Problem Solving by Primary School Children with Particular Reference to Dyslexics

by
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In Memory of

Andrew Tom Stephen Forster

Andrew was a friend and exceptional teacher.
His example has helped me to enjoy teaching and to complete this work.

Abstract

This project looks at how children within the nine to thirteen age group perform during arithmetic problem solving with particular reference to dyslexics. There are many factors which will influence a child's performance and therefore the following questions have been looked at in particular:

1. *Do dyslexics have a different Working Memory Space compared to non - dyslexics?*
2. *Do dyslexics achieve the same success rate as non-dyslexics in arithmetic problem solving?*
3. *Is the approach taken by dyslexics to arithmetic problems different from that taken by non-dyslexics?*
4. *Do children within this age group have a developed network of mathematical words / symbols and their meanings?*

In order to answer these questions the 207 children within the sample group were asked to complete four pieces of work:

A word network questionnaire,used to look at the connections made by the children between words and their meanings.

A symbol network questionnaire,used to look at the connections made by the children between arithmetic symbols and their meanings.

A shape quiz which was used to establish working memory space.

A booklet of arithmetic questions,used to look at how the children tackled arithmetic type questions.

From the results gained from the children it was possible to say that the range of working memory space capacities of the dyslexic group appeared to be no different from the range within non-dyslexic group. It was also established that the overall performance of the dyslexic group was of a lower standard than that of the non-dyslexic group. The results from the network questionnaires indicated that there was a stronger connection between symbols and meanings if a visual stimulus was given, but that there appeared to be no difference in the networks constructed by the dyslexics compared to the non-dyslexic group. It was, however, not possible to gain an insight into how the dyslexic group was tackling the individual questions within the arithmetic booklet. This was due to the fact that no differences could be seen between the written work of both groups and time restrictions dictated that individual discussions with each child were not possible.

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Introduction

Children spend a large percentage of their time in school working within the English and Mathematics areas of the curriculum. However, language work is required within all areas of the curriculum and any difficulty the child experiences within language is therefore a source of anxiety for the child which is encountered in many other areas of life. Some of the skills required for mathematics are also encountered in other areas of the curriculum and so a difficulty with mathematics will also have an effect on other subjects. Hence, a small difficulty in mathematics or language can appear, to the child, to be much larger than it is as a result of the problem being encountered frequently.

A topic which combines mathematics and language work is problem solving. Defining a problem is difficult, in that what one person perceives as a problem may not be the same as another person. It is possible to say that a problem involves a set of data, a desired outcome and a process by which an outcome can be achieved.

The problem may be within any area of the curriculum but the basic skills involved in solving it will be the same. In order to perform well during problem solving it is necessary to be able to read or observe the problem and extract relevant information. This information has to then be processed in some way and a solution to the problem achieved. Hence, this type of work involves the skills of, reading, comprehension, comparison, applying knowledge and checking that outcomes meet targets. Thus, by doing problem solving children are encouraged to develop skills and learn new ways of approaching situations.

One particular type of problem which children within primary schools encounter are the arithmetic based problems within the mathematics curriculum. These particular problems require the child to read the question, understanding the language, decide what is being asked in terms of mathematics, select the correct method for finding a solution and then use this method to produce an answer. One eight year old boy described this type of arithmetic as 'hidden sums', an indication as to how he could not see beyond the language and find the mathematics.

The type of learning encouraged by problem solving can obviously be applied to all areas of living and so it can be classed as an important part of any child's education. The skills required to do this work are demanding for any child but for a child who has to cope with dyslexia they are even harder to achieve.

Dyslexia is very difficult to define precisely. A general definition can be given as:

> *Dyslexia is a disorder which results in the pupils finding difficulty in read and interpreting written language and / or symbols (for example in mathematics or music).*

There has been a great deal of work done with dyslexics and the implications of their difficulties within language work but relatively little work has been done within the mathematics side of the curriculum. Thus we have a much better insight into the difficulties experienced within language then those experienced within mathematics. We are really only just beginning to appreciate the problems which mathematics can present to dyslexics. The difficulties experienced within language will have obvious implications for the dyslexic pupil's mathematics work. The reading and comprehension of questions will be taxing as well as the actual process of writing symbols and giving symbols a meaning.

As a teacher of science and mathematics this is obviously an area which is of interest and, having taught several dyslexics, each with unique difficulties, an appreciation of the challenge teaching dyslexic pupils brings has been developed. This teaching can also be very rewarding as an increased insight into mathematics itself can be achieved as it is viewed from various new angles in order to find a way of making the subject accessible to all.

With this in mind this project has set out to try and find out a little more about how dyslexics approach mathematics and arithmetic problem solving in particular. This is a topic which many children find tricky and, due to it being language based, dyslexics have an extra hurdle to cross.

When a child is doing problem solving, the problem has to be read, understood and key words recognised and stored for later reference. For many dyslexics, however, the actual reading process is very slow and so the significance of specific words can be lost or forgotten by the time the reader has reached the end of the question. When the aim of the question has been established the child then has to decide how to tackle achieving an answer. In order to do this previous knowledge has to be accessed and used or a pattern within the given information identified. Both of these tasks can be very taxing for dyslexics as they find the retention of facts and the retrieval of information hard. If the child reaches this point, life is not yet easy as now all this information has to be manipulated and an answer produced. At this point some sort of written working is usually expected by the teacher. This may help in some cases but hinder in others as the actual process of writing work down can be a tiring and unappealing task. In short, problem solving can be a long and difficult process for some people.

The work within this project was carried out with children within the upper primary school age group. At this stage, children meet this type of problem as part of the mathematics curriculum. The researcher teaches within this age group and therefore has an understanding of what is expected of children within this group and access to children within this group was also more easily achieved.

Thus, it is possible to state the overall aim to the project:

> *'to look at how children within the nine to thirteen age group perform within arithmetic problem solving with particular reference to dyslexics'*

Having established this aim it can be seen that a large number of factors will influence how children perform within this type of question. This initial study will focus on the following:

> *i. The dyslexic tendencies, if any, of the child.*
> *ii. The vocabulary and understanding of it which is available to the child.*
> *iii. The working memory space available to the child.*
> *iv. The age of the child.*

These four factors in turn produced the following research questions which will be addressed by this study:

1. *Do dyslexics have a different Working Memory Space compared to non - dyslexics?*

2. *Do dyslexics achieve the same success rate as non-dyslexics in arithmetic problem solving?*

3. *Is the approach taken by dyslexics to arithmetic problems different from that taken by non-dyslexics?*

4. *Do children within this age group have a developed network of mathematical words / symbols and their meanings?*

The work done has been split into five parts:

- i. *Learning Models.*
- ii. *Dyslexia.*
- iii. *Problem Solving.*
- iv. *Data Collection.*
- v. *Results.*

Learning models were looked at in order to establish how teaching theories have developed and how investigation and problem solving fit into these theories. The information processing theory also introduces the working memory space factor into the equation. Dyslexics are thought to have poor short term memory (Chasty,1989) and so it was of interest to look at their working memory space capacity and compare it to that of non-dyslexics.

The dyslexia side of this work was carried out in order to try and establish what characteristics dyslexics display and how dyslexia can effect their academic and general life. Having done this it was possible to see how arithmetic work in particular might be affected by dyslexia.

Problem solving was surveyed so that the arithmetic type problems could be put into context within the much larger field of problem solving. The approach to problem solving in general was also considered so that any specific difficulties dyslexics may encounter could be highlighted.

A discussion of the data collected and how it was gathered is then given. The last part of the work looks at the implications of the results arising from the data.

Chapter One

Learning Models

How people learn, develop methods of learning and collate information from the world around them has been an area of interest for educators and psychologists for some time. The area has therefore been approached by several people from various angles and starting points. Four main contributors are Piaget, Bruner, Gagne and Ausubel and thus it is useful to look at and compare the contributions of each one.

The Information Processing Model (Baddeley,1986; Johnstone,1988) takes another perspective and will be looked at in greater detail as it has a more direct influence on the work done within this project.

In this chapter, only the characteristics from learning models which seem directly relevant to the project are discussed.

Learning starts as soon as we are born and occurs in all areas of life. Classroom learning is only a small part of the learning process. What learning actually is can be debated from many standpoints but Gagne describes it thus:

> *"Learning is a change in human disposition or capability, which can be retained, and which is not simply ascribable to the process of growth."*
> *Gagne (1964)*

Thus, learning is due to conscious effort and thought rather than chronological development. How people go about this conscious thought and how the information is stored are the questions which the various perspectives of learning try to answer.

1.1 Piaget

Piaget approached the study of children's thinking from a biologist's viewpoint. He wanted to know how children's thinking developed and adapted due to their environment and experiences. (see, for example, pg 83-91 in Atkinson,R.L. *et al.*, Introduction to Psychology)

He suggested that two processes were involved in cognitive development;

accommodation and assimilation:

> *Accommodation is the process of adapting cognitive schemes for viewing the world (general concepts) to fit reality.*
>
> *Assimilation is the complimentary process of interpreting experience (individual instances of general concepts) in terms of current cognitive schemes.*
>
> *Goswami (1998)*

The goal of each thinker is equilibrium between accommodation and assimilation. However, as our understanding of the world is only ever partial, each time equilibrium is thought to have been achieved, new information is received and so a new equilibrium has to be found and hence cognitive development occurs.

Piaget suggests that there are three distinct cognitive stages in logical development. These equate to successive forms of knowledge or systems of thought. The stages are also related to the age of the child and are therefore experienced by each child as growing and maturing occurs. (This later relationship has been questioned by others on many occasions, (Flavell, 1963)).

1. The sensory - motor period: 0 - 2 years.
2. The period of concrete operations: 7 - 11 years.
3. The period of formal operations: 11 - 12 years on.

The gap between the years of two and seven is the period of the pre-operation or preparation for concrete thought. During this time there is a transition from sensory - motor cognition, which is action based and dependent on physical interaction with the world, to internalisation of action and the organisation of symbolic knowledge which is associated with concrete operations.

During the years of concrete operations the results of internal actions (compositions) become reversible thus marking the beginning of mental thought.

The final stage, the formal operational cognitive stage, is when concrete operations become linked together indicating the beginning of scientific thought.

The attainment of each stage was thought to have required basic cognitive restructuring on the part of the child. Piaget acknowledged that this development would not necessarily occur at the same time within each domain of thought. Neither would each child experience the same type of development at the same time and hence the age groups for the different cognitive stages were only approximations (Piaget, 1963).

The stages of development have direct implications for the teaching and learning of science. Johnstone describes the last two stages of Piaget's cognitive development in the following way:

Concrete Operational Stage

> *i. Thinking about or doing things with physical objects.*
> *ii. Ordering, classification and arranging.*
> *iii. Manipulating things in the mind.*
> *iv. Limited exploration of possibilities.*
>
> *Johnstone (1987)*

In other words, the learner can solve problems he has never encountered before but the type of solution will be limited by the concrete experiences he has had.

Formal Operational Stage

> *i. Logical reasoning, drawing conclusions from premises.*
> *ii. Testing hypotheses.*
> *iii. Planning experiments.*
> *iv. Formulating general rules.*
> *v. Manipulating propositions in the mind.*
> *vi. Exploring many possibilities.*
>
> *Johnstone (1987)*

Obviously all of these characteristics are helpful to both senior pupils and their teachers but they are not always present. The main reasons for them being lacking vary: perhaps the learner has not yet reached that type of thinking within a particular domain of thought; maybe the level has not been reached in any area of thought. This, in turn, could be due to not having been required to do so before.

Piaget envisaged that each of the stages of development was not gradual (Piaget, 1963).

His claim required a completely different approach to learning and problem solving: the development happened in discrete jumps. Taken to an extreme this would imply that a concrete thinker could become a formal thinker in one step rather adapting their approach over a period of time. Much work has been to done to show that this assumption is not true in the majority of cases. (Novak, 1978). However, Piaget's great contribution was to emphasis stages of cognitive development and the need to be aware of them in teaching. This may have implications for the work carried out within this project since the children involved are within the 9yr-13yr age group.

1.2 Bruner

Bruner approached the concept of cognitive development from a different standpoint to Piaget. He started with the thought that learning is an on-going process which is influenced by previous experiences / knowledge and the social environment of the learner. Any cognitive structure is therefore required to receive information from various sources and process it. This will then allow the learner to come to an acceptable conclusion. The cognitive structure should enable the learner to extend previous knowledge and predict the results of situations which they have not previously experienced.

Bruner's model (1966) is a framework for instruction based on such cognitive structures. Any such model, he concluded, should tackle the nature of:

i. The knowledge to be learned.
ii. The learning process.
iii. The individual learner.

The knowledge itself can be sub - divided into three overlapping forms:

i. Its mode of representation
ii. Its economy , the amount of data we need in order to understand.
iii. Its power, the ability to stimulate new connections.

The mode of representation can then, in turn, be divided into three:

i. Enactive:- physical action.
ii. Iconic:- internal visual imagery depicts events.
iii. Symbolic:- using a symbol system such as in mathematics and language.

This splitting reflects the approach Piaget took.

Enactive → *Sensory - Motor period.*
Iconic → *Pre - operational period.*
Symbolic → *Concrete operational period.*

Bruner, however, did not relate these stages to the age of the learner but to the learner's experience. Therefore the range of experiences encountered would stimulate and develop cognitive development. Thus, he recommended discovery learning as a teaching method. In this type of learning the student involved encounters a problem and has to gather information regarding it, recall any previous experience which may be useful and combine these to produce a new strategy which can solve the new situation. The role of the teacher within this approach is to set up situations through questions and problem setting where the learner has the opportunity to seek out a solution. This approach to learning has obvious implications for the teaching of mathematics and science where practical work has a large part to play within the curriculum.

Bruner also recommended a spiral approach to teaching. In this type of teaching a topic is revisited many times and further learning / understanding is built on top of the knowledge previously gained. He emphasised how important the interaction is between the learner and the new learning situation. This has implications within this project since during problem solving the children are being asked to transfer knowledge gained in one situation to another in order to help them gain an answer.

1.3 Gagne

Gagne (1964) took a behaviourist's approach to learning and, like Bruner, he placed importance on the learner's environment and the effect that this can have on the learning being done. Since the environment will have affected the previous knowledge of the learner it will subsequently have an affect on how they approach a new learning situation. Gagne's model is based on the following :

i. Learning results in a change in the learner.
ii. Skills should be acquired singly.
iii. Each new skill should build on a previous one (as with Bruner's spiral).
iv. Learning and knowledge are both progressional in nature.

He then splits learning itself into five categories.

> i. *Verbal Information.*
> ii. *Intellectual Skills.*
> iii. *Cognitive Strategies.*
> iv. *Motor Skills v Attitudes.*

For each learning type different internal and external conditions are required and so this will need to be kept in mind when presenting a curriculum to the learner. Gagne's main contribution was the emphasis he gave to the logical sequencing of ideas in the learning process. This has implications for the approaches taken to teaching, however, other work done (Howe, 1975) showed that learners frequently choose not to follow the sequence of learning enforced by the teacher but achieve their learning via another route.

1.4 Ausubel

Ausubel (1968) started with the premise that:

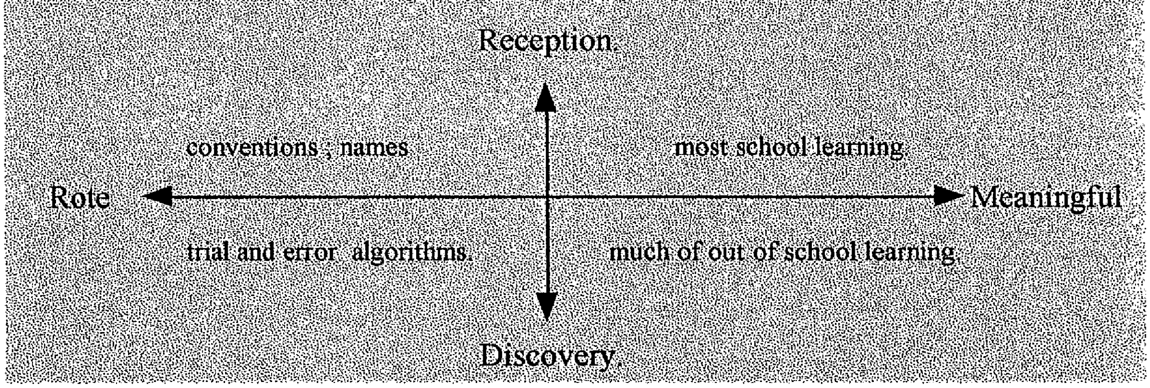
> *"... the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly."*

Thus, in this way, he was similar to Bruner and Gagne. He also felt that the 'spiral' approach of Bruner allowed new material to become attached to existing knowledge and hence good connections between the two could be achieved. This, in turn, would result in a good understanding of topics and their interdependency.

However, Bruner and Ausubel take different paths to achieve learning. Ausubel did not follow Bruner's discovery route but advocated that knowledge should be gained by means of reception. Thus, ideas, concepts and principles which are already known to the world as a whole can be presented to the learner in a manner which will be understandable to them and hence their own knowledge is extended. The emphasis is that each person is not rediscovering each concept but achieving an understanding of it from the teacher.

