child plays with a Mecanno set.

Mental Models as a Strategy in Problem Solving

Mental models were first posited by Craik (1943), stating that the mind constructs 'small-scale models of reality that it uses to anticipate events, to reason and to underlie explanation'. They are constructed in working memory as a result of perception, the comprehension of discourse, or imagination (Johnson-Laird, 1983). Their structure correponds to the structure of what they represent and they represent what is true, but not what is false. Accordingly, each entity (object or person) in the world is represented by a corresponding token in the model; the properties of entities are represented by properties of tokens in the model and relations among entities are represented by relations among tokens (Johnson-Laird, 1983). Notably, a model's construction may be based on language, but its structure corresponds not to the language used but to the situation described. In problem solving the task of constructing a mental model involves making assumptions about the problem and understanding the meaning of terms in the problem in order to reach a conclusion (solve the problem). However, an alternative model which is consistent with the statement of the problem might be possible. The theory of mental models, postulated by Johnson-Laird and Bryne, 1991, predicts that a problem is more difficult if more than one model has to be considered. Additional models impose a load on limited working memory. In Experiment Six of this thesis the spatial problem (problem one) was based on the Theory of Mental Models (Johnson-Laird, and Byrne, (1991) and it consisted of four statements (premises) about utensils on a breakfast table. The overall model of the state of affairs described can be presented in a spatial diagram. It is this diagram that in this author's opinion becomes the strategy that is used to solve the problem. The diagram the individual constructs may also be influenced by factors such as cognitive style. Wholists might use more whole constructs of the utensils on a breakfast table than Analytics. Further investigation needs to be done to classify the mental models used by individuals in problem solving.

Diagrams, Representation and Spatial Ability

As was stated by Newell and Simon (1972), problem solving simply means representing a problem so it makes the solution transparent. One of the types of knowledge representations, used by people since unknown times, but only recently becoming an object of focused research (and computer implementation of the results) is the representation involving visual, graphical and pictorial means (diagrams).

Simon , Pick Jr., Van Den Broek, & Knill, D. (1992) maintained there is much empirical evidence that people, especially people who are good at solving physics problems form internal representations (mentally visualise and arrange the givens and there can be as many diverse schemes of internal representations as there are individuals) of the sort called diagrams and they are identical to mental models (Johnson-Laird, 1983). It is not known what kinds of symbol structures represent such diagrams or how different such symbol structures are from assemblages of sentences. In Experiment Six of this thesis the spatial problem (problem one) was based on the Theory of Mental Models (Johnson-Laird, and Byrne, (1991).

Larkin and Simon (1987) proposed one kind of internal representation for diagrams (not too different from one proposed earlier by Baylor, 1971, and still earlier by Simon and Barenfield, 1969 for modeling chess perception and other cognitive tasks). It is possible that different representations (more closely resembling rasters of pixels) would be required to model some of the tasks used in Kosslyn's (1980) experimental work. In this work Kosslyn found that the ability to form visual images, necessitated activating stored visual information and using it to create a pattern in a spatial short-term memory structure and this was called 'image generation'.

Blindness and Spatial Ability

When blind people are presented with a spatial problem, it is crucial for the teacher or instructor to know at which point their visual deprivation occurred (Thinus-Blanc, 1997).

She reported that some studies of the incidence of early visual experience on spatial abilities have shown profound spatial deficits in early blind participants. In contrast others have not found evidence of harmful effects of early visual deprivation. In late blind individuals spatial abilities are often unaffected, because they have had the experience of visual feedback information generated by locomotion and this sensitivity would endure even when visual information is eliminated.

According to Thinus-Blanc, visual cues are present during early infancy and appear to affect one's later choice of spatial strategies which induce spatial processing resulting in route or map construction (i.e., overall representation). 'Routes' and 'maps' differ inasmuch as the former are organised on the basis of the body referent for example, following a route or locating an object with respect to one's body. Route representations are not inclined to reorganisation because spatial judgements such as inference would be necessary. In contrast, 'maps' refer to the encoding of direction and distance relationships between places, regardless of the individual's position of approach. Their construction depends on the perception of distal clues. Thinus-Blanc maintained the complete absence of sight drastically reduced the amount of available distal information. Thinus-Blanc suggested that early blind individuals tended to use spatial information organised as routes and in contrast late blind continued to organise nonvisual landmarks as visual ones in a maplike form.

Diagrammatic Reasoning and Representation

Corresponding to the inference rules in a system of logic are the productions in a heuristic search system using diagrams. Whenever the cues are present in the diagram that match their conditions productions are evoked. A pulley system, for instance when presenting itself satisfying the conditions of the production or an external (drawing parts, expressing the given as symbols), or mental diagram of one, Simon. et al. (1992) said, one will notice it and notice that the conditions are satisfied. The corresponding actions will be evoked from one's memory, and one will take the action, in this case reach a conclusion about the unknown weight.

Diagrammatic representation and reasoning have close ties with fields like computer processing. Kulpa (1997) stated that diagrammatic representation uses diagrams to represent data and knowledge and diagrammatic reasoning uses direct manipulation and inspection of a diagram as a primary means of inference. Diagrams are a visual kind of analogical (or direct) knowledge representation mechanism characterised by a parallel (though not necessarily isomorphic) correspondence between the structure of the representation and structure of the represented.

According to Kulpa the problem of finding appropriate representations of various types of knowledge has been a subject of continued research in artificial intelligence and related fields since the beginning of these disciplines. Much of the progress in science involved finding new representations of various phenomena or formal constructs: from the diagrams of Euclid, to the calculus notation of Newton and Leibnitz, to Feynman's quantum particle diagrams and others. An appropriate way of representing knowledge about some phenomena, problem or from a system allows for the effective description of the domain knowledge and facilitates reasoning and problem solving in the domain.

MATHEMATICAL WORD PROBLEMS

Introduction to Mathematical Word Problems and External Representations

The literature on mathematical problem solving and subjects' use of self-generated 'external representations' is small. Van Essen and Hamaker (1990) offered an informative study on drawings produced by children in the solving of mathematical word problems. In contrast the literature on subjects being instructed to chose or being given an external representation to assist them in mathematical word problem solving is more extensive. The following section of this thesis discusses external representations as they relate to mathematical word problems.

Many experiments have been done using mathematical word problems with you subjects ranging from children with learning difficulties to university students. A past experience in a mathematics class where an individual was unable to proceed, might not be an uncommon event for most adults to recollect. According to Kantowski (1980) problem solving in mathematics involves a situation for which the individual confronting it has no readily accessible algorithm that will guarantee a solution. Akers (Pelton, 1998) defined it as what you do when you don't know what to do, while Schoenfield (1985) said figuring it out is what problem solving in mathematics is all about. (Pelton, 1998).

According to Orton (1992) problem solving in mathematics problems is divorced both from the mainstream subject matter and real world. Such puzzles may contain great interest for some children but others may not see the point and be demotivated. These puzzles were also unlikely to produce knowledge or rules, which were useful or applicable elsewhere. A well-known feature of research into problem solving was that subjects have been presented with problems, which could be considered almost frivolous. This has advantages in a controlled experiment for it is most likely that all subjects start with the same knowledge of the situation hopefully nil. It has also produced interesting results but there are difficulties in that whatever is deduced about problem solving might not be transferable to a more orthodox sphere of human knowledge. Successful solution of problems depends on the learner not only having knowledge and skills but also being able to tap into them and establish a network or structure. Sometimes a flash of insight occurs and this involves realisation of some previously unacknowledged relationship within the knowledge structure and depends on the richest possible knowledge base from which to draw. It is also known that it helps to turn the problem over in the mind thoroughly to try out avenues of approach and bring to the forefront a whole range of techniques and methods, which might be appropriate. It's known that the solutions might still not come, but might come subsequently after a period of time away from the problem as if the subconscious mind, freed from the constraints of conscious attempts to solve the problem, continues to experiment with combinations of elements from the knowledge base.

The Good Problem Solver

A comprehensive definition of what a mathematical word problem is might be beneficial to teach to children to try and dispel fears that they may have of mathematics. It was pointed out by Whimbley and Lochhead (1986) that in solving mathematical word problems, anxiety and despair may be expressed by students when dealing with these sorts of problems, coming from unfortunate experiences in early math training. Mathematical word problems involve a description of a situation with numerical relationships. The situation and relationships must first be interpreted and grasped. Then simple arithmetic computations need to be performed to get the answer. They are not really very different from nonmathematical problems. The computations are simple and the use of algebra or formulas is not required. Basically, one understands and spells out precisely the situation that is being described. Once a problem has been set up properly, the arithmetic is easy. One of the primary things to learn, according to Whimbley and Lochhead is making a habit of thinking thoroughly and precisely, and one can master mathematics.

Whimbley and Lochhead (1991) in looking at problem solutions agreed that good problem solvers were using thoughts and logic and reading aloud. They were concerned with accuracy, step-by-step analysis and subvocal speech. According to Baddeley (1986) subvocal speech (talking, which is not done aloud) is part of the phonological loop and it is in turn a component of working memory. Good problem solvers were also careful, showing concern and quick retracking when ideas became confusing; constantly rechecking, reviewing and rereading to be sure that errors had not crept in, and observe that nothing has been overlooked.

According to Whimbley and Lochhead good problem solvers could follow ‘a step-by-step approach’ in which ideas are restated in one’s own words, in a form, which is clearer or more useful. For example, if an individual read ‘Sally loaned £7.00 to Betty’ and changed this statement to ‘That means Betty has to return money to Sally’ it would show that the problem solver went through two steps in representing the information to be used in a diagram. The first step involved translating the original statement to one, closer to the form needed for his diagram. The next step incorporated the new statement into his diagram. The new statement enabled him more easily to see that on a diagram he had to draw an arrow pointing toward Sally. Whimbley and Lochhead maintained restating ideas was an important way in which good problem solvers use the step-by-step method to analyse the fine details of a problem.

Greeno and Riley (1987) also asserted that the way problems are worded can aid or hinder mental representation. The problem, 'There are seven marbles and four children.' 'How many more marbles than children are there?' poses more representational difficulties for students than 'If each child takes a marble, how many marbles will be left?'. The second version encompasses a strategy for solving the problem matching elements of each set and counting the leftovers. The first version lacks any suggestion of how to solve the problem. While most students possess knowledge of the strategy suggested by the second phrasing, many don't have the facility in representation to select it without the difficulty some individuals have in solving word problems, namely, the inability to describe the question being asked rather than lacking knowledge of mathematical concepts necessary to complete the problem. In order to choose an appropriate problem solving procedure an individual is required to make a translation from a verbal or verbal/pictorial representation. There is evidence that this translation is a major source of difficulty and major developmental changes enable older children to perform successfully through acquisition of procedures of understanding that construct representations of problem situations being given additional linguistic cues. Given only the first way of phrasing the question, they can't identify comparison as the relevant operation and matching as a useful strategy. Whimbley and Lochhead agreed that 'restating ideas' and 'talking to themselves' while thinking is not something good problem solvers do only when they are asked to work a problem aloud. Studies using electronic amplifying equipment (to monitor speech muscle activity) showed that good problem solvers talk to themselves while they solve problems. They repeat information, rephrase it, weigh it, compare different facts, express thoughts like 'I better read the first sentence again,' and in general, clarify ideas for themselves. This talking, which is not done aloud, known as covert or subvocal speech gives good problem solvers an advantage over poor problem solvers. It keeps thoughts active in their working memory. The authors advised individuals to use the following steps in becoming good mathematical problem solvers:

1. "Try to do all thinking aloud. Read aloud and vocalise (think-aloud) all of your thoughts, decisions, analyses and conclusions. Vocalise how you are starting the problem, questions you are asking yourself, steps you are taking in breaking the problem into parts, conclusions you are drawing—everything. If you have to add some numbers, add them aloud. If you perform any other mental operations (such as translating an

unfamiliar word to a familiar word, or visualising a picture of a relationship described in the text), perform these operations aloud. If you occasionally want to reread and think about something silently, explain your thoughts to your partner as soon as possible."

2. "Adopt the step-by-step analytical procedure and the various other techniques that good problem solvers use. Break a problem into parts. Work one part accurately and then move on to the next part. Translate unfamiliar or unclear phrases into your own words. Visualise or make diagrams of relationships." (Whimbley and Lochhead, 1991, p250)

These steps explain how problem solving involves much more than processes for solving equations. The authors maintained that problem solving was primarily a way of thinking, of analysing a situation, of using reasoning skills not learned through the memorisation of specific facts, but by immersing one-self in the problem-solving process and applying both past experience and knowledge to the problem at hand. What is most overlooked by students is the thinking that one goes through to arrive at a solution. The authors stated it is o.k. to struggle with a problem and problem solving is not necessarily easy. They believed we are often left with the impression that problems can all be solved easily in a short time and if the immediate solution is not seen one becomes frustrated and gives up.

Self-generated Drawings and Mathematical Word Problems

Van Essen and Hamaker (1990) investigated whether encouraging elementary students to generate drawings of arithmetic word problems facilitates problem-solving performance. Accordingly, interventions consisted of 60 to 90 minutes of practice and showed the utility of self-generated drawings for solving word problems. The subjects in the first study were first and second graders and in the second study, fifth graders. The results showed that fifth graders improved in problem solutions after the intervention, whereas the first and second graders did not. The fifth graders generated lots of drawings of word problems whereas the first and second graders did not. Elementary school children find arithmetic word problems difficult to solve. They are caused by a lack of logico-mathematical or linguistic knowledge (Dellarosa, Kintsch, Reuser, & Weiner, 1988 cited in Van Essen and Hamaker, 1990) but problem solutions often are hindered because of a lack of general problem-solving strategies. General problem-solving strategies, are described by the authors as strategies for planning and regulating the solution process, but also include general heuristic strategies for problem analysis and exploration. Relevant knowledge is likely to remain untapped when pupils don't have or use such strategies.

There is insufficient data available on why first and second graders do not making drawings of word problems. In a study, Hamaker and Van Essen (1989) found that having six-year olds generate drawings of simple word problems before solving them did not improve problem solutions. Knowledge and experience of the usefulness of a problem-solving strategy like making drawings is an essential condition if a pupil is expected to apply the strategy in a situation in which the solution process is not algorithmic. Against the (uncertain) benefits of the strategy, there are the efforts of applying an unknown and unpracticed strategy (Frijda and Elshout, 1975). Making drawings of simple addition and subtraction word problems doesn't seem to make problem solving easier for young children, and this condition was realised in the first study. Younger children often misinterpret simple word problems because of the condensed and ambiguous nature of the problem statement (DeCorte, Verschaffel and DeWin, 1985). The children in this study did not perceive that in making a drawing their difficulties in solving the problems they were set would be overcome.

In contrast, the fifth graders mainly used a correct representation to represent the problems. The decision to make a drawing, Vanhamaker and Essen think depends primarily on the assessment that doing so will make the solution easier to find. The perceived benefits might be that a drawing lessens the load on working memory, presents a concrete model on which to act, eases the search for related information, or makes problem characteristics more explicit. Those benefits don't apply (or occur) to young children trying to solve simple word problems. For ten-year olds, the advantages of making drawings of the kind of problems they were presented with were much more apparent. How these benefits are perceived, depends on the problem. The utility of a drawing is also more readily perceived because many of the concepts in complex word problems have been taught with the help of drawings (e.g. area, volume, and fractions). This cues the making of a drawing in the solution process, especially when nonroutine problems are concerned. In all those cases, however, the decision to make a drawing depends on the benefits perceived by the pupil. Van Hamaker and Essen sometimes observed that pupils decided not to make a drawing because they had immediate access to a solution procedure, even though this procedure was incorrect (and could be corrected when a drawing was made).

Strategy Use of Good Mathematical Word Problem Solvers

Several authors have suggested making a drawing to analyse and explore a problem more carefully (Polya, 1957; Schoenfeld, 1985). Good problem solvers apply this strategy more often than poor problem solvers (Proudfit, 1981), overall, elementary students do not often spontaneously visualise arithmetic word problems. Cohen and Stover (1981) found that few sixth graders have knowledge of the facilitating effect of the pictorial format of a word problem. Generating a drawing of an arithmetic word problem may help with the construction of a correct representation in several ways. First, a drawing lessens the load on working memory because an external memory is created. Second, by creating a drawing, the student makes the problem more concrete. Many studies according to Riley et al., (1983) have established that the availability of concrete material such as blocks facilitates problem solving for young children. The construction of a drawing can be thought of as an intermediate step between a mental representation and a physical representation. Third, the information in a problem can be reorganised more efficiently in a drawing. Larkin and Simon (1987) maintained that problem solvers could often look for related information more efficiently in a drawing than in a problem text. Some problem traits are more easily inferred from a drawing because they become more explicit (Fridja and Elshout, 1975). For example, translating a geometry problem into a drawing often makes visual various aspects (e.g. angles) not explicitly referred to in the problem's text. In working out word problems a self-generated drawing acts as both a tool for analysing and for working them out. The drawing is a strategy for analysing a problem because translation of a verbal format into a pictorial format makes a student look at the givens and semantics of the problem. This activity stimulates problem analysis and is a method for working out a problem, because the correct representation of the quantitative relationship(s) in a drawing often solves the problem. For instance, if the relationships in the problem 'John is six centimeters longer than Pete. John is two centimeters shorter than Tom. How many centimeters is Tom longer than Pete?' are visualised correctly, the problem is almost completely worked out and solved (Van Hamaker and Essen, 1990).

Van Hamaker and Essen pointed out several researchers have studied the effects of having elementary students translate verbal presentations of arithmetic problems into prescribed pictorial formats. Two different methods were taught to the children. They were taught to either fit the structure of addition and subtraction problems into a general part-whole diagram (Wolters, 1983) or to generate schematic drawings that were adapted to the semantic structure of the problems (DeCorte and Verschaffel, 1985). They were taught, for example, to represent change problems by a dynamic arrow diagram and to fix combination problems in a static part-whole diagram. Though the research findings were not conclusive, pupils instructed to generate schematic diagrams reflecting the semantic structure of the problems tended to perform better after such an instruction. In the Wolters (1983) study, subjects improved only on problems that fitted the static part -whole relation (combination problems). Pupils were not taught to construct a prescribed diagram but instead were stimulated to construct a pictorial representation that was adapted to their own needs. Cohen and Stove (1981) and Yancey (1981) found that pupils instructed to visualise word problems in this manner outperformed pupils not receiving this instruction. Another positive finding by Zweng et al.(1979) showed pupils who could not solve a problem presented in a verbal format were encouraged to make a drawing of the problem. This hint frequently helped find the solution. All the studies discussed by Van Hamaker and Essen indicated self-generated drawings facilitated the solving of word problems but there have been less conclusive research results. Bell, Swan, and Taylor (1981) asked sixth graders to visualise word problems. Van Hamaker and Essen found in constructing an accurate drawing of a problem, pupils could also solve the problem without a self-generated drawing. In these cases making a drawing was a redundant activity. In contrast, pupils whose solutions reflected interpretational errors often constructed incorrect pictorial representations. For them, the construction of a drawing did not correct the interpretational error. Bell et al. found that only a modest number of the pupils in their study did gain from generating a drawing.

Representation and Transfer in Mathematical Word Problem Solving

Catrambone (1996) reported 'Transfer of Training' involved examining the transfer of success one has after studying training materials such as those containing step-by-step instructions (Kieras and Bovair, 1984). Usually the one finding is that an individual can carry out new procedures or solve new problems that are quite similar to those on which they were trained, but have difficulty when the novel cases involved more than minor changes from what they had previously studied.

The transfer difficulty seems to originate from a tendency by many learners to form representations of a solution procedure that consists of a linear series of steps rather than a more structured hierarchy. An advantage of a hierarchical organisation is that it can provide guidance for adapting the procedure for novel cases. One possibly useful hierarchical organisation for a solution procedure would be a set of goals and subgoals with methods for achieving them (e.g. Anzai and Simon, 1979). Students often learn a solution procedure as a series of steps with little or no higher level organisation (Reed et al., 1985). This results in, being able to solve a new problem that involves the same steps as a previously studied example, but having difficulty with problems that require a change in the steps, even though the conceptual structure from the example to the problem is preserved. The background of a learner plays a role in how likely he is to learn a subgoal, as Ausubel (1968) suggested that the value of 'organisers' hinged upon the learner possessing relevant background information so that the pieces of information being organised already have some meaning. For instance, if a student learning mechanics is told that one part of a solution procedure is to find out the components of force along the x and y axes, this organiser for the subsequent steps will be of little consequence if the learner knows little or nothing about coordinate systems or trigonometry. To assist a learner with a weak mathematics background, Catrambone (1996) maintained that providing meaningful labels might produce better subgoal learning because the extra domain information provided by a meaningful label could help the learner make sense of the steps and understand their purpose {even though the resulting subgoal might have ties to superficial features (Ross, 1989). In contrast, a learner with a stronger mathematics background might be expected to recognise the series of steps, when separated from the other steps in the overall solution procedure through the use of a label such as the one used for 'calculating the total'.

Catrambone pointed out it is intriguing to consider whether the inconsistency in the problem-solving literature concerning difficulties in procedural transfer may potentially be explained through a subgoal 'level' analysis.

Analogy

According to Novick (1990) previous research on transfer in problem solving has mainly been concerned with the transfer of a specific solution procedure from a source problem to an analogous target problem. The author considered whether transfer might also occur at a more general level of description, namely that responsible for specifying a common representation (e.g. a matrix) for two problems. Solving new problems by analogy to familiar problems will often be less difficult than trying to construct a new solution procedure on one's own. The results of an experiment showed convincingly that representational transfer could occur in the absence of a common solution procedure for the problems. Understanding is presumably the most vital component of problem solving (e.g. Greeno, 1977), and representations indicate how solvers understand problems. In summary, the difference between understanding and not understanding is in the nature of the representation and good understanding involves achievement of a coherent representation (Greeno). Clearly, good understanding is a prerequisite for solution (e.g. Cummins, et al.1988). Novick concluded that one cannot solve a problem one does not understand (except by chance).

Schwartz (1971), Schwartz and Fattaleh, (1972) and Polich and Schwartz, (1974) provided an intial investigation of the relation between problem representation and solution. They studied problems for which solvers had to match particular values on each of several dimensions by reasoning deductively from information provided in a set of clues. The problems differed in the number of dimensions involved, the number of values per dimension, whether the clues were stated affirmatively or negatively, and whether the clues involved conjunctions or disjunctions. In all three studies subjects who used a matrix representation were more likely to solve the problems (65% correct). Polich and Schwartz (1974) also looked at the frequency with which subjects failed to make allowable deductive inferences based on the relations presented explicitly. Matrix users were less likely to make these errors of omission than were subjects who used an informal grouping representation.

McGuiness (1986) in summarising much of the work on problem representations, concluded that (a) solvers often do not use the most efficient representation for a problem, (b) using the most efficient representation becomes increasingly important as problem complexity increases, and (c) efficient representations seem to have the special quality of structural integration (Mayer, 1976) or coherence (Greeno, 1977). A coherent (or structurally integrated) representation is one for which all of the important components of the problem are interconnected (i.e. no components remain detached from the rest of the representation) and for which there is a high level relational property or theme to hold the various components together {e.g. the components are not simply connected in a long chain (Greeno, 1977)}. Examples of such representations included rooted tree structures, some flow charts, and matrices. Novick suggests this new area of research on transfer in problem solving may have important implications for education, because problem representations are more flexible than solution procedures. It is not yet known whether the same factors that affect analogical (i.e. procedural) transfer also affect representational transfer. Future research will have to determine the relation between the processes involved in procedural and representational transfer.

Cognitive Strategy Instruction in Mathematical Word Problem Solving

Montague (1997) maintained that cognitive strategy instruction in mathematics provides a framework for understanding and using it to improve students' performance in mathematics. The author states that general problem-solving strategies such as association or mental imagery can be applied in many different situations, and they seem to be gained and applied better when grounded in specific content domains (Posgrow, 1992).

According to Montague strategy instruction for mathematical problem solving has shown generally positive results for upper elementary, middle school, secondary and postsecondary students as evidenced by several authors including Case, Harris, and Graham (1992); and Huntington (1994). Although these studies differ somewhat with respect to specific strategies taught and instructional routines used, they typically include techniques for teaching students to represent problems by drawing a picture, constructing a chart or table, or imagining the important characteristics of a problem. In support, Thinus -Blanc (1997) reported methods based on the study of strategies have been especially successful in arithmetic learning in children. Siegler and Crowley (1994) for example, demonstrated that children can use their conceptual understanding to accurately evaluate strategies that they do not only use yet but also are more conceptually advanced than the strategies they do use. A key factor enhancing strategy efficiency appears to be understanding goals and causal relationships. This notion could be applied to adults when teaching optimal strategies in processing spatial information and needs further investigation.

According to Wong (1992), students who lacked problem-solving strategies generally need explicit instruction in specific cognitive strategies (e.g. visualisation, verbal rehearsal, paraphrasing, summarising, estimating) to facilitate their reading, understanding, executing, and evaluating of problems. In contrast, students who have a repertoire of problem-solving strategies but use them inefficiently or ineffectively may need metacognitive strategies (e.g. self-instruction, self-monitoring, self-evaluation) to help them activate, select and monitor strategy use (Graham and Harris, 1994). The content and duration of instruction vary, depending on its purpose. On the basis of intervention research in this area, several instructional principles, including cognitive modeling, verbal rehearsal, guided practice, corrective and positive feedback, and mastery learning, seems essential for strategy acquisition and application.

Students had considerable difficulty in transforming linguistic and numerical information in word problems into suitable mathematical equations and operations, and, this resulted in them resorting to ineffective trial- and-error solution strategies and frequently performing a series of irrelevant computations, Montague (1997). The most important differences in strategic behavior were associated with problem-representation strategies (Montague and Applegate, 1993a). When taught specific strategies for representing problems, such as paraphrasing or visualising problems, their mathematical problem solving improved (Montague, Applegate, and Marquard, 1993).

Cognitive Strategy Instruction for Children with Mild Disabilities in Mathematical Word Problem Solving

In the literature concerning mathematical word problems in the 1980s and 1990s many educators and researchers focused on the issue of problem-solving. Problem-solving included word problems of varying structures, loosely structured problems, and problems involving many different steps and many different solutions.

Mathematical word problems according to Parmar et al (1996) were described as 'those items in which words and their structures create problems'. To truly solve a mathematical word problem, the individual must analyse and interpret information as the basis for making selections and decisions. Carpenter et al. (1980) posited that problem-solving involves thinking and analysis by students, not just looking for cue words, such as 'left' for subtraction or 'times' for multiplication and that problems may involve more than one step to solution. Similarly, Baroody (1987) proposed that problem-solving activities should include the following kinds of problems: -

. Problems that require analysis of the unknown.
. Problems that provide too much, too little, or incorrect data.
. Problems that can be solved in more than one way.
. Multistep problems.
. Problems with more than one correct answer.
. Problems that require an extended effort. (Parmar et al.1996, p416)

Parmar et al. maintained that in the area of special education students with disabilities continually perform poorly on problems of varying structures and that this failure is evident across students of differing cognitive abilities. The reason for low performance has been attributed to difficulties with 'problem representation' or the inability to identify the relevant information set (e.g. Cawley and Goodman, 1969, Parmar, 1992), in addition to problems with concentration and persistence, reading difficulties, poor computation skills, and an inability to identify the correct operation (Parmar, 1992).

The authors suggested giving students with disabilities instructions to help them become better problem-solvers and move beyond rote application of basic skills. They maintained that one strategy was to give disabled students experience with a variety of word problems that stimulate analytic thinking and that enhance cognitive abilities. They also thought students with special needs required a revised curriculum and instruction to improve their mathematical success.

INDIVIDUAL DIFFERENCE VARIABLES AND PROBLEM SOLVING

Introduction

The literature concerning the differences in how self-generated external representations are used in problem solving solutions is not extensive. Some work has been done using everyday problems (Van Sommers, 1984), mathematical word problems (Van Essen and Hamaker 1990), and analytic reasoning problems (Cox and Brna, 1995). The first two studies found that there were gender and age differences. Other individual differences such as cognitive style and its influence on self-generated external representations have not been investigated. However, Cox and Brna (1995) pointed out there is strong evidence that the 'visualiser-verbaliser' (VV) dimension of cognitive style has a profound effect on reasoning with ERs. Several studies found that subjects who differed along the VV cognitive style dimension used different strategies in the performance of tasks such a syllogistic reasoning, sentence-picture verification and hypertext navigation (Matsuno, 1987; Riding and Douglas, 1993; and Cox, Stenning and Oberlander, 1994). To achieve a better understanding of the external representations used in the solution to problems it was important to first examine the different abilities needed to solve problems. The following section is divided into spatial ability, mathematical ability and cognitive ability in problem solving tasks.

Gender Differences in Solving Spatial Problems

Benyon and Murray (1991) maintained that 'spatial ability' is a cognitive characteristic, which offers a measure of a user's ability to conceptualise the spatial relationships between objects. Regarding sex differences in spatial ability, males are superior to females (Harris, 1978; McGlone, 1980). Annett (1992) maintained that spatial ability varies not with left-or-right handedness, but with the absence or presence of the rs+ gene. The right shift (RS) theory of handedness (Annett, 1972) led to a genetic model (Annett, 1978, 1985) which suggested that there is a gene (rs+) which gives some advantage to the left hemisphere, probably by handicapping the right hemisphere at some critical stage of development (Kilshaw and Annett, 1983). In two tests of spatial ability, 'Mental Paper Folding' and recall of the 'Rey Figure', with 14 -15 year olds and undergraduate, respectively significant relationships between ability and hand preferences were classified in subgroups of left and right- handers (Annett, 1970a). In 14 - 15 year olds and in female undergraduates there was a W-shaped relation between hand preference and spatial ability. The highest scores were in the centre for right-handers with strong sinstral tendencies. Male undergraduates showed a linear trend, with spatial ability highest in strong left-handers and declining from left to right across levels of hand preference. Annett (1992) reported there are costs as well as benefits associated with the typical human biases to the left cerebral hemisphere for speech and to right-handedness.

Again in discussing spatial ability, according to Halpern (1986) males outperform females in disembedding tasks and mental rotation tasks. Differences are maintained whether patterns are simple or complex (Bryden and George, 1990). The male advantage in mental rotation appears at ten years of age (Johnson and Meade 1987). Females approach mental rotation tasks differently from males and they appear to make more rotational hand movements while completing cognitive rotations. Females need concrete aids or verbal strategies to complete the mental rotation task successfully (McGlone 1981). Witkin (1962) established that women are more field dependent and men more field independent resulting in women being more influenced in their problem solving than men by the structure of the total situation.

Masters (1998) reported further, there is no evidence that women's performance suffers differentially when a short time limit is used in investigations of the gender difference on the Mental Rotation Test (MRT), nor is there evidence that the scoring procedure is responsible for the gender difference on the test. The male advantage in performance found in the experiment is consistent with the results of previous investigations of the gender difference on the MRT. As a large gender difference is consistently found on the MRT and that manipulating the time limit and the scoring procedure does not eliminate this difference, Masters believed the hypothesis that performance factors accounting for the gender differences on the test was not to be upheld.

Gender Differences in Mathematical Problem Solving

Bracey (1994) maintained that there might be differences in how boys and girls approach mathematical problems, which may explain why girls get lower scores. On the SCAT (School and College Ability Test) with 50 pairs of quantities to compare, students must choose whether one is larger than the other, whether the two are equal, or whether there is insufficient information presented in order to tell. Boys scored higher than girls did overall at all ages. Boys were more likely to notice when there was insufficient information present to determine an answer, and they were slightly less likely to say that there was not enough information present when, in fact, there was. The authors caution against drawing broad generalisations from their findings: gender differences have generally been more pronounced in studies of select populations than in studies of the whole range of achievement.

Women also tend to score less well on the quantitative SAT (Scholastic Aptitude Test) than men. Linn and Hyde (1989) attributed this to strategic (women being less willing than men to guess and use partial knowledge when answering questions) rather than cognitive differences between males and females. They claimed that gender differences in mathematics should be de-emphasised (being small). Whatever small differences do exist depended on context; and the role of education should be to expose male and female students equally to different contexts.

Low and Over (1994, cited Bracey, 1996) in examining the differences in the way girls and boys solve mathematical word problems proposed that boys use a top-down strategy in which they identify the category to which a problem belongs and then try to find a solution, while girls used a bottom-up strategy in which they try to collect all the information into a pattern. Accordingly, it is possible that the differences originate in a different belief system rather than in a different strategy. Girls might 'trust' the researchers and their environments in general more than boys might. School problems usually consist of only necessary and sufficient information. Girls might tend to assume, more so than boys, that the information presented must be needed.

Gender Differences in the use of Diagrams and Plans in Solving Mathematical Word Problems

Zambo and Hess (1996) maintained that 'drawing a diagram or model' depending on the textbook series used were interchangeable. In a study using routine word problems requiring two steps to solve them, the authors stated the diagrams used were scored two, one, or zero. A (two), for a diagram that completely represented the problem, a (one) for a diagram that reflected some but not all of the problem, and (zero) for a diagram unrelated to the problem. Their research examined gender-related effects of an explicitly stated problem-solving plan for sixth graders. Females and males did equally well on both forms of the test. On the second occasion of testing that included the problem solving plan students scored significantly higher. They concluded that females benefited from free exploration of problem situations followed by an organised exploration, while males appeared to function equally well regardless of the problem-solving plan.

The authors also maintained, views and meta-analyses of research on gender-related differences in mathematics agree on two points. First, females tend to be superior in lower level, computational algorithmic activities; whereas males tend to be superior in arithmetic reasoning, application and problem solving. Second, the differences in problem solving ability increase with age of the subjects (Hyde and Fennema, 1990).

Although researchers agree that age is a factor associated with problem solving ability, studies disagree when males begin to outscore females on tests of problem solving ability.

Some researchers have found differences at the upper elementary level (Maccoby and Jacklin, 1974), while others suggest that differences are not apparent until high school (Linn and Hyde, 1989). The results of the 'Arithmetic Reasoning Subtest of the 'Armed Services Vocational Aptitude Battery' found that the ability to solve arithmetic word problems increased with age for both genders, and that the size of the gender-related difference in word problem solving ability increased with educational level. Another finding was that male superiority in word problem solving was not only present in general mathematics tasks, but also in algebraic tasks.

The majority of research investigating gender-related differences in problem solving ability has focused on the product of word problem solving. Concentrating on the process of problem solving, Zambo (1994) found that females were more capable than males of using a procedural problem solving plan composed of selected strategies. Zambo hypothesised that the difference favouring males on tests of problem solving ability could be mediated through the use of an explicitly stated problem solving plan. A unique accepted description of the problem solving process does not exist, and it is unlikely one will be discovered (Zambo, 1994).

According to Zambo as early as age nine, using strategies becomes apparent in the solution to mathematics word problems. Romberg and Collis (1985) interviewed third graders about their problem solving techniques. Strategies that the students incorporated into their problem solving included: producing a model of the problem (at this grade level the models were not diagrams but were accomplished by using fingers or counting chips), writing open sentences, and applying algorithms to compute. Researchers have found that some of the individual steps commonly found in step-by-step problem solving plans (e.g. diagramming by Van-Essen and Hamaker 1990) are effective in increasing students' problem solving test scores. Zambo pointed out however, research investigating the effectiveness of problem solving plans and the potential gender-differentiated effects of using those plans is limited. Some data suggests that the use of the step-by-step plans does represent an effective approach to problem solving (Zambo, 1992) and that a gender-related difference in favor of females exists with the use of those plans for solving routine two-step word problems (Zambo, 1994).

Gender and Heuristic Attitudes In Mathematics Problem-Solving

Hofmann (1996) investigated the link between heuristic attitudes and problem solving in mathematics problem solving. The subjects were given a questionnaire to establish their heuristic attitude. Gender differences were found and showed schoolboys had a higher heuristic attitude score than schoolgirls.

Age Differences and Problem Solving

Cognitive Skills

As people age physical changes take place in the brain and there is a common belief that mental abilities must be effected (Cerella, 1991). Laursen (1997) reported a study done on the impact of aging on cognitive functioning, observing the performance change vs. performance stability across four age cohorts of 30, 40, 50, and 60 between the first examination in 1982-1983 and the follow-up examination 11 years later. Results of a follow-up study where each subject was his own reference showed two main findings. One general tendency was a decline in performance for parameters of non-verbal learning and memory, retention of verbal material, pyschomotor speed and speed of the visuospatial processing, and concentration. The contrasting general tendency was a performance improvement in relation to verbal learning, visuomotor and visuospatial precision, and visual perception and vigilance.

Laursen pointed out that most of the test parameter means and medians did not change exceptionally during the 11 year follow-up period (e.g. the change of the error parameters of learning and memory tests and the tests of concentration was less than one score point). The noteworthy changes were the prolongation of processing speed in the visuomotor tests and the visuospatial test and the improvement of the precision in these tests. According to Laursen, the performance time prolongation observed among the oldest cohorts might show changes of practical importance for the individual.

In another study by Salthouse (1985) a tendency that cognitive skills decline in old age was found. According to Rabbit (1990) it is possible that cognitive deficits in the elderly are quite specific and not general. He maintained that there may be great individual differences in the rate at which memory declines, but the memory deficit exhibited may be determined by the specific context in which it is tested. For example, he stated that repeated testing leads to improvements in the elderly that may get rid of an age difference altogether.

Age and Imagery Tasks

Dror and Kosslyn (1994) reported young and elderly subjects performed four visual mental imagery tasks, each of which tapped different component processes. In this study the young subjects were aged 18-23 and the elderly subjects were aged 55-71. The elderly had relatively impaired image rotation and image activation (the process of accessing and activating stored visual memories) and there was a hint that aging impairs the ability to maintain images.

In contrast, the elderly were able to compose (the process of generating the segments of the shape, one by one) and scan visual mental images as well as young adults. These findings suggested that although there was a slowing with age, individual imagery processes were affected selectively by aging. Specifically, processes used to add segments to an image and those used to scan an imaged object do not decay as much over age as other processes, such as those used to activate stored representations during image generation and to rotate imaged objects. Dror and Kosslyn also found a possible hint that the elderly may have a deficit in maintaining images, indicated by a trend for errors in this area in their overall analysis. The authors questioned if aging does not have uniform effects on imagery, it is natural to ask whether similar performance differences occur during childhood. Some findings of Kosslyn et al.(1990) suggested that young children are relatively poor at scanning, rotating, and generating objects in images. Image maintenance was barely impaired, if at all, in the elderly in the age range that Dror and Kosslyn investigated and they do not have evidence that image scanning and generating individual segments of shapes are impaired with increasing age (at least up to the age they examined), so, for imagery abilities nevertheless, Dror and Kosslyn found the course of aging was not simply the inverse of the course of development.

Cognitive Styles and Solving Spatial and Mathematical Problems

Spatial Ability

Benyon et al. (1987) found that a user's short-term memory capacity may influence his or her ability to absorb data displayed on a computer. Garceau et al. (1988) found that subjects with a logical cognitive style were able to locate a particular item with a tabular representation of data easier than with a graphical representation. From the performance of the high and low spatial ability groups on the five interfaces in their experiment {Button interface-Macintosh Hypercard applications, Command interface-MS-DOS, Iconic interface-MacPaint and MacDraw, Menu interface -many Apple Macintosh applications, and Question interface-many commercial data entry systems} it was evident that any of the five interfaces would be suitable for the high spatial ability group who were mostly high on field independence as well, but that users with a low spatial ability who were mostly low on field independence should not use interfaces such as the button, question and command interfaces which contain a navigational component and also a flexible dialogue structure in the case of the command interface.

Mathematics

Chinn and Ashcroft (1998) used cognitive style in mathematics to refer to the way a person thinks through a problem. Allport (1937, quoted in Riding and Cheema, 1991) describes cognitive style as a person's habitual mode of problem solving, thinking, perceiving and remembering. Mathematically, its history can be dated back as far as Descartes (1638, cited in Krutetskii, 1976), who described two types of problem-solver. The first involves problems by a succession of logical deductions, whilst the second uses intuition and immediate perceptions of connections and relationships. Indeed, Polya (1962) who led the way in establishing a routine for problem solving identified four styles of problem solving in mathematics (groping, bright idea, algebra and generalisation). The first two described intuitive thinkers and the last two sequential thinkers.

According to Chinn and Ashcroft (1998) the 'Test of Cognitive Style in Mathematics' (Bath et al., 1986) distinguished between the step-by-step 'inchworm' and the intuitive, holistic 'grasshopper'. Chinn and Ashcroft described the cognitive styles of the inchworm and grasshopper in relation to problem solving. In analysing the problem inchworms focus on the parts and details and grasshoppers are holistic and tend to overview. In solving the problem the inchworm is formula and procedure oriented, works in serially ordered steps, prefers using paper and pen, and documents the method he uses. In contrast the grasshopper is answer oriented, works back from a trial answer and uses a multi-method rarely documents his method, and performs calculations mentally.

Mathematical word problems according to Whimbley and Lochhead (1991) involve a description of a situation with numerical relationships and are not very different from nonmathematical problem e.g. verbal reasoning problems. The authors advised in solving a mathematical word problem that the situation and relationships must first be interpreted and grasped. Then simple arithmetic computations need to be performed to get the answer. This author presented subjects with a 'mathematical word problem' in Experiment Six and examined the external representations used in the solution to the problem. An instrument to test cognitive styles in mathematics such as 'The Test of Cognitive Style in Mathematics (Bath et al., 1986), could be included in future experiments to see if students' mathematical cognitive style influenced their external representations in solving mathematical word problems.

CONCLUSION

In conclusion to Chapter Three, it was found that external representations have been used in different areas of learning: analogical reasoning (Beveridge and Parkins, 1987), algebra word problems (Singley, 1989), logical and analytical reasoning (Barwise and Etchemendy, 1995) and more generally, in scientific and mathematical discovery (Davis and Hersh, 1981).
However, they are also used by individuals in everyday life for example, in buying a new floor covering an annotated plan is drawn and taken to the carpet store (Cox and Brna, 1995).

In Chapter Two of this thesis four studies were conducted using three different sets of words. The result of these four studies was that being taught learning strategies and using booklets with written instructions to describe the strategies, for learning lists of words was not as effective in improving the recall of the words as was hoped. So for further experiments, it was decided not to continue using lists of words and teaching learning strategies to learn the lists. It was decided to look at another way in which the individual approaches a learning task and the use of external representations was chosen instead of taught learning strategies and using booklets with written instructions.

It was decided to look at problems and the use of external representations in solving them, instead of wordlists and teaching learning strategies and giving written instructions in how to learn them which was the focus of the first part of this thesis. This is because when learning a list of words, the act of writing them down is the way in which they are represented. In other words the subject in a list learning exercise can only rewrite the list, conveying to the teacher or instructor he has completed the task. Problems on the other hand, might provide a richer source of representations in solving them. Cox and Brna (1995) were concerned with the role of external representations in problem solving. They maintained the use of external representations was about the spontaneous construction of a variety of external representational forms in a self-communicative manner as subjects develop and examine their own ideas. They asked subjects to solve analytic reasoning problems in an experiment and told them to solve the problems and show their 'working out'. In this way their subjects were not given any assistance in their solutions to the problems except they were told that they may wish to draw a rough diagram in answering some of the questions. Cox and Brna reported that the analytical reasoning problems they used in their 1995 experiment could be classified according to difficulty by the number of dimensions they contained. Martinson (1993) pointed out analytic reasoning problems are solved using notational devices and diagramming techniques and it would seem that these problems lend themselves to representation as they are not one-dimensional. Cox and Brna found that their subjects used a range of external representations in their solutions to the analytic reasoning problems including plan diagrams, various tabular representations, and natural language. Cox and Brna also pointed out that the large variation in the type of external representations that subjects used might be due to individual differences in cognitive style. They cited several studies in which the "visualiser-verbaliser" (VV) dimension of cognitive style effected reasoning with ERs. They were in the areas of syllogistic reasoning, sentence-picture verification and hypertext navigation (Campagnoni and Ehrlich, 1989; Cox, Stenning and Oberlander, 1994; Frandsen and Holder, 1969; Macleod et al., 1978; Matsuno, 1987; Riding and Douglas, 1993 and Cox, Stenning and Oberlander, 1995). Riding and Douglas (1993) found Imagers used more diagrams in their answers to questions about the workings of a car braking system than subjects who were Verbalisers when the stimulus information was presented in the form of text and pictures. In a condition where the material was presented in the form of text only, there was no difference between the subject groups in the use of drawings.

A new experiment was developed in Chapter Four using Cox and Brna's three analytic reasoning problems. The Cognitive Styles Analysis (Riding, 1991) was also to be given to each student. The students in this experiment, known as Experiment Five would not be taught problem solving strategies nor given written instruction in how to solve problems so as not to influence them in any way. It was hoped that in analysing the 'working out' of the students or sometimes referred to as 'external representations' (ERs), these ERs might be able to be categorised and used by future students in helping them in problem solving.

CHAPTER FOUR

EXPERIMENT FIVE: EXTERNAL REPRESENTATIONS AND COGNITIVE STYLES IN THE SOLUTION OF ANALYTIC REASONING PROBLEMS

SUMMARY

According to Kulpa (1997) one of the types of knowledge representations, used by people since unknown times, but only recently becoming an object of focused research is the representation involving visual, graphical and pictorial means (diagrams) and known in this thesis as 'external representations'.

External representations refer to a wide variety of representations in both the linguistic and graphical modalities. Lohse et al. (1994) in their analysis of visual representations identified 11 basic categories: Graphs, tables, graphical tables, time charts, networks, structure diagrams, process diagrams maps, cartograms, icons and pictures. Cox and Brna (1995) did an experiment with a large number of Philosophy undergraduates using three analytic reasoning problems. They reported that their subjects were not taught learning strategies prior to solving the three analytic problems. They were instructed that in answering some of the questions related to each problem, that the drawing of a rough diagram might be useful.

The term ER (external representation) as discussed by Cox and Brna also included sentences of natural language, sentences of formal languages (e.g. first order language logic), tables, lists, graphs, maps, plans, and set diagrams. Cox and Brna concentrated on external representations in their experiment in 1995 and set out to find out if subjects use external representations in solving analytic reasoning problems. They found subjects used a range of external representations in their solutions to problems including plan diagrams, various tabular representations, and natural language.

The subjects in Experiment Five of this thesis were postgraduates in Education in a British University. They were presented with a booklet containing the same three analytical reasoning problems used by Cox and Brna (1995) and a blank sheet was inserted between

each problem on which they were told to show their working and/or draw diagrams if they found this useful. They were not taught any learning strategies prior to doing the problems.

INTRODUCTION

The subjects in Experiment Five of this thesis were postgraduates in Education in a British University. They were presented with a booklet containing the same three analytical reasoning problems used by Cox and Brna (1995) and a blank sheet was inserted between each problem on which they were told to show their working and/or draw diagrams if they found this useful. They were not taught any learning strategies prior to doing the problems. The students ranged in age from 21 - 49.

AIM

The aim of the fifth experiment was to find out what external representations subjects use in answering analytic reasoning problems and if they vary according to Cognitive Style.

METHOD

Sample

The sample in the fifth experiment consisted of 70 postgraduate students aged 21 - 49 and there were 38 females and 32 males.

Materials

A booklet was presented to the students consisting of general instructions and three analytic reasoning problems. They were given the computer-presented CSA (Riding, 1991) determining their position on each of the cognitive style dimensions the Wholist - Analytic and Verbaliser - Imager (WA and VI).

Booklet 5 consists of instructions and three analytic reasoning problems with questions as follows:

Instructions

You will be given three problems to do one at a time. You may use the blank page facing each problem for your working or diagrams if you find that helpful. You have 30 minutes in total.

Problem 1 - Office Arrangements

An office manager must assign offices to six staff members. The available offices, numbered 1 - 6 consecutively, are arranged in a row, and are separated only by six-foot-high dividers. Therefore, voices, sounds and cigarette smoke readily pass from each office to those on either side.
Ms. Braun's work requires her to speak on the telephone frequently throughout the day.

Mr. White and Mr. Black often talk to one another in their work, and prefer to have adjacent offices.
Ms. Green, the senior employee, is entitled to Office 5, which has the largest window.
Mr. Parker needs silence in the office(s) adjacent to his own.
Mr. Allen, Mr. White, and Mr. Parker all smoke.
Ms. Green is allergic to tobacco smoke and must have non-smokers in the office(s) adjacent to her own.

Unless otherwise specified, all employees, maintain silence in their offices.

Questions:

1. The best location for Mr. White is in Office 1,2,3,4,5, or 6?
2. The best employee to occupy the offices furthest from Mr. Black would be Mr. Allen, Ms. Braun, Ms. Green, Mr. Parker, Mr. White?
3. The three employees who smoke should be placed in Offices 1,2, & 3; 1,2, & 4; 1,2 & 6; 2,3, & 4; 2,3 & 6?
4 Which of the following events, occurring one month after the assignment of offices, would be most likely to lead to a request for a change in office assignment by one or more employees?
   Ms. Braun's deciding that she needs silence in the office(s) adjacent to her own
   Mr. Black's contracting laryngitis
   Mr. Parker's giving up smoking
   Mr. Allen's taking over the duties formerly assigned to Ms. Braun
   Ms. Green's installing a noisy teletype machine in her office

Problem 2- Poetic Tastes

Professor Kittredge's literature seminar includes students with varied tastes in poetry.
All those in the seminar who enjoy the poetry of Browning also enjoy the poetry of Elliot.
Those who enjoy the poetry of Elliot despise the poetry of Coleridge.
Some of those who enjoy the poetry of Elliot also enjoy the poetry of Auden.
All those who enjoy the poetry of Colerdige also enjoy the poetry of Donne.
Some of those who enjoy the poetry of Donne also enjoy the poetry of Eliot.
Some of those who enjoy the poetry of Auden despise the poetry of Coleridge.
All those who enjoy the poetry of Donne also enjoy the poetry of Frost.

Questions:

1. Miss Garfield enjoys the poetry of Donne. Which of the following must be true?

   She may or may not enjoy the poetry of Coleridge.
   She does not enjoy the poetry of Browning.
   She enjoys the poetry of Auden.
   She does not enjoy the poetry of Elliot.
   She enjoys the poetry of Coleridge.

2. Mr Huxtable enjoys the poetry of Browning. He may also enjoy any of the following Poets, except:

   Auden Coleridge Donne
   Eliot Frost

3. Ms. Inaguchi enjoys the poetry of Coleridge. Which of the following must be false?

   She does not enjoy the poetry of Auden.
   She enjoys the poetry of Donne.
   She enjoys the poetry of Frost.
   She does not enjoy the poetry of Browning
   She may enjoy the poetry of Elliot.

4. Based on the information provided which of the following statements concerning the members of the seminar must be true?

All those who enjoy the poetry of Elliot also enjoy the poetry of Browning.
None of those who despise the poetry of Frost enjoy the poetry of Auden.
Some of those who enjoy the poetry of Auden despise the poetry of Coleridge.
None of those who enjoy the poetry of Browning despise the poetry of Donne.
Some of those who enjoy the poetry of Frost despise the poetry of Donne.

Problem 3 Prize Dogs

In this year's Kennel Show;

1. An Airedale, a boxer, a collie, and a Doberman win the top prizes in the show. Their owners are Mr Edwards, Mr Foster, Mr. Grossman, and Ms. Huntley, not necessarily in that order. Their dogs'names are Jack, Kelly, Lad and Max, not necessarily in that order.
2. Mr. Grossman's dog wins neither first nor second prize.
3. The collie wins first prize.
4. Max wins second prized.
5. The Airedale is Jack.
6. Mr. Foster's dog, the Doberman, wins fourth prize.
7. Ms. Huntley's dog is Kelly.

Questions:

1. First prize is won by: Mr.Edward's dog, Ms. Huntley's dog, Max, Jack, Lad?
2. Mr. Grossman's dog: is the collie, is the boxer, is the Airedale, wind 2nd prize, is Kelly?
3. Which statement correctly lists the dogs in descending order of their prizes?

  I. Kelly; the Airedale; Mr. Edwards' dog
  II. The boxer; Mr. Grossman's dog; Jack
  III. Mr. Edwards' dog; the Airdale; Lad

      I only?
      III only?
      II and III only?
      II only?
      I and III only?

Lad:

  is owned by Mr. Foster?
  is owned by Mr. Edwards?
  is the boxer?
  is the collie?
  wins third prize?

On the basis of statements 1,3,4,5 and 6 only, which of the following may be deduced?

  I. Max is the boxer.
  II. The doberman is Kelly or Lad.
  III. Jack wins third prize.

      I and II only?
      I and III only?
      II and III only?
      I, ll and lll only?

      Neither, l, ll nor lll?

Procedure

There were seventy subjects in the sample. The computer-presented Cognitive Styles Analysis (Riding, 1991) was given to each student before they did the three problems in the booklet. The 70 subjects were all given three analytical reasoning problems with the same written instruction. They were told to do each of the problems as well as given written instructions to do this. The subjects were allowed 30 minutes in total to complete the three problems.

Scoring Method used for Experiment Five and Experiment Six

The three analytic problems in Experiment Five were taken from Cox and Brna's experiment found in the article 'Supporting the Use of External Representations in Problem Solving: The Need for Flexible Learning Environments' (1995). Cox and Brna categorised their subjects's external representations according to the type of representation they used. For example, a subject might have used a 'vertical plan' in solving problem one. In this author's thesis representations used by the subjects in Experiment Five were first categorised according to Cox and Brna's categories. It was thought that the representations used by the subjects in Experiment Five could be assigned such categories as 'table' and 'plan'. It was decided to use 'Hiloglinear Analysis', to analyse the results of the experiment. It was found that in categorising the representations in this way there were not always enough cases in each category to justify using the Hiloglinear Analysis. Also, it became difficult to differentiate between very similar representations, for example in Problem Two of Experiment Five the categories 'directed graph' and 'letters and lines' were too much alike to differentiate them as were the representations 'wordline diagram', 'line diagram', 'words' and 'word diagram' used in Problem Three of Experiment Six. It was thought that collapsing the categories would result in losing the preciseness of each variable. The Hiloglinear Analysis did not produce many significant results and so it was then decided to change the statistics to analysis of variance and count the number of different types of representations used by the subjects. There had to be a new system of scoring invented to deal with the data (frequency changed to quantity).

In analysis of variance the target of the model is the individual score of a subject in the experiment. In Loglinear analysis, the target is the total frequency of observations in a cell. The ANOVA model can't predict the individual scores with perfect accuracy because the inevitable presence of error, errors of measurement, individual differences, and experimental error. In contrast it is possible by including all the terms in the Loglinear model, to predict the cell frequencies in a contingency table. A model that contains all the possible effect terms is a 'saturated model'. The purpose of Loglinear analyses is to see whether the cell frequencies may be adequately approximated by a model that contains fewer than the full set of possible treatment effects.

In employing analysis of variance it was decided to count every 'mark' the subject used in working out the answer to the three analytic problems in Experiment Five and each of the three problems was scored individually. Every mark that a subject made on the test paper (the printed booklet containing the three problems) and the blank sheet inserted between each printed page of the booklet including crossings out, was counted as (1) and the representation was called 'characters'. Every line drawn became known as the representation 'line' and was counted as '1'. Every idea which included all nouns and proper nouns became known as the representation 'idea' and was counted as '1'. In Experiment Six, problems were much less difficult than in Experiment Five and some different external representations evolved from that experiment. They became known as 'letters', 'picture', 'line', and 'idea'. 'Line' and 'idea' were representations used in both Experiment Five and Experiment Six. Only 'letters' and 'picture' were representations used in Experiment Six.

Scoring -

The problems were scored according to how many 'representations' were used in the working out of each problem. The categories of representations used were known as the following: 'characters', 'lines' and 'ideas'. For example, each line used scored '1' and if there were no lines used the score was '0'.

character = every word, abbreviation, or symbol
line = every line
idea = every idea

Rules -

1. in scoring 'characters' all symbols, answers and any crossings out are included and they are counted as 1, e.g. 1st=dog is scored 7 . All 'commas and full stops' are excluded.
2. 'ideas' includes all nouns and proper nouns and they are counted as 1, e.g. 'Mr. Parker' = 1.

RESULTS AND DISCUSSION

Characteristics of the Sample

On each cognitive style dimension the sample was divided on the basis of their style ratios, with almost equal numbers in each division. For the analyses, the Wholist-Analytic dimension was split into two divisions: Wholist 0.63 to 1.07 = 1 and Analytics 1.08 to 2.82 = 2 (mean = 1.20, median = 1.09, SD = 0.42). Similarly, the Verbal-Imagery dimension was split into two divisions: Verbalisers 0.69 to 1.04 = 1 and Imagers 1.05 to 1.40 = 2 (mean = 1.05, median = 1.06, SD = 0.15). The correlation between the two styles was -0.12 confirming the independence of the measures (see also Riding & Douglas, 1993; Riding & Mathias, 1991). Subjects were divided in terms of age into younger, 21 - 22 years and older, 23 - 49 years. The results were analysed in terms of how many 'characters', 'lines' and 'ideas' a subject used in their working out of analytic reasoning problems.

The Analysis

Analysis of variance of Wholist-Analytic cognitive style, Verbal-Imagery cognitive style, Sex and Age with repeated measures on three problems was performed on the data. There were three analyses done and each one focused on a different variable used in the solution to the same three analytic reasoning problems. Analysis One looked at the number of 'characters' (every word, abbreviation, or symbol) used, Analysis Two looked at the number of 'lines'(every line) used and Analysis Three looked at the number of 'ideas' used.