Ausubel splits learning into two types: rote and meaningful. He also split the methods of learning into two groups: reception and discovery. By considering both the type of learning and the type of teaching he produced the Dimensions of Learning, see Fig.**1.1.**

Figure 1.1 Types of learning.



Meaningful learning was described by Johnstone (1997) as:

> *"... good, well - integrated, branched, retrievable and usable learning"*

while rote learning is:

> *"... at best , isolated and boxed learning that relates to nothing else in the mind of the learner."*

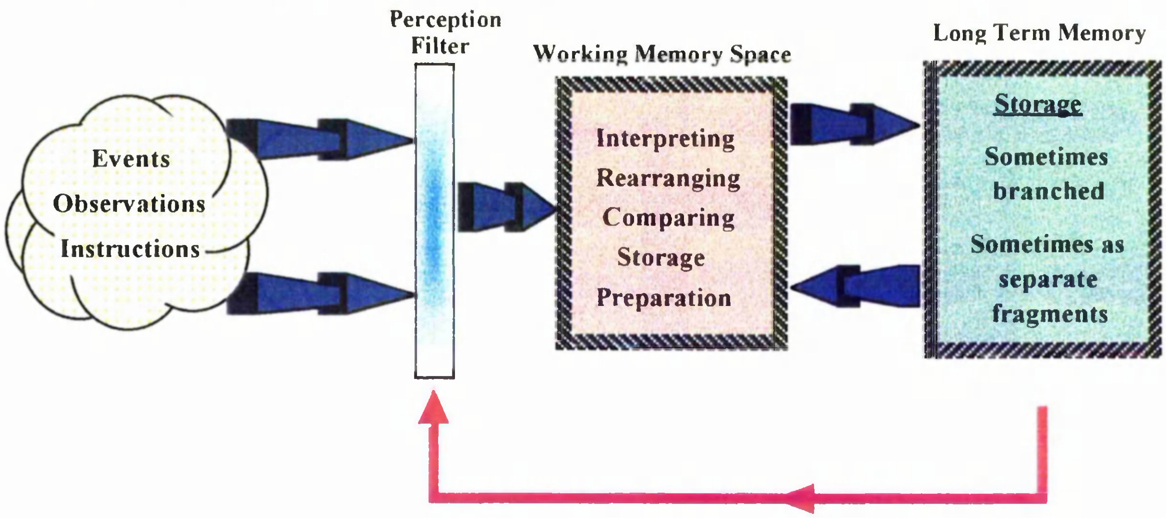
Therefore, it can be seen that the presentation of any curriculum to a learner needs to be the result of considering the previous experience of the learner, what is to be learned and also how it is best learned.

1.5 The Information Processing Model

Piaget's contribution was to *describe* what was observed while learning actually took place. Others (e.g. Baddely, 1986 and Case, 1985) moved on to seek for an explanation or rationalisation of what was being observed. From this work the information processing model emerged.

The information processing model is a model for learning which looks at how the learner takes information in, manipulates it and then stores it. Those three components are called: the sensory register or perceptive filter, working memory space and long term memory. They connect together as shown in figure **1.2**.

Figure 1.2 The Information Processing Model



This model was proposed by Johnstone, (1993) and has been used and accepted by many researchers. It is based on the ideas of Ashcraft (1994) and Baddely (1986). The model also incorporates many of the contributions of psychologists previously discussed: Piaget's stage model, Ausubel's importance of prior knowledge and meaningful learning and Gagne's progressional learning. It also includes Pascal - Leone's idea of limited working space being related to age. By using this model, the flow of information through the memory system can be traced. The model can also be used to predict how information will be handled and thus it gives an insight onto how meaningful learning can take place.

The three main sections of the model are related to the three types of memory as discussed by Ashcraft (1994).

Ashcraft	Information Processing Model
sensory memory.	perception filter.
short-term memory.	working memory space.
long-term memory.	long-term memory.

Information is received by the learner from the outside world via the senses; primarily the eyes and ears. This information is initially received by the Perception Filter. How this information is perceived, with openness or preconceived barriers, is determined by previous knowledge and experience due to the feedback loop. There is so much information being collected by our senses at any one time that it cannot all be processed.

Therefore, a selection process occurs and some of the incoming information is ignored whilst some information goes on to be processed. This selection process is again influenced by previous knowledge and experience.

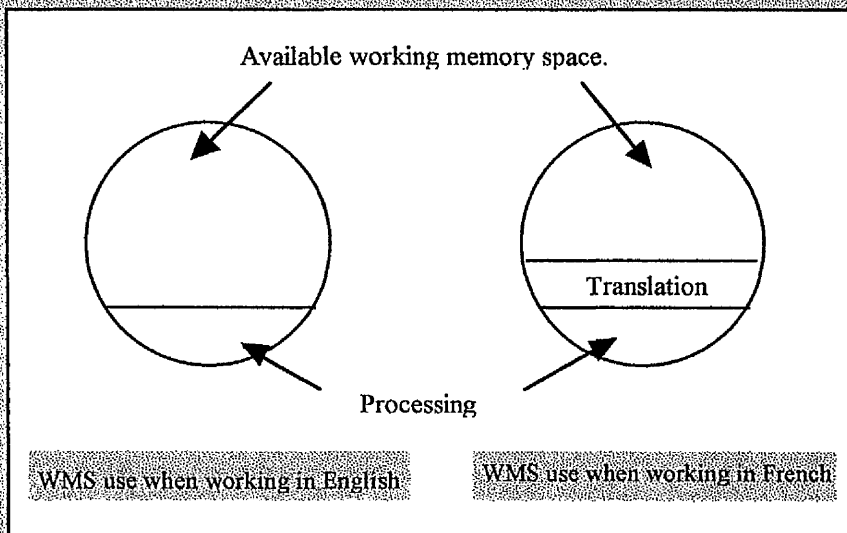
The working memory space (W.M.S.) is the area which then accepts information from the perception filter. (Johnstone 1988; Baddeley 1986) There are two main functions of the W.M.S. :

> i. *It is the conscious part of the mind that is holding ideas and facts while it thinks about them. It is shared holding and thinking space where new information coming through the perceptive filter consciously interacts with itself and with information drawn from the long term memory store in order to make sense.*
>
> ii. *It is a limited shared space in which there is a trade - off between what has to be held in conscious memory and the processing activities required to handle it, transform it, manipulate it and get it ready for storage in the long term memory. If there is too much to hold there is not enough space for processing; if a lot of processing is required, it cannot hold much.*
>
> *Johnstone (1997)*

The use of the term 'short term memory' is often used instead of 'working memory space' but the two are actually different uses of the same space. If information is only being stored and then passed on, then the space is acting as short term memory. If the information is being manipulated in any way (added together, rearranged, etc.) then the space is also being used as a working memory. Working memory can work very quickly but it does not retain information for long unless the information is being repeatedly rehearsed. The number of pieces of information which can be handled by the W.M.S. at any one time can be measured (see chapter 4) and has been found to be related to the age of the learner involved. Obviously this working space has boundaries and is not ever expanding. It has been established that an adult will have a working memory space of 7 ± 2. (Miller,1956) When this space is full, another method of working with the information needs to be found. This can be done by regrouping the information and then temporarily storing it and working the problem out in segments. Alternatively, the working space can be extended externally by using pencil and paper to record and manoeuvre information. This leads to an obvious question where dyslexics are concerned: will a child who finds the writing and interpretation of symbols and language difficult, use the latter method of extending their working space or will other strategies be employed?

It has been found (Johnstone and Selepeng, 2001) that the working memory space available for manipulation of data is reduced significantly if the pupil is working in a second language: some of the working memory space is being used to translate the second language to the first. (see figure **1.3**.) This has implications for dyslexics in that they could be using working memory space to translate seen symbols into their sounds or meanings and hence the available space for manipulation of the data is reduced. For non-dyslexics connecting the symbol with its meaning is more likely to become automatic and therefore this procedure will not require an actual translation process.

Figure 1.3 Use of WMS when translating.



It has also been noted that anxiety can cause a reduction of the working memory space available to the pupil. (Ashcraft *et al,* in press) Thus, if a pupil has a poor experience with a topic or type of question, the anxiety caused by this can result in lowering the space available to tackle the question. This is a negative loop which obviously has to be broken before any progress can be made.

The long term memory is where information from the working memory space is stored, concepts are developed and attitudes formed, (Johnstone *et.al.*,1993). It is where what we want to learn and have access to can be stored on a fairly permanent basis. The long term memory is connected to the perception filter via the feedback loop and so has an influence on the data being taken in. This allows attitudes towards issues to develop and gives each person a unique view of the world. Thus, learning involves all areas of the information processing model and, as learning occurs, attitudes will be adjusted and so the perception filter will vary as part of the ongoing development of the learner.

This model uses the observation that information in the long term memory is stored in a way which allows related information to be accessed easily by the use of key word networks (Kempa, 1983). That is, one word has an association with others which, in turn, can lead to yet more information. Since dyslexics can have difficulty in identifying key words this leads to the question: how do dyslexics access long term memory if this method is difficult?

It has been noted that many dyslexics find the learning of new concepts easier if they have a pictorial or practical stimulus; something other then words onto which the new information can be attached. Hence, it may be possible that language symbols are being replaced by pictorial ones.

Thus, although this model gives us a good insight into how information manipulation is carried out within the brain, it produces questions regarding what happens if the learner does not learn in what is regarded as the 'normal' fashion.

Chapter Two

Dyslexia

2.1 What is dyslexia?

The word dyslexia comes from two Greek words: 'dys' meaning defective as in dysfunctional and 'lexia', meaning the use of words - words in this situation being a means of communication through reading, writing and listening (Huston, 1992). Thus a basic definition of a dyslexic would be someone who has difficulty with words. The difficulty experienced with words is not due to a physical problem with the eyes reading the words or the ears hearing the words but is due to how the brain is processing and interpreting the words it receives through the eyes and ears.

The first recorded case of dyslexia was recorded by W.P.Morgan in 1896. He wrote an article entitled 'A case of congenital word blindness' in which he described a boy who was of normal intelligence but who, after many years of being taught, could still not read and, therefore, appeared to be 'blind' to words. Since then much work has been done with pupils displaying this problem. Through this work, it has become clear that, although dyslexia is language based, it has implications for all aspects of learning and recently the specific difficulties experienced within mathematics and numeracy have been included within the definition for dyslexia (Chinn,1998). The type of work being done has changed direction from purely studying the displayed behaviour due to dyslexia to attempting to establish what is causing the behaviour (Uta,1997). It is estimated that 4% - 5% of the UK population suffer from some form of dyslexia (Dyslexic Institute, 2000).

Due to the continued development of our understanding of dyslexia, it is very difficult to give a specific definition for the condition and it is well known that no two dyslexics will experience exactly the same difficulties. For these reasons, Miles (1992) describes dyslexia as a syndrome:

> *"... that is a pattern of signs which regularly go together; any one of these signs on its own would be of no significance, but if several of them co-occur in the same individual they take on a meaning which none of them would have in isolation."*
>
> *Miles (1992)*

Thus, any definition of dyslexia appears to be a list of possible difficulties which could be experienced but which may not be. There are three main types of dyslexics:

i. Visual Dyslexics.
ii. Auditory Dyslexics.
iii. Visual / Auditory Dyslexics.

Visual dyslexia or visuospatial dyslexia causes difficulties in processing information in the written form. Auditory dyslexia causes problems with the processing of heard sounds and the matching of what is being heard to what is written. The third category is a combination of the first two. It therefore results in varying degrees of each of the previous group of characteristics being seen. It is at this point that it becomes important to remember that each dyslexic is an individual and will have a unique way of viewing the world just as no two non-dyslexics have the same view of the world. It also means that the term dyslexia can be used to describe a range of levels of difficulties. Severe dyslexics will experience a wide range of problems in all areas of the curriculum whilst pupils with mild dyslexia may only experience a few problems in one or two areas. This view has led to the definition used by Moray House Centre for the Study of Dyslexia:

> *"Specific Learning Difficulties / Dyslexia can be identified as distinctive patterns of difficulties relating to the processing of information within a continuum from very mild to extremely severe which result in restrictions in literacy development and discrepancies in performances within the curriculum."*
>
> *Reid (1996)*

2.2 What causes Dyslexia?

Dyslexia is not dependent on the socioeconomic background of the person although, for some time, it was labelled as a middle class syndrome. It is also not related to the intelligence of the person either. Dyslexia occurs throughout the range of intelligence levels.

Dyslexia does occur more often in boys than girls and the ratio of 4 boys to 1 girl is generally accepted (Miles,T. and E., 1983) and there is frequently a family history of dyslexia or similar disorders (Critchley and Critchley, 1978). Due to this, there has been work done at looking at the genetic make up of dyslexics in order to establish which gene may be responsible for dyslexia. It has been accepted that dyslexia is due to a genetic factor and, in 1950, Hallgren tried to find out how this factor operated. He concluded that the dyslexic gene was dominant and autosomal: it was not part of the gene determining the sex of the person (neither the X nor Y gene) and, due to the high number of dyslexics who have at least one dyslexic parent, the gene must be dominant rather than recessive. Stewart (1989) took this conclusion further when he stated that the gene was dominant and autosomal but also that there was less penetrance in females. Penetrance refers to the portion of the phenotypically affected individuals; phenotype being the visible or measurable characteristics of the individual which, in turn, are due to their genotype. Hence, although the dyslexic gene may be present in a female, it may not result in the characteristics being observable. The work isolating a gene which could be responsible for dyslexia has been done by Smith *et al* (1983, 1991) and it is now felt that chromosomes 15 and 6 may be involved. It is more than likely that there will not be one gene for dyslexia. It is more probable that a gene or group of genes working together will produce the effects on the biochemistry of the body to create the anomalies in the developing brain which result in dyslexia. This work is still very much in its infancy and so only time and work will tell if this thinking is correct and going in the correct direction.

2.3 What characteristics do Dyslexics have?

In general the observable traits of dyslexia are poor reading skills and / or a reluctance to read. Often the physical process of reading does not necessarily result in comprehension of what is being read. Reading requires the reader to correctly match the grapheme being seen with the phoneme it represents. In other words, the written English (grapheme) has to be matched with the spoken English (phoneme). This is not easy for any new reader but if phonics are not easily identified and the relevant graphemes are not remembered, life is even harder. Saying these words out loud reveals the problems:

does / goes / shoes , man / many, ought / bough / cough
key / they; home / some, bead / bread / break.

There are also homophones; words which sound alike but have different spelling and meanings:

meet / meat, blew / blue.

Homographs also cause problems in that they are words which are spelled alike but have different meanings anc

home **produce** *and hens* **produce** *eggs and*
I will ***read*** *the book which you* ***read*** *last week.*

home **produce** *and hens* **produce** *eggs and*
I will ***read*** *the book which you* ***read*** *last week.*

Homonyms have different meanings but sound alike and are spelled the same. Down is such a word. The meanings could be: down the road, feeling down, soft feathers. The following quote from a poem cleverly shows the inconsistencies in the English language (Huston 1992).

Our Queer Language.

When the English Tongue we speak
Why is "break" not rhymed with "freak"?
Will you tell me why it's true
We say "sew" and likewise "few"?
And the maker of this verse
Cannot cap his "horse" with "worse"?
Anon.

The physical process of reading may be difficult because of the way words appear to the reader. To most readers the use of black print on white paper is a natural choice and the print is easily brought into focus and read. This is not true for all readers. Helen Irlen, in America, found that some readers are 'scotopic sensitive' (Pollock and Waller, 1994). This means that their eyes are sensitive to the combination of black print on white paper and this causes the print to appear to move around on the page and so reading becomes difficult if not impossible. This problem can also be increased if the reading is being done under fluorescent lighting. Irlen found that if the print is viewed through tinted lenses then the glare from the lights can be removed and the print starts to stay 'still' for these readers. Different colours work for different people and therefore some experimenting needs to be carried out before the correct colour is found for each person. The use of the colours can result in readers being able to work for longer and with more accuracy.

Spelling may be poor and words learnt but not retained for long. Rogue letters may appear in a word which have no relation to the word or even its phonetical spelling. Common spelling mistakes are given below (Pollock and Walker,1994):

1. The outline or shape of the word may be similar to the correct word, but some of the letters are muddled, for example:

day / dog **beteew** / between **amiad** / animal

'I' s may be crossed and 't's left uncrossed producing words such as

onty, plenly, Auslratia.

2. Some letters may be reversed or mirrored:

b	d
p	q g

h / y t / f m / w n / u s / z

This obviously causes confusion due to the reversal producing another letter. Other letters which are often reversed are:

ᗡ Я ⅃ И

Punctuation can also be reversed:

, ⸮

All of this can result in spelling mistakes such as:

word written	actual word
de	be
wusf	must
bog	dog
vomel	vowel

3. The letters of the word may all be present, just in the wrong order resulting in the following type of errors:

word written	actual word
hlep	help
felt	left
Jhon	John
hared	heard

4. The letters used may be those whose sounds are nearer to the correct ones:

a / u / o, e / i, m / n, th / v / f, d / t , p / d, s / sh / ch, j / ch , g / k, n / ng

and this can result the following type of errors being made:

word written	**actual word**
cat	cut
hup	hop
set	sid
wip	web

5. The dyslexic person may not be aware of certain sounds, especially in blends (nt, mp, pl, cr). This can result in some sounds being added to words or left out of words:

the **n** sound in **went**, with the result that **wet** is written instead.
Similar mistakes would be **pum** for **plum**, **cash** for **crash**, **stars** for **starts**.