ANALYSIS ONE - NUMBER OF CHARACTERS

Findings

The means and standard deviations for Problem 1 Characters - Problem 3 Characters, Sex, Wholist-Analytic and Verbal-Imagery Cognitive Style are given in Table 5.1

Table 5.1

P1Chars	Mean	Std. Dev	N	P2Chars	Mean	Std. Dev.	N	P3Chars	Mean	Std. Dev	N
Younger				Younger				Younger			
Male				Male				Male			
Wh				Wh				Wh			
V	19.40	9.38	5	V	21.00	28.02	5	V	23.72	15.88	5
I	12.30	13.45	5	I	12.60	16.58	5	I	12.36	10.45	5
An				An				An			
V	18.50	20.51	2	V	5.75	7.43	2	V	29.10	5.23	2
I	21.08	4.69	3	I	2.67	3.79	3	I	50.47	24.91	3
Female				Female				Female			
Wh				Wh				Wh			
V	14.25	2.46	3	V	9.83	3.64	3	V	23.80	5.91	3
I	19.59	17.16	8	I	3.91	9.10	8	I	23.38	10.10	8
An				An				An			
V	10.34	9.15	8	V	11.78	17.78	8	V	16.95	14.90	8
I	25.11	16.69	9	I	33.19	27.93	9	I	32.29	10.81	9
Older				Older				Older			
Male				Male				Male			
Wh	18.50	15.62	4	Wh	18.94	24.17	4	Wh			
V	39.75	31.20	3	V	52.33	54.66	3	V	17.00	11.97	4
I				I				I	49.33	28.96	3
An				An				An			
V	21.21	20.49	7	V	16.93	18.77	7	V	21.20	14.17	7
I	23.67	16.91	3	I	23.17	20.08	3	I	25.20	21.88	3
Female				Female				Female			
Wh				Wh				Wh			
V	34.88	12.43	4	V	29.81	23.63	4	V	28.85	16.55	4
I	7.25		1	I	3.50	.00	1	I	5.00	.00	1
An				An				An			
V	2.50	2.12	2	V	5.00	7.07	2	V	19.60	10.75	2
I	10.58	4.48	3	I	19.08	2.65	3	I	59.93	53.64	3
For Entire Sample	19.48	15.80	70		17.89	22.80	70		26.49	19.75	70

Analysis of variance of sex (2), age (2), Wholist-Analytic and Verbal-Imagery Cognitive Style (2) with repeated measures on problem (3) and the number of characters used as the dependent variable was performed on the data. The summary is given in Table 5.2.

Table 5.2

Summary of Repeated Measures ANOVA for Sex, Age, Wholist-Analytic and Verbal-Imagery Cognitive Style by Problem and the number of Characters used as the dependent variable

Tests of Between-Subjects Effects.

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	54	569.58		
AGE	1	655.32	1.15	.288
SEX	1	735.32	1.29	.261
WA	1	1.07	.00	.966
VI	1	1092.25	1.92	.172
AGE BY SEX	1	615.01	1.08	.303
AGE BY WA	1	917.87	1.61	.210
AGE BY VI	1	104.47	.18	.670
SEX BY WA	1	427.22	.75	.390
SEX BY VI	1	224.61	.39	.533
WA BY VI	1	1817.01	3.19	.080
AGE BY SEX BY VI	1	262.29	.46	.500
AGE BY WA BY VI	1	1932.64	3.39	.071
AGE BY WA BY VI	1	77.14	.14	.714
SEX BY WA BY VI	1	3163.73	5.55	.022*
AGE BY SEX BY WA BY VI	1	2892.84	5.08	.028*

Tests involving ‘Problem’ Within - Subject Effect.

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	108	228.39		
PROBLEM	2	1601.12	7.01	.001*
AGE BY PROBLEM	2	179.27	.78	.459
SEX BY PROBLEM	2	48.98	.00	.807
WA BY PROBLEM	2	723.96	1.92	.046*
VI BY PROBLEM	2	185.52	1.08	.447
AGE BY SEX BY PROBLEM	2	432.02	1.61	.156
AGE BY WA BY PROBLEM	2	58.21	.18	.775
AGE BY VI BY PROBLEM	2	91.39	.75	.671
SEX BY WA BY PROBLEM	2	497.16	.39	.118
SEX BY VI BY PROBLEM	2	4.99	.02	.978
WA BY VI BY PROBLEM	2	128.54	.56	.571
AGE BY SEX BY WA BY PROBLEM	2	1124.54	4.92	.009*
AGE BY SEX BY VI BY PROBLEM	2	161.16	.71	.496
AGE BY WA BY VI BY PROBLEM	2	14.85	.06	.937
SEX BY WA BY VI BY PROBLEM	2	62.42	.27	.761
AGE BY SEX BY WA BY PROBLEM	2	235.62	1.03	.356

characters = any symbol

There were four significant effects, two between-subject effects and two within-subject effects. The significant between-subject effect which was an interaction of Age by Sex by WA by VI (F=5.08; d.f.=1,54; p= 0.028) was too complicated to analyse. The three other significant effects will be discussed in turn:

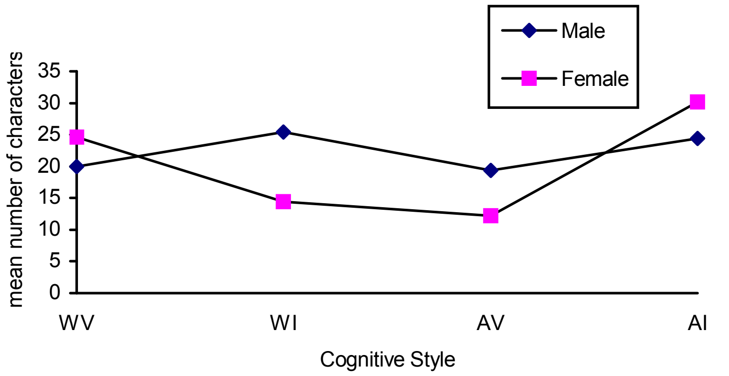
There was a significant between-subject interaction of Sex and WA and VI (F= 5.55; d.f. = 1,54; p = .022). The means of the groups is given in Table 5.3. The interaction is illustrated in Figure 5.1.

Table 5.3 Means number of Characters used by male and female Wholist-Analytic and Verbal-Imagery Cognitive Style

Variable	Mean	Std. Dev.	N
MWV	19.94	14.21	9
MWI	25.44	28.25	8
MAV	19.38	9.54	9
MAI	24.38	12.03	6
FWV	24.66	12.68	7
FWI	14.47	6.86	9
FAV	12.23	10.79	10
FAI	30.12	13.54	12

Figure 5.1 shows the mean number of Characters for males and females and Cognitive Style in which Female Wholist Verbalisers used more ‘characters’ than Male Wholist Verbalisers, Male Wholist Imagers used more ‘characters’ than Female Wholist Imagers, Male Analytic Verbalisers used more ‘characters’ than Female Analytic Verbalisers, and Male Analytic Imagers used less ‘characters’ than Female Analytic Imagers.

Figure 5.1 Mean number of Characters by Sex and Wholist-Analytic and Verbal-Imagery Cognitive Style



Analysis One - Characters by Sex by Wholist-Analytic Cognitive Style by Verbal-Imagery Cognitive Style

Male Wholist-Verbalisers and Female Wholist-Verbalisers

The data showed one significant between-subjects effect. This was an interaction of Sex by WA by VI. Female Wholist-Verbalisers used more 'characters' than Male Wholist-Verbalisers. Wholist-Verbalisers (males and females) might both prefer using a verbal form when presented with information. According to Maccoby (1966) girls say their first words sooner, articulate more clearly and at an earlier age use longer sentences than boys. It might be that the Female Wholist-Verbalisers used more characters than Male Wholist-Verbalisers in solving the problems in Experiment Five because of their superior verbal ability. Wholist Verbalisers also like having learning materials structured for them. In the case of the three analytic problems in Experiment Five the student would not have been given any assistance in restructuring the problems because the aim of Experiment Five was to find out what external representations subjects use in answering analytic reasoning problems, without any additional information given other than the written instruction 'it might be useful to draw a diagram'.

Male Wholist-Imagers and Female Wholist-Imagers

The Female Wholist-Imagers used less ‘characters’ than the Male Wholist-Imagers in Experiment Five. It might be that even though both male and Female Wholist-Imagers are field dependent and influenced by the structure of the total situation that females needed less ‘characters’ to solve the problems than Male Wholist-Imagers. It might be that female Wholist-Imagers generated less mental pictures than male Wholist-Imagers in solving the problems and would need less ‘characters’ to describe their solution to the problems.

Male Analytic-Verbalisers and Female Analytic-Verbalisers

Female Analytic-Verbalisers used less ‘characters’ than Male Analytic-Verbalisers in the solving of the three problems in Experiment Five. Analytic-Verbalisers use a structured approach to learning and like information presented in verbal forms. The Female Analytic-Verbalisers being superior in verbal ability (Maccoby, 1966) might have been able to use more concise language such as abbreviations in the solution to the three problems than the Male Analytic-Verbalisers.

Male Analytic-Imager and Female Analytic-Imager

The Female Analytic-Imagers used more ‘characters’ than Male Analytic-Imagers.. According to Zambo (1996) females benefit from examining problems first and then analysing them in the context of a problem solving plan. He also stated that females benefited from first exploring problems on their own and then seeing those problems combined with an organised format for analysis and solution. The Female Analytic-Imagers and Male Analytic-Imagers were not given any organised format in Problem One. Analytics impose their own structure on materials so this would have been redundant. The Female Analytic Imagers might have been superior in written mode. According to Douglas and Riding (1994) individuals of the same ability and similar on the Wholist-Analytic dimension, that the Verbalisers are superior in speech benefiting from involuntary verbal fluency, and relatively inferior in writing where the lack of verbal control due to spontaneous involuntary verbal associations may be a hindrance. By contrast, Imagers may be superior in written mode but inferior in the spoken mode. This possibility is still being investigated.

In contrast to Female Analytic-Imagers, Male Analytic Imagers used less characters in their solution to the problems. Bracey (1996) found that females and males were equally able to identify problems containing only necessary and sufficient information. Males were more able than females to detect irrelevant information in a problem. Low and Over (1994) pointed out that boys used a top down strategy in which they identify the category to which a problem belongs and then try to find a solution, while girls use a bottom-up strategy in which they collect all the information into a pattern. It was also pointed out in this study that the difference in males and females originates in a different belief system rather than in a different strategy. Girls might 'trust' their environments in general more than boys. When presented with 'school problems' containing only necessary and sufficient information, females might tend to assume more so than males that the information presented must be needed. The ability to detect irrelevant information in a problem (Bracey, 1996) might explain why Male Analytic-Imagers needed less characters than Female Analytic-Imagers in the solution to the three problems in Experiment Five.

There was a significant within-subject effect and this was a main effect of Problem (F=7.01; d.f.=2,108; p=.001). This showed that more 'characters' were used in some problems than in others. The means are shown in Table 5.4

Table 5.4 Mean Number of Characters used in Problem 1 - Problem 3

	Problem 1		Problem 2		Problem 3	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Characters	19.47	15.80	17.89	22.80	26.49	19.75

Analysis One - Main Effect of Problem

The most 'characters' were used in Problem Three and the least 'characters' were used in Problem Two. Problem Three had four dimensions (prize order, dog owner, dog name, and and breed) with four values along each. It used the most external representations in its solution and this might be because it had more dimensions than the other two problems. Problem Two was the most difficult problem, probably accounting for it using the least amount of external representations in its solution. Having a background in ‘set theory’ and/or ‘logic’ would have been helpful to enable a subject to use ERs in this problem. However, the subjects did not have this background.

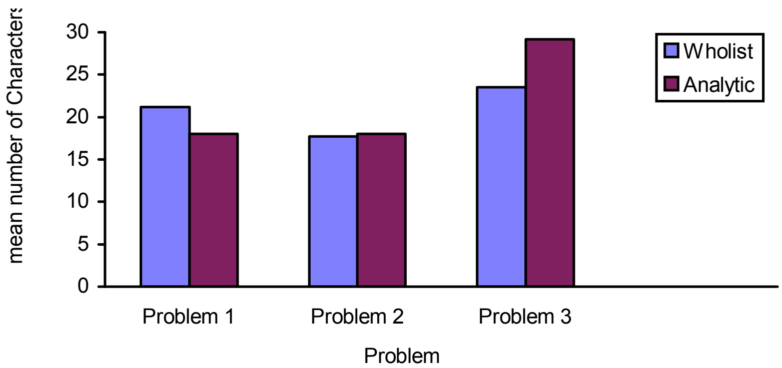
There was another significant within-subject interaction of Wholist-Analytic Cognitive Style and Problem (F= 1.92; d.f.= 2,1.08; p = .046). The means of the groups are given in Table 5.5. The interaction is illustrated in Figure 5.2.

Table 5.5 Mean Number of Characters used by Wholists and Analytics for Problems 1 - 3

	Problem 1		Problem 2		Problem 3	
	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev
Wholist	21.15	16.65	17.70	25.33	23.49	16.20
Analytic	17.98	15.07	18.05	20.65	29.16	22.33

Figure 5.2 shows the mean score for ‘characters’ and Cognitive Style in which Wholists used more ‘characters’ than Analytics in Problem One, Analytics used more characters than Wholists in Problem Two and Analytics used more ‘characters’ than Wholists in Problem Three.

Figure 5.2 Mean number of Characters against Wholist-Analytic Cognitive Style and Problem



Analysis One -Characters by Wholist-Analytic Cognitive Style by Problem

The significant interaction of WA by Problem showed that Wholists used more ‘characters’ in Problem One than Analytics. Wholists used more ‘characters’ than Analytics in Problem Two. Analytics used more ‘characters’ than Wholists in Problem Three.

Problem One was about the arrangement of offices and most subjects drew the offices as an array of boxes. It might be that Wholists used more ‘characters’ than Analytics in Problem One because they were trying to represent a more complete picture of an office. Analytics habitually divide information into its parts and since Problem One divides people into distinct offices Analytics would not need to use as much representation as Wholists to achieve the desired arrangement of people and offices.

Problem Two, according to Cox and Brna (1995) was distinctly divided into seven parts and the answer to the problem can be inferred from only two of the seven premises in the problem. In this problem Wholists used more ‘characters’ than Analytics and this might be because they could not easily see the seven different parts of the problem. The Analytics being able to analyse a situation in its parts might have been quicker to see that the answer to the problem could be deduced from only two of the seven premises.

In Problem Three Analytics used more ‘characters’ than Wholists. Problem Three lends itself naturally to external representations such as ‘tabular representations’ and ‘contingency tables’, which are complex and need to be divided into many parts. Analytics in their ability to analyse a situation into its parts might be more suited to this type of problem but might have used more characters to solve it because the problem itself had more dimensions than problem one and problem two.

ANALYSIS TWO - NUMBER OF LINES

Findings

The Means and standard deviations for P1Lines - P3Lines, Age, Sex, Wholist-Analytic and Verbal-Imagery Cognitive Style are give in Table 5.6.

Table 5.6

P1Lines	Mean	Std. Dev.	N	P2Lines	Mean	Std. Dev.	N	P3Lines	Mean	Std. Dev.	N
Younger				Younger				Younger			
Male				Male				Male			
Wh				Wh				Who			
V	3.30	3.05	5	V	.00	.00	5	V	.32	.46	5
I	4.30	4.11	5	I	.70	1.57	5	I	2.16	4.29	5
An				An				An			
V	3.50	1.77	2	V	1.13	1.59	2	V	.00	.00	2
I	5.67	.88	3	I	.00	.00	3	I	3.80	5.10	3
Female				Female				Female			
Wh				Wh				Wh			
V	4.17	1.01	3	V	.67	.76	3	V	.00	.00	3
I	3.00	2.11	8	I	.25	.71	8	I	1.50	2.63	8
An				An				An			
V	1.59	2.23	8	V	.22	.62	8	V	.98	2.68	8
I	3.56	2.34	9	I	1.61	2.17	9	I	1.89	2.40	9
Older				Older				Older			
Male				Male				Male			
Wh				Wh				Wh			
V	2.50	2.89	4	V	.00	.00	4	V	1.45	2.64	4
I	2.67	1.81	3	I	.92	1.59	3	I	.00	.00	3
An				An				An			
V	4.07	3.38	7	V	.79	.98	7	V	1.54	1.58	7
I	2.75	2.29	3	I	.58	1.01	3	I	4.67	6.74	3
Female				Female				Female			
Wh				Wh				Wh			
V	4.31	2.61	4	V	2.63	3.90	4	V	1.60	1.91	4
I	4.75	.00	1	I	.00	.00	1	I	.00	.00	1
An				An				An			
V	.00	.00	2	V	.00	.00	2	V	.20	.28	2
I	3.42	2.77	3	I	7.25	11.69	3	I	5.13	3.16	70
For Entire Sample	3.29	2.56	70		.98	2.81	70		1.62	3.16	70

Wh= Wholist V=Verbaliser
An= Analytic I=Imager

Analysis of variance of Sex (2), Age (2), Wholist-Analytic and Verbal-Imagery Cognitive Style (2) with repeated measures on Problem (3) and the number of Lines used as the dependent variable was performed on the data. The summary is given in Table 5.7.

Table 5.7

Summary of Repeated Measures ANOVA for Sex , Age, Wholist-Analytic and Verbal-Imagery Cognitive Style by Problem and the number of Lines used as the dependent variable

Tests of Between-Subjects Effects.

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	54	8.84		
AGE	1	3.15	.36	.553
SEX	1	.24	.03	.870
WA	1	11.37	1.29	.262
VI	1	43.12	4.88	.031*
AGE BY SEX	1	10.77	1.22	.275
AGE BY WA	1	2.37	.27	.607
AGE BY VI	1	.02	.00	.967
SEX BY WA	1	3.41	.39	.537
SEX BY VI	1	2.68	.30	.584
WA BY VI	1	47.95	5.42	.024*
AGE BY SEX BY WA	1	.08	.01	.925
AGE BY SEX BY VI	1	14.35	1.62	.208
AGE BY WA BY VI	1	16.21	1.83	.181
SEX BY WA BY VI	1	27.55	3.12	.083
AGE BY SEX BY WA BY VI	1	13.58	1.54	.221

Tests involving ‘Problem’ Within - Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	108	7.84		
PROBLEM	2	73.28	9.35	.000*
AGE BY PROBLEM	2	7.74	.99	.376
SEX BY PROBLEM	2	9.26	1.18	.311
WA BY PROBLEM	2	12.64	1.61	.204
VI BY PROBLEM	2	3.06	.39	.678
AGE BY SEX BY PROBLEM	2	1.55	.20	.821
AGE BY WA BY PROBLEM	2	4.76	.61	.547
AGE BY VI BY PROBLEM	2	3.33	.42	.655
SEX BY WA BY PROBLEM	2	12.21	1.56	.215
SEX BY VI BY PROBLEM	2	2.37	.30	.740
WA BY VI BY PROBLEM	2	2.22	.28	.754
AGE BY SEX BY WA BY PROBLEM	2	2.77	.35	.672
AGE BY SEX BY VI BY PROBLEM	2	1.17	.15	.832
AGE BY WA BY VI BY PROBLEM	2	9.60	1.22	.294
SEX BY WA BY VI BY PROBLEM	2	11.44	1.46	.238
AGE BY SEX BY WA BY VI BY PROBLEM	2	1.17	.15	.861

There were two significant between-subject effects, one was a significant main effect and the other was a significant interaction. There was also one significant within-subject effect, which was a main effect. These will be discussed in turn:

There was a significant between-subject main effect of Verbal-Imagery Cognitive Style ($F=4.88$; d.f. = 1,54; $p=.031$). The means and standard deviations for the number of 'lines' used by Verbalisers and Imagers is given in Table 5.8. The main effect is illustrated in Figure 5.3.

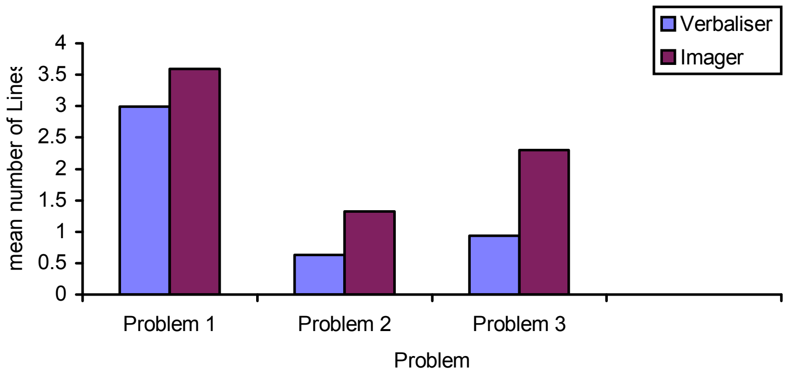
Table 5.8

Means and Standard Deviations of Lines used by Verbalisers and Imagers in Problem One - Problem Three

Variable		Mean	Std Dev	N
P1Lines				
	Verbaliser	2.99	2.69	35
	Imager	3.59	2.43	35
For Entire	Sample	3.29	2.56	70
P2Lines				
	Verbaliser	.63	1.53	35
	Imager	1.32	3.67	35
For Entire	Sample	.98	2.81	70
P3Lines				
	Verbaliser	.94	1.80	35
	Imager	2.30	4.00	35
For Entire	Sample	1.62	3.16	70

Figure 5.3 shows the mean number of 'lines' used by Verbalisers and Imagers in Problems One - Three in which Verbalisers used more 'lines' than Imagers in Problem One, Imagers used more 'lines' than Verbalisers in Problem Two and Imagers used more 'lines' than Verbalisers in Problem Three.

Figure 5.3 Mean number of Lines against Verbal-Imagery Cognitive Style and Problem



Analysis Two - Main Effect of Verbal-Imagery Cognitive Style

Imagers used more 'lines' in the three problems than Verbalisers. The results indicate that Imagers preferring to present information using 'lines' might have been performing in their habitual mode of choosing diagrams over words. This is because the lines used by some subjects divided the solution to the problems into diagrams that resembled boxes.

It is evident from the results of the workscratchings according to Cox and Brna (1995) that, for any given analytical reasoning problem, there is a large variation between subjects in the types and modalities of ERs that individual subjects use on different problems. One source of the variation is likely to be individual differences in cognitive style. Riding and Douglas (1993) found that subjects who were Imagers in terms of their cognitive style used more diagrams in their answers to questions about the workings of a car braking system than subjects who were Verbalisers when the stimulus information was presented in the form of text and pictures. In a condition where the material was presented in the form of text only, there was no difference between the subject groups in the use of drawings.

Zhang in his 1996 experiment used the game Tic-Tac-Toe to illustrate how external representations influence problem solving. In Tic-Tac-Toe the winning triplets are represented externally by three horizontal, three vertical, and two diagonal straight lines. To identify a winning triplet is to search for three circles lying on a straight line. The external representations (line, shape, and colour) were the directly perceivable information that strongly guided subjects' selections of moves in Zhang's experiment and 'line' was the easiest among the isomorphs to follow. In 'line' the three symmetry categories are represented externally by spatial symmetry: the center, four corners, and four sides. He gives the example that the four corners are spatially symmetrical to each other and consequently equivalent to each other and spatial symmetry can be directly perceived. In Experiment Five it might be that more 'lines' were chosen by Imagers than Verbalisers because they found them easier to visualise and draw than Verbalisers, as they habitually process information pictorially.

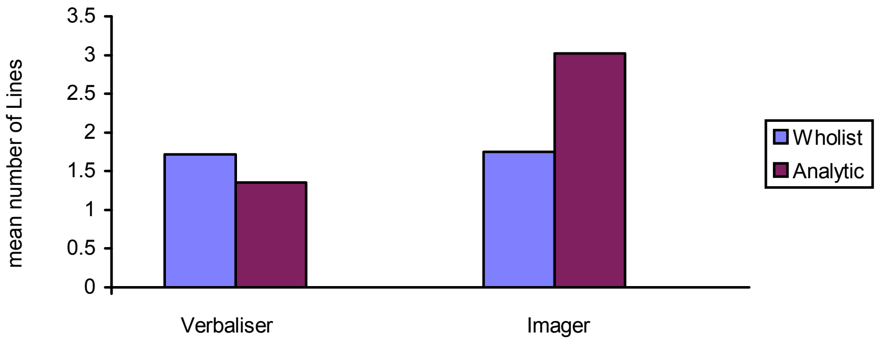
There was a significant between-subject interaction of WA by VI (F=47.95; d.f.= 1,54; p=.024). The means number of lines used by WA and VI Cognitive Style is given in Table 5.9. The interaction is illustrated in Figure 5.4.

Table 5.9 Mean number of Lines used by WA and VI Cognitive Style

	Mean	Std. Dev		Mean	Std.Dev.		Mean	Std. Dev.		Mean	Std. Dev.
WV	1.72	1.58	WI	1.75	1.69	AV	1.35	1.36	AI	3.02	2.20

Figure 5.4 shows the mean score for 'lines' used by Wholist-Analytic and Verbal-Imagery Cognitive Style in which Wholist-Verbalisers used more 'lines' than Analytic-Verbalisers and Analytic-Imagers used more 'lines' than Wholist-Imagers.

Figure 5.4 Means number of Lines against Wholist-Analytic Cognitive Style And Verbal-Imagery Cognitive Style



Analysis Two - Lines by Wholist-Analytic Cognitive Style by Verbal-Imagery Cognitive Style

Wholist-Verbalisers used more 'lines' than Analytic-Verbalisers. It might be that they needed more lines to structure the solutions of the three problems. In contrast, Analytic-Verbalisers readily analyse information into its structure.

Analytic-Imagers used more lines than Wholists-Imagers. It might be that Analytic-Imagers in imposing their own structure on materials and preferring to use diagrams rather than words, found lines easier to use than Wholist-Imagers in solving the three problems. Analytic-Imagers used the most lines in working out their answer to the three analytic reasoning problems. This is in accord with their ability to see things in parts and visualise things. It might be they were able to visualise the information associated with the problems by mentally drawing the lines and then drawing them on paper. In contrast the Analytic-Verbalisers used the least lines and this may be because they also see things in parts, but might have changed the pictorial information (lines) into text as they prefer to use words.

There was a significant within-subject main effect of Problem ($F= 9.35$; $d.f.= 2,108$; $p = .000$). This showed that more Lines were used in some problems than others. The means are shown in Table 5.10.

Table 5.10 Mean Number of Lines used in Problem 1 - Problem 3

	Problem 1		Problem 2		Problem 3	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Lines	3.29	2.56	.98	2.81	1.62	3.16

Analysis Two - Main Effect of Problem

The most lines were used in Problem One and the least lines were used in Problem Two. The least number of lines being used in Problem Two might be because the problem did not need representations such as ‘tables’(constructed with lines). Problem One using the most lines was an unusual result because it has less dimensions than Problem Three.

ANALYSIS THREE - NUMBER OF IDEAS

Findings

The means and standard deviations for P1Ideas - P3Ideas, Age, Sex, Wholist-Analytic and Verbal-Imagery Cognitive Style are given in Table 5.11

Table 5.11

P1Ideas	Mean	Std. Dev.	N	P2Ideas	Mean	Std. Dev.	N	P3Ideas	Mean	Std. Dev.	N
Younger				Younger				Younger			
Male				Male				Male			
Wh				Wh				Wh			
V	4.20	2.78	5	V	.60	1.34	5	V	2.92	3.07	5
I	2.40	2.34	5	I	.80	1.79	5	I	4.40	4.96	5
An				An				An			
V	3.25	2.48	2	V	1.13	1.59	2	V	4.80	.849	2
I	4.75	.90	3	I	.25	.43	3	I	5.47	5.16	3
Female				Female				Female			
Wh				Wh				Wh			
V	2.67	1.28	3	V	1.33	1.26	3	V	5.40	3.14	3
I	3.25	1.86	8	I	.25	.71	8	I	3.73	1.89	8
An				An				An			
V	2.88	2.73	8	V	.22	.62	8	V	3.03	2.82	8
I	5.22	4.50	9	I	1.56	1.72	9	I	4.87	2.84	9
Older				Older				Older			
Male				Male				Male			
Wh				Wh				Wh			
V	2.69	2.27	4	V	.88	1.75	4	V	3.20	2.36	4
I	7.33	3.75	3	I	.42	.72	3	I	7.93	4.44	3
An				An				An			
V	4.79	4.09	7	V	.79	.98	7	V	4.11	2.91	7
I	4.92	1.67	3	I	3.42	4.49	3	I	8.87	5.51	3
Female				Female				Female			
Wh				Wh				Wh			
V	4.19	.85	4	V	3.38	3.55	4	V	5.10	2.22	4
I	3.00	.00	1	I	.00	.00	1	I	.000	.000	1
An				An				An			
V	1.63	2.30	2	V	1.75	2.48	2	V	2.60	3.68	2
I	3.08	.14	3	I	2.75	3.31	3	I	8.20	5.57	70
For Entire Sample	3.87	2.86	70		1.11	1.89	70		4.55	3.46	70

Analysis of variance of Sex (2), Age (2) and Wholist-Analytic and Verbal-Imagery Cognitive Style (2) with repeated measures on Problems (3) and the number of Ideas used as the dependent variable was performed on the data.

The Summary for Repeated Measures ANOVA for Sex, Age, Wholist-Analytic and Verbal-Imagery Cognitive Style by Problem and the number of Ideas used as the dependent variable is given in Table 5.12.

Table 5.12

Tests of Between-Subjects Effects.

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	54	12.24		
AGE	1	16.11	1.32	.256
SEX	1	13.32	1.09	.302
WA	1	13.34	1.09	.301
VI	1	24.62	2.01	.162
AGE BY SEX	1	11.26	.92	.342
AGE BY WA	1	.73	.06	.808
AGE BY VI	1	6.99	.57	.453
SEX BY WA	1	.71	.06	.811
SEX BY VI	1	16.54	1.35	.250
WA BY VI	1	42.50	3.47	.068
AGE BY SEX BY WA	1	.63	.05	.822
AGE BY SEX BY VI	1	26.87	2.20	.144
AGE BY WA BY VI	1	3.41	.28	.600
SEX BY WA BY VI	1	42.47	3.47	.068
AGE BY SEX BY WA BY VI	1	10.84	.89	.351

Tests involving 'Problem' Within - Subject Effect.

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	108	5.42		
PROBLEM	2	161.18	29.74	.000*
AGE BY PROBLEM	2	.89	.16	.849
SEX BY PROBLEM	2	8.80	1.62	.202
WA BY PROBLEM	2	3.59	.66	.518
VI BY PROBLEM	2	8.46	1.56	.215
AGE BY SEX BY PROBLEM	2	5.62	1.04	.358
AGE BY WA BY PROBLEM	2	8.48	1.56	.214
AGE BY VI BY PROBLEM	2	2.89	.53	.588
SEX BY WA BY PROBLEM	2	.09	.02	.984
SEX BY VI BY PROBLEM	2	5.04	.93	.398
WA BY VI BY PROBLEM	2	5.17	.95	.388
AGE BY SEX BY WA BY PROBLEM	2	7.30	1.35	.265
AGE BY SEX BY VI BY PROBLEM	2	.26	.05	.953
AGE BY WA BY VI BY PROBLEM	2	13.06	2.41	.095
SEX BY WA BY VI BY PROBLEM	2	6.36	1.17	.313
AGE BY SEX BY WA BY PROBLEM	2	6.50	1.20	.305

There was one significant within-subject main effect of Problem ($F= 29.74$; d.f. = 2, 108; $p < 0.001$). This showed that more 'ideas' were used in some problems than others. The means are given in Table 5.13.

Table 5.13. Mean Number of Ideas used in Problem One - Problem Three

	Problem 1		Problem 2		Problem 3	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Ideas	3.87	2.86	1.11	1.89	4.55	3.46

Analysis Three - Main Effect of Problem

The most 'ideas' were used in Problem Three and the least 'ideas' were used in Problem Two. Problem Three had the most dimensions and values (four and four, respectively) and might have used the most ideas simply to restate the information in the problem. Problem Two using the least number of 'ideas' might be because the subjects did not have sufficient training in set theory and logic to understand the problem.

CONCLUSION

Summary and Comparison of the Findings in Experiment Five and the Cox and Brna (1995) Study

The same three analytic reasoning problems were used in Cox and Brna's (1995) Study and Experiment Five. The first and third problem were determinate (a single, unique model of the information given may be constructed). Problem One was easier than Problem Three because it had less dimensions and in Problem Three some of the information was presented negatively (e.g. 'Mr. Grossman's dog wins neither first nor second prize'). Problem Two was 'indeterminate' (reasoning with several quantifiers). Problem Two was the most difficult problem.

Subjects used a wide range of ERs in Cox and Brna's study. They also used a wide range of ERs in the British study. The subjects in Cox and Brna's study were American Philosophy undergraduates and would have had training in answering analytic reasoning problems in their course of study, and in the SAT (Scholastic Aptitude Test) taken prior to university entrance. The British subjects would not have had this training.

Subjects in the Cox and Brna's Study (1995) and in Experiment Five found Problem Two the most difficult to solve. In the former study subjects used the greatest number of different ERs in solving Problem Two but the total amount of representation used in solving it was less than the amount used in Problems' One and Three. In Experiment Five subjects used the least amount of different representations to solve Problem Two. In summary the amount of representation used in solving the three problems was 91% on problem one, 71% on problem two and 92% on problem three in the Cox and Brna Study and 87.1% on problem one, 52.9% on problem two and 81.4% on problem three in Experiment Five. The reason that the British subjects used the least amount of ERs in solving Problem Two might have been that they were not trained in Set Theory and Logic, as the problem necessitated that knowledge to solve it. The American subjects were trained in those disciplines. The reason that the American subjects used more ERs in solving Problem Three than Problem One might be because Problem Three contained more dimensions than Problem One. The

British subjects used more representations to solve Problem One than Problem Three and this needs further investigation.

Subjects sometimes used more than one ER in solving the three problems in the Cox and Brna Study. Cox and Brna pointed out that multiple ERs are effective and that no single ER is universally best for answering all questions associated with a problem. In the Cox and Brna Study subjects used wrong ERs successfully. Cox and Brna found that it is often better to use a partially incorrect ER than to abandon it completely. The data in the Cox and Brna Study also provided support for specificity theory as the results for Problem Two showed set diagrams and logic were the most effective for that problem. These two ERs are both capable of expressing the indeterminacy expressed by that problem's quantifier information. In the British study Problem Two produced the least amount of ERs. In the British study the ERs used were not classified in the same way as those in the Cox and Brna study and so it was not possible to discuss the use of multiple ERs, wrong ERs being used successfully, and the use of partially incorrect ERs.

The results of both the Cox and Brna study and Experiment Five reveal that the three analytic reasoning problems produced a large variation in the type and amount of ERs used. According to Cox and Brna (1995), one source of the variation may be individual differences in cognitive style. In the Cox and Brna study the cognitive style of the subjects was not known. In Experiment Five the Cognitive Styles Analysis (Riding, 1991) was given to all subjects and their cognitive style was determined.

In summary:

(1) Subjects in the Cox and Brna (1995) study and Experiment Five used external representations in their solutions to analytic reasoning problems.

(2) Some subjects in the British Experiment chose ERs that reflected their Cognitive Style determined by the Cognitive Styles Analysis (Riding, 1991) and this was best exemplified by the main effect of VI (($F=4.88$;d.f.=1,54; $p=.031$) in which Imagers used more 'lines' than Verbalisers in solving the three analytic reasoning problems.

It was decided to do another experiment with simpler problems than those used in Experiment Five, because the three analytic reasoning problems proved too difficult in some cases. Some students could not do Problem Two and left it out. Another experiment was proposed to do with undergraduates. There would be four problems (two verbal reasoning, one spatial and one mathematical word). The Cognitive Styles Analysis (Riding, 1991) would be given to each subject.

CHAPTER FOUR

EXPERIMENT SIX: EXTERNAL REPRESENTATIONS AND COGNITIVE STYLES IN THE SOLUTION OF SIMPLE SPATIAL, VERBAL REASONING AND MATHEMATICAL WORD PROBLEMS

SUMMARY

In Experiment Five subjects' use of ERs in solutions to analytic reasoning problems and the the influence of Cognitive Style was examined. The three analytic reasoning problems were taken from Cox and Brna's 1995 experiment. It was found that subjects used external representations when doing analytic reasoning problems and that in some cases the use of external representations reflected their cognitive style. These representations became known as 'characters', 'lines' and 'ideas'. In Experiment Six, problems were much less difficult than those in Experiment Five and some different representations evolved from the experiment. They became known as 'letters', 'picture', 'lines' and 'ideas'. Lines and 'ideas' were representations used in Experiment Five and Experiment Six, only 'letters' and 'pictures' were representations used in Experiment Six.

The four problems in Experiment Six were taken from two sources. The two verbal reasoning and one mathematical word problem were from Whimbley, and Lockhead, (1991) the spatial problem was from Johnson-Laird and Byrne, (1991). These four problems were much easier than those used in Experiment Five. It was thought that, because of their simplicity the answers would be easy to figure out, and subjects would be much less constrained than in Experiment Five to show their external representations. For example, in Problem Two of Experiment Five those who did not have any previous knowledge of 'logic' or 'set theory', might possibly be unable to show any 'working out' for the problem as it required this knowledge.

INTRODUCTION

The subjects in Experiment Six were second year undergraduates in a British University doing a BA in Education. They ranged in age form 18 - 43. They were presented with a booklet containing four simple problems (one spatial, two verbal reasoning and one mathematical word) and one problem per page. They were told to do any rough work on the page designated for each problem. The time allotted for the four problems was 30 minutes.

AIM

The aim of the Experiment Six was to find out what external representations subjects used in answering four problems (two verbal reasoning, one spatial and one mathematical word.) and if this varies according to cognitive style

METHOD

Sample

The sample in the sixth experiment consisted of 60 undergraduate students aged 18-43, 50 females and 10 males. All 60 participants were given a booklet and they all did the CSA.

Materials

A booklet was presented to the students consisting of general instructions and four problems. The students were given the computer-presented CSA (Riding, 1991) determining their position on each of the cognitive style dimensions of the Wholist-Analytic and Verbaliser-Imager (WA and VI).

BOOKLET SIX

Instructions

You will be given four problems to do one at a time. You may use the sheet of paper provided for each problem to show your working or diagrams if you find that helpful. You have 30 minutes in total.

Problem 1

Spatial problem (setting a table)

The fork is on the right of the spoon.
The fork is on the right of the cup.
The knife is in front of the cup.
The plate is in front of the fork.
What is the relation between the plate and the knife?

Problem 2

Verbal reasoning (foreign languages) * hint: begin by making a diagram showing the order of difficulty of the languages

Cathy knows French and German, Sandra knows Swedish and Russian. Cindy knows Spanish and French, Paula knows German and Swedish. If French is easier than German, Russian is harder than Swedish, German is easier than Swedish, and Spanish is easier than French, which girl knows the most difficult language?

Problem 3

Verbal reasoning (street names)

Belvedere Street is parallel to Anthony Street. Davidson Street is perpendicular to River Street. River Street is parallel to Anthony Street. Is Davidson Street parallel or perpendicular to Belvedere?

Problem 4

Mathematical word problem (two men running)

John can run 7 ft. in the time that Fred runs 5 ft. How far will John run in the time that Fred runs 15 ft?

Procedure

There were sixty students in this experiment. The computer presented Cognitive Styles Analysis (Riding, 1991) was completed by each student before being given a booklet. Each student was then given a booklet with four problems to solve (one spatial, two verbal reasoning and one mathematical word. The students were told to do each of the problems as well as given written instructions to do this. The total time was 30 minutes.

Scoring -

The problems were scored according to how many 'representations' were used in the working out of each problem. The categories of representation were: 'picture', 'letters', 'lines', 'ideas' and for example, each line used scored 1.

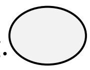
picture = every picture (complete or incomplete)

letters = characters - answer

line = every line

idea = every idea

Rules -

1. in scoring 'picture', every complete or incomplete picture = 1, e.g.  a plate = 1.
2. in scoring 'letters' letters = characters - answer
3. 'characters' include all symbols including answers and any crossings out and excludes all'commas and full stops'.
4. 'ideas' include all nouns and proper nouns and are counted as 1, e.g. 'knife' = 1.

RESULTS and DISCUSSION

Characteristics of the Sample

On each cognitive style dimension the sample was divided on the basis of their style ratios, with almost equal numbers in each division. For the analyses, the Wholist-Analytic dimension was split into two divisions: Wholists 0.44 to 1.26=1 and Analytics 1.27 to 3.57 =2 (mean = 1.34, median = 1.28, SD = 0.58). Similarly, the Verbal-Imagery dimension was split into two divisions: Verbalisers 0.82 to 1.05 = 1 and Imagers 1.06 to 1.64 = 2 (mean = 1.11, median = 1.06, SD = 0.20). The correlation between the styles was low -.036 confirming the independence of the measures (see also Riding & Douglas, 1993; Riding & Mathias, 1991). The results were analysed in terms of how many 'pictures', 'letters', 'lines' and 'ideas' a subject used in their 'working out' of one spatial, two verbal reasoning and one mathematical word problem. The subjects were divided in terms of age into younger, 18-21 years and older, 22-43 years.

The Analysis

Analysis of variance was performed on the data in twelve separate analyses for Experiment Six. The results of these separate analyses are discussed under the headings entitled Section One through Section Four as follows:

Section One - Letters, Pictures, Ideas

Findings

<u>Letters and Age and Verbal-Imagery Cognitive Style</u>

The means and standard deviations for Letters against Age and Verbal-Imagery Cognitive Style are shown in Table 6.1

Table 6.1

Means and Standard Deviations for the Number of Letters Used against Age and Verbal-Imagery

Cognitive Style

Variable	Value	Mean	Std.Dev.	N
LETTERS	Younger	8.81	6.12	31
	Verbaliser	8.33	5.98	15
	Imager	9.25	6.40	16
	Older	10.86	12.11	29
	Verbaliser	16.33	14.64	15
	Imager	5.00	3.66	14
For Entire	Sample	9.80	9.47	60

Letters= Characters - Answer

Analysis of variance of Age (2) by Wholist-Analytic (2) and Verbal-Imagery Cognitive Style (2) with the number of Letters used as the dependent variable was performed on the data. The summary is given in Table 6.2

Table 6.2

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal - Imagery Cognitive Style with the number of Letters used as the dependent variable

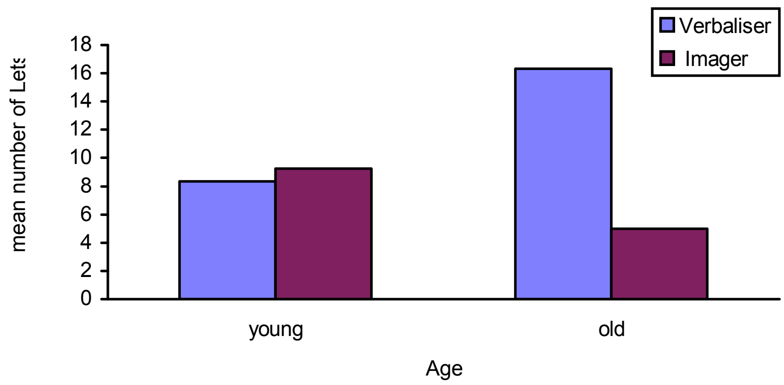
Test of Within-Subject effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	80.12		
AGE	1	48.05	.60	.442
WA	1	123.96	1.55	.219
VI	1	376.32	4.70	.035
AGE BY VI	1	570.80	7.12	.010*

There was one significant within-subject effect. It was a significant within-subject interaction of Letters by AGE by VI (F=570.80; d.f.=1,52; p=.010) and it showed that Younger Imagers used more ‘letters’ than Younger Verbalisers and Older Verbalisers use more ‘letters’ than Older Imagers.

Figure 6.1 shows the mean scores for Letters and Age and Cognitive Style in which Younger Imagers used more 'letters' than Younger Verbalisers and Older Verbalisers used more 'letters' than Older Imagers.

Figure 6.1 Means number of Letters against Age and Verbal-Imagery Cognitive Style



Problem One - Letters by Age by Verbal-Imagery Cognitive Style

There was a significant interaction of Letters x Age x Verbal-Imagery Cognitive Style. Younger Imagers used more 'letters' than Younger Verbalisers in Problem One. It might be that Verbalisers find verbal associations tend to be less stable for them during involuntary information processing than they would be when consciously evoked by Imagers (Riding and Dyer, 1980).

Older Verbalisers used more letters than Older Imagers in Problem One. Problem One was a spatial problem. When presented with some description in Problem One the subjects were asked to write down the relation between two objects, which had not been stated directly. The Theory of Mental Models, developed by Johnson-Laird and Byrne, (1991) predicted that a problem was more difficult if more than one model had to be considered. Models added on meant an imposition on limited working memory. A model may be constructed on the basis of language, and its structure corresponds not to the language used but to the situation described. It might have been that, Older Verbalisers used more 'letters' than Older Imagers in solving Problem One because of their working memory being overloaded.

Verbalisers think in terms of words as their means of expression and the use of 'letters' aided them in solving Problem One. Older Imagers in contrast to Older Verbalisers might have used less 'letters' in solving Problem One as the problem is describing easily imaged entities such as 'knife'. Older Imagers habitually thinking in terms of 'pictures' might not have needed to use as many letters as Older Verbalisers to solve Problem One.

Picture and Wholist-Analytic Cognitive Style

The means and standard deviations for Picture and Wholist-Analytic Cognitive Style in Problem One are given in Table 6.3

Table 6.3

Means and standard deviations for the number of Pictures used and Wholist-Analytic Cognitive Style

Variable		Mean	Std.Dev.	N
PICTURE	Wholist	4.47	3.06	30
	Analytic	2.67	2.47	30
For Entire	Sample	3.57	2.90	60

Picture (every complete or incomplete picture) = 1 e.g. a picture of a plate = 1

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with the number of Pictures used as the dependent variable was performed on the data. The summary is given in Table 6.4

Table 6.4

Summary of ANOVA for Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the number of Pictures used as the dependent variable

Test of Within Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	8.02		
AGE	1	2.28	.28	.596
WA	1	47.36	5.91	.019*
VI	1	.30	.04	.848
AGE BY WA	1	.26	.03	.858
AGE BY VI	1	8.94	1.12	.296
WA BY VI	1	1.64	.20	.653
AGE BY WA BY VI	1	18.29	2.28	.137

There was one significant within-subject main effect of WA (F=5.91; d.f.=1; 52; p=.019). The mean and standard deviation for Wholists were 4.47 and 3.05. The mean and standard deviation for Analytics were 2.67 and 2.47. This showed that Wholists used more 'pictures' than Analytics.

Problem One - Main Effect of Wholist-Analytic Cognitive Style

There was a significant main effect of Wholist-Analytic Cognitive Style. Wholists used more 'pictures' than Analytics in Problem One. According to Johnson-Laird (1983, 1993) an entity is an object or a person in the world and is represented by a corresponding token in a model. Relations among entities are represented by relations among tokens. Problem One was about concrete entities that could be represented by pictures. The wording of the problem effects the construction of the model but it might be that drawing whole pictures of the objects suited Wholists rather than Analytics. Analytics might have used less 'pictures' than Wholists because they see things in parts and drawing an incomplete picture might have sufficed as a representation for the complete picture. This finding needs further investigation.

Ideas and Age and Verbal-Imagery Cognitive Style

The means and standard deviations for Ideas against Age and Verbal-Imagery Cognitive Style in are given in Table 6.5

Table 6.5

Means and standard deviations for the number of Ideas used against Age and Verbal-Imagery Cognitive Style

Variable		Mean	Std Dev.	N
IDEAS	Younger	2.26	2.84	31
	Verbaliser	1.80	2.51	15
	Imager	2.69	3.13	16
	Older	2.00	3.49	29
	Verbaliser	3.60	4.20	15
	Imager	.29	1.07	14
For	Entire	2.13	3.15	60

Ideas = nouns and proper nouns, e.g. plate = 1

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with the number of Ideas used as the dependent variable was performed on the data.   The summary is given in Table 6.6

Table 6.6

Summary of ANOVA for Age and Wholist-Analyitc Cognitive Style and Verbal-Imagery Cognitive Style with the number of Ideas used as the dependent variable

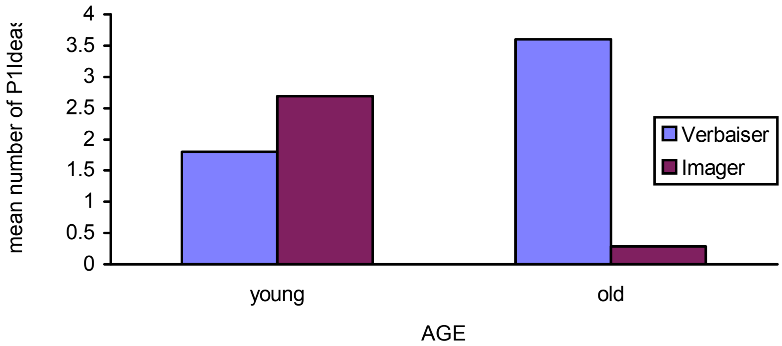
Test of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	9.47		
AGE	1	1.52	.16	.691
WA	1	.00	.00	.989
VI	1	22.33	2.36	.131
AGE BY WA	1	4.82	.51	.479
AGE BY VI	1	63.72	6.73	.012*
WA BY VI	1	44	. 05	.831
AGE BY WA BY VI	1	49	.05	.822

There was one significant within-subject interaction of Ideas by Age by VI ($F=6.73$; d.f.=1,52; $p=.012$). This showed that Younger Imagers used more ideas than Younger Verbalisers and Older Verbalisers used more ideas than Older Imagers.

Figure 6.2 shows the mean scores of Ideas and Age and Cognitive Style in which Younger Imagers used more ‘ideas’ than Younger Verbalisers and Older Verbalisers used more ‘ideas’ than Older Imagers.

Figure 6.2 Mean number of Ideas against Age and Verbal-Imagery Cognitive Style



Problem One - Ideas by Age by Verbal-Imagery Cognitive Style

In Problem One, Younger Imagers used more ‘ideas’ than Younger Verbalisers and Older Verbaliser used more ‘ideas’ than Older Imagers. The Younger Imagers using more ideas than Younger Verbalisers might be according to Riding and Dyer (1980), that they found the information in Problem One about concrete entities such as eating utensils (knife,spoon, and fork) easy to visualise and describe.

Older Verbalisers used more ideas than Older Imagers in Problem One. It might be that Older Imagers did not need to use as many ideas in solving Problem One as Older Verbalisers because Older Imagers could visualise the problem in their heads. In contrast, Older Verbalisers might have gained experience over time in using ideas. Laursen (1997) points out that performance improves in verbal learning with age. The age groups used in Laursen’s study were 30, 40, 50 and 60. In Experiment Six the older age group was aged

22 - 43. There would have to be further experiments done with larger samples of younger and older age groups to investigate the improvement of verbal learning with age.

Section Two - Letters, Lines, Ideas

Findings

Letters and Age and Wholist-Analytic Cognitive Style

The means and standard deviations for Letters against Wholist-Analytic Cognitive Style are given in Table 6.7

Table 6.7

Means and standard deviations for the number of Letters used against Age and Wholist-Analytic Cognitive Style

Variable		Mean	Std.Dev.	N
LETTERS	Younger	43.61	48.09	31
	Wholist	32.20	41.60	15
	Analytic	54.31	52.52	16
	Older	53.62	39.86	29
	Wholist	64.73	43.83	15
	Analytic	41.71	32.51	14
For	Entire	48.45	44.22	60

Letters = Characters - Answer

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal- Imagery Cognitive Style (2) with the number of Letters used as the dependent variable was performed on the data. The summary is given in Table 6.8

Table 6.8

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the number of Letters used as the dependent variable

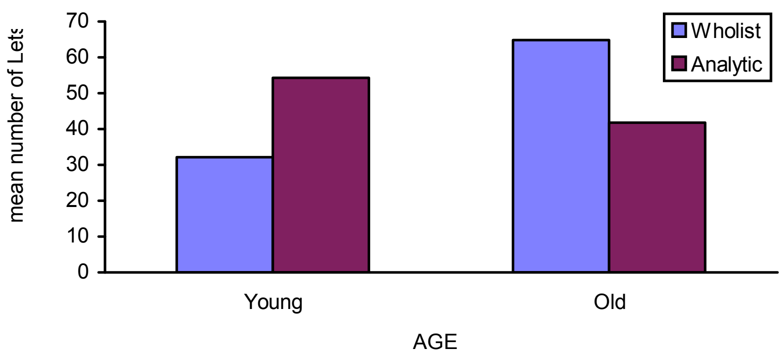
Test of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	1916.69		
AGE	1	1220.33	.64	.429
WA	1	.13	.00	.993
VI	1	2058.29	1.07	.305
AGE BY WA	1	7129.15	3.72	.059*
AGE BY VI	1	3491.25	1.82	.183
WA BY VI	1	20.25	.01	.919
AGE BY WA BY VI	1	1071.19	.56	.458

There was one almost significant within-subject interaction of Letters by Age by WA ($F=3.72$; d.f.=1,52; $p=.059$). This showed that Younger Analytics used more ‘letters’ than Younger Wholists and Older Wholists used more ‘letters’ than Older Analytics.

Figure 6.3 shows the mean scores for Letters and Age and Cognitive Style in which Younger Analytics used more ‘letters’ than Younger Wholists and Older Wholists used more ‘letters’ than Older Analytics.

Figure 6.3 Mean number of Letters against Age and Wholist-Analytic Cognitive Style



Problem Two - Letters by Age by Wholist-Analytic Cognitive Style

Problem two was a verbal reasoning problem. There was an almost significant interaction showing Younger Analytics used more 'letters' than Younger Wholists in solving the problem. This might be because the Younger Analytics considered more possibilities than the Younger Wholists as Analytics habitually analyse things in parts. Problem Two could be divided into parts as it was about comparing different languages and individual's knowledge of the languages.

In Problem Two, Older Wholists used more 'letters' than Older Analytics. It might be as one gets older one writes things down in more detail in order to remember them. Wholists habitually do not process information in detail but choose to get an overview of a situation. Styles probably develop learning strategies with age and Older Wholists might have found ways of coping with detail by using more letters in their solution to Problem Two than Older Analytics (Riding and Al-Sanabani, 1998).

<u>Lines and Age and Verbal-Imagery Cognitive Style</u>

The means and standard deviations for Lines and Age and Verbal-Imagery Cognitive Style are give in Table 6.9

Table 6.9

The means and standard deviations for the number of Lines used against Age and Verbal-Imagery Cognitive Style

Variable		Mean	Std.Dev.	N
LINES	Younger	3.03	2.83	31
	Verbaliser	2.67	2.58	15
	Imager	3.37	3.09	16
	Older	6.62	5.29	29
	Verbaliser	8.40	6.17	15
	Imager	4.71	3.41	14
For	Entire	4.77	4.54	60

Lines = any line e.g. every line drawn = 1

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with the number of Lines used as the dependent variable was performed on the data. The summary is given in Table 6.10

Table 6.10

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery
Cognitive Style with the number of Lines used as the dependent variable

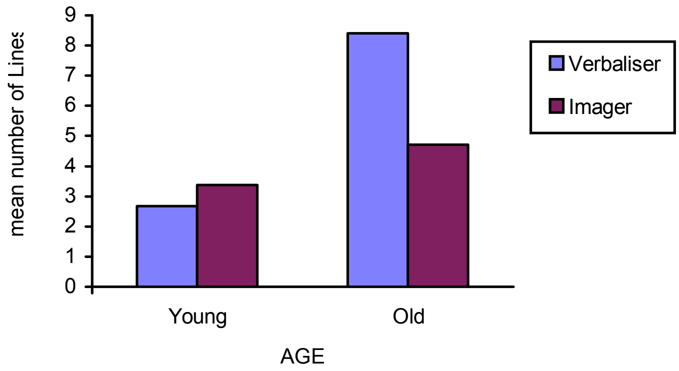
Test of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	15.61		
AGE	1	177.49	11.37	.001
WA	1	13.04	.83	.365
VI	1	30.68	1.97	.167
AGE BY WA	1	43.80	2.81	.100
AGE BY VI	1	63.93	4.10	.048*
WA BY VI	1	23.97	1.54	.221
AGE BY WA BY VI	1	28.43	1.82	183

There was one significant within-subject effects. This was a significant within-subject interaction of AGE by VI (F=4.10; d.f.=1,52; p=.048). The interaction showed that Younger Imagers used more lines than Younger Verbalisers and Older Verbalisers used more lines than Older Imagers.

Figure 6.4 shows the mean scores of Lines and Age and Cognitive Style in which Younger Imagers used more ‘lines’ than Younger Verbalisers and Older Verbalisers used more ‘lines’ than Older Imagers.

Figure 6.4 Mean number of Lines against Age and Verbal-Imagery Cognitive Style



Problem Two - Lines by Age by Verbal-Imagery Cognitive Style

In Problem Two Older Verbalisers used more ‘lines’ than Older Imagers. The problem involved arranging the names of languages and female students. Styles probably develop learning strategies with age and Older Verbalisers might have found ways of coping with images by drawing more lines than Older Imagers (Riding and Al-Sanabani, 1998). Another possible reason that Older Verbalisers used more lines than Older Imagers might be that they were accustomed to using lines in problem solving at school. They might have been asked to show their working out of a problem in exams as there were less multiple choice questions and more questions requiring an answer without being given any choices. They would also be drawing diagrams and tables by hand because computers were not available.

Imagers recall highly visually descriptive text better than accoustically complex and unfamiliar text (Riding and Calvey, 1981; Riding and Dyer, 1980). It might be that the text in Problem Two was difficult to image for the Older Imagers and to represent with ‘lines’. In contrast, the Younger Imagers used more ‘lines’ than Younger Verbalisers. This is in accord with Imagers preferring to process information using pictures in preference to words.

Ideas and Age

The means and standard deviations for Ideas and Age are given in Table 6.11

Table 6.11

Means and standard deviations for Ideas and Age

Variable		Mean	Std. Dev.	N
IDEAS	Younger	11.00	8.55	31
	Older	16.21	9.15	29
For Entire	Sample	3.52	9.16	60

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with the number of Ideas used as the dependent variable was performed on the data. The summary is given in Table 6.12

Table 6.12

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the Number of Ideas used as the Dependent Variable

Test of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	78.02		
AGE	1	375.36	4.81	.033*
WA	1	1.34	.02	.896
VI	1	37.39	.48	.492
AGE BY WA	1	216.71	2.78	.102
AGE BY VI	1	170.77	2.19	.145
WA BY VI	1	32.51	. 42	.521

There was one significant within-subject main effect of Age (F=4.81; d.f.=1,52; p=.033). The mean and standard deviation for younger subjects using ideas was 11.00 and 8.55. The mean and standard deviaton for older subjects using ideas was 16.21 and 9.15. This main effect showed that the older subjects used more ideas in their answer than younger subjects.

Problem Two - Main Effect Of Age

This significant main effect of Age in Problem Two, showed older subjects used more 'ideas' in their solution to the problem than younger subjects. This might be because as subjects get older they might have gained experience of using more 'ideas' in solving problems. For example, they might have by trial and error tried more 'ideas' and combinations of 'ideas' in solving problems just based on their age.