When some blends have been learnt they may well be inserted when they are not needed:

camp for cap, plan for pan.

6. Dyslexics often do not realise that letter names and sounds are different and so this kind of error can happen:

word written	**actual word**
nd	end
fit	felt
tmper	temper
bgan	began

7. Words or phrases may also be foreshortened or telescoped:

rember for remember, sdly for suddenly, horsn for horizon.

8. There may also be confusion over whether there should be one word or two.

a bout , aslong as, yes terday , in stead.

9. The hand may not always do what the brain intends. That is, a 'g' may have been intended but 'd' is written. So we could end up with **kind** instead of **king.**

The problems mentioned in parts, 4, 5 and 6 also have obvious knock on effects on the reading skills of the dyslexic. Difficulties with spelling and reading are what cause dyslexics the most embarrassment and heartache due to the fact that society demands a certain degree of competence in reading and spelling (Collins 1996).

Writing can sometimes be untidy due to poor fine motor control, poor spatial awareness or it may be an attempt to disguise poor spelling: if the reader cannot quite make it out they may assume it is spelt correctly.

Learning of common lists of items may be very difficult and need constant reinforcement. Therefore things like the days of the week, months of the year and times tables may take a long time to become well known, and in some cases, times tables never reach the stage of instant recall. School timetables can fall into this category and hence a child may need constant reminding of what is happening next and in general a disorganised approach seems to be taken to school life. Books are forgotten or what happened during the last class is forgotten and a more detailed review of that lesson is required before further progress can be made. This difficulty would imply a problem with the storage and retrieval of information from the long term memory.

Spatial orientation may be poor and it will therefore take longer to become familiar with the layout of rooms and the school as a whole. Coupled with this, many dyslexics find remembering their left from their right very hard and need help with this. Hand eye coordination can also be affected and hence the pupil may appear to be clumsy and everyday tasks can be a chore: tying shoe laces, fastening small buttons and tying neck ties. Concentration spans are often short, particularly during tasks which involve a lot of language and so teaching has to be adapted to account for this. In short, many tasks which become second nature to many people as they grow and learn continue to take constant effort from a dyslexic and so, everyday life at school can be quite exhausting.

Very often dyslexics will perform well in the morning but by afternoon they have no more energy or concentration to give and performance deteriorates. This decline in performance can also be seen during exams in some cases. Questions done at the beginning of a paper are often of a better standard of spelling and layout then those done towards the end of the paper. Time limitations will obviously influence this as well.

Often a child with dyslexia finds the processing and interpretation of oral instructions difficult. This can result in classroom instructions being only partially followed if too much information is given at one time. It may also result in the dyslexic asking for instructions to be repeated several times until they are sure that they have a grasp of the complete thing. This is particularly true for auditory dyslexics .

It is necessary to understand the difficulties experienced by dyslexics when they read as these difficulties will affect them when they work in all areas of the school curriculum, not just during language work.

2.4 Dyslexics and Mathematics

Thomson (1990) gives this definition of dyslexia from which it is possible to see where any problems experienced with mathematics in particular may spring from:

> *'Developmental dyslexia is a severe difficulty with the written form of language independent of intellectual, cultural and emotional causation. It is characterised by the individual's reading, writing and spelling attainments being well below the level expected based on intelligence and chronological age. The difficulty is a cognitive one, affecting those language skills associated with the written form, particularly visual - to - verbal coding, short - term memory, order perception and sequencing.'*
>
> *(Thomson, 1984; 1990)*

The last sentence of this definition is of particular interest when discussing mathematics as it implies that the child will encounter problems with the following: new mathematical language, symbols used in mathematics, recognition of patterns and sequences, retention of number facts, direction of calculations, place value and the actual process of writing the numbers down. These problems fall into two categories: those relating to purely number work work and those related to language.

The language problems experienced are the actual reading and interpretation of the questions. This requires the reading to be done accurately as the missing out of words such as 'not', will change the whole meaning of the question. Once the question has been read, mathematical definitions have to be given to the keywords within it, in order to allow the mathematical meaning to be obtained. These words may already be established within the vocabulary but with a quite different meaning to that now required (Henderson,1989). For example 'take away' has many meanings within everyday life other than implying a subtraction sum. Thus, time has to be taken to ensure that once the word has been read it has the relevant meaning attached to it. Symbols also have to be given meanings and interpreted and it can take time to establish connections between the symbols and the words of mathematics language and the English equivalent. Thinking of mathematics as a language in its own right (Sharma 1989) gives a new viewpoint from which to look at the subject as a whole and the teaching of it. This approach is discussed more fully in chapter three.

Number work problems include writing down the sum which can be worked through and this can result in the answer to the question. This is not always straightforward for the dyslexic due to the possibility of number reversals and / or confusion over place value.

For example;

14 . 7 + 9 . 34 may become

		1	4	.	7
+	9	.	3	4	

Although this kind of error can be seen in many young pupils' work it is more common among dyslexics. The numbers may not only be transposed but written in reverse also:

Ɛ for 3.

There may also be problems with distinguishing between the mathematical symbols, +, ÷ and x especially if written carelessly (Chinn 1995). Numbers can get misinterpreted when read, for example, 6 and 9 may be interchanged or 3 substituted for 5 .

Many dyslexics, as already mentioned, have problems remembering left from right and have to be reminded where to start reading a page and some physical reminder of which hand is which is often required. Such a reminder may be " I wear my watch on my left hand" or " I hold my pencil in my right/ left hand". This is particularly important when having to deal with arithmetic algorithms and mathematical expressions. In order to evaluate an algorithm, it needs to be worked through in a specific direction (mathematical syntax).

ie. addition, subtraction and multiplication are all done right to left. division is done left to right.

Problems with sequencing may result in difficulties in counting when using on-to-one correspondence or when counting backwards. Seeing number patterns may also be difficult:

$4^2, 4^3, 4^4, 4^5$

Spatial awareness is required when working with place value and distinguishing between two and three dimensional geometry. This also has implications for topics such as angle chasing and three figure bearings.

A child's ability to form concepts depends on the number and diversity of the experiences they have encountered (Chinn and Ashcroft, 1995). Due to the dyslexic child working at a slower pace, they may not experience the same range of work and hence the forming of generalisations and concepts can be harder for them.

Overlying all of this is the child's self-image and their degree of "mathematics anxiety" (Buxton, 1981). Mathematics anxiety is the child's degree of worry about tackling mathematics questions and failure to achieve success in the subject. This is obviously cyclic in that anxiety can lead to failure which, in turn, leads to more anxiety and so on. This type of anxiety can also have an effect on the available working memory space (as discussed in chapter one).

The implications that dyslexia can have on mathematics learning are now more greatly appreciated and so the teaching approach taken with these children can be adapted to suit the child. This will, in turn, hopefully help to break the anxiety-failure cycle. As mathematics is a sequential subject it is particularly important that early difficulties are addressed and addressed effectively in order to prevent further difficulties later on in school life (Chinn and Ashcroft 1995).

2.5 Diagnosing Dyslexics

Due to dyslexia not being caused by one factor or resulting in the display of a fixed number of characteristics, diagnosing a dyslexic can be very difficult. The diagnosis cannot be given by a class teacher but their role in establishing what problems the child is experiencing is vital. The teacher can spot any discrepancies within the child's work: their reading ability may not reflect their ability to communicate orally, or their written work may not reflect their ability and understanding shown during practical work. If these indicators are noticed, there are some general tests which the teacher can then supervise to try and gain a more detailed picture of the child's specific problems.

The following list comprises a selection of some of the more commonly used Standardised Tests which can be used in the assessment of specific learning difficulties (McGhee,1996).

Tests to establish ability level.	
Crichton Vocabulary Scale	Measures Oral Linguistic Ability.
Raven's Matrices	Non - verbal test of ability.
Reading Tests.	
Neale Analysis (Revised)	Reading in context. A Reading and Comprehension Age within an age range is provided.
MacMillan Reading Analysis	As above.
Word Reading Tests.	
Burt	Provides a Reading Age but also an indication of the de-coding strategies which the pupil uses.
Spelling tests.	
Vernon Schonell	Provide a Spelling Age but also highlight specific phonic rules which have not yet been mastered.
Arithmetic Tests.	
Ballard Oral Arithmetic	An arithmetic test is part of the battery of tests which make up Intelligence Tests. Included here to form an overall picture of ability, simple sequencing ability and as a measure of mental

agility.

Tests Designed to Diagnose Specific Learning Difficulties.

Bangor Dyslexia test.	Tests areas which researchers have found over the years to indicate a Specific Learning Difficulty. Provides little information which can be of use in planning a remedial programme but seven of the more positive indicators along with other evidence can help in the diagnosis of a Specific Learning Difficulty. (see below for further details)
Aston Index	Attempts to provide a profile comparing ability with Reading Age and a profile of the areas of difficulty, i.e. auditory and visual, but is poorly constructed and standardised. Recent research (Sutherland and Smith, 1991) has suggested that it is unwise to attempt to make distinction between auditory and visual causes but that a lack of phonological awareness is more likely to be the root cause of a Specific Learning Difficulty. In practice, it is unlikely that the whole battery of tests would be administered but selected tests would be helpful in profiling strengths and weaknesses. (see below for further details).

The Bangor Dyslexia test (T.R. Miles 1997).

This test is based on the observations of Miles while he was assessing both children and adults who had been referred to him. During these assessments he noticed that many of those he was working with were uncertain over left and right, that some had difficulty in repeating 'tongue-twisting' words such as 'preliminary' and 'statistical', that many had difficulty in reciting mathematical tables, that many confused 'b' and 'd' even at ages of 9 and 10 and over, and that, in many cases, more than one member of the family was affected. No one of these signs is decisive on its own, but it is the overall pattern which constitutes evidence for dyslexia.

The Aston Index (Newton and Thomson,1976).

This test contains both a measure of intelligence, the Goodenough draw-a-man test, and measures of reading and spelling. Other tests include free writing, recall of auditory presented digits (Digit Span test - this will be looked at again in chapter 4), memory for visually presented material, both symbolic and non-symbolic, and tests of sound blending and sound discrimination (Miles and Miles 1999).

These tests give a wide range of results and information. In general, any result which reveals a significant discrepancy between the child's chronological age and their reading, spelling or arithmetical age should be investigated further. Similarly a discrepancy between their listening comprehension abilities and their reading comprehension abilities should be investigated.

The child may also show signs of mixed laterality. This may result in directional confusion and difficulty in copying written work. Although this does not indicate a specific learning difficulty in itself, it may give an indication of other problems and steps can be taken to alleviate the problems caused by mixed laterality.

Throughout these tests, it is very often how the child goes about them that gives as much, if not more, information than the actual results. With very young children any discrepancy revealed may be due to a maturational lag and, therefore, it is often better to wait a while and see how the child develops.

If the child is older, the child can then be referred to an Educational Psychologist who is in the position to do further testing and give a diagnosis and recommend a teaching strategy which could help.

Tests which can be done by an Educational Psychologist.

Wechsler Intelligence Scale for Children (WISC)
Revised Adult Dyslexia Check List (Vinegrad 1994)
Phonological Assessment Battery (PhAB)
Graded Non word reading Test (Snowling et al. 1996)
Children's Test of Non word Repetition (CNRep)
(Gathercole and Baddeley 1996)
Computerised Cognitive Profiling System (COPS 1)
(Singleton et al 1996/ 1997)
The Dyslexia Early Screening Test (DEST)
(Fawcett and Nicolson 1994)
The Dyslexia Screening Test (DST)
(Fawcett and Nicolson 1997)

The Dyslexia Adult Screening Test (DAST)
(Fawcett and Nicolson 1998)

Miles and Miles (1999) do not see the above tests as being in competition with each other. It is more that they have varying emphases. Thus the Aston Index and the Bangor Dyslexia test are basically fact finders without major commitment to one theory. The PhAB, COPS 1 and the non-word reading test are based on the theory that certain children have difficulties at the phonological level, while the CNRep places special emphasis on weakness in short term memory. Finally, the DEST, DST and DAST take account of the theory of a phonological deficit but go beyond it in testing for an exact deficit within the cerebellum.

2.6 Other languages and Dyslexics

Dyslexia is not limited to English speaking people. Examples of dyslexia have been found in Austria, Belgium, Czechoslovakia, Chile, Denmark, France, Germany, Hungry, Holland, the Philippines, Japan, China and Portugal (Huston, 1992). The numbers of recorded dyslexics in Japan, however, are very few. The reasons for this may be that they do not have a written language based on an alphabet but use a more graphic script or it could be that the dyslexics are going unnoticed. There was a case of a bilingual (English / Japanese) boy who showed no dyslexic tendencies when working in Japanese but who did when working in English (Wydell, 1999). However, at the moment, the variance of dyslexia from language to language cannot really be explained.

It is however, interesting to consider the fact that mathematics can be considered as a language and that written mathematics is made up of both symbols and letters which all have their associated meanings.

Chapter Three

Problem Solving

3.1 What is Problem Solving ?

Problem solving is a wide ranging term and aspects of problem solving can be found in all areas of life - paying bills, time management, arranging furniture within a room. Each of these situations, however, could be considered a problem by one person but may not be considered to be so by another depending on each person's past experiences.

This is due to the fact that any situation which involves the receiving of information and the use of that input to produce a result can be classed as problem solving. Polya defined a problem as something which requires us:

> *"... to search consciously for some action appropriate to attain a clearly conceived, but not yet immediately attainable, aim."*
>
> *(Polya, 1962)*

Within any problem there are three main parts: the data, the method and the aim. These three requirements can be found within any everyday situation. We are constantly asked to take in information, process it and use it to influence our actions and reactions to the world around us. Due to the fact that our environment is constantly developing and changing we have to adapt to it and reassess input from our surroundings all the time. On a day to day level, this can be done almost unconsciously. However, when larger decisions have to be made, a more conscious approach to the problem is used and true problem solving skills can be an advantage. Therefore, pupils need to be equipped with the skills required to deal with known problems and the yet unknown.

When this is being done, we take in all the information important to the situation and try to find a similar, previous experience which can give us a clue as to how to deal with this one. We may then adapt this previous experience to the new situation and hence a result is achieved or we may need to find a whole new approach altogether and thus develop a new method of working. The actual number of problems encountered by any one person increases daily as they get older and as the world becomes more complex. It is therefore impossible to count them all but, it is possible to categorise the type of problems which the pupils are likely to address. Johnstone (Wood and Sleet, 1993) has done this as shown in table **3.1**.

Table 3.1 Problem Types (Johnstone, 1993)

Type	Data	Methods	Goals	Skill Bonus
1	Given	Familiar	Given	Recall of algorithms
2	Given	Unfamiliar	Given	Look for parallels to known methods
3	Incomplete	Familiar	Given	Analysis of problem to decide what further data are required. Data seeking.
4	Incomplete	Unfamiliar	Given	Weighing up possible methods and then deciding on data required
5	Given	Familiar	Open	Decision making about appropriate goals. Exploration of knowledge networks
6	Given	Unfamiliar	Open	Decisions about goals and choices of appropriate methods. Exploration of knowledge and technique networks
7	Incomplete	Familiar	Open	Once goals have been specified by the student these data are seen to be incomplete
8	Incomplete	Unfamiliar	Open	Suggestions of goals and methods to get there; consequent need for additional data. All of the above skills.

This categorises problems in a simple but accurate way. It allows problems to be identified accurately and so teaching can be adapted to help pupils develop the a appropriate method for solving the problem they are faced with.

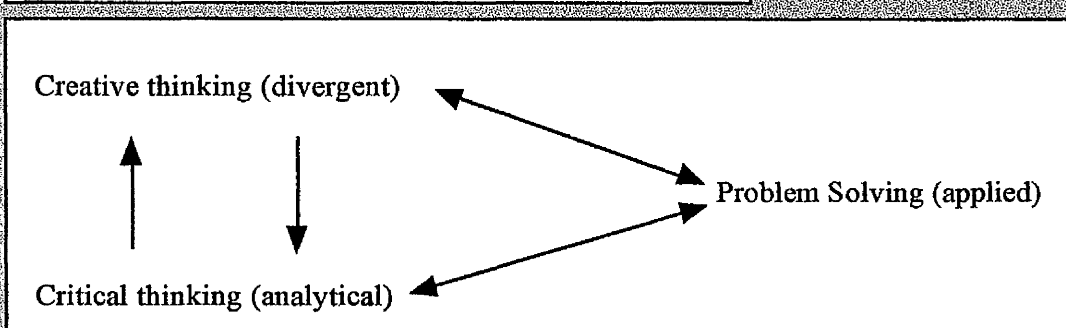
Problem solving can be thought of as:

> *"... applied thinking and can be contrasted with the two other kinds of thinking, creative (divergent) thinking and critical (analytical) thinking."*
>
> *Fisher (1998)*

Fisher (1998)

All three types of thinking are closely linked due to both creative and critical thinking being involved in investigative thinking. This investigation may be a task in its own right or may be part of problem solving (Figure 3.1).

Figure 3.1 Kinds of Thinking : investigative and problem solving Fisher (1998)

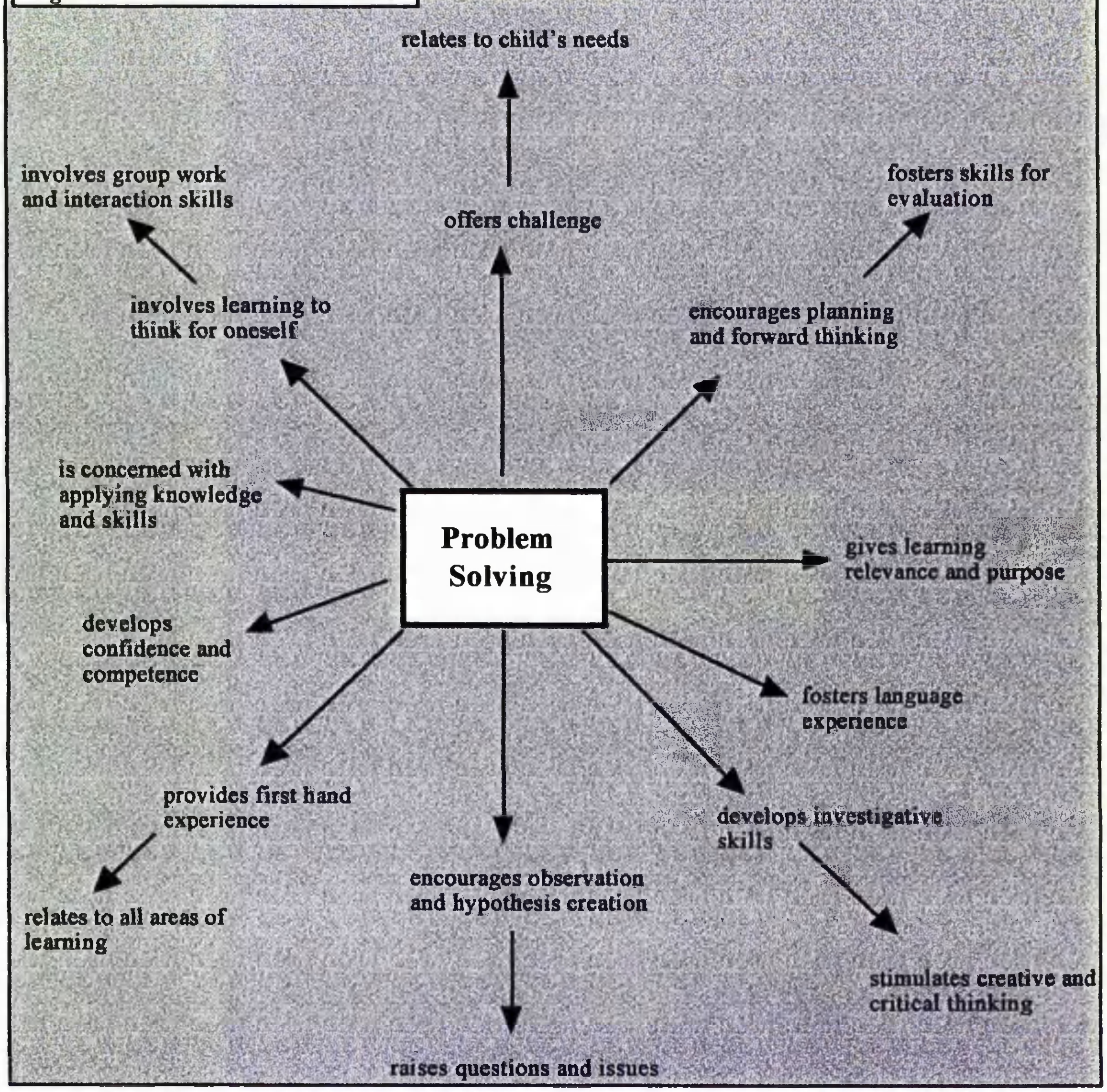


The ability of the child to solve problems and apply their thinking will help the child to develop strategies which can help in life as a whole and not just in classroom situations. By exposing a child to problem solving situations it is possible to have a wide ranging effect on their thinking and their approach to situations.

> *Problem solving activities will stimulate and develop skills of thinking and reasoning. They utilise and make relevant the child's knowledge of facts and relationships. Getting results helps develop confidence and capability.*
>
> *Fisher (1998)*

It will help children to adopt an attitude where they feel confident to work out a problem for themselves or be able to discuss the problem with others and, therefore, come to a group conclusion. Thus, problem solving can be used as a starting point for many skills as the following diagram shows.

Figure 3.2 Charles and Lester 1984.



Each type of problem requires different techniques to be employed in order to solve them. Polya suggests that there are four main stages in solving any problem:

> *a) understanding the problem*
> *b) devising a plan*
> *c) carrying out the plan*
> *d) looking back*
>
> *Polya (1957)*

This is, however, an ideal situation and it was observed by Yang (2000) that there was a complete absence of planning when pupils faced open ended problems (of type 3 - 6 in Table 1). Planning may be an adult way of tackling problems. The planning being based on previous experience which is being used and adapted in this new situation. Young pupils do not have this wealth of knowledge to choose from therefore they find planning difficult if not impossible.

Charles and Lester (1984) suggested that solving problems of the algorithmic type (type 1 in table **3.1**) involves the following stages.

> *i. an effort to understand the problem at both syntactic and semantic levels*
> *ii. organising information to plan an attack on the problem*
> *iii. skills associated with implementing a plan*
> *iv. and the mental processes related to evaluating what has been done and what has been learned.*
>
> *(Charles and Lester, 1984)*

Although all problems can be tackled using this basic structure, each group of problems requires different techniques within the planning and implementing stages mentioned above. Mathematical problem solving is one such type and so it has its own techniques associated with it.

3.2 Mathematical Problem Solving

It has been established that problem solving in general is an important skill for life. It is now necessary to look at problem solving within mathematics in particular. It is obvious that mathematics and problem solving are inter-related and this has been stated by policy documents.

> *"...the essential aim of mathematical education is to help pupils to learn how to describe, tackle and ultimately solve problems which require the use of mathematical knowledge and techniques."*
>
> *Standard Grade Arrangements in Mathematics,SEB 1984.*

> *"The ability to solve problems is at the heart of mathematics."*
>
> *Cockcroft Report 1982.*

Thus, problem solving is part of the mathematics curriculum within both Primary and Secondary schools.

Polya (1962) defines two main types of mathematical problem solving: the problems where an unknown is to be identified and the problems in which it is necessary to prove something.

In the former type of problem, the unknown to be found must satisfy the conditions laid down by the problem and be in keeping with any given data. So, for this type of problem solving, we need an aim, some data and a method by which we can find the unknown.This relates very well to the classical arithmetic based work found in Primary schools. The child is given a situation where the data can be used with a known algorithm or procedure to obtain the answer.

The latter type of problem requires a statement to be proved right or wrong. This type of problem consists of two rather than three main parts. These are the hypothesis and the conclusion. In order to solve this type of problem we need to find a way of connecting the hypothesis and the conclusion together or show that the hypothesis does not imply the conclusion. This is a much harder concept for young children to grasp and is, therefore, not used often within the 10-13 years age group.

The type of problem which is used within this age group can also be classified within Johnstone's categories, 1 and 2, as discussed previously. More specifically there are six groups of problems encountered within the curriculum (Charles and Lester 1984).

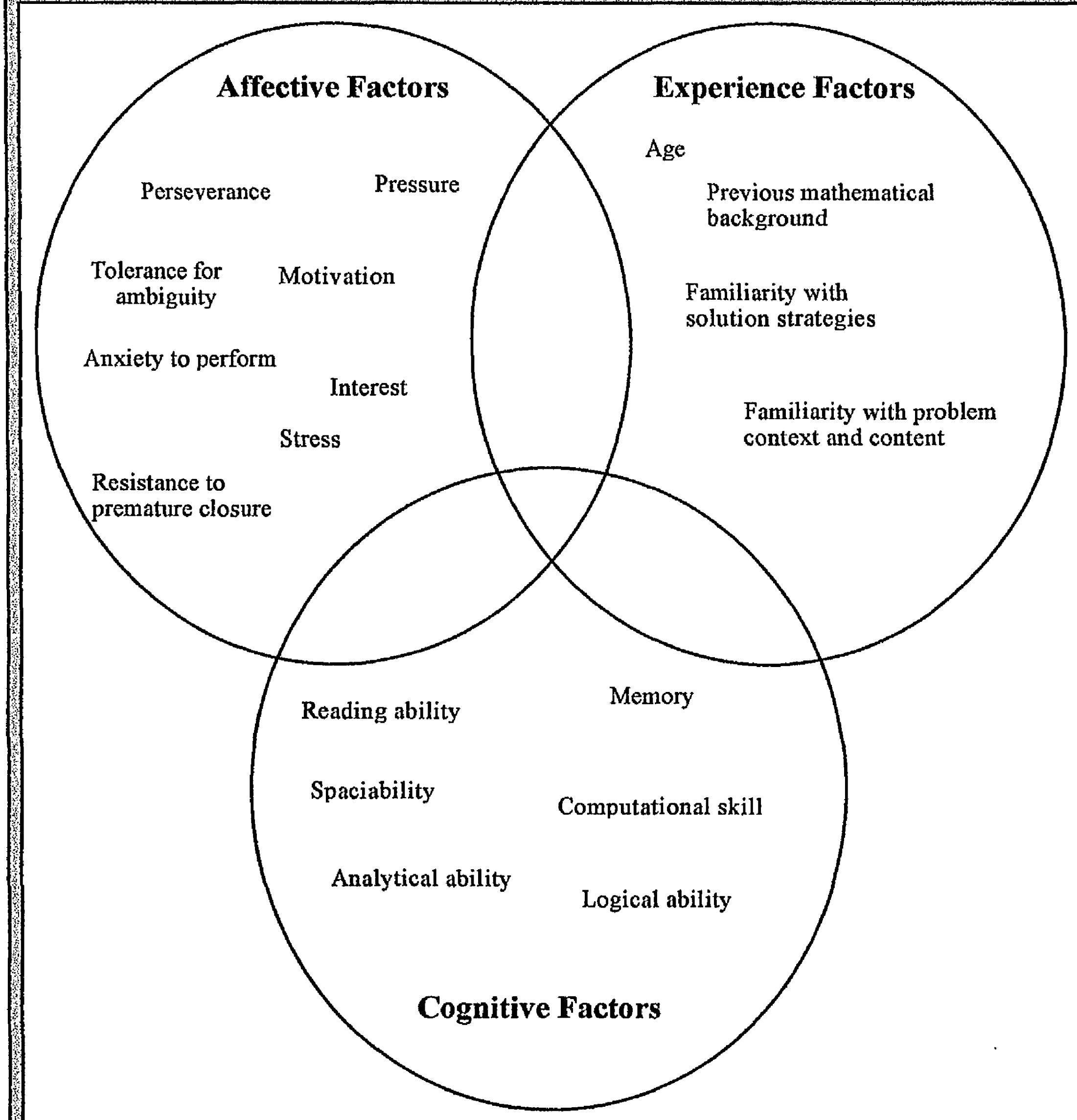
Table 3.2 Charles and Lester, 1984	
1) Drill Exercises.	These give practice in using algorithms and help to maintain a working knowledge of the basic computational facts.
2) Simple Translation Problems.	These provide practice in translating real world situations into mathematical expressions.
3) Complex Translation Problems.	These provide experience similar to those in type two but now two or more translations are required.
4) Process Problems.	These help to develop general strategies for understanding planning and solving problems as well as evaluating attempts at solutions.
5) Applied Problems.	Provide an opportunity for students to use a variety of mathematical skills, processes, concepts and facts to solve realistic problems. These have the intention of increasing awareness of the value and usefulness of
6) Puzzle problems.	These allow an opportunity to engage in potentially enriching recreational mathematics. It is also an opportunity to point out the fact that problems can be tackled from more that one angle and that flexibility is important.

Each type of problem helps pupils to expand their experience of problem solving and gives them the opportunity to experiment with approaches and consolidate techniques.

How mathematical problem solving is tackled by an individual will be influenced by several factors: their previous experience, mathematical learning personality (Sharma, 1989, discussed later), working memory space available and level of motivation will all have an effect on how the problem is approached and dealt with. These factors will influence how the individual views the situation and thus whether a problem is seen at all; one person's problem is not necessarily a problem for another. These factors are summarised by Charles and Lester (1984) in the figure **3.3**.

Interactive factors involved in problem solving.

Figure 3.3 (Charles and Lester,1984)



The cognitive approach of any individual can also be defined as their 'mathematics learning personality' (Sharma, 1989).

There are two extreme categories of cognitive style which have been given various labels by different writers .
For example.

Polya (1962)	groping/ bright	ideas algebra/ generalisation
de Bono (1970)	lateral	vertical
Harvey (1982)	geometers	algebraists
Bath *el al* (1986)	grasshoppers	inchworms
Sharma (1989)	qualitative	quantitative

A pupil's cognitive style will affect their route through a problem but, obviously, no matter which approach is taken, the same answer should be achieved. In each of the above labels the former is a step by step approach while the latter is more intuitive and lateral. Bath *et al.* (1986) used the terms 'Inchworms' and 'Grasshoppers' which are the most instantly descriptive of the techniques involved.

The three areas of problem solving (analysis, method and verification) will be tackled in different ways by the two groups. Table **3.3** below (Bath *et al.*) compares the two approaches.

Table 3.3 Bath *et al* (1986)

	Inchworm	Grasshopper
1. Analysing and Identifying the problem.	1. Focuses on parts, attends to detail and separates.	1. Holistic, forms concepts and puts together.
	2. Objective of looking at facts to determine useful formula.	2. Objective of looking at facts to determine an estimate of answer or range of restrictions.
2. Methods of solving the problem.	3. Formula, recipe orientated.	3. Controlled exploration.
	4. Constrained focusing using single method or serially ordered steps along one route(Rifle approach), generally in one direction.	4. Flexible focusing using multi-methods or paths, frequently occurring simultaneously(Shot gun approach), generally reversing or working back from the answer and trying new routes.
	5. Uses numbers exactly as given.	5. Adjusts breaks down / builds up numbers to make easier calculations.
	6. Tending to add and multiply; resists subtraction and division.	6. Tending to subtract.
	7. Tending to use paper and pencil to compute.	7. Tending to perform all computation mentally.
3. Verification.	8. Verification unlikely; if done uses same procedure or method.	8. Likely to verify; will probably use alternative procedure or method.

As can be seen, the inchworm will work logically, step-by-step, throughout the problem while the grasshopper has a more intuitive, trial and error approach to the problem in hand. The grasshopper and the inchworm are the two extreme categories and the majority of people will show characteristics of both and / or use a different combination of the characteristics as and when required. From a teaching point of view, it is important to be aware of the child's learning personality so that teaching methods can be adapted to appeal to the pupil's preferred style first and then, if appropriate, reinforcement can be done using another approach, expanding the pupil's experience.

Evidence indicates that the cognitive approach used is determined by the hemispheric dominance within the brain (Kane and Kane 1979). The right hemisphere encourages thinking which is deductive, intuitive, holistic, divergent, related to concepts, and geometry. This corresponds with those known as the grasshoppers. When the left hemisphere is dominant, the thinking is more in keeping with that of the inchworm: inductive, convergent, segmented, logical and algebraic. It is generally accepted that someone who is good at problem solving can use a combination of both modes of thinking. However, the fact that one approach does not rely on the use of pencil and paper leads to the question: do more dyslexics use the grasshopper approach rather than the inchworm approach? This question has been addressed by Chinn *et al* (2001). In a study involving children from Ireland, England and The Netherlands, he looked at the cognitive styles of both dyslexics and non-dyslexics. It was found that the dyslexic group were predominately at the inchworm end of the personality spectrum while the non-dyslexics were nearer the middle of the range. His hypothesis drawn from these findings is that the dyslexics would:

> *"... rather attempt a method that they know will hopefully give the correct answer, and therefore will go for the 'safe' procedural option when solving a problem."*
>
> *Chinn et al (2001).*

There were discrepancies between the three countries; the Netherlands had a greater number of inchworm personalities than either England or Ireland. This reflects the differences in the approach to mathematics and the curriculum used in each country.

If we are looking at how a child approaches problem solving we have to establish their view of the problem. We have to be able to look at the situation as they experience it. This will be determined by their cognitive style, their ability to interpret the language

involved, their working memory space, their ability to relate the problem to previous experiences and their ability to adapt their knowledge in order to apply it in a new situation. Any dyslexic tendencies will, of course, have an underlying influence on some of these factors.