Section Three - Letters, Lines, Ideas

Findings

Letters and Age and Wholist-Analytic Cognitive Style

The means and standard deviations for Letters and Age against Wholist-Analytic Cognitive Style are give in Table 6.13

Table 6.13

Means and standard deviations for the number of Letters used and Age against Wholist-Analytic Cognitive Style

Variable		Mean	Std.Dev.	N
LETTERS	Younger	24.58	17.45	31
	Wholist	20.20	19.00	15
	Analytic	28.69	15.32	16
	Older	23.21	13.39	29
	Wholist	30.40	13.59	15
	Analytic	15.50	7.98	14
For Entire	Sample	23.92	15.50	60

Letters = Characters - Answer

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with the number of Letters used as the dependent variable was performed on the data. The summary is given in Table 6.14

Table 6.14

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the number of Letters used as the dependent variable

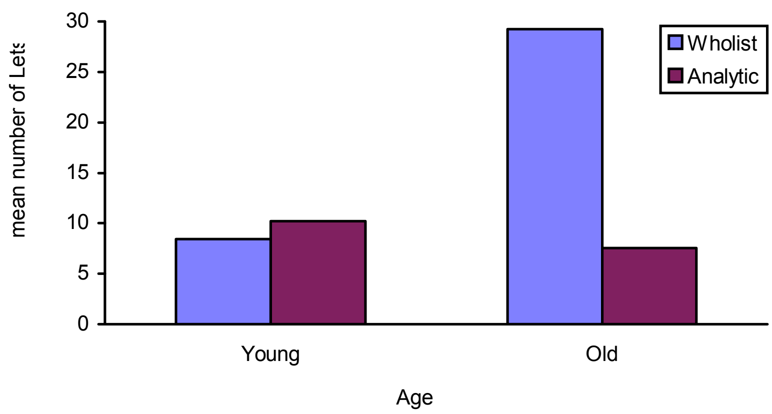
Test of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	215.25		
AGE	1	55.11	.26	.615
WA	1	153.24	.71	.403
VI	1	3.79	.02	.895
AGE BY WA	1	1990.80	9.25	.004*
AGE BY VI	1	189.35	.88	.353
WA BY VI	1	256.95	1.19	.280
AGE BY WA BY VI	1	341.32	1.59	.214

There was one significant within-subject interaction of Age by WA (F=15.29; d.f.=1,52; p=.004). This showed that Younger Analytics used more 'letters' than Younger Wholists and Older Wholists used more 'letters' than Older Analytics.

Figure 6.5 shows the mean scores for Letters and Age and Cognitive Style in which Younger Analytics used more 'letters' than Younger Wholists and Older Wholists used more 'letters' than Older Analytics.

Figure 6.5 Mean number of Letters against Age and Wholist-Analytic Cognitive Style



Problem Three - Letters by Age by Wholist-Analytic Cognitive Style

In Problem Three, which was about the position of streets Younger Analytics used more 'letters' than Younger Wholists. It might be that they considered information in more detail to solve the problem as Analytics process information in more detail than Wholists.

Older Wholists used more 'letters' than Older Analytics in problem three. Wholists habitually do not process information in detail but choose to get an overview of a situation. Styles probably develop learning strategies with age and Older Wholists might have found ways of coping with detail by using more 'letters' than Older Analytics (Riding and Al-Sanabani, 1998).

<u>Lines and Age</u>

The means and standard deviations for Lines and Age are given in Table 6.15

Table 6.15

The means and standard deviations for Lines and Age

Variable		Mean	Std.Dev.	N
LINES	Younger	3.16	1.73	31
	Older	4.10	1.47	29
For Entire	Sample	3.62	1.67	60

Analysis of variance of Age (2) by Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with Lines used as the dependent measure was performed on the data. The summary is given in Table 6.16

Table 6.16

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive with the Number of Lines used as the Dependent Variable

Test of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	2.63		
AGE	1	13.26	5.03	.029*
WA	1	.19	.07	.788
VI	1	.03	.01	.921
AGE BY WA	1	5.69	2.16	.148
AGE BY VI	1	7.08	2.69	.107
WA BY VI	1	.00	.00	.995
AGE BY WA BY VI	1	.24	.09	.763

There was one significant within-subject main effect of Age (F=5.03; d.f.=1,52; p=.029). The mean and standard deviation for younger subjects using lines were 3.16 and 1.73. The mean and standard deviation for older subjects using lines were 4.10 and 1.47. This showed that older subjects used more 'lines' than younger subjects.

Problem Three - Main Effect of Age

There was one significant main effect of Age concerning the use of 'lines' in Problem Three. In Problem Three, older subjects used more 'lines' than younger subjects. It may be that older subjects were more experienced in drawing 'street maps' in geography lessons at school than the younger subjects.

Ideas and Age and Wholist-Analytic Cognitive Style

The means and standard deviations for Ideas and Age and Wholist Analytic Style are given in Table 6.17

Table 6.17

Means and standard deviations for Ideas and Age and Wholist-Analytic Cognitive Style

Variable		Mean	Std.Dev	N
IDEAS	Younger	3.29	1.62	31
	Wholist	2.60	1.84	15
	Analytic	3.94	1.06	16
	Older	4.21	2.04	29
	Wholist	4.73	2.40	15
	Analytic	3.64	1.45	14
For Entire	Sample	3.73	1.88	60

An analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with the number of Ideas used as the dependent variable was performed on the data. The summary is given in Table 6.18

Table 6.18

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the number of Ideas used as the dependent variable

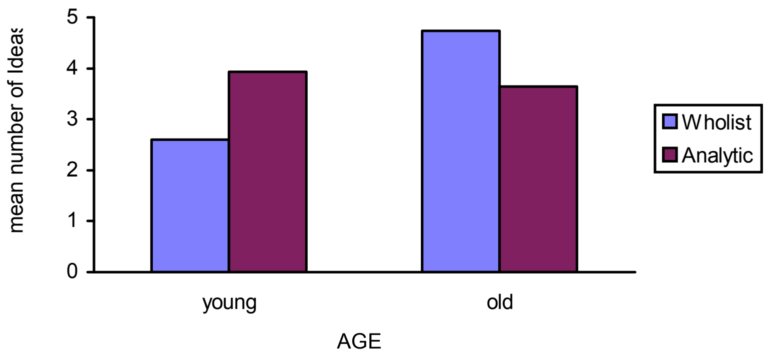
Tests of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	3.09		
AGE	1	12.03	3.90	.054
WA	1	.44	.14	.707
VI	1	10.20	3.30	.075
AGE BY WA	1	22.03	7.13	.010*
AGE BY VI	1	.70	.23	.636
WA BY VI	1	1.24	.40	.530
AGE BY WA BY VI	1	.03	.01	.927

There was a significant within-subject interaction of Ideas by Age by WA (F=7.13; d.f.= 1,52; P=.010) showing that Younger Analytics used more ideas than Younger Wholists and Older Wholists used more ideas than Older Analytics.

Figure 6.6 shows the mean scores for Ideas and Age and Cognitive Style in which Younger Analytics used more 'ideas' than Younger Wholists and Older Wholists used more 'ideas' than Older Analytics.

Figure 6.6 Mean number of Ideas against Age and Wholist-Analytic Cognitive Style



Problem Three - Ideas by Age by Wholist-Analytic Cognitive Style

In Problem Three, Younger Analytics used more 'ideas' than Younger Wholists. It might be that the Younger Analytics considered more details about the streets in Problem Three because of the way they process information. They process information in its parts and attach each part to what they already know.

In Problem Three Older Wholists used more 'ideas' than Older Analytics. Styles probably develop learning strategies with age and Older Wholists might have found ways of coping with detail by using more ideas than Older Analytics (Riding and Al-Sanabani, 1998).

Section Four - Letters, Lines, Ideas

Findings

Letters and Age and Wholist-Analytic Cognitive Style

The means and standard deviations for Letters and Age and Wholist-Analytic Cognitive Style are given in Table 6.19

Table 6.19

Means and standard deviations for the number of Letters used against Age and Wholist-Analytic Cognitive Style

Variable		Mean	Std.Dev.	N
LETTERS	Younger	4.84	9.09	31
	Wholist	4.07	6.69	15
	Analytic	5.56	11.06	16
	Older	9.52	15.98	29
	Wholist	14.87	20.47	15
	Analytic	3.79	5.52	14
For Entire	Sample	7.10	12.99	60

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style with the number of Letters used as the dependent variable was performed on the data. The summary is given in Table 6.20

Table 6.20

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery

Cognitive Style with the number of Letters used as the dependent variable

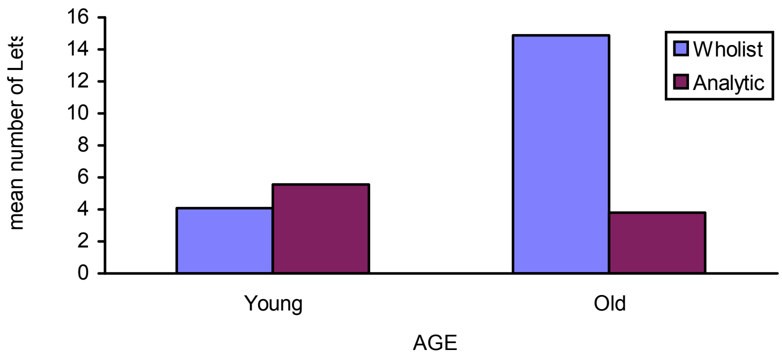
Test of Within Subject-Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	158.40		
AGE	1	306.49	1.93	.170
WA	1	365.78	2.31	.135
VI	1	29.11	.18	.670
AGE BY WA	1	513.01	3.24	.078*
AGE BY VI	1	266.11	1.68	.201
WA BYVI	1	140.90	.89	.350
AGE BY WA BY VI	1	38.57	.24	.624

There was an almost significant within-subject interaction of Age by WA (F=3.24; d.f.=1,52; p=.078). This showed that Younger Analytics used more Letters than Younger Wholists and Older Wholists used more Letters than Older Analytics.

Figure 6.7 shows the mean scores for Letters and Age and Cognitive Style in which Younger Analytics used more ‘letters’ than Younger Wholists and Older Wholists used more ‘letters’ than Older Analytics.

Figure 6.7 Mean number of Letters against Age and Wholist-Analytic Cognitive Style



Problem Four - Letters by Age by Wholist-Analytic Cognitive Style

There was an almost significant interaction in this mathematical word problem in which Older Wholists used more ‘letters’ than Older Analytics. It might be as one gets older one writes things down in more detail in order to remember them. Wholists habitually do not process information in detail but choose to get an overview of a situation. Styles probably develop learning strategies with age and Older Wholists might have found ways of coping with detail by using more ‘letters’ than Older Analytics (Riding and Al-Sanabani ,1998)

<u>Lines and Age</u>

The means and standard deviations for Lines and Age are given in Table 6.21

Table 6.21

Means and standard deviations for the number of Lines used and Age

Variable		Mean	Std.Dev.	N
LINES	Younger	.26	1.00	31
	Older	.93	1.07	29
For Entire	Sample	.58	1.08	60

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the number of Lines used as the dependent variable was performed on the data. The summary is given in Table 6.22.

Table 6.22

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the Number of Lines used as the Dependent Variable

Test of Within Subject-Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	1.06		
AGE	1	6.50	6.16	.016*
WA	1	2.10	1.99	.165
VI	1	.04	.04	.843
AGE BY WA	1	1.45	1.37	.247
AGE BY VI	1	3.08	2.91	.094
WA BY VI	1	.20	.19	.664
AGE BY WA BY VI	1	.04	.04	.843

There was one significant within-subject main effect of Age (F= 6.16; d.f.=1,52; p=.016). The mean and standard deviation for younger subjects using lines were .26 and 1.00. The mean and standard deviation for older subjects using lines were .93 and 1.07. This showed that older subjects used more ‘lines’ in their answer than younger subjects.

Problem Four - Main Effect of Age

There was a significant main effect of Age. When older subjects learned mathematics they might have been taught to express themselves in their problem solving using diagrams and tables which are essentially composed of lines, more than the younger subjects.

<u>Ideas and Age and Verbal-Imagery</u>

The means and standard deviations for Ideas and Age and Verbal-Imagery Cognitive Style are given in Table 6.23

Table 6.23

Means and standard deviations for the number of Ideas used against Age and Verbal-Imagery Cognitive Style

Variable		Mean	Std.Dev.	N
IDEAS	Younger	1.45	2.40	31
	Verbaliser	.80	1.47	15
	Imager	2.06	2.91	16
	Older	2.07	2.02	29
	Verbaliser	2.60	2.20	15
	Imager	1.50	1.70	14
For Entire	Sample	1.75	2.21	60

Analysis of variance of Age (2) and Wholist-Analytic Cognitive Style (2) and Verbal-Imagery Cognitive Style (2) with the number of Ideas used as the dependent variable was performed on the data. The summary is given in Table 6.24

Table 6.24

Summary of ANOVA for Age and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style with the number of Ideas used as the dependent variable

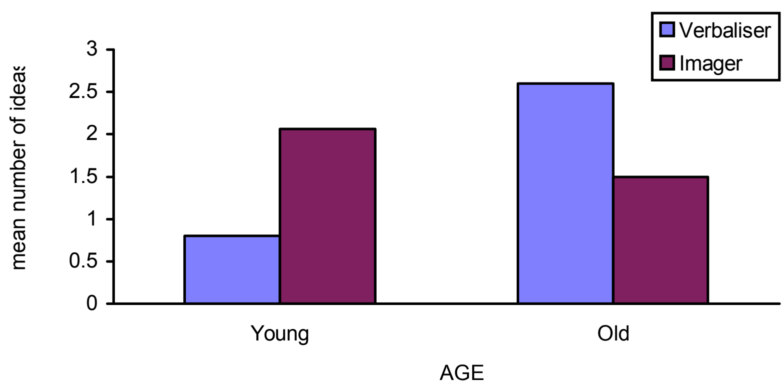
Test of Within-Subject Effect

Source of Variation	DF	MS	F	Sig of F
WITHIN CELLS	52	4.73		
AGE	1	5.05	1.07	.306
WA	1	9.87	2.09	.155
VI	1	.19	.04	.840
AGE BY WA	1	4.38	.93	.340
AGE BY VI	1	20.91	4.42	.040*
WA BY VI	1	2.87	.61	.439
AGE BY WA BY VI	1	.05	.01	.915

There was one significant within-subject interaction of Age by VI ($F=4.42$; d.f.=1,52; $p=.040$). This showed that Young Imagers used more ideas in their answer than younger Verbalisers and Older Verbalisers used more ideas in their answer than Older Imagers.

Figure 6.8 shows the mean scores for Ideas and Age and Cognitive Style in which Younger Imagers used more 'ideas' than Younger Verbalisers and Older Verbalisers used more 'ideas' than Older Imagers.

Figure 6.8 Means number of Ideas against Age and Verbal-Imagery Cognitive Style



Problem Four - Ideas by Age by Verbal-Imagery Cognitive Style

In this mathematical word problem, Younger Imagers used more 'ideas' than Younger Verbalisers. It might be that the Younger Imagers were better able to visualise the problem and associate more 'ideas' with the problem than Younger Verbalisers, because they prefer material which can be visualised. It might be that Younger Imagers were able to draw mental pictures of mathematical word problems in their heads and consider a wider range of ideas than the Younger Verbalisers on account of generating more mental pictures. As Van Essen and Hamaker (1990) and Larkin and Simon (1987) point out, a diagram helps the learner in solving a mathematical word problem. Van Essen and Hamaker (1990) found that 1^{st} and 2^{nd} graders do not draw spontaneously because they judge that visualising simple addition and subtraction word problems is of little help in overcoming their difficulties. However, the authors found by fifth grade when taught to generate drawings, the subjects found them beneficial. In Experiment Six the Younger Imagers were aged 18 - 21 and not given any guidance about drawing diagrams to assist them in solving mathematical word problems. Larkin and Simon (1987) stated that problem solvers could often look for related information more efficiently in a drawing than in a problem text. Some problem characteristics are more easily inferred from a drawing because they become more explicit (Fridja and Eldhout, 1975). Translating a geometry problem into a drawing, for example, often makes visual various aspects (e.g. angles) not explicitly mentioned in the problem text. According to Van Essen and Hamaker (1990) a self-generated drawing is both a tool for analysing and working out mathematical word problems. The drawing is a strategy for analysing a problem because translation of a verbal format into a pictorial format forces a subject to pay attention to the givens and semantics of the problem. This activity stimulates problem analysis and is a method for working out a problem, because correct representation of the quantitative relationship(s) in a drawing often solves the problem. For instance, if the relationships in the problem 'John is six centimetres longer than Pete. John is two centimeters shorter than Tom. How many centimeters is Tom longer than Pete?' are visualised correctly, the problem is almost completely worked out and solved. In Problem Four, Older Verbalisers used more 'ideas' than Older Imagers and this might because verbal performance improves with age (Laursen, 1997).

Overall Discussion for Experiment Six

The subjects in Experiment Six were not given any learning strategies to answer the four problems other than being instructed to do any rough work on a blank page and the hint that drawing a diagram might be useful. The subjects could only rely on their problem solving abilities acquired through past experience and training when solving the problems. In Problems Two, Three and Four Older Wholists used more 'letters' than Older Analytics and older subjects used more ‘lines’ than younger subjects. Wholists habitually do not process information in detail but choose to get an overview of a situation. Styles probably develop learning strategies with age and Older Wholists might have found ways of coping with detail by using more ‘letters’ in their solution than Older Analytics (Riding and Al-Sanabani, 1998). Older subjects using more ‘lines’ than younger subjects in Problem Two, Three and Four might be because visuospatial precision and visual perception improve as individuals age (Laursen, 1997). Dror and Kosslyn (1994) reported that the processes used to add segments to an image do not decay as much over age as the processes used to rotate imaged objects and it may be that the ability to draw lines might not decline much with age. However, in the Dror and Kosslyn study the younger subjects were aged 18 - 23 and the older subjects were aged 55 - 71. In Experiment Six the younger subjects were aged 18 - 21 and the older subjects were aged 22 - 43. There would need to be more experiments done with subjects in a similar age range to Experiment Six to determine if there was any decline in the ability to add segments to an image. A selection of six different representations used by six different subjects for Problem One of Experiment Six follows.

Six Different Representations Used in Problem One

Diagram One

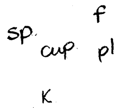
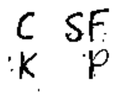


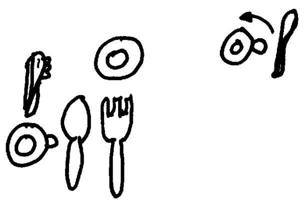
plate is on the right of the knife.

Diagram Two



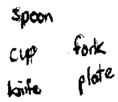
They are next to each other.
the plate is on the right of the knife

Diagram Three



The knife is next to the plate.

Diagram Four



The knife is to the left of the plate.

Diagram Five

The plate is on the right of the knife

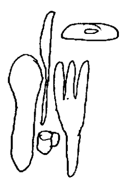
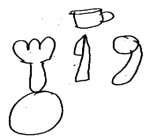


Diagram Six



The plate is on the right of the knife.
(Please excuse the drawings!).

Discussion of Six Different Representations Used in Problem One

Problem One was a spatial problem and six different diagrams representing the problem are shown on the previous page. The problem was about concrete entities (cup, spoon, fork, knife, and plate). All the subjects were female. Diagram One was drawn by a female Analytic-Verbaliser and it is an incorrect representation of the problem but the subject answered the problem correctly. The subject used a single letter to represent the objects fork and knife (f and k) and combinations of letters for example, 'sp' to represent spoon and 'pl' to represent plate and also the word 'cup' to represent cup. A single sentence was written under the entire representation. Diagram Two was drawn by a Intermediate-Imager, correctly, and the subject answered the problem correctly. The subject used five separate letters to represent the objects and two sentences were written under them. Diagram Three was drawn by a female Wholist-Verbaliser, correctly, and the subject answered the problem correctly. The subject drew the five objects in the order - cup, spoon, fork, knife and plate and a sentence to the right of the objects. Diagram Four was drawn by an Analytic-Imager, and it is an incorrect representation of the problem, and the subject answered the problem correctly. The subject drew a knife, spoon, fork, cup and plate and a sentence to the right of these objects. Diagram Five was drawn by an Analytic Bimodal incorrectly, but the subject answered the problem correctly. The subject drew a spoon, knife, cup, plate and fork and a sentence to the left of the objects. Diagram Six was drawn by a Wholist-Imager incorrectly but the subject answered the problem correctly. The subject drew a fork, plate, cup, knife and spoon and two sentences below the objects. There are also different sized letters drawn in Diagrams' One and Two. In Diagrams Three, Four, Five and Six there are different sized objects drawn. The Analytic Bimodal and Wholist-Imager drew larger objects than the Analytic-Imager. It is interesting to note that in the six cases chosen, those using a correct or incorrect representation (drawing a diagram) the subject answered the problem correctly. In Problem One out of the 60 cases, 55 (91.7%) subjects used a representation and five did not. Out of the five cases that did not use a representation in Problem One, only one subject answered the problem correctly.

CONCLUSION

Summary and Comparison of Experiments Five and Six

Two studies on problem solving, were conducted in Chapter Four to find out what sort of external representations subjects used in their working out of problems. In Experiment Five there were three analytic reasoning problems taken from Cox and Brna (1995). In Experiment Six there were four problems (two verbal reasoning, one spatial and one mathematical word) taken from two different sources. The spatial problem was from Johnson-Laird and Bryne (1991) and the verbal reasoning problems were from Whimbley and Lockhead (1991). The Cognitive Styles Analysis (1991) was used in both experiments.

The subjects in both experiments were university students (postgraduates in Education in the former and undergraduates in Education in the latter). The subjects in both experiments were not taught any learning strategies to assist them in solving the problems. The 'working out' of the subjects was analysed in both experiments and it was decided to categorise the external representations used by the subjects according to the number of 'characters', 'lines' and 'ideas' in Experiment Five. In Experiment Six, problems were much less difficult and some different external representations evolved from the experiment. They became known as 'letters', 'picture', 'line', and 'idea'. 'Line' and 'idea' were representations used in both Experiment Five and Experiment Six. Only 'letters' and 'picture' were representations used in Experiment Six. In Experiment Five subjects on the whole found that they did not have adequate time to answer the problems. Experiment Six, in which the problems were much easier did not pose this issue. In summary:

(1) The subjects in Experiment Five and Experiment Six used external representations to solve the problems given.

(2) Some subjects in Experiment Six chose ERs that reflected their Cognitive Style determined by the Cognitive Styles Analysis (1991) and this was best exemplified in Problem One. The significant main effect of WA in Problem One revealed Wholists used more 'pictures' than Analytics in solving a spatial problem.

CHAPTER FIVE

GENERAL DISCUSSION, SUMMARY OF RESULTS, IMPLICATIONS AND FURTHER RESEARCH

GENERAL DISCUSSION

Individuals are faced with situations in which they are asked to solve tasks. For example these tasks can be such things as remembering a list of words and solving a problem. There are methods that are available to help one learn and remember. The findings in the first part of the thesis suggest that learning strategies taught to assist the learner in remembering lists of words were not as helpful as was hoped. In the second part of the thesis learning strategies were not taught and instead the external representations the learner used in solving problems were examined. It was found that most people used external representations in their solution to problems. The introduction of the Cognitive Styles Analysis (Riding, 1991) in Experiment Four of the first part of the thesis showed that cognitive style had an influence on learning performance but it did not have an influence on strategy use. In Experiments' Five and Six cognitive style had an influence on the use of external representations used in the solution to problems.

SUMMARY OF MAIN FINDINGS

Major Investigated Areas

(1) Learning Strategies -
  a) The teaching of and instruction in Learning Strategies, in List Learning Problems
  b) Cognitive Styles and the teaching of and instruction in Learning Strategies, in List Learning Problems

(2) External Representations -
  a) The use of External Representations in the solution to Problems
  b) Cognitive Styles and the use of External Representations in Problem Solving

RESULTS OF THE STUDIES - CHAPTER TWO - (STUDIES ONE TO FOUR) AND CHAPTER FOUR - (STUDIES FIVE TO SIX)

Gender Differences in Studies One to Four

In Study One in the significant interaction of Sex by Treatment (P=0.016) girls outperformed boys in the control group and boys out-performed girls in the experimental group. In Study Two, the significant interaction of Sex by List (P=0.017) showed, girls out-performed the boys on lists two, three and four in the experimental group and boys out-performed the girls on list one, in the experimental group. The significant main effect of Sex in Study Three
(p = 0.012) showed that girls out-performed the boys in both the control and experimental groups. In Study Four the significant interaction of Sex by Strategy by List by Position (P=0.009) revealed that girls after learning a learning strategy out-performed the boys using strategy one (first letter mnemonics), strategy two (story mnemonic) equally on strategy three (grouping) and boys outperformed the girls using strategy four (imagine a picture). Overall, girls outperformed the boys on the learning of the words in the word lists in Studies one to four. According to Maccoby (1966) in 22 studies on research in sex differences involving children three years old and under, in 18 of these girls were superior to boys in verbal ability. In support of Maccoby in girls being superior to boys in verbal ability are Ballard (1920), Vernon (1960), Beard (1965), Thackray (1965), Maccoby and Jacklin (1974), and Halpern (1989).

Gender and Strategy Use in Studies One to Four

There was a significant interaction of Sex by Strategy by List by Position (P=0.009).
The girls outperformed boys using strategy one (initial letter strategy), and strategy two (make into a story) and equally with boys using strategy three (grouping strategy). Boys outperformed girls using strategy four (imagery strategies). The girls outperforming boys using strategy one (initial letter strategy) and strategy two (make into a story) might be because they are superior in verbal ability and vocabulary (Maccoby 1966). Girls and boys performed equally well using strategy three (grouping). This might be according to

Baddeley (1987) because the learner is an active organiser of information and performs the clustering of material naturally, but the literature does not indicate whether the ability to cluster is gender related. The boys outperformed girls using strategy four (imagery). The literature suggests that boys have greater spatial ability than girls and according to Baddeley (1990) imagery is not purely spatial or visual, but may be both.

Cognitive Style and Learning Performance in Study Four

In Study Four there were two significant effects in which cognitive style had an effect on performance in learning lists of words. These were a significant within-subject interaction of List and Wholist-Analytic cognitive style and Verbal-Imagery cognitive style (P= .015) and a significant within-subject interaction of WA and List and Position (P=0.050) showing that Analytics significantly outperformed Wholists in list 1last.

In the significant interaction of List and Wholist-Analytic and Verbal Imagery Cognitive Style (P=.015) the Analytic-Verbalisers outperforming Wholist-Verbalisers in list one might have been able to remember the words by breaking them down into their parts where possible, better than the Wholist-Verbalisers. In list two Wholist-Imagers outperforming Analytic-Verbalisers might be because that list included ‘body parts’ and they are concrete entities, easily visualised. In list three Wholist-Imagers outperforming Analytic-Verbalisers might be again the inclusion in that list of body parts and for the same reasons given for list two. In list four Analyltic-Imagers outperformed Wholist-Imagers and this might be because Analytics tend to organise information into precise conceptual groups and the words in the list were concrete nouns that were easily visualised and could easily be grouped into the categories of furniture, animals and clothing.

Hulme and Mackenzie (1992) showed that recall of words that took less time to say was better than for those that took longer. Even when the number of syllables is the same, words with shorter articulation time are better recalled. The only words that contained the same amount of syllables (two) were in list 4middle. The articulation time of all the words in lists 1-4 would have to be known to make a comparison with the articulation time needed for the words in list 4middle. This would have to be done in a further experiment

In the significant interaction of WA and List and Position (P=.050) in Study Four Analytics significantly outperformed Wholists in list 1last. The words in this position of the list were (orange, truck, elephant, and apple). The words 'apple' and 'orange' could be broken down into two syllables and 'elephant' into three syllables. 'Truck' was monosyllabic. It might be that Analytics remember words of more than one syllable by their syllabic divisions better than Wholists.

The four lists in Experiment Four were compiled by using concrete nouns and mixed categories, for example transport, animals, and food in list one. There were four words per list for each of the three categories per list. The four lists contained words with one syllable, two syllables, three syllables and four syllables. Serial recall of short, one syllable, words is maintained by Baddeley, Thomson and Buchanan (1975) to be considerably better than that for long five syllable words. This word-length effect can be explained by the fact that long words take longer to articulate than short words. In experiment four since the lists were of mixed word length another study could be done to find out if specific long or short words were causing a problem in recall.

Witkin and Goodenough (1981) identified three separate but related cognitive restructuring skills: (a) providing structure for an ambiguous stimulus complex, (b) breaking up an organised field into its basic elements and (c) providing a different organisation to a field other than that which is suggested from the inherent structure of the stimulus complex. Analytics are better at doing tasks that require restructuring skills. The four lists in experiment four were composed of words from ten different categories, for example the categories in list one were vehicles, animals and fruit. The words in the lists did not appear in category order. The Analytics did not do as well as the Wholists in learning the lists and it would appear that they were not using their restructuring skills to learn the lists.