It can be seen that the most important factor influencing how a problem is solved is not the problem itself but the problem solver. Each person will have a unique viewpoint of the problem and its level of difficulty. It is possible to look at what areas within problem solving can in general cause difficulty. The following seven points can all contribute to a problem's difficulty.

1. *Complexity of the problem statement.*
2. *Methods of problem presentation and representation.*
3. *Problem solver's familiarity with acceptable solution procedures.*
4. *Misleading incorrect solution or solution procedures.*
5. *Difficulty in locating reachable subgoals (where to start, unwillingness to 'have a go'.)*
6. *Constraints arriving from misconceptions or misunderstandings of information given within a problem.*
7. *Affective factors associated with the problem solver's reaction to the problem (Pupil needs to be motivated and have a 'need' to solve the problem).*

Charles and Lester, 1984

Points one and two have obvious implications for dyslexics in that if the problem is stated within a lot of surplus information, the reading process may not filter out the important data from the extra information given.

Points five and seven can also be influenced by the pupil's confidence within mathematics. If the pupil has a fear of mathematics and failing within the subject then obviously they will be less willing to have a go and then retry the problem if their first attempt does not succeed.

All of these points can be categorised as follows:

Category	Difficulty factors.
Problem	1,2,4
Problem Solver	2,3,4,5,6,7
Processes	3,4
Environment	2,7

This bears out the fact that most of the problems associated with problem solving are related to the solver and how they perceive the question. The first hurdle to overcome is the reading and understanding of the question. This involves the physical reading process and the internal comprehension of what is being read. The identification of keywords here can then help to retrieve from long term memory a method or algorithm which can lead to a solution. At some point the language of the question has to be translated into the language of mathematics in order to achieve an answer. Thinking of mathematics as a language in its own right (Sharma 1989) gives a new viewpoint from which to look at the subject as a whole and the teaching of it.

Mathematics can be thought of as a language having its own alphabet, symbols, vocabulary, syntax, grammar and literature (Sharma). Hence, in order to improve a pupil's understanding of mathematics, it is necessary to develop their mathematics vocabulary, their understanding of the syntax of mathematics and the ease with which they can translate expressions from their native language to that of mathematics and vice versa. The syntax of mathematics is very rigid and precise and it therefore has to be well understood.

Some calculations can be read and worked out by working from left to right.

eg. $12 + 9$; $21 - 8$

whilst some are read left to right but worked out right to left.

eg. $675 \div 5$

Translation is the hardest part of this approach as children have to think about and understand the mathematics behind the expression they are looking at.

eg. $1 < y < 4$

Pupils need to ask ' What is this actually saying?' and put it into words.

'y is bigger than one but smaller than 4.'

Therefore y equals two or three (assuming whole numbers).

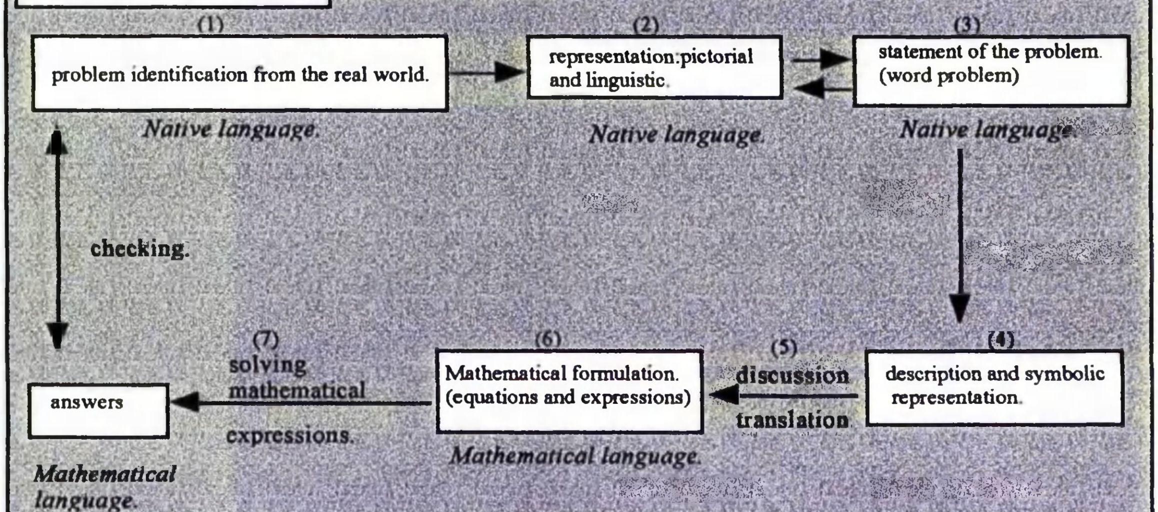
It is also important to be able to translate the child's native language into that of mathematics.

eg. ' y is bigger than two but less than ten.'
becomes $2 < y < 10$.

This type of translation has obvious implications for problem solving when the problem is presented in word form rather than set out as a calculation.

This movement from one language to an other is summarised in the diagram below.

Figure 3.4 Sharma (1989)



(1) Understanding the environment (concrete experiences and the use of natural language).
(2) Translation (natural language to pictorial).(3) Representation(in natural language).
(4) Description and verbalisation (in natural language) of the representation.
(5) Discussion (in natural language).(6) Mathematical formation of the problem (in mathematical language).
(7) Manipulation of mathematical language.

It can be seen from this that a good understanding of the pupil's native language will make the process of problem solving much easier. Thorndike said that:

> *"Our measure of ability in arithmetic actually is a measurement of two different things; sheer mathematical insight and knowledge, on the one hand; and acquaintance with language on the other."*
>
> *Thorndike (1912)*

Although this statement was made in 1912 it is still true today. This gives us an indication of the insight into the situation which Thorndike had.

For dyslexics, however, this prerequisite is not always met due to the problems they have with language as already discussed.

Being able to work between the two languages is a big advantage when it comes to problem solving as it allows a mathematical expression or arithmetic algorithm to be produced as a result of reading or observing the problem. This having been done, a result can be achieved.

Chapter Four

Data Collection

4.1 Aim

The overall aim of the project was to look at how children and, in particular, dyslexic children, tackle arithmetic based problems as encountered in Primary Schools.

This aim produced the follow questions :

1. *Do dyslexics have a different Working Memory Space compared to non - dyslexics?*

2. *Do dyslexics achieve the same success rate as non-dyslexics in arithmetic problem solving?*

3. *Is the approach taken by dyslexics to arithmetic problems different from that taken by non-dyslexics?*

4. *Do children within this age group have a developed network of mathematical words / symbols and their meanings?*

To try and answer these questions the following groups of data were collected:

i. *Working memory space capacity.*
ii. *Word / symbol / meaning networks.*
iii. *Answers to ten Arithmetic based questions.*
iv. *Age of each child.*
v. *Whether the child was dyslexic or not.*

In order to collect this data the children completed four tasks:

i. *A Word Network Questionnaire*
ii. *A Symbol Network Questionnaire*
iii. *A Working Memory Space Quiz*
iv. *A Booklet of Arithmetic questions*

4.2 Working Memory Space Capacity

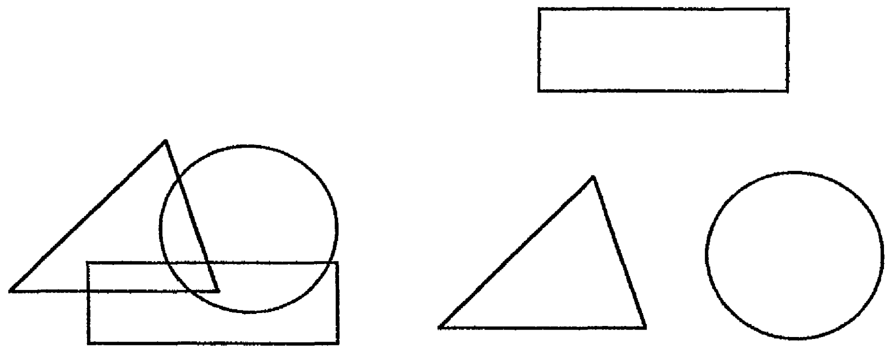
It has been noted that the working memory space is the area of memory where data can be temporarily stored and manipulated if necessary. The limitations on working memory space determines the amount of data which can be stored and manipulated. This can be measured in various ways, two of which are:

i. The digit span test.
ii. The Pascual-Leone Figural Intersections test.

The Digit Span test involves the pupil repeating a group of numbers which they hear. They repeat the numbers initially in the same order as heard and then in the reverse order during the second half of the test. This test is one of those which make up the Aston Index as discussed in Chapter 2. Obviously this test has to be done on a one to one basis and it is therefore very time consuming. Due to the fact that schools could only provide limited access to the children and that the researcher's time was also limited the digit span test was not suitable to use within this study.

Pascual-Leone's test is based on his Theory of Constructive Operators, which states that the working memory space increases in power with age and is largely responsible for a child's developmental progression through the Piagetian stages. The figural intersections test (FIT) is a pencil and paper test which can be used to measure working memory space capacity. Being pencil and paper based, it can be carried out by groups of children at the same time and is therefore less time consuming than the digit span test. This test does not require any written language work and so will not leave dyslexics at a disadvantage. It does, however, rely on the children being spatially aware and this is not always the case for either dyslexics or non - dyslexics. However, the advantages which this test provides outweigh this disadvantage. It is acknowledged, however, that there will be a few children who will not perform well in this test and so a working memory space capacity cannot be accurately established. Within the test the children are asked to look at two groups of geometric shapes.

e.g.



The shapes on the right are the presentation set and the shapes do not overlap but the number of shapes varies between questions. The shapes on the left are the test set. The test set is made up of the same shapes as those in the presentation set but are arranged such that there is a common area of overlap. The object of the test is to identify and mark this area of overlap. The shapes in the test set may differ in size and orientation from those in the presentation test, but they match in shape and proportions. In some questions there is an extra shape in the test set which is not present in the presentation set. This is there to mislead and should be treated as background noise and ignored by the child. The questions get harder the greater the number of shapes present in the sets. The test which was used was based on Pascual-Leone's test and is shown in full in appendix **A**. The test was made up of twelve questions; the number of shapes in each question is shown below.

Question.	Number of Shapes.
1	3 shapes
2	4 shapes
3	5 shapes
4	3 shapes + 1 irrelevant.
5	3 shapes.
6	5 shapes.
7	4 shapes + 1 irrelevant.
8	6 shapes.
9	3 shapes
10	5 shapes.
11	6 shapes.
12	3 shapes.

The difficulty of the questions did not increase throughout the test. Instead the harder questions were interspersed with easier ones in order to allow the children a breathing space. Each question within the test was done within a specific time. This task was presented to the children as a 'Shape Quiz'. The intention of this approach was to present the task in a way which would allow the children to tackle it in a relaxed and attentive manner. Hence, it would hopefully be something fun rather than something daunting.

In order to establish the child's working memory space capacity, the number of correct answers for each number of shapes within the presentation set was noted. Thus, if the highest number of shapes the child could handle was five (that is the questions involving six shapes were answered wrongly) then a capacity of five was assigned.

4.3 Word / Symbol / Meaning Networks

It has been established that it is important to be able to identify keywords within a problem in order to establish what is being asked. These keywords relate to mathematical symbols, concepts and / or algorithms and are interrelated or connected through their meaning. Thus, one word or symbol will be related to another and so on forming a network.

Previous work (Bahar, 1999) had used various techniques to explore pupil understandings of concepts in biology. One of his methods was based on word association ideas and this is known to give helpful insights into the way concepts are linked. This approach was adapted and two tests were developed. The intention was to see what evidence could be gained about pupil conceptual understandings (including use of symbols and algorithms) of the key processes in arithmetic story problems.

The first test gave them the name of an arithmetic procedure and asked them to write down as many other words or phrases as they could which they thought meant the same thing as the original word.

They were given five words in total (addition, subtraction, multiplication, division and equals), each on a separate page with lots of space provided for answers.

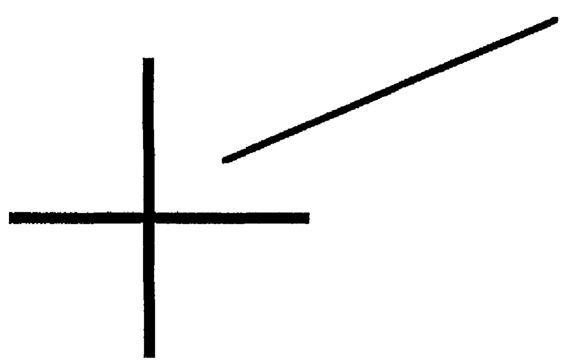
e.g.

Addition.

The full questionnaire is shown in appendix **B**.

The second questionnaire asked the children to match the correct meaning to the arithmetic symbol shown on the page by drawing a line from the correct word to the symbol. Again five symbols were considered in total: + , - , x , ÷ , = .

e.g.



addition
product
sum of
total
minus
add up
share
increase
more than
and
decrease
plus

On each sheet an example was given so that the children were clear about what they were being asked to do. The full questionnaire is shown in appendix **C**.

To interpret the results from questionnaire one, the frequency of each word given as an alternative to the given word was noted. Thus an indication of the strength of the association between the word and its alternatives could be built up.

The interpretation of the results from questionnaire two was done in the same way as those from questionnaire one, in that the frequency of each word matched was established and so the strength of the association could be seen.

4.4 Arithmetic problems

In order to test the pupils' ability in arithmetic story problems it was decided to develop a set of test items. These would be based on the kind of problems that pupils would be likely to meet at this stage or their formal classroom work. The items were designed to offer a variety of situations and formats, some including some pictorial information.

The ten questions within the booklets did not increase in difficulty throughout the booklets but easier questions were placed in between the harder ones. This allowed the children to have a greater chance of finding success throughout the booklet and so reduce the possibility of them giving up when faced with increasingly difficult questions. Within the booklets, considerable space was provided for working to be written down and the children were encouraged to show their working when the test was introduced to them. There were two versions of the booklet, one which had very few diagrams provided, while the other gave more in the way of diagrammatical help, although the same questions were used in each. This was done in order to see if the success rate was affected by the type of presentation used for the questions. The booklet with the greater diagrammatic help had a white cover while the other had a pink cover. This was done to allow them to be easily distinguished. Both booklets are shown in appendix **D** in their entirety but the questions are listed below in a condensed format, so that they can be referred to and discussed.

Arithmetic Questions

(1) Jimmy had 320 stamps.

He was given 49 for his Birthday.

How many does he now have?

(2) Susan has 90p pocket money. She went to the sweet shop and bought the following :-

A bar of chocolate for 50p.

A sherbet dip for 15p.

And 2 toffees at 2p each.

How much did she spend altogether ?

....

(3) A video stand has 6 shelves.

Each shelf has 4 sections and each section can hold 3 videos.

How many videos can the stand hold altogether?

....

(4) A fruit seller had two baskets of oranges.

One basket had 476 oranges and the other had 298.

During the day 577 oranges were sold.

How many oranges are left?

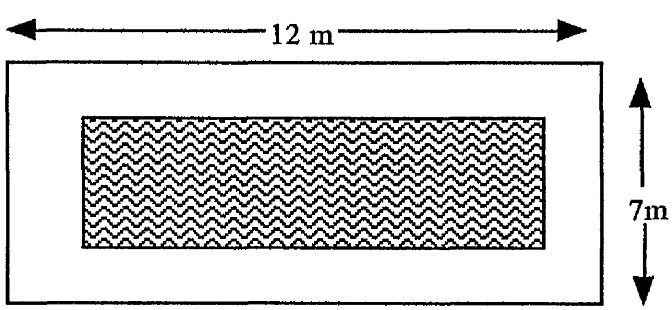
....

(5) The diagram on the below shows a swimming pool.

Around the pool there is a path.

The path is one meter wide.

Find the area of the path.



(6) 80 people came to a party.

42 of them only enjoyed Pepsi.

26 of them only enjoyed Coca - cola.

How many did not enjoy either?

....

(7) Tom had 196 jelly Babies.

He ate 29 while watching T.V.

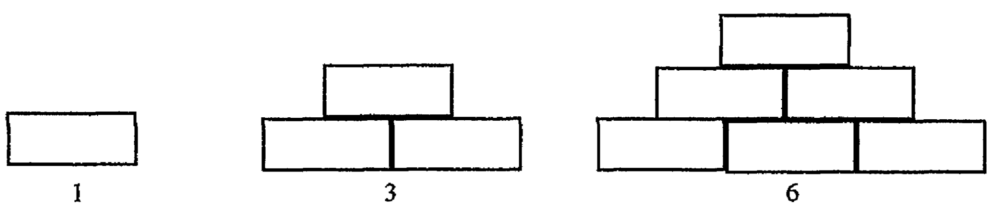
How many does he have left?

....

(8) What would the next two numbers be in the following sequence,

1,3,6,10, , ,

This number sequence can be used to build a display of boxes in a shop window.



What would the display look like if 10 boxes were used?

....

(9) The lunch menu at the local cafe reads as follows.

Starters	Main courses	Desserts
Soup	Burger	Ice Cream
Melon	Fish	Jelly

If you had to eat a two course meal how many different meals could you possibly have?

(10) Jane bought 375cm of ribbon.

She cut it into 5 equal pieces.

How long is each piece?

....

The more graphic version of question two is shown below.

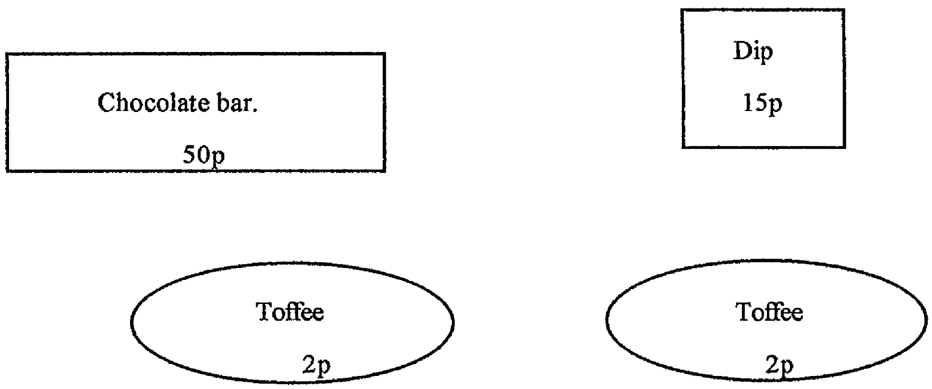
(2) Susan has 90p pocket money. She went to the sweet shop and bought the following :-

A bar of chocolate for 50p.

A sherbet dip for 15p.

And 2 toffees at 2p each.

How much did she spend altogether ?



The questions were written bearing in mind the possible limitations of the children due to working memory space. Thus no questions involved the manipulation of more than 4 pieces of information at one time. The limitations were also reduced by the fact that working was being encouraged and so information could be stored on paper rather than within the working memory space. Doing the working on paper was also encouraged because it would allow the method of calculation to be seen and so a comparison between the dyslexics and non - dyslexics could be made.

Questions 1,2,3,4,6,7 and 10 are all solvable by the use of arithmetic algorithms. It is necessary to establish which algorithm is needed and then to insert the correct numbers from the data given in the question.

Question 5 requires knowledge of how areas are calculated. It also requires the pupil to be able to identify the correct area and then calculate that in an appropriate way: either by subtracting the area of the pool away from the overall area, or, by finding the individual areas of the path and then adding these together.

Question 8 requires the pupil to be able to establish how the pattern is being built up, then to extend the pattern and produce a diagram which also represents the pattern.

Question 9 requires a systematic approach, either systematic listing, or a diagram which can help establish the total number of possible combinations.

When looking at the answers given by the children the following things were noted:

i. Was the correct method used?
ii. Was a diagram used or drawn to help gain an answer?
iii. Was the correct answer achieved?

Due to question eight having two parts the total number of correct answers became eleven.

The children worked through the tasks during two sessions,

Session 1
Word Network (1 minute per page)
Symbol Network (30 seconds per page)
Working Memory Space Test (30 seconds per page)
Session 2
Workbook (untimed)

It should be noted that all the children did the tasks in the same order. This ensured that the word network was done before the symbol one and so the results for the former were not influenced by the visual stimulus in the latter.

All of the tasks were pretested by a group of thirty children, three of whom were dyslexics. How they worked through the tasks and their final success was noted. Due to this initial work some adjustments were made to the symbol network questionnaire and the word plus was added to page 1, having been previously omitted. Question 8 within the problem booklet was reduced from three parts to two. The third part required the pattern being extended much further and it was decided that if the pattern could be established in part two then extending it further achieved no further insight into how the children were thinking. The children were asked how difficult they found each task and how they felt after completing each session. They all said that they found session one more tiring than session two but it was not too much to do at one time. The shape quiz was enjoyed but some found it tricky (this was to be expected). The children felt that the arithmetic problems did not contain materials which they were unfamiliar with and so they did not feel intimidated by them.

4.5 Sample of Children who took Part

Following the pretest and the subsequent modifications, a further sample of 207 children completed the tasks. They were from both the Independent and State Sectors and were aged between nine and thirteen (see table **4.1**).

Table 4.1 Distribution of sample.

Sample	Independent	State	Dyslexics
Test sample	48%	52%	11%
National	5%	95%	5%

There is a greater percentage of children in Independent Education within the sample than the National average due to the fact that the researcher works within this sector and therefore knows people within the sector who were willing to give access to classes.

The percentage of dyslexics is higher since all of the schools were asked if all of the dyslexics within the age group could take part: not only those within the class or classes which were taking part.

The distribution of dyslexics is shown in table **4.2**.

Table 4.2 Number of Dyslexics / Non-Dyslexics.

	Non - Dyslexic	Dyslexic
Male	93	13
Female	93	8

Thus there are more male dyslexics than female. This is what is expected based on the known trends in society.

The age distribution is shown in table **4.3**.

Table 4.3 Age Distribution

Age	**9**	**1 0**	**11**	**12**	**13**
Number	9	74	89	30	5

Seven schools from a wide range of environments and catchment areas took part. The work carried out by the children is such that it should not be influenced by social factors.

Four of the schools chose to have the class teacher or learning support teacher do the work with the children. This gave the schools greater flexibility as to when the work was done. The work to be done was discussed with the teachers involved and a set of instructions (appendix I) was left with them to ensure that the same approach was taken with all the children. It was emphasised to all the children that this was not an examination situation and that it was how they did their work that was important, not just correct answers. The work in the other three schools was collected from the children by the researcher.

Chapter Five.

Results

5.1 Working Memory Space Capacity

Of the 207 children who completed the test, it was possible to establish a working memory space capacity for 86% of them, full results are given in appendix **E**. There are several possible reasons why it was not possible to achieve a result: it may have been that either the task was not understood and so the performance was poor, or the spatial abilities of the child were such that this type of task was beyond them. A full breakdown of the results is shown below.

Table 5.1 W.M.S. Results.

W.M.S.	3	4	5	6	Unknown
Dyslexics	2	6	8	2	4
Non dyslexics	17	53	83	7	25

As can be seen, the majority of both the dyslexics and non-dyslexics have a working memory space of 4 or 5. For the age of the children involved, this result is what might be expected. The average working memory space capacity for ten year olds is accepted as 4 and that of twelve year olds as 5 (Miller,1956).

It should be noted, however, that most definitions for dyslexia comment on the fact that working memory may be poor within dyslexics and so a reduced working memory space capacity would not have been surprising. The indications here are that the working memory space capacity of both groups is the same. Thus, it would appear to be that it is how the dyslexics *use* the working memory space which can result in what appears to be a reduced working memory space capacity.

While answering mathematics questions there are two types of translating occurring: the written or heard English language has to be given a meaning and any mathematical expressions also have to be interpreted and given meanings. Hence, two units of working memory space may be being used before any manipulation of the data has occurred. This obviously means that less manipulation can be done due to shortage of space.

Both of these translation processes can become automatic for non-dyslexics with little or no conscious thought given to them and hence no working memory space is used. Thus, it would seem to be that, although the working memory space capacity of dyslexics starts off being equal to that of the non-dyslexics, it is reduced due to the interpreting process and hence less space is available for manipulation of the data. It is how the space is used which differs not the actual size of the working memory space.

This finding is consistent with the observations by Selepeng (Johnstone and Selepeng, 2001) where some working memory space is used for language translation. It is also supported by the findings of Danili (2001) and Christou (2001) who suggested that field dependent (those who have difficulty in distinguishing the 'message' from the noise in any communication) pupils have less available working memory space to solve problems in Chemistry and Mathematics respectively.

If the recall of number facts is difficult then multiplication answers and basic number facts will have to be worked out each time. This will obviously result in some working memory space being used for these calculations. If recall is good and a calculation is not required more working memory space will be available for another use.

5.2 Arithmetic Booklets

The booklets were completed by all 207 children and a set of results was obtained from each child. For each child the following things were noted:

i. *Whether each individual answer was correct.*
ii. *Whether a correct method was used.*
iii. *Whether a diagram had been used.*
iv. *Which booklet had been done.*

The aspects of this data which will be discussed are:

i. *A comparison of the dyslexic / non-dyslexic groups' overall performance.*
ii. *A comparison of overall performance with age.*
iii. *A comparison of performance within the white and pink booklets.*
iv. *A comparison of performance in individual questions within the dyslexic and non-dyslexic groups.*
v. *A general observation of how the questions were done.*

(The full results obtained from this are shown in appendix **E**.)

5.2.1 Overall Performance

When the total number of correct answers were collected together the results in Table **5.2** were obtained:

Table 5.2 Total number of correct answers.

Total	0	1	2	3	4	5	6	7	8	9	10	11
Dyslexic	1	0	0	1	4	3	0	8	3	1	1	0
Non Dyslexics	2	0	1	1	3	15	24	34	37	38	26	4

The average dyslexic result was **6.05**
The average non - dyslexic result was **7.65**

When a statistical comparison of the two means was done the following result was obtained:

t-test result (using SPSS, appendix **J**). **t = -3.71 (p< 0.01%)**

Thus it can be said that there is a significant difference between the performance achieved by the dyslexics and non-dyslexics.

It would seem, therefore, that although there is no difference in working memory space between the dyslexic and non-dyslexic groups, the overall performance of the dyslexic pupils is not as high as the non-dyslexic group. This could be due to the working memory space becoming 'clogged up' due to translation processes or the inefficiencies of the connections between the working memory space and the long term memory resulting in poor recall of algorithms and / or number facts.

5.2.2 Performance and Age

There were differences in the average marks gained by the different age groups:

Table 5.3

Age	9	10	11	12
Average Total	6.6	6.9	7.8	8.3

A correlation of age against average total (Pearson correlation using SPSS, appendix **J**) gave a coefficient of **0.2424**, significant at less than **0.1%**.

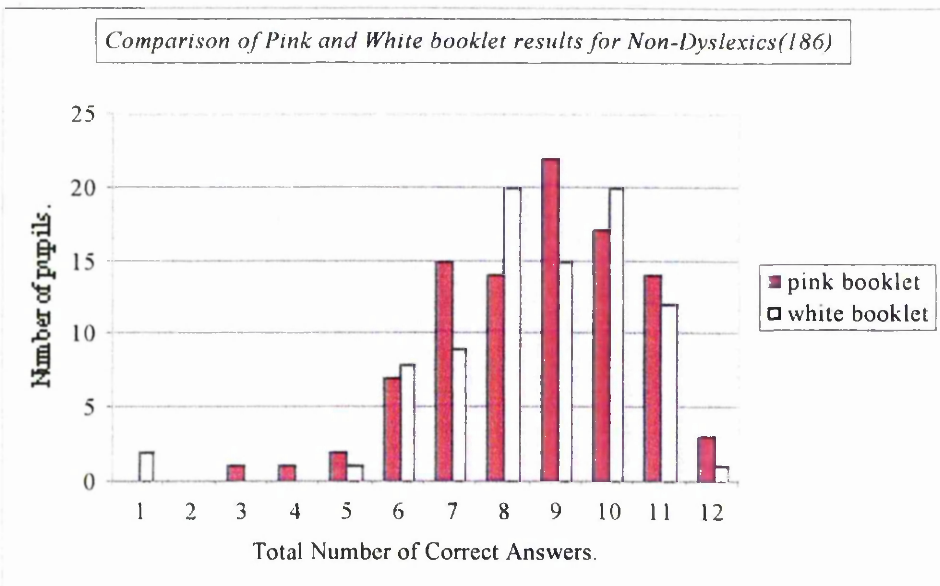
This increase in success with maturity could be related to the pupils having achieved a wider range of mathematical experience and therefore they can apply known methods confidently and / or adapt methods if appropriate. In short, they have a greater number of tools to help them find an answer than the younger less experienced and less confident pupils.

5.2.3 Comparison of Pink and White booklets

109 pupils completed the pink booklet which had only a few diagrams while **98** pupils did the white booklet which contained more diagrammatic help (Equal numbers of each booklet were given to each school and they were given out randomly).

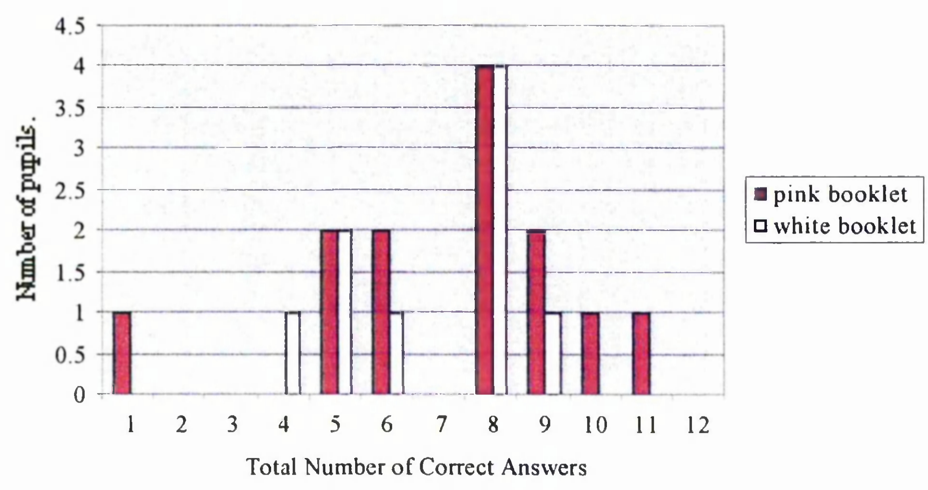
When the two books are looked at separately, graphs **5.1** and **5.2** are obtained.

Graph 5.1



Graph 5.2

Comparison of results between Pink and White for Dyslexics (22)



It should be noted that the scales of graphs 5.1 and 5.2 are different and so a direct comparison of the graphs is difficult. The scale difficulties occur due to the large discrepancy between the sizes of the dyslexic and non-dyslexic groups.

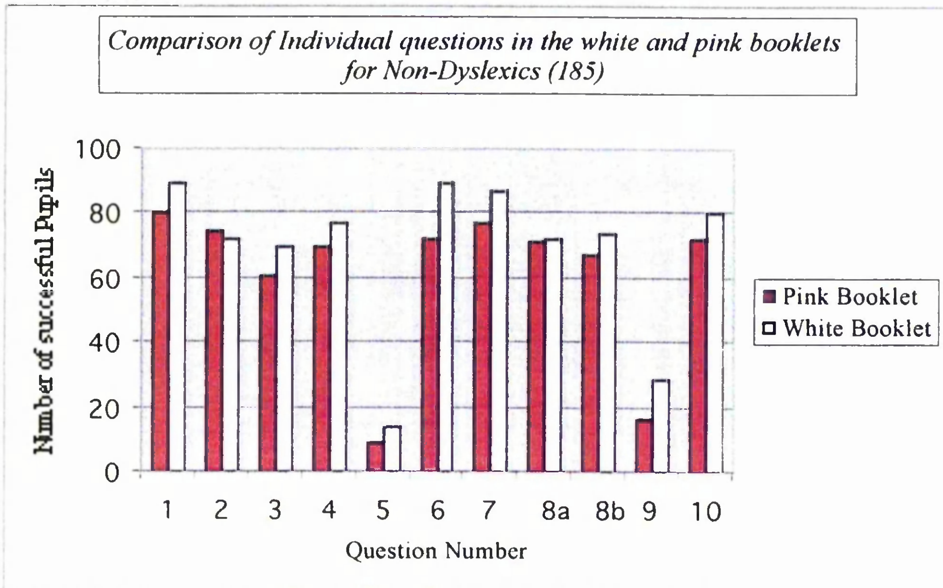
Because the White booklet gave more diagrammatic help than the Pink booklet, there may have been a discrepancy between how pupils performed in each booklet. The graphs above, however, show there were very few differences in the overall success achieved in both booklets remembering that slightly more children completed the pink booklet then the white.

Why there is little difference between the two may be due to the type of diagrams which were used. The diagrams may have helped some pupils while hindering others. This may have been due to the layout of the question: it may have intimidated some pupils while reassuring others. The background information within the question may have caused some pupils to miss key information. Some pupils may prefer symbolic representation, while others prefer more graphical representation. There is therefore the possibility of helping the later while hindering the former.