The use of External Representation in Study Five

There was a significant main effect of Problem and the use of external representation. The main effects were in the use of Characters (P=.001), Lines (P=.000) and Ideas (P=.000). The most 'characters' were used in Problem Three and the least 'characters' were used in Problem Two. Problem Three had four dimensions (prize order, dog owner, dog name, and and breed) with four values along each. Problem Two was the most difficult problem and having a background in 'set theory' and/or 'logic' might have helped subjects use the appropriate external representations to solve this problem. However, the subjects did not have this background.

The most lines were used in Problem One and the least lines were used in Problem Two. The least number of lines being used in Problem Two might be because the problem did not need representations such as 'tables'(constructed with lines) to solve it. Problem One using the most lines was an unusual result because it had less dimensions than Problem Three.

The most ideas were used in Problem Three and the least ideas were used in Problem Two. Problem Three had the most dimensions and values (four and four, respectively) and might have used the most ideas because of having more information in it than the other two problems. Problem Two using the least number of ideas might be because the subjects did not have sufficient training in set theory and logic to understand the problem.

The three analytic reasoning problems in Study Five were the same used by Cox and Brna (1995). The first and third problem were determinate (a single, unique model of the information given may be constructed). Problem One was easier than Problem Three because it had less dimensions and in Problem Three some of the information was presented negatively (e.g., 'Mr. Grossman's dog wins neither first nor second prize'). Problem Two was 'indeterminate' (reasoning with several quantifiers) and it was the most difficult problem.

In contrasting the British study and Cox and Brna's study, Problem Two produced the most interesting results. The British subjects and the subjects in Cox and Brna's study used the least amount of external representations in solving Problem Two. This was not unexpected in the case of the former study as the subjects did not have the training in set theory and logic to solve the problem. Cox and Brna's study used the largest variety of types of ERs in solving Problem Two. External representations used in the British study were categorised differently to those used in the Cox and Brna study so the variety of types of ERs used in the former study were not comparable to those used by Cox and Brna.

Cognitive Style and the Use of External Representations in Study Five

There were several significant interactions and a main effects of cognitive style and the use of external representation. These were the interactions of Wholist-Analytic Cognitive Style and Problem, Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style, and Sex and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style, and the main effect of Verbal-Imagery Cognitive Style.

In Study Five it was found that the use of representations and an individual's cognitive style interact in their solutions to analytic reasoning problems. There was a significant interaction of WA and Problem ($P = .046$). It appears that Wholist-Analytic cognitive style interacts with the use of 'characters' such that Analytics used more characters than Wholists in their solutions in two out of the three analytic reasoning problems. Wholists used more 'characters' than Analytics in Problem One. Analytics used more 'characters' than Wholists in Problems Two and Three.

Problem One was about the arrangement of offices and most subjects drew the offices as an array of boxes. It might be that Wholists used more 'characters' than Analytics in Problem One because they were trying to represent a more complete picture of an office. Analytics, habitually divide information into its parts and since problem one divides people into distinct offices the analytic would not need to use as much representation as the Wholist to achieve the desired arrangement of people/offices.

In Problem Two Analytics used more 'characters' than Wholists. This problem could be distinctly divided into seven parts. Analytics see things in parts and the answer to the problem can be inferred from only 2 of the 7 premises in the problem. It might be that the Analytics needed more 'characters' in their solution than Wholists because their processing is more detailed. In Problem Three Analytics used more 'characters' than Wholists. It might be that Analytics used more representations (characters) than Wholists in Problem Three because the problem has more dimensions than the other two problems and requires more detail which is characteristic of Analytics.

In Study Five there was also a significant main effect of Verbal-Imagery cognitive style (P=.031) in the use of representations such that Imagers used more 'lines' than Verbalisers. Riding and Douglas (1993) found that Imagers used more diagrams in their answers to questions about the workings of a car braking system than Verbalisers when the stimulus information was presented in the form of text and pictures. In a condition where the material was presented in the form of text only, there was no difference between the subject groups in the use of drawings.

In Study Five there was also a significant interaction of Wholist-Analytic and Verbal-Imagery Cognitive Style. Analytic-Imagers used the most 'lines' in working out their answer to the three analytic reasoning problems. This is in accord with their ability to see things in parts and in using 'lines' they may have been conveying their visual interpretation of solving the problems.

Cognitive Style and Gender Differences in Study Five

There was a significant between-subject interaction of Sex and WA and VI. This showed that gender interacted with cognitive style in the use of representation. There was a significant interaction of Sex by WA by VI.(P=.022). Female Wholist-Verbalisers used more 'characters' in Problem One than the male Wholist-Verbalisers . In the literature on sex differences in cognitive styles it appears that women are more field dependent and more influenced in problem solving by the structure of the total situation. Wholist-Verbalisers (males and females) might both prefer using a verbal form when presented with information. Maccoby (1966) maintained at an earlier age girls used longer sentences than boys. It might be that female Wholist-Verbalisers used more 'characters' than the male Wholist-Verbalisers in solving the problems in Experiment Five because the solutions to the problems necessitated the amount of 'characters' used and the females' superior verbal ability (Maccoby).

Female Wholist-Imagers used less 'characters' than male Wholist-Imagers. It might be that both styles were influenced by the structure of the total situation being Wholists. However, the female Wholist-Imagers might have produced less mental pictures than the males and would need less 'characters' to describe their solution to the problems.

Female Analytic-Verbalisers used less 'characters' than male Analytic-Verbalisers in solving the three problems. Analytic-Verbalisers use a structured approach to learning and like information presented in verbal forms. The female Analytic-Verbalisers being superior in verbal ability (Maccoby, 1966) might have been able to use more concise language such as abbreviations in their solutions.

Female Analytic-Imagers used more 'characters' than male Analytic-Imagers. Analytics impose their own structure on information. It might be that male Analytic-Imagers needed less 'characters' in their solution to the three problems because of the superior ability of males to detect irrelevant information in a problem (Bracey, 1996).

The Use of External Representation in Study Six

In Study Six there was not a main effect of Problem. Subjects used external representations to solve the four problems in this study. They were known as 'letters', 'picture', 'lines' and 'ideas'. In Study Six on Problem One 68.3% used a representation. On Problem Two 96.7% used a representation. On Problem Three 86.7% used a representation and on problem four 91.7%. The least amount of representation was used in solving Problem One. Problem one was a spatial problem and by presenting some description and then asking subjects to write down the relation between two objects, which had not been stated directly might have been difficult. The theory of mental models (Johnson-Laird and Byrne, 1991) predicted that a problem was more difficult if more than one model had to be considered. Models added on meant an imposition on limited working memory. This is perhaps why the least amount of representation was used in Problem One.

Cognitive Style and the Use of External Representations in Study Six

The findings in Chapter Four, Study Six suggests that the use of representations and an individual's cognitive style have an effect on their solutions to problems (two verbal reasoning, one spatial, and one mathematical word). There was a main effect of Wholist-Analytic cognitive style (P=.019) in problem one (Spatial Problem). Wholists used more 'pictures' than Analytics in their solution. According to Johnson-Laird (1983, 1993) an entity is an object or a person in the world and is represented by a corresponding token in a model. Relations among entities are represented by relations among tokens. Problem One was about concrete entities that could be represented by pictures. The wording of the problem effects the construction of the model but it might be that drawing whole pictures of the objects suited Wholists rather than Analytics. Analytics might have used less 'pictures' than Wholists because they see things in parts and drawing an incomplete picture might have sufficed as a representation for the complete picture.

Cognitive Style and Age Differences in Study Six

In Study Six there were several significant interactions of Age and Cognitive Style and Representation and a main effect of Age. The most interesting main effect was of 'Lines' (P= .040) in Problems Two, Three and Four in which older subjects used more 'Lines' than younger subjects. These older subjects using more lines than younger subjects might be because visuospatial precision and visual perception also improve as individuals age (Laursen, 1997). Dror and Kosslyn (1994) reported that the processes used to add segments to an image do not decay as much over age as the processes used to rotate imaged objects and it may be that the ability to draw lines might not decline much with age. The older subjects in Experiment Six were age 22 - 43. Another experiment would have to be done with a much larger number of people in an older age range for example, 50 - 70 year olds to observe the effects of aging on verbal learning and visuospatial ability.

In Problem Four, there was a significant interaction of Age by Verbal-Imagery Cognitive Style (P=0.40). Younger Imagers used more ideas than Younger Verbalisers in the solution to Problem Four. It might be that the Younger Imagers were better able to visualise the problem and visualise more ideas associated with the problem than Younger Verbalisers. Imagers do better on material which can be visualised in mental pictures than Verbalisers. It might be that Younger Imagers draw mental pictures of mathematical word problem in their heads and consider a wider range of ideas than the Younger Verbalisers because of generating more mental pictures. Van Essen and Hamaker (1990) found that 1st and 2nd graders do not draw spontaneously because they judged that visualising simple addition and subtraction word problems is of little help in overcoming their difficulties. Fifth graders recognised that a self-generated drawing is both a tool for analysing and for working out word problems. The drawing is a strategy for analysing a problem because translation of a verbal format into a pictorial format forces a subject to pay attention to the givens and semantics of the problem. This activity stimulates problem analysis and is a method for working out a problem, because correct representation of the quantitative relationship(s) in a drawing often solves the problem. For instance, if the relationships in the problem 'John is six centimetres longer than Pete. John is two centimeters shorter than Tom. How many centimeters is Tom longer than Pete?' are visualised correctly, the problem is almost completely worked out and solved.

Larkin and Simon (1987) stated that problem solvers can often look for related information more efficiently in a drawing than in a problem text. Some problem characteristics are more easily inferred from a drawing because they become more explicit (Fridja and Eldhout, 1975). Translating a geometry problem into a drawing, for example, often makes visual various aspects (e.g., angles) not explicitly mentioned in the problem text.

In Problem Four, Older Verbalisers used more 'ideas' than Older Imagers. It might be that verbal performance improves with age (Laursen. 1997).

Cognitive Style and the use of External Representation in Study Five and Study Six

In the two studies cognitive style had an effect on the representation used to solve the problems. The significant main effect of Verbal-Imagery cognitive style in Study Five and the significant main effect of Wholist-Analytic cognitive style best illustrate how cognitive style influences the use of external representations in solving problems.

The significant main effect of Verbal-Imagery cognitive style showed that Imagers used more 'lines' than Verbalisers. Riding and Douglas (1993) found that Imagers used more diagrams in their answers to questions about the workings of a car braking system than subjects classified as 'Verbalisers' when the stimulus information was presented in the form of text and pictures. In a condition where the material was presented in the form of text only, there was no difference between the subject groups in the use of drawings.

In Study Six the use of representation and an individual's cognitive style had an effect in the solutions to problems (two verbal reasoning, one spatial, and one mathematical word). There were several interactions and a main effect of Wholist- Analytic cognitive style in problem one (Spatial Problem). Wholists used more 'pictures' than Analytics in their solution. Wholists used more 'pictures' than Analytics in Problem One. According to Johnson-Laird (1983, 1993) an entity is an object or a person in the world and is represented by a corresponding token in a model. Relations among entities are represented by relations among tokens. Problem One was about concrete entities that could be represented by pictures. Johnson-Laird maintained the wording of the problem effects the construction of the model but it might be that drawing whole pictures of the objects suited Wholists rather than Analytics. Analytics might have used less 'pictures' than Wholists because they see things in parts and drawing an incomplete picture might have sufficed as a representation for the complete picture. This finding needs further investigation.

Summary of Studies One to Four

In Studies One - Study Four children were presented with learning strategies to learn lists of words. In these studies there was a clear sex difference observed in learning the lists of words in which overall, girls outperformed boys. In Study Four the Cognitive Styles Analysis (1991) was introduced. There were two significant within subject effects. One was a three-way interaction of List and Wholist-Analytic Cognitive Style and Verbal-Imagery Cognitive Style. In list one Analytic-Verbalisers outperformed Wholist-Verbalisers. In list two Wholist-Imagers outperformed Analytic-Verbalisers, in list three Wholist-Imagers outperformed Analytic-Verbalisers. In list four Analytic-Imagers outperformed Wholist-Imagers.

The second within-subject effect was an interaction of WA and List and Position showing that Analytics significantly outperformed Wholists in list 1c. There needs to be more investigations done in order to determine which words are easier for which cognitive styles to remember. There was only one four-way interaction in which 'Strategy' had an effect on list learning performance (Sex by Strategy by List by Position) and it showed that girls after learning the Strategies 1,2 outperformed boys, girls and boys performed equally after learning Strategy 3 and after learning Strategy 4 boys outperformed girls. There needs to be more studies done using the CSA, learning strategies, and word lists perhaps devoting more time to the teaching and practicing of learning strategies to remember word lists, in order to find out how individuals differ in their ability to learn words.

Comparison of Study Five and Study Six

In Study Five and Study Six it appears that the representation 'lines' had an interesting effect in both studies. In Study Five Imagers used more 'lines' than Verbalisers in all three problems. In Study Six Younger Imagers used more 'lines' than Younger Verbalisers in Problem Two. The three problems in Study Five were analytic reasoning problems and Problem Two in Study Six was a verbal reasoning problem. Imagers using more 'lines' than Verbalisers in solving the three problems is in accord with their preference to processing information using pictures over words. Imagers recall highly visually descriptive text better than accoustically complex and unfamiliar text (Riding and Calvey, 1981; Riding and Dyer, 1980). It might be that the text in Problem Two was difficult to image for the older Imagers and they represented it using less lines than older Verbalisers.

The subjects in Study Six were not given any learning strategies to answer the four problems other than being instructed to do any rough work on a blank page. The subjects could only rely on their problem solving abilities acquired through past experience and training when solving the problems.

It was interesting to note that in Study Six (Problems Two, Three and Four) older subjects used more 'lines' than younger subjects. In Problems Two and Three and Four Older Wholists used more 'letters' than Older Analytics. Problem Two and Problem Three were verbal reasoning problems, and the representation 'letters' was used more by Wholists than Analytics. According to Laursen (1997) there is a trend that cognitive skills improve in ‘verbal learning’ as individuals age. Older subjects using more ‘lines’ in Problems Two, Three and Four might be because visuospatial precision and visual perception also improve as individuals age (Laursen, 1997). It is also interesting to note that Dror and Kosslyn (1994) reported that the processes used to add segments to an image do not decay as much over age as the processes used to rotate imaged objects. The ability to draw lines might not decline with age.

Older Wholists used more ‘letters’ than Older Analytics in Problems Two, Three and Four. Wholists habitually do not process information in detail but choose to get an overview of a situation. Cognitive skills decline with age Salthouse (1985) and for this reason it may be that Wholists compensate for memory decline by having to incorporate more information into representing a problem in order to remember what the problem was about.

In Study Five and Study Six subjects used representations to solve problems. The type of problem, gender, age and Cognitive Style of the individual might have influenced how much representation was used. For example in Study Six, Problem One, ‘drawing pictures’ was a way of representing this problem and was used more by Wholists than Analytics. Problem Two in Study Five produced the least amount of representations in the British study and the most in the Cox and Brna (1995) study. The subjects in the latter study were familiar with ‘logic’ which would have been advantageous in doing analytic reasoning problems. This possibly enabled them to use more representations in their solution to Problem Two than the subjects in the British study to illustrate their knowledge of logic, or to use no representation as according to Cox and Brna (1995) Problem Two was distinctly divided into seven parts and the answer to the problem can be inferred from only two of the seven premises in the problem.

In Study Five and Study Six, adults were instructed to show their ‘working’ as they did the problems in both studies. Their working became known as external representations in Study Five and Study Six. In Cox and Brna’s (1995) experiment on which Study Five is based resulted in subjects using some form of ER. - 91% on problem one, 71% on Problem Two and 92% on Problem Three. In Study Five 87.1% used a representation on Problem One, 52.9% used a representation on Problem Two and 81.4% used a representation on Problem Three. In Study Five, Problem Two was the most difficult problem to solve and to represent. this problem was described by Cox and Brna (1995) as ‘indeterminate’ (reasoning with several quantifiers) and is by definition a more difficult problem to solve than Problems One and Three.

In Study Six on Problem One 68.3% used a representation, 96.7% used a representation on Problem Two and 86.7% used a representation on Problem Three and 91.7% used a representation on Problem Four. Problem One was a spatial problem and it used the least representation. The theory of mental models, developed by Johnson-Laird and colleagues (e.g., Johnson-Laird and Byrne, 1991) predicted that a problem was more difficult if more than one model had to be considered. Models added on meant an imposition on limited working memory. This is perhaps why the least amount of representation was used in Problem One.

LIMITATIONS OF THE STUDIES

The work in the first part of this thesis is based on research in learning strategies and how they are used to assist in the learning and remembering of learning materials (word lists). Four studies were conducted in Part One of this thesis. Experiment Two was designed in view of the limitations of Experiment One. In Experiment One subjects were taught seven learning strategies and also given a booklet containing instructions to learn these strategies. The limitations of Experiment One were related to the number of strategies (seven) the students were expected to learn as well as the word lists, containing concrete and abstract words. In the second experiment an instruction booklet was given to the subjects in the experimental group containing specific instructions on how to learn just one strategy and this same strategy was taught to them by the experimenter. The list of words were changed from concrete and abstract words to single category (all concrete nouns) because it was thought that abstract words were too difficult to remember as they were harder to image than concrete words (Paivio, 1969). In the third experiment the experimental group was given an instruction booklet on how to learn just one strategy and were also taught this strategy by the experimenter. The lists were changed to mixed categories and simpler words than those used in Experiment Two because the age group was younger and it was thought that using single category lists of easy words might produce a ceiling effect. The instructions to learn the strategies were changed to better suit the new wordlists, which were all concrete nouns in three different categories. In the fourth and final experiment in the first part of this thesis, the same design as Experiment Three was used and the Cognitive Styles Analysis (Riding, 1991) was introduced.

Two studies were conducted in the second part of this thesis. The Cognitive Styles Analysis (Riding, 1991) was used in both. Experiment Six was designed in view of the limitations of Experiment Five. In that experiment it was found that the problems chosen (analytic reasoning) were too difficult for some of the subjects to solve. This resulted in some students not being able to use any representation in solving a problem because they did not understand the problem. This lack of understanding was addressed in Experiment Six in which much easier problems (spatial, verbal reasoning and mathematical word) were chosen. In Experiment Six the sample size was small (60) consisting of 50 females 10 males. This sample size would need to be larger and the ratio of females to male would need to be adjusted in a future sample. The problems chosen in Experiment Six were easy to understand and did not pose any obvious difficulties in their solution.

In Experiments Five and Six the scoring of the use of external representations was derived by counting the number of representations used by a subject to solve a problem. Experiments Six's means of scoring was based on the method used in Experiment Five. Difficulties arose in Experiment Five in the categorising of external representations. An attempt was made to adopt the categories of representation used by Cox and Brna (1995) such as 'tabular representation'. However, this was not possible (see pages 207 - 208 earlier in chapter four : in the section, 'Scoring Method used for Experiment Five and Experiment Six') and it was decided to categorise the representations via a new scoring method. This new method was then used in both experiments.

Summarising the Limitations

1. The size of the first two samples were small (50) so it was decided to increase the sample size in Experiments Three and Four to 99 and 76, respectively.

2. In Experiment One there were seven strategies to learn. The subjects were taught the strategies by the experimenter and also given an instruction booklet to read. The abstract words proved difficult to remember and there were too many strategies to learn. In Experiment Two the strategies were therefore, reduced to one from seven and all the words were concrete nouns. The students were expected to learn one strategy by being given an instruction booklet to read and also being taught the same strategy by the experimenter.

3. Similar words pertaining to one category such as 'transport' were grouped together in Experiment Two. In Experiment Three similar words were grouped together by three categories. It was proposed to use younger students and word lists grouped by three categories in Experiment Three because it was thought using word lists grouped by only one category might prove to be too easy to learn.

4. In Experiment Five the three analytic reasoning problems proved to be too difficult to solve for some students so it was decided to use different problems in Experiment Six and four were chosen (one spatial, two verbal reasoning and one mathematical word) that were much easier.

FUTURE WORK

Four related experiments were conducted in the first part of this thesis. After each experiment it was decided to alter the design of the experiment to accommodate the next one. The second experiment reduced the number of learning strategies from seven to four and changed the words on the lists from concrete and abstract of any category to concrete only of one category. The implications of the first four experiments were that investing more time in the teaching of learning strategies and the learning of written instructions about learning strategies might help in learning word lists. This would involve spending more time in teaching the strategies, as well as reading and practicing the strategies. Lessons about learning strategies could be incorporated into reading lessons for children corresponding to the SATs tests set at ages seven, eleven and fourteen to help children improve their test scores.

The areas of further interest arising from this research emerge mainly from the second half of the thesis and focus on Chapter Four (Studies Five and Six). It was found in Studies Five and Six that subjects used external representations in their solution to problems. It was also found that individual differences such as cognitive style, gender and age had an influence on the external representations used by subjects in their solutions to problems. Following from the results of Studies Five and Six several future experiments could be done using a variety of problems and age groups. The Cognitive Styles Analysis (Riding, 1991) would be given in each experiment.

(1) Cognitive Style and Children's Use of External Representation in Spatial Problems

One such line of research might be in giving subjects spatial problems to solve similar to Problem One, Experiment Six which was based on the theory of mental models, developed by Johnson-Laird and Byrne, 1991. The theory predicted a problem was more difficult if more than one model had to be considered as models added on meant an imposition on limited working memory. By examining the external representations young children of different ages such as those corresponding to the age a child takes the SATs tests (seven, eleven and fourteen) might reveal how their understanding of such problems develop over time.

(2) Cognitive Style and Children's Use of External Representation in the Solution of Mathematical Word Problems

Several authors have suggested that making a diagram helps to analyse and explore a problem more carefully (Polya, 1957; Schoenfield, 1985). Bell et al. (1981) and Van Hamaker and Essen (1990) indicated self-generated drawings facilitated the solving of mathematical word problems in which the solution process is not algorithmic. In a future experiment the Cognitive Styles Analysis (Riding, 1991) could be given first and mathematical word problems similar to Problem Four, Experiment Six could be given to children at aged ten, eleven, and twelve corresponding to the age ranges recommended by Bell et al.and Van Hamaker and Essen when children were able to use self-generated in solving simple mathematical word problems.

(3) Cognitive Style and Children's Use External Representation in the Construction of Simple Maps

Siegler and White (1975) on the basis of a large body of data from developmental studies on spatial behaviour found that children have an overall representation of the district where they live and where their school is located, but they don't understand the relationships between the district and the school.. Spatial problem solving can be achieved for a specific and known area; but if two places are not located on the same map a straight line link is impossible. The child reaches the map level when he links together partial representations of subspaces within the same overall representation. In the best case, mental computations strictly independent of the child's position with regard to the spatial layout can be accurately performed on such spatial representations. It would be interesting to choose children aged 9 -10 and ask them to draw short maps e.g. from their classroom to their assembly hall. The Cognitive Styles Analysis could be taken first. The way the map was drawn could be interpreted through the subject's use of external representation e.g. the amount of detail in the map. Knowing the cognitive style of the student and the external representations used might inform the experimenter if a student was in some way influenced by his cognitive style e.g. using lots of detail might be indicative of an Analytic.

(4) Cognitive Style and Adults' Use of External Representation in the Construction of a Direction-Giving Map

In a study with adults by Van Sommers (1984) it was found that when drawings were produced for an audience 'direction-giving maps' were the most frequently used. In a future experiment the Cognitive Styles Analysis (1991) could be given first and adult subjects (younger - 21-40 and older 41-60) could be asked to draw direction-giving maps. The external representations used to draw the maps could then be categorised according to those used in Experiments Five and Six of this thesis.

(5) Cognitive Style, Handedness and Children's use of External Representation in the Construction of a Direction-Giving Map

Another experiment could be done with children drawing a direction-giving map and taking into account handedness (Annett, 1992). The Cognitive Styles Analysis could be taken first and then children 14-15 years old could be asked to draw a direction-giving map.

(6) Cognitive Style and Adults' use of External Representation in the Construction of a House Plan

The drawing of house plans is an ordinary task. Laursen (1997) and Salthouse (1985) reported memory and cognitive skills decline with age, respectively. Young and elderly (same age ranges as used in number 4. above) adults could take the Cognitive Styles Analysis (1991) and then be told to draw a plan of a room in their house. Afterwards, their external representations would be examined according to age and cognitive style.

Young children and adults will be taking exams throughout their school lives. An individual might solve a problem quicker if he knew his Cognitive Style and the external representation that suited this style in different problem solving situations. The Cognitive Styles Analysis could first be taken. A pretest would follow to see how much an individual uses representation in solving problems e.g. verbal reasoning. Once this is established an individual could learn how to deal with increasingly difficult problems by extracting representations or parts of representations, or combinations of representations, from a repertoire of representations, that were thought to best suit every aspect involved in a problem's solution according to one's Cognitive Style. Posttests could then be given throughout specified periods of time, like the present SATs tests (taken at age seven, eleven and fourteen) in British state schools, to monitor a child's progress.

(7) **Course Development**

The findings of this thesis suggest that children when taught learning strategies are able to use them in an experimental framework. In addition, most people use external representations in their everyday lives and are not always aware they are doing so. Since children and adults are increasingly finding themselves in situations of learning new material and taking exams for various qualifications, it might be important for schools and institutions of further and higher education to consider incorporating courses of 'learning strategy instruction' into their curriculum. It might also be that courses could take place in which the external representations that individuals use in solving problems (analytic, verbal reasoning, spatial and mathematical word) could be examined. These external representations could then be developed into learning strategies. Through further experiments the external representations could be classified according to cognitive style and Imagers for example could be shown the external representation used by Imagers to solve a particular type of problem such as Problem One in Experiment Six about breakfast utensils. These newly evolved learning strategies could then serve as teaching tools for different subjects in the National Curriculum and the GCSE and A- level curriculums. The Cognitive Styles Analysis (Riding, 1991) would be given to all participants in both types of courses mentioned above (learning strategy instruction and external representation development). The participants could then be assigned to the courses based on their cognitive style.

References

Adams, D. K. (1929) Experimental studies of adaptive behaviour in cats. *Comparative Psychology, Monographs*, 6, 1-168.

Adams, J.A. (1967) *Human Memory.* New York: McGraw - Hill.

Adams, J.A. & Montague, W.E. (1967) Retroactive inhibition and natural language mediation. *Journal of Verbal Learning and Verbal Behaviour,* 6, 528 - 535.

Alexander, J. Carr, M. & Schwanenflugel, P. (1995) Development of metacognition for future research. *Developmental Review*, 15, 1-37.

Alley, G. & Deshler, D. (1979) *Teaching the Learning Disabled Adolescent: Strategies and Methods.* Denver: Love.

Allport, G.(1937) Pictorial-Verbal and Analytic-Holistic learning strategies in science learning. *Journal of Educational Psychology*, 73, 358 - 368.

Anastasi, A.(1958) *Differential Psychology, 3rd edition*. New York: Macmillan.

Anderson, J. A. (1990) *Cognitive Psychology, 3rd edition*. San Francisco: Freeman.

Anderson, M. A. (1985) *Information processes used by gifted and average elementary students when solving discourse problems*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, Illinois.

Anderson, R.& Hidde, J. (1971) Imagery and sentence learning. *Journal of Educational Psychology*, 62, 526 - 530.

Anzai, Y. & Simon, H. (1979) The theory of learning by doing. *Psychological Review*, 86, 124-140.

Aristotle (1938) *De Interpretations* (H.P. Cook, Trans.) London: Loeb Classical Library.

Ashcroft, M. (1990) Strategic pressing in children's mental arithmetic. A review and proposal. In D.F. BJORKLUND (Ed.), *Children's Strategies*: *Contemporary views of Cognitive Development*, 185 - 211. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Atkinson, R. L., Atkinson, R. C., Smith, E. E., Bem, D.J. (1993) *Introduction to Psychology*, 11th Edition. Fort Worth: Harcourt Brace College Publishers.

Ausubel, D. P.(1963) *The Psychology of Meaningful Verbal Learning.* New York: Grune & Stretton.

Bachrach, D.L. (1964) Sex differences in reaction to delayed auditory feedback. *Perceptual and Motor Skills*, 19, 81 - 82.

Baddeley, A. (1986) *Working Memory.* Oxford: Oxford University Press.

Baddeley, A. (1990) *Human Memory,Theory and Practice*. Hove: Lawrence Erlbaum Associates.

Baddeley, A. (1996) *Your Memory*. London: Prion.

Baddeley, A.,Thomson, N. & Buchanan, M. (1975) Word length and the structure of short-term memory. *Journal of Verbal Learning and Verbal Behaviour,* 14, 575-589.

Baker-Ward, L., Ornstein, P., Holden, D. (1984) The expression of memorization in early childhood. *Journal of Experimental Child Psychology*, 37, 555 - 575.

Ballard, P. (1920) *Mental and Group Tests*. London: University of London Press.

Baltes, P. (1991) The many faces of human aging. *Psychologica Med*, 21(4) 837 - 854.

Bannatyne, A.D. (1969) A comparison of visuo-spatial and visuo-motor memory for designs and their relationship to other sensori-motor and psycholinguistic variables. *Journal of Learning Disabilities,* September.

Bannatyne, A.D. (1971) *Language, Reading and Learning Disabilities.* Illinois: Charles C. Thomas Publishers.

Barody, A. (1987) *Children's Mathematical Thinking.* New York: Columbia Teachers' College Press.

Baron, T. & Sternberg, R. (1987) *Teaching Thinking Skills, Theory and Practice*. New York: Freeman.