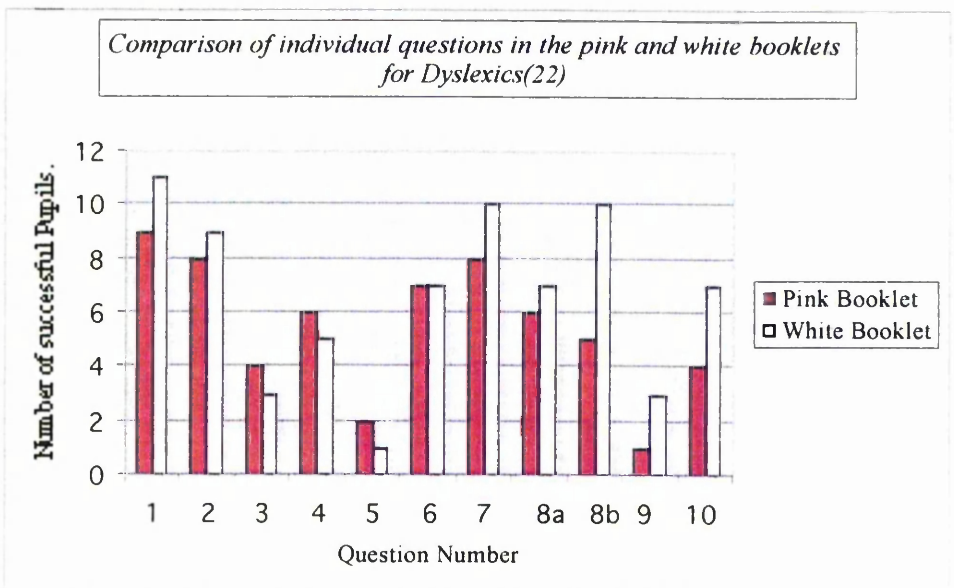
5.2.4 Individual Questions

When we look at the success in each individual question, the graphs **5.3** and **5.4** are obtained:

Graph 5.3



Graph 5.4.



It is again necessary to note that the scales within graphs **5.3** and **5.4** are different and so any comparison between the graphs needs to be done carefully.

As can be seen the questions which gave pupils the most difficulties were numbers 5 and 9. Both of these questions did not require a straightforward application of an algorithm.

Questions 5 required the knowledge of how areas are calculated and also the establishing of which area was to be found. Some children (3%), did not attempt the question. The technique may not have been known or how to apply the formula may not have been appreciated. 29% of the children found the perimeter of the rectangle which may imply that the definitions of area and perimeter were confused or that the method for finding area was unknown but that for finding perimeter was and so they did what they could. 34% of the children found the area of the path plus the pool showing that they did not appreciate that the centre of this rectangle had to be removed in order to find the path alone.

Question 9 required the total number of combinations to be found. 5% of the children included duplicate meals within their lists. This error may have been an oversight or a lack of understanding of the fact that reversing the order of the meal did not change the meal. Some children (4%), did not attempt this question.

The first part of question eight was attempted by 95% of the pupils and the success rate was high. The second part was also done well.

Very few of the children did not attempt questions 1,2,3,4,6,7 and 10. Even if the wrong algorithm was used or an arithmetical error was made the question was attempted. This would seem to imply that, firstly, the basic algorithms were well known and, secondly, they were much more confident when dealing with this type of question.

The confidence may come from being familiar with this type of question and / or a secure feeling arising from having identified which algorithm is required and the knowledge that, barring arithmetical errors, an answer is obtainable. Question 9, however, veers away from a well known procedure and asks the pupil to adapt a procedure which may have been previously used in another setting. In other words, question 9 gives more scope to do your own thinking and this can be a more intimidating option compared to the much more automated or rote procedure required in the other questions.

The success within the individual questions in the white booklet appears to be higher for some questions than the success rate for the pink booklet. When comparing performance between the booklets, it is necessary to compare questions 2,3,4 and 10 specifically as it was their presentation which differed (see table **5.4**) This table shows the number of pupils within both the dyslexic and non-dyslexic groups who successfully completed the questions in the white (more pictorial) and pink booklets.

Table 5.4. Comparison of questions 2,3,4 and 10.					
Question		2	3	4	10
Dyslexics	White	9	3	5	7
	Pink	8	4	6	4
Non-dyslexics	White	72	70	77	80
	Pink	75	60	70	72

The average mark for the four questions was

2.9 for the pink booklet
3.0 for the white booklet

When a statistical analysis of the two means was done the result showed clearly that there was no significant difference between the two.

t-test result (using SPSS, Appendix J) **t = - 0.55 (not significant)**

Hence, it can be said that, in this case, the type of presentation used for the questions has not affected the overall success rate in the whole test or within questions 2,3,4 and 10 specifically.

There was no correlation between the overall result (appendix J) and the working memory space of the children nor was there a correlation between success in individual questions and working memory space. This is not surprising since the questions were written with working memory space in mind and therefore the number of pieces of data which needed to be manipulated at any one time was not high. The children were also given the opportunity to write down working and so information did not all have to be stored and manipulated within the working memory space.

5.2.5 General Observations

Unfortunately no differences between how the dyslexics and non-dyslexics solved the questions could be determined by looking at their written answers. To establish any hidden differences the individual children would have to be interviewed in order to explore how they did each question.

There were similarities within schools as to how written working was done and set out.

For example:

In some schools all the pupils wrote with a pencil while in others a mixture of ink and pencil was used.

In some schools working was set out neatly and a ruler was used by the majority of pupils while in others this did not happen and the written work was untidy and sometimes difficult to follow.

In some schools many pupils did not show working whereas in other schools all the pupils provided written working.

These points would seem to imply that the drilling of the children, the repeated practising of this type of answer in a specific way, will have a strong influence on how the children perform the tasks, even in exercises which are not done for the class teacher. These influences may overshadow any personal preferences the children may have and thus, their natural approach to problems is not being given the opportunity to show through.

Although all the children were encouraged to show working, some did not. This could be due to several reasons:

i. The child thought the questions too easy to require written work and therefore did working mentally.

ii. The child was not used to showing working and therefore worked in a way which was familiar.

iii. The child was unsure of the method and therefore did not write it down in case it was wrong. (Children tend to do this due to fear of failure within the question.)

5.3 Networks

Results from the network booklets were initially collated in two different ways:

i. Age groups: dyslexic and non-dyslexic.
ii. Working Memory Space: dyslexic and non-dyslexic.

The tables of results from these groupings can be found in appendices **F** and **G**. Various aspects of these results will now be discussed.

5.3.1 General Overview

When asked informally, the children commented that they found the symbol booklet much easier to complete than the word booklet. This is probably due to the fact that the symbol booklet gave the visual stimulus of the written words, while the word booklet required the pupil to obtain the meanings, unaided, from their own vocabulary.

If we compare the words associated with the word 'multiplication' with those associated with the symbol 'x', table **5.5** is obtained. It can be seen that the symbol stimulated much stronger connections than the word did.

Table. 5.5 Comparing Word and Symbol Results for all pupils.

Word.	% From Words	% From Symbols
Times	86	99
Square	2	18
Split	0	3
Sum	1	20
Power	0.5	16
Means	0	2
Product	12	56
Of	3	12
Increase	0	50
Multiply	67	97

5.3.2 Age Comparisons

When comparing the results gained from the different age groups within the word booklets, it was found that there was a consistently strong connection between the stimulant word (ie. addition, subtraction, multiplication and division) and two or three others. The range of words used increased as the age of the children increased.

It is worth noting that the range of words associated with the word 'equals' was very high, but, the number of children choosing each word was low. This suggests that there was not a strong connection to any particular word or group of words. This could be due to the children not having a true understanding of the word in the mathematical sense or it could be that they have an understanding but not the vocabulary to verbalise it accurately.

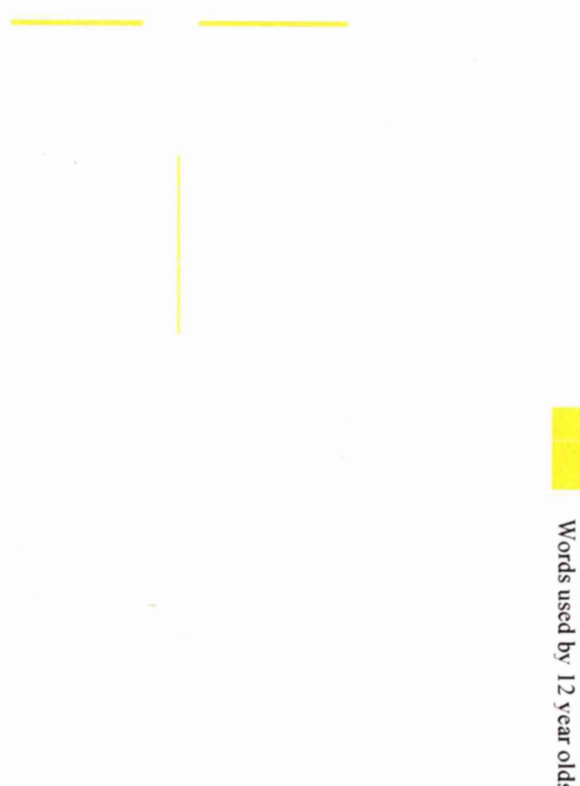
The increase in the range of the words used may be due to the network expanding as the children mature or the result may be due to the fact that the number of children within the 10 and 11 age group is much greater than the 9 and 12 age groups and so there is less diversity within the smaller group.

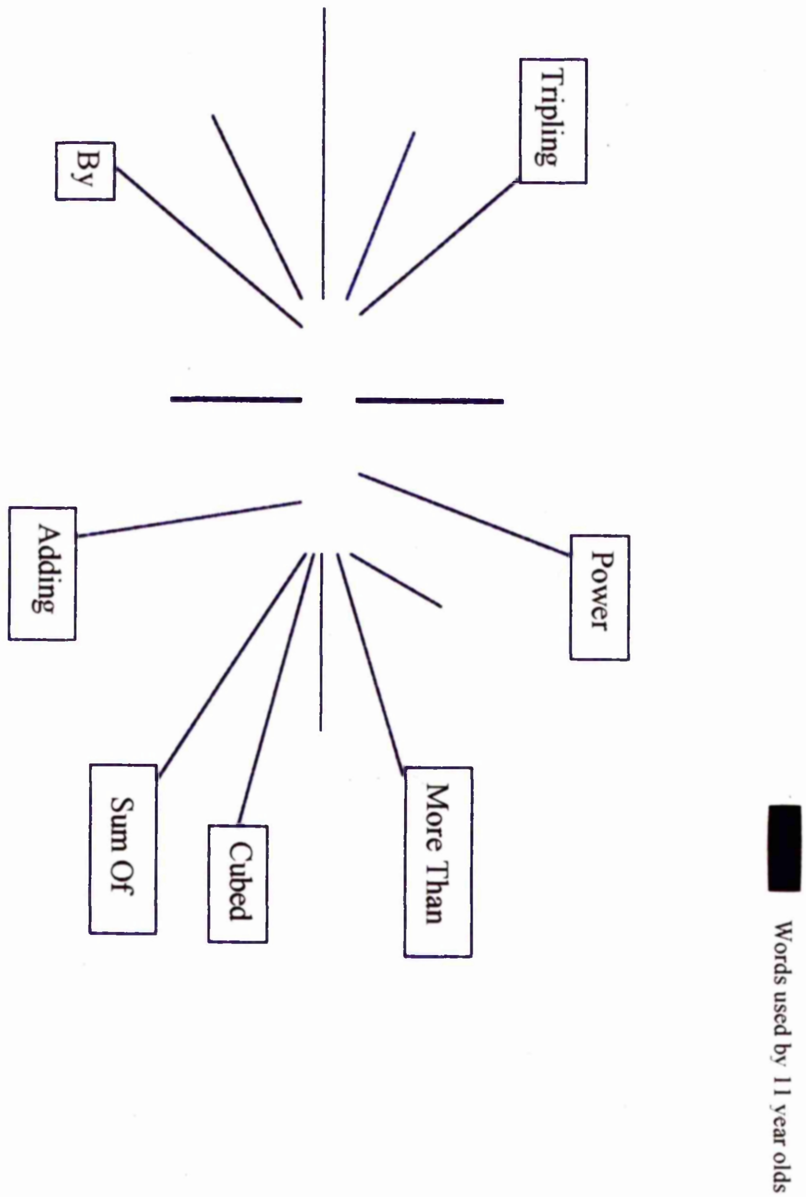
If the results for the word 'multiplication' are compared, table **5.6** is obtained. This table shows the percentage of children within each age group who made the connection between the word 'multiplication' and the words listed in column one of the table.

Table 5.6 Comparing words used within age groups.

Word	9 years %	10 years %	11 years %	12 years %
Times	90	86	93	76
Multiply	80	82	61	43
Double	10	0	2	0
Of	10	1	1	0
Product		16	21	10
Groups of		19	1	
Into		1	0	
Square Number		1	7	
Quotient		1	0	
By			1	
Cubed			4	
Power			2	
Tripling			1	
Adding			1	
More Than			2	
Sum of			4	

Another way of looking to see how the range of words increases due to age is shown in Figure **5.1**. This figure shows the connections made within each age group. Each age group is shown in a different colour so that new connections can be seen as well as those which were already established by other groups. The thicker lines indicate a stronger connection than those represented by the fine lines.