Bartlett, F. (1932) *Remembering*: *A Study in Experimental and Social Psychology*. Cambridge: Cambridge University Press.

Barwise, J. & Etchemendy, J. (1995) *Hyperproof.* CSLI Publications,Cambridge: Cambridge University Press.

Bath, J., Chinn, S., & Knox, D. (1986) *The Test of Cognitive Style in Mathematics*. East Aurora, New York: Slosson.

Beard, R. (1965) The structure of perception: A factorial study. *British Journal of Educational Psychology*, 35 (Pt. 2), 210.

Bell, A., Swan, M., & Taylor, G. (1981) Choice of operation in verbal problems with decimal numbers. *Educational Studies in Mathematics*, 12, 399 - 420.

Bellezza, F. (1981) Spontaneous use of mnemonics devices by the elderly individuals. *Review of Educational Research*, 51, 247.

Bentzen, F. (1966) Sex ratios in learning and behavior disorders, *The National Elementary School Principal,* XLVI (2) Nov.

Benyon, D., Milan, S. & Murray, D. (1987) *Modelling users' cognitive abilities in adaptive systems.* Paper presented at the fifth Empirical Foundations of Software Sciences (EFISS) Conference, Riso National Laboratory, Denmark.

Best, D.L. (1993) Inducing children to generate mnemonic organizational strategies. *Journal of Developmental Psychology*, 29(2) 324 -336.

Beveridge, M. & Parkins E. (1987) Visual representation in analogical problem solving. *Memory and Cognition*, 15 (3) 230-237.

Birenbaum, M., Kelly, A., Levikeren, M. (1994) Sex differences in spatial abilities. *Intelligence*, 19 (1) 51 -64.

Bjorklund, D. & Bernholtz, D. (1992) The role of IQ expertise and motivation in the recall of familiar information, *Contemporary Educational Psychology*, 17 (4) 340-353.

Bleasedale, F. (1987) Concreteness - dependent associative priming. *Journal of Experimental Psychology: Memory & Cognition,* 13, 582 - 594.

Bloomfield, L.(1993) *Language*. New York: Holt, Rhinehart & Winston.

Borowski, J. & Peck, V. (1986) Causes and consequences of metamemory in gifted children. In R. STERNBERG & J. DAVIDSON (Eds), *Conceptions of Giftedness*, 182-200. Cambridge, England: Cambridge.

Bousefield, W. (1953) The occurrence of clustering in recall of randomly arranged associates. *Journal of General Psychology*, 49, 229 - 240.

Bower, G. & Winzenz, D. (1970) Comparison of associative learning strategies. *Psychonomic Science*, 20, 119.

Bracey, G. (1996) Differences in cognition and learning styles, sex and mathematics, revisited. *Phi Delta Kappan* 75 (5), 417 - 418.

Bransford, J.(1984) *The Ideal Problem Solver.* New York: W.H. Freeman & Co.

Bransford, J., Franks, J. , & Morris, C. (1979) Some general constraints on learning and memory research. In L. CERMAK & F. CRAIK (Eds.), *Levels of processing in human memory*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Bray, N.W., Saarnio, D., Borges, L. & Hawk, L. (1994) Intellectual and developmental differences in external memory strategies. *American Journal on Mental Retardation*, 99, 19-31.

Bray, N.W. Saarnio, D., Borges, L. & Hawk, L. (1997) Cognitive competencies and strategy use in individuals with mild retardation. In W.E. MACLEAN JR. *Handbook of mental deficiency, psychological theory and research* (3rd ed., 197-217). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Brna, P., Cox, R. and Good, J. (1996) Learning to Think with Diagrams 14 Questions to Consider. *AI Review,* 1-19.

Broadbent, D.E. (1958) *Perception and Communication.* New York: Pergamon Press.

Brown, A. (1978) Knowing when, where, and how to remember: a problem of metacognition, In R. GLASER (Eds.), *Advances in Instructional Psychology*, 1, Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Brown, A. & Kane, M. (1988) Pre-school children can learn to transfer: Learning to learn and learning from example. *Cognitive Psychology*, 20, 493-523.

Brown, A & Smiley, S (1978) The development of strategies for studying texts. *Child Development*, 49, 1076 - 1088.

Bryden and George (1990) Sex differences and the role of figural complexity in determining the rate of mental rotation. *Perceptual and Motor Skills*, 70, 467-477.

Burt, C. (1950) *The Backward Child.* London: University of London Press.

Butterfield, E., Belmont, J., & Peltzman, D. (1971) Effects of recall requirements on acquisition strategies. *Journal of Experimental Psychology*, 90(2), 347 - 348.

Byrne, R. & Johnson-Laird, P. (1989) Spatial reasoning. *Journal of Memory & Language*, 28, 564-575.

Camp, C., Kramer, J. & Markley, R. (1983) What the do-nothing control group does. *American Journal of Psychology*, 96 (4), 503-511.

Campagnoni, F. & Ehrlich, K. (1989) Information retrieval using a hypertextbased help system. *ACM Transactions on Information Systems*, 7(3), 271 - 291.

Carpenter, T., Corbett, M., Kepner, H., Lindquist, M., & Reys, R.(1980) Solving word problems: Results and implications from national assessment. *Arithmetic Teacher*, 28 8 - 12.

Case, L., Harris, K., & Graham, S., (1992) Improving the mathematical problem solving skills of students with learning disabilities: Self-instructional strategy development. *The Journal of Special Education,* 21, 1-19.

Catrambone, R (1996) Generalising Solution Procedures Learned From Examples. *Journal of Experimental Psychology: Learning, Memory and Cognition,* 22 (4), 1020-1031.

Cavanaugh, J. & Perlmutter, M. (1982) Metamemory. *Child Development*, 52 (1), 11 - 28.

Cawley, J. & Goodman, J (1969) Arithmetic problem solving: A demonstration with the mildly handicapped. *Exceptional Children*, 35, 83 - 88..

Cerella, J. (1991) Age effect may be global, not local: Comment on Fisk and Rogers. *Journal of Experimental Psychology: General,* 120, 215 - 223.

Cermak, L. S. (1983) Information processing deficits in children with learning disabilities. *Journal of Learning Disabilities*, 16, 599 - 605.

Chan, L. (1994) Relationship of motivation, strategic learning, and reading achievement in Grades 5,7, and 9. *Journal of Experimental Education,* 62(4), 319 - 339.

Chi, M.T.H. (1978) Knowledge structures and memory development In R.S. SIEGLER *Children's Thinking: What develops*? Hillsdale, N.J: Lawrence Erlbaum Associates.

Chi, M., Bassok, M., Lewis, M., Reimann, P. & Glaser, R.(1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science,* 13, 145-182.

Chinn, S. and Ashcroft, R. (1998) *Mathematics for Dyslexics 2nd ed.* London: Whurr.

Chisko, A.and Davis, L.(1986) The analytic connection: Problem solving across the curriculum. *Mathematics Teacher*, 79(8) 592-596.

Cofer, C. (1975) *The Structure of Human Memory.* San Francisco: Freeman.

Cohen, S. & Stover, G. (1981) Effects of teaching sixth-grade students to modify format variables of math word problems. *Reading Research Quarterly*, 16, 175 - 200.

Cornoldi, C. & Debeni, R. (1991) Memory for discourse. *Journal of Applied Psychology*, 5(6) 511 - 518.

Cox, R. (1996a) *Analytic reasoning with multiple external representations.* Ph.D.Thesis, University of Edinburgh.

Cox, R. (1996b) The role of externalisation in reasoning with self-constructed representations. *IEE Digest,* 1-7.

Cox, R.and Brna, P. (1995) Supporting the use of external representations in problem solving. *The Journal of Artificial Intelligence in Education,* 6(2/3), 239-302.

Cox, R and Inder, R. (1994) Words or pictures. *Interact: European Platform for Interactive Learning* 2.1., November, 4-5.

Cox, R. Stenning, K. & Oberlander, J. (1994) Graphical effects in learning logic: reasoning, representation and individual differences. In RAM, A. & EISELT, K. (Eds), *Proceedings of the 16th Annual Conference of the Cognitive Science Society* (237 - 242). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Cox, R., Stenning, K., & Oberlander, J. (1995a) The effect of graphical and sentential logic teaching on spontaneous external representation. *Cognitive Studies: Bulletin of the Japanese Cognitive Science Society*, 2(4), 1 - 2.

Cox, R., Stenning, K., & Oberlander, J. (1995b) The effect of interactive multimedia interfaces upon representation selection. In J. LEE (Ed.), *Proceedings of the First International Workshop on Intelligence and Multimedia in Multimedia Interfaces: Research and Applications.* IMMI-1, Edinburgh, July.

Craik, F. (1973) “Levels of Analysis” view of memory. In P. PLINER et al. (Eds.), *Communication and affect*: *language and thought*. New York: Academic Press.

Craik, F. & Lockheart, R.(1972) Levels of Processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behaviour*, 11, 671 - 684.

Crawford, M., Herrmann, D., Holdsworth, M., Randall, E. & Robbins, E. (1992) Gender - Linked Differences in Everyday Memory Performance. *British Journal of Psychology*, 83, 221 - 231.

Cronbach, L. & Snow, R. (1977) *Apptitudes and Instructional Methods*: A Handbook on Research on Interactions. New York: Irvington.

Crovitz, H. (1979) Story method based on airplane list in which the 10 words to be remembered were embedded in a story. *Cortex*, 15, 225 .

Cummins, D., Kintsch, W., Reusser, K. & Weiner, R.(1988) The role of understanding in solving word problems. *Cognitive Psychology, 20*, 405-438.

Curry, L (1983) An organisation of learning styles theory and constructs. *ERIC Document 235: 185.*

Daneman, M. & Carpenter, P.(1980) Individual differences integrating information between and within sentences. *Journal of Experimental Psychology*: *Learning, Memory & Cognition*, 9, 561 - 584.

Dansereau, D. F., Long, G., McDonald, B., & Atkinson, T.(1975) *Learning Strategies Inventory, Development and Assessments* (Air Force Human Resources Laboratory). Colorado: Lowry Air Force Base.

Dansereau, D. F. (1978) The Development of a Learning Strategies Curriculum, In H. O’NEIL JR, *Learning Strategies*. New York: Academic Press.

Das, J.(1988) Implications for School Learning, in R. SCHMECK (Ed.), *Learning Strategies & Learning Styles.* New York: Plenum Press.

Davis, J. & Cochran, K. (1989) An information processing view of field dependence. *Early Child Development* 51, 31 - 47.

Davis, P. & Hersh, R. (1981) *The Mathematical Experience*. Brighton: Harvester Press.

Davis, G. & Proctor, J. (1976) The Recall of Concrete and Abstract Sentences as a Function of Interpolated Task. *British Journal of Psychology*, 67, 63 - 72.

Davis, R. (1961) Information content in recognition and recall. *Journal of Experimental Psychology*, 61, 422 - 429.

Day, R. (1988) Alternative representations. In G.H. BOWER (Ed.), *The psychology of learning and motivation*, 22, 262-305. New York: Academic Press.

DeCorte, E. & Verschaffel, L. (1985). Working with simple word problems in early mathematics instruction. In L. STREETLAND (Ed.), *Proceedings of the Ninth International Conference for the Psychology of Mathematics Education, 1, Individual contributions,* 304-309. University of Utrecht.

DeCorte, E.,Verschaffel, L, & DeWin, L. (1985). Influence of rewording verbal problems on children's problem representations and solutions. *Journal of Educational Psychology*, 77, 460-470.

DeGroot, A.(1989) Representational aspects of word imageability and word frequency as assessed through word association. *Journal of Experimental Psychology: Learning Theory & Cognition,* 15, 824 - 845.

DelGiorno, W., Jenkins, J., & Bausell, R. (1974) Effects of recitation in the acquisition of prose. *Journal of Educational Research*, 67, 293-294.

Deloache, J. (1989) The development of representation in young children. In REESE (Ed.), *Advances in Child Development and Behavior*, 22, 1-39. New York: Academic Press.

Denno, D. (1983) Neuropsychological and early maturation correlates of intelligence. *ERIC Document 234 920*, *August*.

Dewey, J. (1933) *How We Think*. Chicago: D. C. Heath

DiVesta, F., Schultz, C. & Dangel, I. (1973) Passage organization and imposed learning strategies in comprehension and recall of connected discourse. *Memory & Cognition*, 1, 471 - 476.

Douglas, L. (1981) *A developmental study of rehearsal strategies in the serial recall of learning of disabled and normal children*. Paper, Atlanta.

Douglas, G & Riding, R.J. (1994) Cognitive style and gender differences in drawing from memory versus copying in 11-year old children. *Educational Psychology,* 14, 493 - 496.

Dror, I. and Kosslyn, S. (1994) Mental imagery and aging. *Psychology and Aging,* 9(1), 90-102.

Dykstra, R. (1966) Auditory discrimination abilities and beginning reading achievement. *Reading Research Quarterly*, 1, 5 - 34.

Ehri, L., Deffner, N., & Wilce, L. (1984) Pictorial mnemonics for phonics. *Journal of Educational Psychology,* 76(5), 880 - 893.

Ehrman, M. & Oxford, R. (1990) Adult language learning styles and strategies. *The Modern Journal,* 74, 312 - 327.

Ehrman, M. & Oxford, R. (1990b) Effects of sex differences, career choice, and psychological type on adult's language learning strategies. *Modern Language Journal*, 74, 311 - 327.

Ehrman, M., & Oxford, R. (1995) Cognition plus: Correlates of language learning success. *The Modern Language Journal*, 79, (1), 67 - 89.

Eisner, E (1997) Cognition and representation. *Phi Delta Kappan,* 78(5), 349-353.

Entwistle, N. (1981) *Styles of Learning and Teaching*. Chichester: Wiley.

Ernest, C.H. & Paivio, A. (1971) Imagery and verbal associative latencies as a function of imagery ability. *Canadian Journal of Psychology*, 25, 83 - 90.

Eysenck, M. W. (1977) *Human Memory*: *Theory, research and individual differences.* Oxford, England: Pergamon.

Eysenck, M.W. (1995) *Cognitive Psychology*: *A Student's Handbook.*: Hove: Lawrence Erlbaum Associates.

Eysenck M. W. (1998) *Individual Differences: Normal and Abnormal.* Hove: Psychology Press.

Fabricus, W.V. and Cavalier, L.(1989) The role of causal theories about memory strategy choice. *Child Development*, 60, 298 - 308.

Flavell, J. (1971) What is memory development? *Memory and Human Development,* 14, 272 - 286.

Flavell, J. (1978) The Development of Knowledge about Visual Perception in C. KEASY (Ed.), *Nebraska Symposium in Motivation*, 43 - 76. University of Nebraska Press: Lincoln.

Flavell, J. & Wellman, H. (1977) Metamemory. In R. KAIL & J. HAGAN (Eds.), *Perspectives on the Development of Memory and Cognition.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Fletcher, K. & Bray, N. (1997) Instructional and contextual effects on external memory strategy use in young children. *Journal of Experimental Child Psychology,* 67, 204 - 222.

Fox, P. (1964) Stimulation and prediction of verbal recall and misrecall. *Journal of Experimental Psychology*, 68, 321 - 322.

Frank, B. & Keene, D. (1993) The effect of learners' field independence, cognitive strategy instruction, and inherent word - list organization on free - recall, memory and strategy use. *Journal of Experimental Education*, 62 (1) 14 - 25.

Franks, J. & Bransford, J. (1972) The acquisition of abstract ideas. *Journal of Verbal Learning & Verbal Behavior*, 11, 311 - 315..

Fransden, A. & Holden, J. (1969) Spatial visualization in solving verbal problems. *The Journal of Psychology*, 73, 229 - 233.

Frase, L.T. (1969) Structural analysis of the knowledge that results from thinking about text. *Journal of Educational Psychology Monograph*, 60.

French, C and Colman, A.(1995) *Cognitive Psychology.* London: Longman Group Ltd.

Fridja, N. & Elshout, J. (1975) Problem Solving and Thinking. In J. MICHON et al. (Eds.), *Handbook of psychonomics*, 413 - 446. Deventer: Van Loghum Slaterus.

Gaddes, W. H. (1983) Applied educational neuropsychology: Theories and problems. *Journal of Learning Disabilities*, 16(9), 511 - 514.

Gaddes, W.H. & Edgell, D. (1995) *Learning Disabilities and Brain Function*: *A Neuropsychological Approach, 3rd Edition*. New York: Springer-Verlag.

Gagne, R. (1970) *The Conditions of Learning and Theory of Instruction*. New York: Holt, Rinehart & Winston.

Gagne, R. (1973) Educational technology as technique. In INTRODUCTION TO EDUCATIONAL TECHNOLOGY, *Educational Technology Review Series*, 1. New Jersey: Educational Technology Publications.

Galton, F. (1883) *Inquiries Into Human Faculty and its Development.* London: MacMillan.

Garceau, S., Oral, M., & Rahn, R. (1988) The influence of data presentation mode on strategic decision making performance. *Computer Operations Research,* 15, 479 - 488.

Gardner, R., Jackson, D., & Messick, S. (1960) Field articulation, constricted-flexible control, and the abilities of flexibility of closure and spatial relations and orientation, *Psychological Issues*, 2(4), No. 8, Part 3.

Gates, A. (1917) Recitation as a factor in memorizing. *Archives of Psychology*, 7 (Whole No. 40), 1 - 104.

Gathercole, S. & Baddeley, A. (1989) Development of vocabulary in children and short-term phonological memory. *Journal of Memory and Language*, 28, 200 - 213.

Goldschmidt, G. (1991) The dialectics of sketching. *Creative Research Journal*, 4, 123 - 143.

Goran-Nilsson, L. (1987) Motivated memory: Disassociation between performance data and subject reports. *Psychological Research*, 49, 183 - 189.

Gorman, A.M. (1961) Recognition memory for nouns as a function of abstractness and frequency. *Journal of Experimental Psychology*, 61, 23 - 29.

Graham, S. & Harris, K. (1994) The role and development of self-regulation in the writing process. In D. SCHUNK & B. ZIMMERMAN (Eds.), *Self-regulation of learning and performance: Issues and educational applications,* 203 - 228. Hillsdale, NJ: Lawrence Erlbaum Associates.

Greeno, J. (1977) Process of understanding in problem solving. In N. CASTELLAN et al. (Eds.), *Cognitive theory* 2, 43 - 83. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Greeno, J. and Hall, R.(1997) Practicing representation. *Phi Delta Kappan*, 18, 361 - 367.

Greeno, J. and Riley, M. (1987) Processing and development of understanding. In R.E. WEINERT and R.H. KlUEVE (Eds), *Metacognition, Motivation and Understanding,* 289 - 313. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Gregory, R. (1966) *Eye & Brain - The Psychology of Seeing*. London: World University Library.

Groninger, L. (1966) Natural language, mediation and covert rehearsal in short - term memory. *Psychonomic Science*, 5, 135 - 136.

Gruneborg, M. (1995) http:// www.Mindtools.com/forlangu.html

Gruneburg, M.(1993) The facilitating effects of mnemonic strategies on two learning tasks in learning disabled adults. *Neuropsychological Rehabilitation,* 4 (3), 241 - 254.

Hall, V. Bailey, J & Tillman, C.(1997), Can student-generated illustrations be worth ten thousand words? *Journal of Educational Psychology,* 89 (4), 677 - 681.

Hall, R., Kibler, D., Wenger, E., & Truxas, C. (1989) Exploring the episodic structure of algebra story problem solving. *Cognition and Instruction*, 6 (3), 223 - 283.

Halpern, D.F. (1986) *Sex Differences in Cognitive Abilities.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Halpern, D.F. (1989) The disappearance of cognitive gender differences. *American Psychologist,* 44 (8), 1156 - 1158.

Hamaker, C., & Essen, G. van (1989). *Making drawings of simple addition and subtraction word problems*. Unpublished manuscript. University of Amsterdam, Department of Psychology, The Netherlands.

Harris, J. (1992) Ways to help memory. In B. WILSON and N. MOFFAT (Eds.), *Clinical management of memory problems,* 2nd ed., 59 - 85. London: Chapman Hall.

Hart, R.P. (1992) Recall of clustered and unclustered word lists in elderly adults. *Journal of Clinical Psychology,* 48 (3), 341 - 354.

Hebb, D. O. (1949) *The Organization of Behaviour: A Neuropsychological Theory.* New York: Wiley.

Higbee, K.L. (1994) More motivational aspects of an imagery mnemonic. *Applied Cognitive Psychology,* 8 (1), 1 - 12.

Hinton, G. (1979) Some demonstrations of the effects of structural descriptions in mental imagery. *Cognitive Science*, 3, 231-251.

Hofmann, H (1996) Heuristic versus algorithmic orientation as a cognitive style in mathematical problems. *Zeitschrift fur Padagogische Psychologie,* 10 (2), 77 - 84.

Holzman, P & Klein, G. (1954) Cognitive system principles of levelling and sharpening. Individual differences in visual - time error assimilation effects. *Journal of Psychology*, 37, 105 - 122.

Honeck, R. (1973) Interpretation vs. structural effects on semantic memory. *Journal of Verbal Learning & Verbal Behaviour*, 12, 448 - 455.

Hulme, C. (1984) Developmental differences in the effects of acoustic similarity on memory span. *Developmental Psychology*, 20, 650 -652.

Hulme, C. Maugham, S. & Brown, G. (1991) Memory for familiar and unfamiliar words. *Journal of Memory and Language*, 30, 685 - 701.

Hulme, C. & Tordoff, V. (1989) Working Memory Development: The effects of speech rate, word length and acoustic similarity on serial recall. *Journal of Experimental Child Psychology,* 48, 1- 19.

Hunt, J. (1971) Parent and child centers: Their basis in the behavioral educational sciences. *American Journal of Orthopsychiatry*, 4, 13 - 38.

Hunt, E., Lunneborg, C & Lewis, J. (1975) What does it mean to be high verbal? *Cognitive Psychology*, 7, 194 - 227.

Huntington, D. (1994) *Instruction in concrete, semi-concrete, and abstract representation as an aid to the solution of relational problems by adolescents with learning disabilities.* Unpublished doctoral dissertation, University of Georgia, Athens.

Hyde, J.& Fennema, E. (1990) *Gender differences in mathematics performance and affect: Results of two meta-analyses*. Paper presented at the annual meeting of the American Educational Research Association, Boston.

Intons - Peterson, M. J. & Fournier, J. (1986) External and internal memory aids. When and how often do we use them. *Journal of Educational Psychology*: *General*, 115, 267 - 280.

Jenkins, J.J. & Russell, D. (1952) Acoustic clustering during recall. *Journal of Abnormal & Social Psychology,* 47, 818 - 821.

Jennings, F. and Benyon, D. (1991) Adapting systems to differences between individuals. *Acta Psychologica,* 78, 243 - 256.

Jensen, A. & Frederiksen, J. (1973) Free recall of categorized and uncategorized lists. *Journal of Educational Psychology,* 3, 304 - 313.

Jensen, A. & Rohwer, W. (1963) Verbal mediation in paired-associate serial learning. *Journal of Verbal Learning and Verbal Behavior*, 1, 346 - 352.

Johnson, E.S. and Mead, A.C. (1987) Developmental patterns of spatial ability - an early sex difference. *Child Development,* 58, 725 - 740.
Johnson-Laird, P. and Byrne, R (1991) *Deduction*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Jones, G. (1988) Images, predicates and retrieval cues. In M. DENIS et al. (Eds.), *Cognitive and Neuropsychological Approaches to Mental Imagery*, 89 - 98. Dodrecht.

Kagan, J. (1965) Impulsive and Reflective Children: Significance of Conceptual Tempo. In: J. KRUMBOLTZ (Eds.), *Learning and the Educational Process.* McNally: Chicago.

Kail, R. (1979) *The Development of Memory in Children.* New York: W.H. Freeman.

Kail, R. (1984) *The Development of Memory in Children.* New York: W. H. Freeman.

Kantowski, M.G. (1980) Some thought on teaching for problem solving in school mathematics. *National Council of Teachers of Mathematics,* 195 - 203.

Kieras, D. & Bovair, S. (1984) The role of a mental model in learning to operate a device. *Cognitive Science*, 8, 255 - 273.

Kingsears, M. E. (1992) Toward independence with keyword mnemonics. *Remedial & Special Education,* 13(5), 22 - 33.

Knowlton, B. J. and Squire, L. (1993) The Learning of Categories: Parallel Brain Systems for Item Memory and Category Knowledge. *Science,* 269, 1747 - 1749.

Kogan, N. (1976) *Cognitive Style in Infancy and Early Childhood.* New Jersey: Lawrence Erlbaum Associates.

Kolb, D. (1976) *The Learning Style Inventory: Technical Manual*. McBer & Company: Boston.

Kolb, D. (1979) *Organizational Psychology: An Experiential Approach, 3rd ed*. Prentice Hall: New Jersey.

Kosslyn, S. (1980) *Image and Mind.* Cambridge, MA: Harvard University Press.

Kosslyn, S. (1981) The medium and the message in mental imagery: a theory. *Psychological Review*, 88, 46 - 66.

Kosslyn, S., Margolis, J., Barrett, A., Goldknopf, E., and Daly, P., (1990) Age difference in imagery abilities. *Child Development*, 61, 995-1010.

Kotovsky, K & Fallside, D. (1989) Representation and transfer in problem solving. In D. KLAHR & K. KOTOVSKY (Eds.), *Complex information processing. The contributions of Herbert A. Simon*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Koussy, A. (1955): *The Directions of Research in the Domain of Spatial Abilities*. Centre National de la Recherche Scientifique: Paris.

Krinsky, R. & Krinsky, S.G. (1994) The peg word mnemonic facilitates immediate but not long - term memory in 5th grade children. *Contemporary Educational Psychology,* 19 (2), 217 - 229.

Krutetskii, V. (1976) In KILPATRIC J, WIRZUP I (Eds.), *The Psychology of Mathematical Abilities in School Children*. Chicago: University of Chicago Press.

Kulpa, Z. (1997) Diagrammatic representation and reasoning. *Graphics and Vision,* 6(1), 5 - 24.

Kurtz, B. & Weinert, F. (1989) Metacognition, memory and performance, and causal attributions in gifted and average children. *Journal of Experimental Child Psychology,* 48, 45 - 61.

Laird, J., Newell, A., & Rosenbloom, P.(1987) SOAR: An architecture for general intelligence. *Artificial Intelligence*, 33, 1 - 64.

Larkin, J. & Simon, H. (1987) Why a diagram in (sometimes) worth ten thousand words. *Cognitive Science*, 11, 65 - 100.

Larsen - Freeman, D & Long, M. (1991) *An Introduction to Second Language Acquisition Research*. Oxford University Press: Oxford.

Laursen, P (1997) The impact of aging on cognitive functions. *Acta Neurologica Scandinavia,* 96 (5172), 1 - 75.

Lenz, K. (1996) *Teaching Learning Strategies to Adolescents and Adults with Learning Disabilities.* Pro-Ed, Inc.: Texas.

Lesevre, N. (1966) Les Movements Oculaires d'Exploration. *World Blind Bulletin*, 1, Spring.

Lewis, B.N. (1976) Avoidance of Aptitude Treatment Trivialities, In S. MESSICK (Ed.), *Individuality in Learning*, Jossey-Bass: San Francisco.

Linn, M. & Hyde, J. (1989). Gender, mathematics and science. *Educational Researcher,*18, 17-19, 22 - 27.

Linn, M & Petersen, A. (1985) A meta-analysis in spatial ability, In J. HYDE & M. LINN (Eds.), *The Psychology of gender: advances through meta-analysis, 67 - 101.* Baltimore Maryland: John Hopkins University Press.

Liu, C. & Kennedy, J. (1994) Symbolic forms can be mnemonics for recall. *Psychonomic Bulletin and Review,* 1 (64), 494 - 498.

Loftus, E. (1980) *Memory, Reading.* MA: Addison-Wesley.

Lohse, G., Biolsi, K., Walker, N., & Rueter, H. (1994) A classification of visual representations. *Communications of the ACMV*, 37 (12), 36 - 49.

Lovelace, E. & Twohig, P. (1990) Healthy older adults' perceptions of their memory functioning and use of Mnemonics. *Bulletin of the Psychonomic Society,* 28 (2), 115 - 118.

Lowe, R. (1996) Search strategies and inference in the exploration of scientific diagrams. *Educational Psychology*, 9 (11), 27 - 44.

Luria, A. & Tzvetkova, L. (1966) *Neuropsychological Analysis of Problem Solving by Patients With Local Brain Damage*. Moscow: Prosveshchenie Publishers.

Lynn, R. (1994) Sex differences in intelligence and brain size. *Personality and Individual Differences,* 17 (2), 257 - 271.

Maccoby, E. (1966) *The Development of Sex Differences.* Stanford. California: Stanford University Press.

Maccoby, E. & Jacklin, C. (1974) *The Psychology of Sex Differences.* California: Stanford University Press.

Macleod, C., Hunt, E., & Matthews, N. (1978) Individual differences in the verification of sentence-picture relationships. *Journal of Verbal Learning and Verbal Behavior*, 17, 493 - 507.

Maier, N. (1970) *Problem Solving and Creativity*. California: Brooks/Cole.

Marosi, E. (1993) Sex differences in EEG coherence in normal children. *International Journal of Neuroscience,* 72 (1-2), 115 - 121.

Masters, M. (1998) The gender difference on the mental rotations test. *Memory and Cognition,* 26 (3), 444 - 448.

Masur. E., McIntyre, C. & Flavell, J. (1973) Developmental changes in appointment of study time in a multi-trial free-recall task. *Journal of Experimental Child Psychology*, 15, 232 - 246.

Matthews, G & Dorn, L. (1995) Cognitive and Attentional Processes. *International Handbook of Personality & Intelligence.* New York: Plenum Press.

Matsuno, J. (1987) Cognitive style and representational strategies in categorical syllogistic reasoning. *Tohoku Psychologica Folia*, 46 (1-4), 97 - 102.

Mayer, R. (1975) Forward transfer of different reading strategies evoked by testlike events in mathematics. *Journal of Educational Psychology*, 67 (2), 165-169.

Mayer, R. (1976) Integration of information during problem solving due to a meaningful context of learning. *Memory & Cognition*, 4, 603 - 8.

McConkie, G. & Meyer, B. (1974) Investigation of reading strategies: a replication of pay-off condition effects. *Journal of Reading Behavior*, 6, 151 - 158.

McConkie, G., Rayner, K., & Wilson, J. (1973) Experimental manifestation of reading strategies. *Journal of Educational Psychology*, 65(1), 1 - 8.

McCusker, L., Hilinger, & Bias (1981) Phonological, recoding and reading. *Psychological Bulletin*, 89, 217-245.

McGeoch, J (1932) Meaningful relation and retroactive inhibition. *American Journal of Psychology,* 43, 579 -588.

McGlone, J.(1981) Sexual variations in behaviour during spatial and verbal tasks. *Canadian Journal of Psychology,* 35, 277 - 282.

McGuinness, C. (1986) Problem representation: The effects of spatial arrays. *Memory & Cognition*, 14, 270-280.

Messick, S. (1976) *Personal Styles and Individuality in Learning.* San Francisco: Jossey-Bass.

Milgram, N. (1967) Verbal context versus visual compound in paired-associate learning by children. *Journal of Experimental Child Psychology*, 5, 597 - 603.

Miller, G.A. (1956) The magical number seven, plus or minus two: Some limits on our capacity to process information. *Psychological Review*, 63, 81 - 97.

Miller, G. A., Gallant, G. & Pribram, K. (1960) *Plans and the Structure of Behavior.* New York: Holt.

Mishkin, M. (1983) Object vision and spatial vision. *Perception*, 20(3), 307 - 314.

Miyake, N & Norman, D. (1979) To ask a question one must know enough to know what is not known. *Journal of Verbal Learning & Verbal Behaviour*, 18, 357 - 364.

Moeser, S. (1974) Memory for meaning and wording in concrete and abstract sentences. *Journal of Verbal Learning and Verbal Behavior*, 13, 682 - 697.

Montague, M. (1992) The effects of cognitive and metacognitive strategy instruction on mathematical problem solving of middle school students with learning disabilities. *Journal of Learning Disabilities*, 25, 230 - 248.

Montague, M.(1997) Cognitive strategy instruction in mathematics for students with learning disabilities. *Journal of Learning Disabilities,* 30 (2), 164 - 177.

Montague, M. & Applegate, B. (1993a) Mathematical problem-solving characteristics of middle school students with learning disabilities. *The Journal of Special Education*, 27, 175 - 201.

Montague, M., Applegate, B., & Marquand, K. (1993) Cognitive strategy instruction and mathematical problem-solving performance of students with learning disabilities. *Learning Disabilities Research & Practice*, 8, 223 - 232.

Montague, M. & Bos, C. (1986) The effect of cognitive strategy training on verbal math problem solving performance of learning disabled adolescents. *Journal of Learning Disabilities*, 19, 26 - 33.

Morley, M. E. (1965) *The Development and Disorders of Speech in Childhood.* London: E & S Livingstone.

Nass, R. D. (1993) Sex Differences in Learning Abilities and Disabilities. *Annals of Dyslexia,* 43, 61 - 77.

Neisser, U. (1967) *Cognition and Reality*. San Francisco: Freeman.

Nelson, D. L. (1993) Implicit memory and inhibition. *Journal of Memory and Language,* 32, 667 - 691.

Newell, A. (1958) Elements of a theory of human problem solving. *Psychological Review*, 65, 151 - 166.

Newell, A. (1990) *Unified Theories of Cognition*. Cambridge: Harvard University Press.

Newell, A and Simon, H. (1972) *Human Problem Solving*. Englewood Cliffs, New Jersey: Prentice Hall.

Noble, C.E. (1954) The familiarity - frequency relationship. *Journal of Experimental Psychology*, 47, 13 - 16.

Novick, L.R. (1990) Representational Transfer in Problem Solving. *Psychological Science*, 1(2), 128 - 132.

Oberlander, J., Cox, R., Monaghan, P., Stenning, K., & Tobin, R. (1996) Individual differences in proof structures following multimodal logic teaching. *Proceeding of the 18th Annual Conference of the Cognitive Science Society*, San Diego, July, Hillsdale, New Jersey: Lawrence Erlbaum Associates, 201 - 206.

Ornstein, R. (1972) *The Psychology of Consciousness.* New York: Viking.

Ornstein, R. (1977) *The Psychology of Consciousness,* 2nd Ed. San Diego, California: Harcourt, Brace & Javonovich.

Orton, A. (1992) *Learning Mathematics.* Cassell: London.

Oxford, R. L. (1990) *Language Learning Strategies*: What Every Teacher Should Know. New York: Harper & Row.

Oxford, R. L. (1993) Instructional implication of gender differences in language learning styles and strategies. *Applied Language Learning*, 4 (1 - 2) 65 - 94.

Oxford, R. & Cohen, A. (1992) Language learning strategies: Crucial issues in concept and classification, *Applied Language Learning* 3, 1 - 35.

Paivio, A. (1966) Latency of verbal association and imagery to noun stimuli as a function of abstractness and generality. *Canadian Journal of Psychology*, 20, 378 - 386.

Paivio, A (1968) A factor-analysis study of individual attributes and verbal learning. *Journal of Verbal Learning and Verbal Behavior*, 7, 41 - 49.

Paivio, A. (1969) Mental imagery in associative learning and memory. *Psychological Review*, 76, 241 - 263.

Paivio, A. (1971) *Imagery and Verbal Process.* New York: Holt.

Paivio, A. & Ernest, C. (1971) Imagery ability and visual perception of verbal and nonverbal stimuli. *Perception and Psychophysics*, 10, 429 - 432.

Paris, S. (1978) The development of inference and transformation as memory operations. In P. A. ORNSTEIN (Ed.), *Memory Development in Children*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Parmar, R. (1992) Protocol analysis of strategies used by students with mild disabilities when solving arithmetic word problems. *Diagnostique,* 117 (4), 227 - 243.

Parmar, R, Cawley, J. and Frazita, R. (1996) Word problem-solving by students with and without mild disabilities. *Exceptional Children,* 62 (5), 415 - 429.

Pask, G. (1972) A fresh look at cognition and the individual. *International Journal of Man-Machine Studies,* 4, 211 - 216.

Pask, G. (1976a) *Conversation, Cognition and Learning*: *A cybernetic theory and methodology.* Amsterdam: Elsevier.

Pask, G. (1976b) Styles and strategies of learning. *British Journal of Psychology*, 46, 128 - 148.

Pask, G. & Scott, B.(1972) Learning strategies and individual competence. *International Journal of Man - Machine Studies,* 4, 217 - 253.

Patterson, C. & Mischel, U. (1975) Plans to resist distraction. *Developmental Psychology*, 11 (3), 369 - 378.

Pelton, Leslee F. (1998) http// www.math.byu.edu/~lfrancis/readings302/ProbSolv.html.

Pemberton, L. et al. (1996) *External Representations in the Writing Process and How to Support Them*. AIEd 96 External Representations.

Penfield, W. and Roberts, L.(1959) *Speech and Brain Mechanisms.* Princeton, New Jersey: Princeton University Press.

Polich, J. & Schwartz, S. (1974) The effect of problem size on representation in deductive problem solving. *Memory & Cognition*, 2, 683 - 686.

Polya, G.(1945) *How to Solve It*: *A New Aspect of Mathematical Method, Second Edition*. Princeton University Press: New Jersey.

Polya, G. (1957) *How to Solve It*. New York: Doubleday-Anchor.

Polya, G. (1962) *Mathematical Discovery, Volume 1*. New York: Wiley.

Posgrow, S. (1992) A validated approach to thinking development for at-risk populations. In C. COLLINS & J. N. MANGIERI (Eds.), *Teaching thinking: An agenda for the 21st Century*, 87-101. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Postman, L. (1965) *Invariance in Learning and Retention*. Paper, New Orleans.

Postman, L., Stark, K. & Fraser, J. (1968) Studies of Learning to Learn: General transfer effects in the three stages of mediation. *Journal of Verbal Learning and Verbal Behavior*, 6, 659 - 664.

Postman, L. & Underwood, B. (1973) Critical issues in interference theory. *Memory & Cognition*, 2, 19 - 40.

Pribram, K. H. (1962) Discussion of session on interhemispheric integration in the visual system. In MOUNTCASTLE. Downer.

Proudfit, L. (1981) The examination of problem-solving processes by fifth grade children and its effects on problem-solving performance. *Dissertation Abstracts International, 41, 3932A*. (University Microfilms No. 8105942).

Pylyshyn, Z. (1973) What the mind's eye tells the mind's brain - A critique of mental imagery. *Psychological Bulletin*, 80, 1 - 24.

Rabbitt, P. (1990) Applied Gerontology: some problems, methodologies and data. *Applied Cognitive Psychology*, 4, 225 - 246.

Rasco, R. W. (1975) Imagery Instruction and Drawings in Learning Prose. *Journal of Educational Research,* 62 (2), 188 - 192.

Reed, S. Dempster, A. & Ettinger, M. (1985) Usefulness of analogous solutions for solving algebra word problems. *Journal of experimental psychology: Learning, Memory and Cognition,* 11, 106 - 125.

Reichman, S. & Grasha, A.(1974) A rational approach to developing and assessing the construct validity of a study. Learning Style Scales Investment. *Journal of Psychology*, 87, 213 - 223.

Reid, M. & Borkowski, J. (1987) Causal attributions of hyperactive children: Implications for teaching strategies and self control. *Journal of Educational Psychology*, 79, 296 - 307.

Reisberg, D. (1987) External representations and the advantages of externalising one's thoughts. *Proceedings of the Eight Annual Conference of the Cognitive Science Society*, New Jersey: Lawrence Erlbaum Associates..

Resnick, L. (1989) *Learning to think, thinking to learn*. Proceedings of OECD Conference. Oxford: Pergamon Press.

Rezler, A & Reznovic, V. (1981) The Learning Performance Inventory. *Journal of Applied Health*, 10, 28 - 34.

Richards, J. & DiVesta, F. (1974) Types and frequencies of questions in processing textual material. *Journal of Educational Psychology*, 68, 359 - 362.

Richardson, A. (1977) Verbaliser - Visualiser: A Cognitive Style Dimension. *Journal of Mental Imagery*, 1, 109 - 126.

Riding, R. (1991) *Cognitive Styles Analysis.* Birmingham, Learning and Training Technology.

Riding, R.J. & Buckle, C.F. (1990) *Learning Styles Training Performance.* Sheffield: Training Agency.

Riding, R. J., Buckle, C.E., Thompson, S., & Hagger, E. (1989) The computer determination of learning styles as an aid to individualised computer-based training. *Educational Training Technology International,* 26, 393 - 398.

Riding, R.J & Calvey, I (1981) The assessment of verbal-imagery learning styles and their effects on the recall of concrete and abstract prose passages by eleven-year old children, *British Journal of Psychology*, 72, 59 - 64.

Riding, R. J.& Cheema, I. (1991). Cognitive Styles - an overview and integration. *Educational Psychology,* 11, 193 - 215.

Riding, R. J.& Douglas, G. (1993). The effect of cognitive style and mode of presentation on learning performance. *British Journal of Psychology*, 63, 297 - 307.

Riding, R.J. & Dyer, V.A. (1980) The relationship between extraversion and verbal-imagery learning style in twelve-year old children. *Personality & Individual Differences*, 1, 273 - 279.

Riding, R.J. & Taylor, E.M. (1976) Imagery performance and prose comprehension in seven year old children. *Educational Studies*, 2, 21 - 27.

Riefer, D. & Rouder, J. (1992) A Multinomial Modeling Analysis of the Mnemonic Benefits of Bizarre Imagery. *Memory & Cognition*, 20 (6), 601 - 611.

Rigney, J. (1976) *On Cognitive Strategies for Facilitating Acquisition, Retention and Retrieval in Training and Education.* Technical Report No. 78, University of Southern California, Los Angeles, May.

Riley, M., Greeno, J.,& Heller, J. (1983) Development of children's problem-solving ability in arithmetic. In H. GINSBURG (Ed.), *The development of mathematical thinking,* 153-196. New York: Academic Press.

Rogers, C. (1952) *A Factorial Study of Verbal Fluency and Related Dimensions of Personality.* Ph.D. dissertation, University of London.

Rogers, W.T. (1991) Introduction to Special Section on Gender Differences in Achievement. *Alberta Journal of Educational Research*, 37 (3), 193 - 194.

Rohwer, W.D. Jr., Lynch, S., Levin, J., Suzuki, N. (1967) Pictorial and verbal factors in the efficient learning of paired associates. *Journal of Educational Psychology*, 58, 278 - 84.

Romberg, T. & Collis, K. (1985) Cognitive functioning and performance on addition and subtraction word problems. *Journal for Research in Mathematics Education*, 16, 375 - 382.

Ross, D. (1971) Retention and transfer of mediation set in paired-associate learning and educable retarded children. *Journal of Educational Psychology*, 62, 323 - 327.

Ross, J. & Lawrence, K. (1968) Some observations on new artifices. *Psychonomic Science*, 13, 107 - 108.

Ross, D., Ross, S. & Downing, M. (1973) Intentional training versus observational learning of mediation strategies in EMR children. *American Journal of Mental Deficiencies*, 78, 292 - 299.

Rothkopf, E. & Bisbicos, E. (1967) Selective, facilitative effects of interspersed questions in learning from written materials. *Journal of Educational Psychology*, 58, 56 - 61.

Rumelhart, D. & Norman, D. (1978) Accretion, tuning and restructuring. In COTTON, J. and KLATZKY, R. (Eds.), *Semantic Factors of Cognition*. NewYork: Lawrence Erlbaum. Associates.

Rundus, D. (1971) Analysis of rehearsal processes in free recall. *Journal of Experimental Psychology,* 89, 63 - 77.

Ruskai, M.R. (1991) Are there innate cognitive gender differences? *American Journal of Physics*, 59 (1), 11 - 14.

Sachs, J. (1967a) Recognition memory for syntactic and semantic aspects of connected discourse. *Perception and Psychophysics*, 2, 437 - 442.

Sachs, J. (1967b) *Recognition of semantic, syntactic and lexical changes in sentences*. Paper presented at Psychonomic Society Meetings, Chicago, Ill.,

Salame, P. & Baddeley, A. (1987) Noises unattended speech and short-term memory. *Ergonomics*, 30, 1185 - 1193.

Saloman, G. (1994) Interaction of media. *Cognition and Learning*. Hillsdale, New. Jersey.: Lawrence Erlbaum Associates.

Salthouse, T. (1985) Speed and behavior and its implications for cognition. IN J. BUREN and K. SCHARE (Eds.), *Handbook of Psychology of Aging,* 2nd ed., 400 - 426. New York: Van Nostrand Rheinhold.

Sarason, S. et al. (1960) *Anxiety in Elementary School Children.* New York: Wiley.

Sassure, F. (1983) *Courses in General Linguistics*. London: Duckworth.

Scandura, J. & Wells, J.(1967) Advanced organizers in learning abstract mathematics. *American Educational Research Journal*, 4, 295 - 301.

Schechter, S. (1991) Gender differences in apparent motor perception. *Perception,* 20 (3), 314 - 317.

Schmeck, R.R. (1983) Learning styles of college students. In R. F. DILLON & R.R. SCHMECK (Eds.), *Individual Differences in Cognition*, 1, 233 - 279. Academic Press: New York.

Schmeck, R.R. (1988) Individual differences and learning strategies. IN C. WEINSTEIN et al., *Learning and Study Strategies: Issues in Assessment, Instruction and Evaluation,* 171 - 191. New York: Academic Press.

Schmeck, R.R., Ribich, F. & Ramaniah, N. (1977) Development of a self-report inventory for assessing individual differences in learning processes, *Applied Psychological Measurement*, 1, 413 - 431.

Schneider, W. & Pressley, M. (1989) *Memory development between 2 and 20.* New York: Springer-Verlag.

Schweigert, W. (1994) *Research Methods & Statistics.* California: Brooks/Cole

Schoenfield, A.(1985) *Guidance to Find Solutions , Mathematical Problem Solving*. New York: Academic Press.

Schwanenflugel, P & Shoben, E (1983) Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 9, 82 - 102.
Schwartz, S.(1971) Modes of representation and problem solving: Well evolved is half solved. *Journal of Experimental Psychology*, 91 (2), 347 - 350.

Schwartz, S. & Fattaleh (1972) Representation in deductive problem solving: Well evolved in half solved. *Journal of Experimental Psychology*, 95, 343 - 348.

Scruggs, T. E., Mastropieri, M., Sullivan, G., & Hesser, L. (1992) Effects of Mnemonic Reconstruction on the Spatial Learning of Adolescents with Learning Disabilities. *Learning Disability Quarterly*, 15 (3), 154 - 162.

Scruggs, T. E., Mastropieri, M., Sullivan, G., & Hesser, L. (1993) Improving reasoning and recall learning. *Learning Disability Quarterly*, 16 (3), 233 - 240.

Shaywitz, M (1995) Sex differences in the functional organization of the brain for language. *Nature*, 373 (6515), 607 - 609.

Shepard, R. N. (1967) Recognition memory for words, sentences and pictures. *Journal of Verbal Learning and Verbal Behavior*, 6, 156 - 163.

Shibley - Hyde, J. & Linn, M.(1988) Gender differences in verbal ability: A meta-analysis. *Psychological Bulletin*, 104 (1), 53 - 69.

Siegel, A.& White, S. (1975) The development of spatial representation in congenitally blind and sighted subjects. *New Outlook for the Blind*, 4, 188 - 194.

Siegler, R. & Cowley, K. (1994) Constraints on learning in nonprivileged domains. *Cognitive Psychology*, 27, 194 - 226.

Simon, H. & Barenfeld, M. (1969) Information processing analysis of perceptual processes in problem solving. *Psychological Review*, 76, 473 - 483.
Simon, H. & Hayes, J. (1976) The understanding process: Problem isomorphs. *Cognitive Psychology*, 8, 165 - 190.

Simon, H., Pick Jr. H., Van Den Broek, P and Knill, D.(1992) *Cognition,Conceptual and Methodological Issues*. American Psychological Association: Washington,D.C.

Singley, M. et al. (1989). The algebra word problem tutor. In D. BIERMAN et al. (Eds), *Artificial Intelligence and education*. Proceedings of the 4th International Conference on AI and Education 267 - 275, May. Amsterdam: IOS.

Smith, I. M.(1964) *Spatial Abilities: The Educational and Social Significance.* London: University of London Press.

Spearman, C. (1946) Theory of general factor. *British Journal of Psychology*, 36 (3), 117 - 131.

Squire, L. (1987) *Memory & Brain.* New York: Oxford University Press.
Stenning, K. & Oberlander, J. (1995) A cognitive theory of graphical and linguistic reasoning. *Cognitive Science*, 19 (1), 97 - 140.

Sternberg, R.J. (1980) Representation and process in linear syllogistic reasoning, *Journal of Experimental Psychology: General*,109, 119 - 159.

Stewart, J. C. (1965) *An experimental investigation of imagery.* Unpublished Ph.D. thesis, Toronto.

Stoff, D. & Engle, M. (1971) The relationship among reported strategies, presentation rate and verbal ability and other effects on free recall learning. Journal of Experimental Psychology, 87, 423 - 428.

Strong, E. K., Jr. (1912) The effect of length series upon recognition memory. P*sychological Review*, 19, 447 - 462.

Svensson, L. (1977) On quantitative differences in learning, study skills and learning. *British Journal of Educational Psychology*, 47, 233 - 243.

Svensson, L. (1984) *Skill in Learning. The Experience of Learning*. In MARTON, F. et al. 56 - 70, Scottish Academic Press: Edinburgh.

Swanson, H. (1989) The effects of central processing strategies on learning disabled, mildly retarded, average and gifted children's elaborative encoding abilities. *Journal of Experimental Child Psychology*, 47, 270 - 397.

Talmadge, G. & Shearer, J. (1971) Interactive relationships among learner characteristics, types of learning, instructional methods and subject matter variables. *Journal of Educational Psychology*, 62, 31 - 38.

Tamir, P & Cohen, S. (1980) Factors that correlate with cognitive preferences of medical school teachers. *Journal of Educational Research*, 74 (2).

Templin, M. C. (1957) *Certain Language Skills in Children.* University of Minneapolis Press: Minneapolis.

Thackray, D.V. (1965) The relationship between reading readiness and reading progress. *British Journal of Educational Psychology*, 35, 252 - 254.

Thinus-Blanc, C and Gaunet, F (1997) Representation of space in blind persons: Vision as a spatial sense? *Psychological Bulletin*, 121 (1), 20 - 42.

Thorndike, E. (1898) Animal intelligence: An experimental study of the associative processes in animals. *Psychological Review, Monographs,* 8, 1 - 109.

Torgensen, J. (1977) The role of non-specific factors in the task performance of learning - disabled children. A theoretical assessment. *Journal of Learning Disabilities*, 10, 27 - 34.

Travers, J. (1993) *Effective Teaching, Effective Learning.* Chicago: Brown & Benchmark.

Tulving, E. (1962) Subject organization in free recall of unrelated words. *Psychological Review*, 69, 344 - 354.

Tulving, E. (1967) The effects of presentation and recall of material in free recall learning. *Journal of Verbal Learning and Verbal Behaviour*, 6, 175 - 184.

Tulving, E. (1968) Theoretical issues in free recall. In T.DIXON and D. HORNTON (Eds), *Verbal behaviour and general behaviour theory*. Englewood Cliffs, New Jersey: Prentice Hall.

Tulving, E. (1983) *Elements of Episodic Memory.* London: Oxford University Press.

Tulivng, E. & Pearlstone, Z. (1966) Availability versus accessibility information in memory for words. *Journal of Verbal Learning and Verbal Behavior,* 5, 381 - 391.

Turnure, J. & Thrulow, M. (1973) Verbal elaboration and the promotion of transfer of training in educable mentally retarded children. *Journal of Experimental Child Psychology*, 15, 137 - 148.

Tyler, L. (1965) *The Psychology of Human Differences*. Appelton - Century - Crofts: New York.

Underwood, B. J. (1963) Stimulus Selection in Verbal Learning. In C. COFER & B. MUSGRAVE (Eds), *Verbal Behavior and Learning*. McGraw-Hill: New York.

Underwood, B. J. (1964) Degree of learning and measurement of forgetting. *Journal of Verbal Learning and Verbal Behavior,* 112 - 129.

Vann, R. & Abraham, R. (1989) *Strategies of unsuccessful language learners*. Papers presented at the annual meeting of Teachers of English to Speakers of Other Languages, San Francisco, CA.

Van Essen, G. and Hamaker, C. (1990) Using self-generated drawings to solve arithmetic word problems. *Journal of Educational Research,* 83, 301 - 312.

Vernon, P. (1960) *Intelligence and Attainment Tests*. University of London Press: London.

Vernon, P. (1961) *The Structure of Human Abilities*. London: Methuen

Vitulli, W. F. (1991) Sex, modality and cognitive strategy effects on short term memory. *Perceptual & Motor Skills*, 1-3 (3), 899 - 903.

Volf, N. V. (1994) Sex differences in memorizing of dichotically-administered lists of words. *Zhurnal Vysshei Nervnoi Deyatelnosti*, 94 (1), 18 - 24.

Walter, W.G. (1953) *The Living Brain.* Norton: New York.

Wang, A. Y. and Thomas (1992) Long term retention under condition of intentional learning and the keyword mnemonic. *Bulletin of the Psychonomic Society*, 31(6), 545 - 547.
Watson, J. (1914) *Behavior: An Introduction to Comparative Psychology*. New York: Holt.

Weinstein, C. E. (1975) *Learning of Elaboration Strategies*. Unpublished Doctoral Dissertation, University of Texas at Austin.

Weinstein, C. E. Schulte, A., & Cascallar, E. (1983) The Learning and Studies Strategies Inventory (LASSI): *Initial Design and development. Technical Report*, U.S. Army Research Institute for the Social and Behavior Sciences. Alexandria, VA.

Wellman, H. (1977c) Preschooler's understanding of memory relevant variables. *Child Development,* 48, 1720 - 1723.

Wellman, H. (1978) Knowledge of the interaction of memory variables; a developmental study of metamemory. *Developmental Psychology*, 14, 24 - 29.

Wertsch, J. & Toma, C. (1995) *Voices of the mind*: A sociocultural approach to mediated action. Cambridge, MA: Harvard University Press.

Whimbley, A. and Lochhead, J.(1986) *Problem Solving and Comprehension,4th Edition.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Whimbley, A. and Lochhead, J.(1991) *Problem Solving and Comprehension*,5th Edition, Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Wickelgren, W. (1965) Acoustic similarity and intrusion errors in short-term memory. *Journal of Experimental Psychology*, 70, 102 -108.

Wickelgren, W. (1974) *How to Solve Problems*. San Francisco: Freeman.

Wilson, B. (1991) Long-term prognosis of patients with severe memory disorders. *Neuropsychological Rehabilitation*, 1, 117 - 134.

Wilson, B. (1995) *Handbook of Memory Disorders*. Wiley: Chichester.

Wilkin, B. (1994) The self-explanation effect with self-generated diagrams. *Technical Report No. SM-9*, School of Education, University of California at Berkley.

Witkin, H. (1962) *Psychological Differentiation Studies of Development.* New York: Wiley.

Witkin, H. (1978) Cognitive Styles in Personal and Cultural Adaptation. *Heinz Werner Series,* 11.

Witkin, H. & Goodenough, D. (1981) *Cognitive Style Essence and Origins*. International University Press: New York.

Witkin, H., Moore, C., Goodenough, D., & Cox, P (1977) Field-dependent and field independent cognitive styles and their educational implications. *Review of Educational Research*, 47, 1 - 64.

Wolf, C.W.(1967) An experimental investigation of specific language disability (dyslexia). *Bulletin, Orton Society*, 17.

Wollman, E. & Jacob, F. (1956) Sexuality in bacteria. *Scientific America*, July.

Wolters, M. (1983) The part-whole schema and arithmetical problems. *Educational Studies in Mathematics*, 14, 127 - 138.

Wong, B. (1992) On cognitive process-based instruction: An introduction. *Journal of Learning Disabilities*, 25, 150 - 152.

Wood, G. (1967) Mnemonic systems in recall. *Journal of Educational Psychology*, 58 (6) 1 - 27.

Wood, C. (1992) A cultural-cognitive approach to collaborative writing. *Cognitive Science Research Paper CSRP 242*, University of Sussex.

Wulf, W. (1922) Uber Die Veranderung, *Psychologisch Forschung* 1, 333 - 373.

Yaniv, I. & Meyer, D. (1987) Activation and metacognition of inaccessible stored information: Potential bases for incubation effects in problem solving. *Journal of Experimental Psychology*, 13, 187 - 295.

Yancey, A. (1981) Pupil-generated diagrams as a strategy for solving word problems in elementary mathematics. University of Louisville. *ERIC Document Reproduction Servic* , No. ED 260 922.

Yates, F. (1966) *The Art of Memory.* Chicago University Press: Chicago

Yuille, J. and Catchpole, M. (1974) Effects of delay and imagery training on the recall and recognition of object pairs. *Journal of Experimental Psychology*, 17, 474 - 481.

Yussen, S. & Bird, J. (1979) The development of metacognitive awareness in memory, benefits associated with different types of picture organization. *Developmental Psychology*, 15, 447 - 449.

Zambo, R. (1992) Word problem solving in the middle grade mathematics. *Research in a Middle Level Education*, 16 (1), 143 -157.

Zambo, R. (1994) Gender-related differences in the process of solving mathematical problems at the 6th and 8th grade levels. *Focus on Learning Problems in Mathematics*, 16 (2), 20 - 38.

Zambo, R and Hess, R.(1996) The gender differential effects of a procedural plan for Solving Mathematical Word Problems. *School Science and Mathematics,* 96 (7), 362 - 369.

Zeigarnik, B. (1927) Das behalten erledigter und unerledigter handlungen. *Psychologische Forschungen*, 9, 1 - 85.

Zhang, J. (1997) The nature of external representations in problem solving. *Cognitive Science,* 21 (2), 179 - 217.

Zhang, J. and Norman, D.(1994) Representations in distributed cognitive tasks. *Cognitive Science,* 18, 87 - 122.

Zweng, M., Geraghty, J. & Turner, J. (1979) Children's strategies of solving verbal problems. *ERIC Document Reproduction Service, No. ED 178 359*.