Words used by 12 year olds


By
Tripling
Adding
Power
Sum Of
Cubed
More Than
Words used by 11 year olds

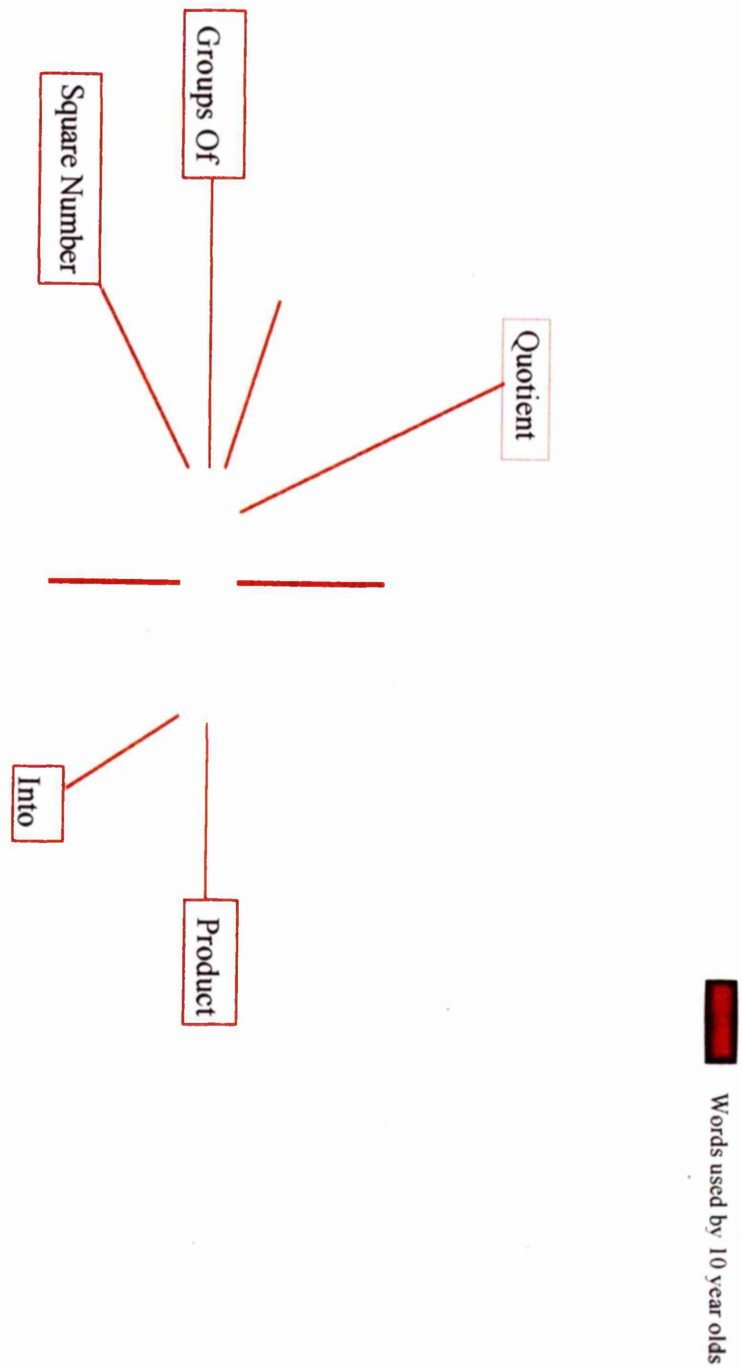

Groups Of
Square Number
Quotient
Into
Product
Words used by 10 year olds

Figure 5.1 Diagram showing the range of words used in each age group

Words used by 9 year olds

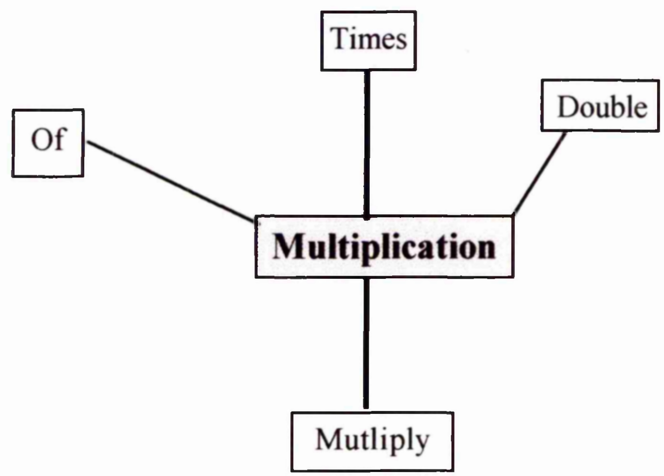
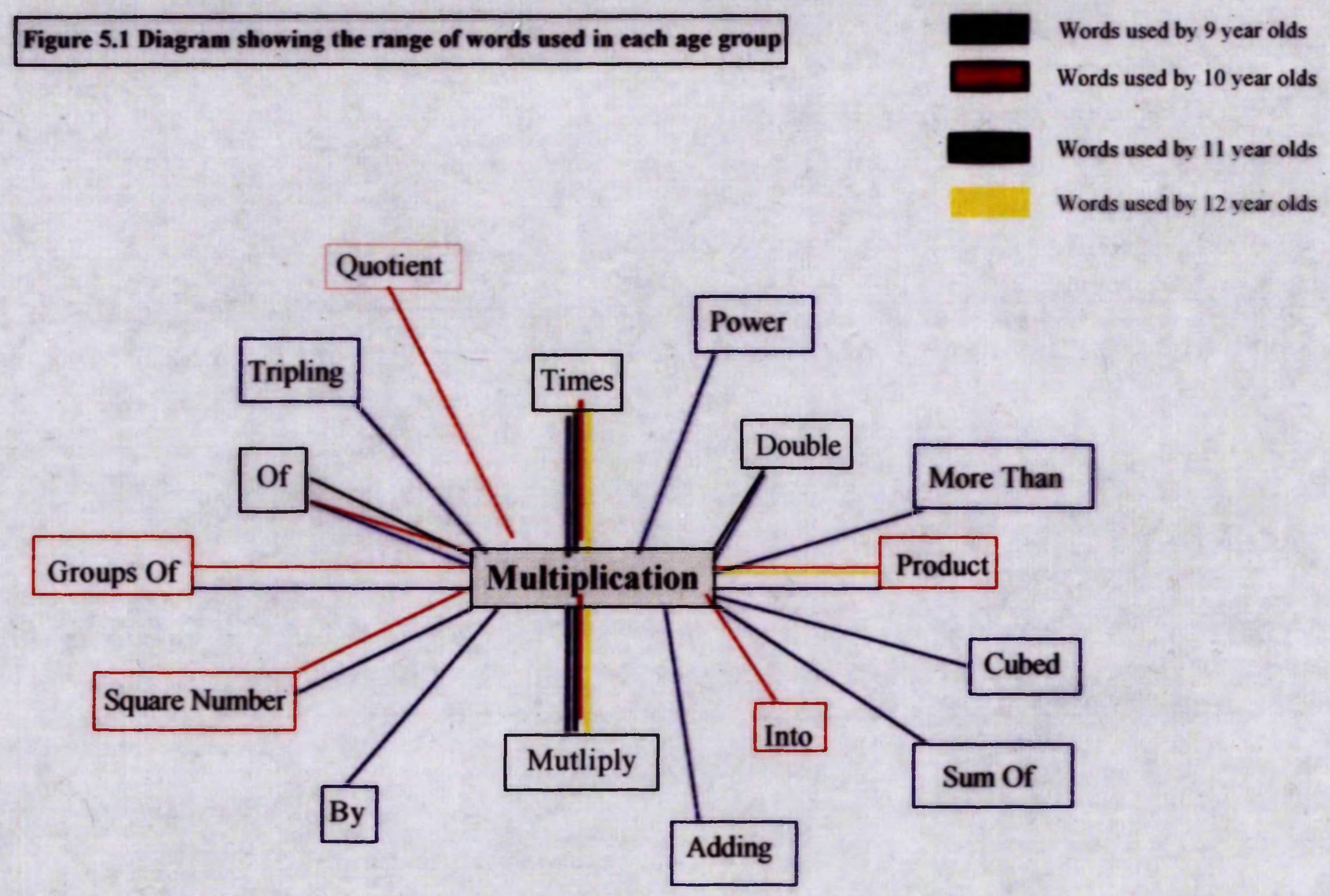


Figure 5.1 Diagram showing the range of words used in each age group



A comparison of the results from different ages within the symbol questionnaire shows that there are strong connections to all the correct words given within the test. For example, if we look at the results gained for the '-', symbol table **5.7** is obtained:

Table 5.7 Comparison of Results for '-' Symbol.

Word	9 years %	10 years %	11 years %	12 years %
Decrease	90	88	81	86
Total		1		
Subtract	100	97	95	100
Square		65	2	5
Take away	100	97	96	100
Difference	90	65	61	38
Less than	80	83	52	57
How many		6	1	
Minus	90	89	90	100
Equals			1	

As can be seen, there is a high percentage of the children making a connection between the symbol and the correct meanings which are given within the list of options. The visual stimulus may be helping to trigger these connections.

5.3.3 Working Memory Space Comparison

When the results are grouped according to working memory space (see appendix **H**), there is not a great deal of difference between the outcomes gained here and those achieved when the data is grouped according to age. The associations made within the word networks are shown in table **5.8** and those for the symbol networks are shown in table **5.9.**

Table 5.8 Comparison of Results for the word Addition.

Word	WMS 3 %	WMS 4%	WMS 5%	WMS 6%
Product	20	15	10	17
Sum Of	46	58	45	67
Total	40	35	32	50
Add up	100	74	93	100
Increase	75	75	61	67
More Than	27	31	21	50
And	40	53	54	50
Plus	100	100	94	100

Table 5.9 Comparison of Results for the Symbol '-'

Word	WMS 3%	WMS 4%	WMS 5%	WMS 6%
Decrease	87	85	85	83
Subtract	93	98	100	100
Take Away	100	98	100	83
Difference	53	71	58	67
Less Than	75	73	63	67
How Many	7	4	2	67
Minus	100	93	93	100

The fact that working memory space does not appear to have an effect on the network of meanings available is not surprising. The recall of meanings and words does not require any manipulation of information, only the brief storing of the word until the answer is written. Thus working memory space does not play a part in this particular process.

5.3.4 Results from the Dyslexic group

The results from the dyslexic group were then taken on their own and this produced the results in appendix **H.**

Results from the dyslexic group were similar to those obtained from the non-dyslexic group in that there was a stronger connection seen when a visual stimulus was given. An example of this can be seen in table **5.10** where a comparison of the results for the word 'division' with the symbol '÷' has been done.

Table 5.10 Comparing Word and Symbol results Dyslexics.

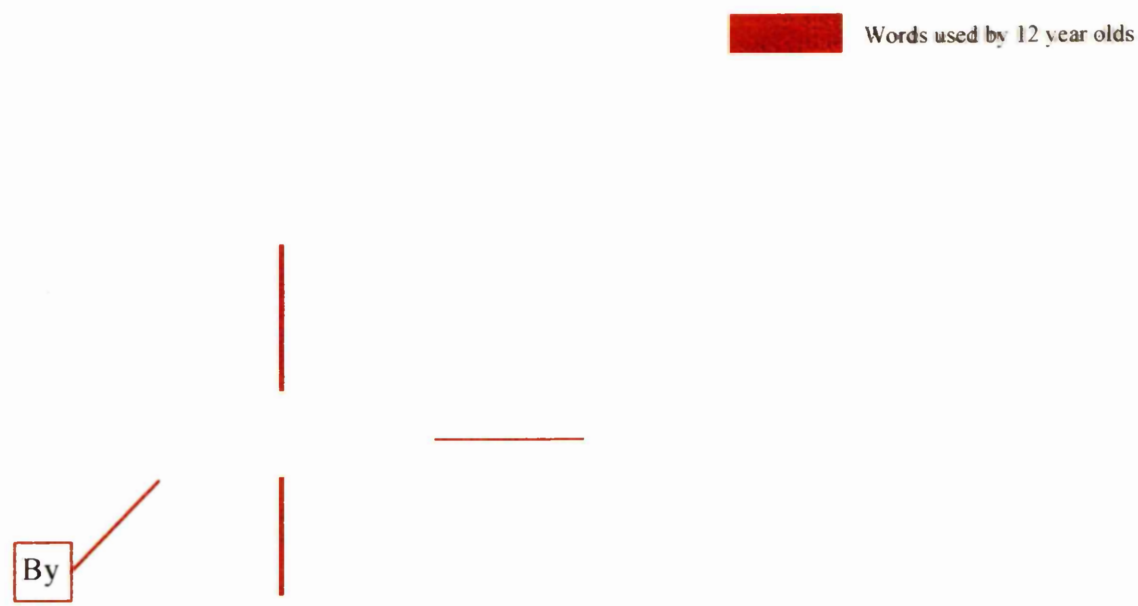
Word	Word %	Number %
Divide	65	100
Split	12	71
Means		6
Group	6	29
Share	6	71
Sum Of		6
How Many		24

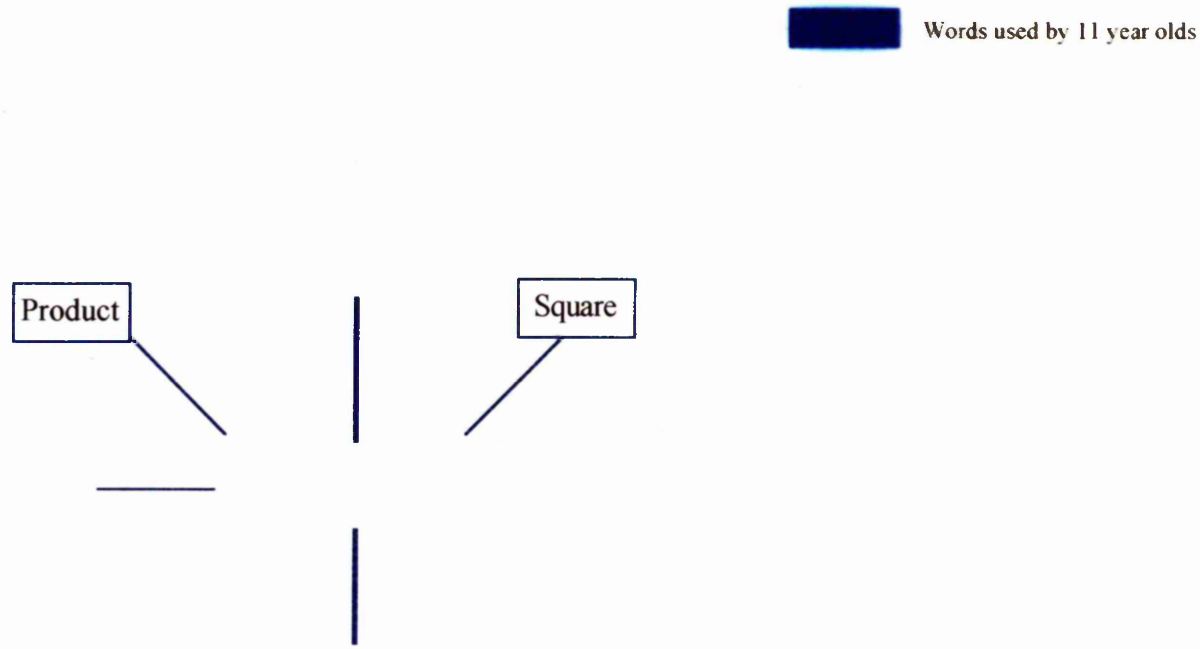
Despite the low sample it is clear that the connections are stronger when a visual stimulus is given, similar to the result for the non-dyslexic group.

When the range of words used within each age group is considered, there is a slight increase as the age increases (see figure **5.2** overleaf). It should be remembered, however, that the numbers within each age group are very small and so to compare results by using percentages can be misleading. Hence, the same type of comparisons cannot be done here as were done for the non-dyslexics. This is also true when the results were grouped in terms of working memory space. By looking at the overall picture obtained from the results in appendix **7** a general conclusion can be made.

Hence, it can be said that the dyslexic group, looked at here, appeared to have the same understanding of the words and symbols within the booklets. This implies that they would therefore have the same ability to identify them within an arithmetic problem and know their meaning. This is not what would be expected given the present understanding of dyslexics.

It should be remembered, however, that the process of identifying the word may not be straightforward for the dyslexic child, particularly if the keywords are within background material which is not vital to answering the question. The keyword may be lost, or, read but its significance not recognised.


Words used by 12 year olds
By


Words used by 11 year olds
Product
Square

Words used by 10 year olds

Figure 5.2 Diagram showing range of words used within each age group

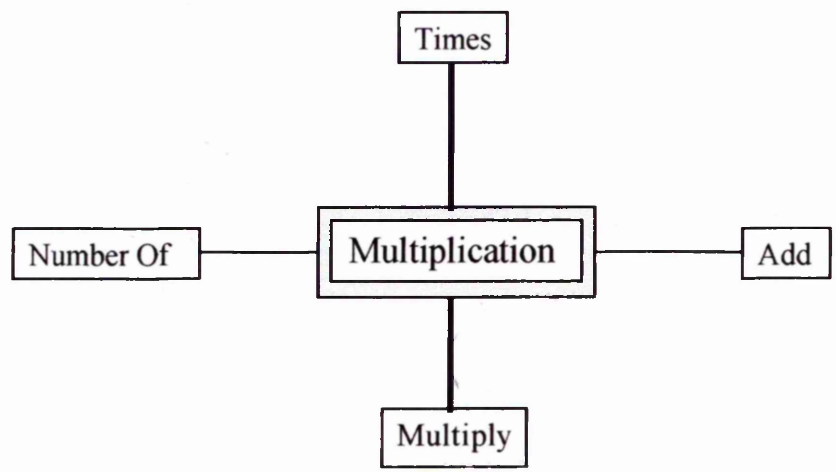
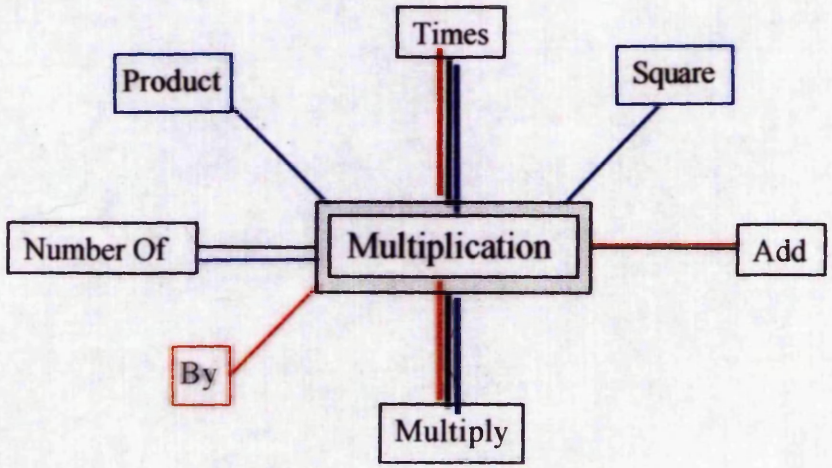


Figure 5.2 Diagram showing range of words used within each age group



Chapter Six

Conclusions and Further Study

6.1 Conclusions

The overall aim of this project produced four questions. The answers to these questions will therefore form the basis for any conclusions which can be drawn.

> *1. Do dyslexics have a different working memory space compared to non-dyslexics?*

From the work done here, the answer to this would appear to be no. This result is initially surprising given the established observation that dyslexics work with a lower working memory space. This would then imply that the working memory space is being used differently as the manipulation of data by dyslexics is known to be poorer than that of non-dyslexics (Chasty,1989). The working memory space could be being blocked by translation processes or anxiety may reduce the space available for manipulation. Poor long term memory to working memory connections could result in poor recall of multiplication tables, number bonding and algorithms which may, in turn, result in a greater number of manipulations being required and hence an overload of the working memory space could occur.

> *2. Do dyslexics achieve the same success rate as non-dyslexics?*

The success rate of the dyslexics was significantly lower than that of the non-dyslexics. This could be due to poor recall of algorithms and number facts or the fact that the working memory space becomes blocked and data manipulation is therefore more difficult. In general, the overall confidence of the children might have had an affect on their performance.

3. Is the approach taken by dyslexics to arithmetic problems different from that taken by non-dyslexics?

From this study it is not possible to answer this question. The written answers from the dyslexic group did not vary from those given by the non-dyslexic group. Therefore, to answer this question fully, the children would have to be interviewed individually and a note of their strategies taken as they talked about them. Because of time restrictions, it was not possible to complete this type of study. However, future study could focus on this particular aspect more closely.

It was seen, however, that the way in which the children are drilled within the classroom has a great effect on how they tackle this type of question.

4. Do children within this age group have a developed network of mathematical words / symbols and their meanings.

All the children, both dyslexics and non-dyslexics, would appear to have a good network established for the four basic arithmetic procedures; addition, subtraction, multiplication and division. These networks function particularly well if the pupil has a visual stimulus. The network for 'equals' was less well established and this could be due to a lack of understanding of the concept or an inability to verbalise the meaning accurately. The process of handling data within the working memory space may be hampered due to poor communication between the long term memory and the working memory space. This would result in poor recall of information. Many of the characteristics of dyslexia are consistent with this explanation.

6.2 Further Study

In looking back over the project it is now apparent how difficult it is to 'see' into pupils minds to find out the areas of difficulty which they are experiencing. In this project emphasis was placed on drawing conclusions from written work in order to gain an overall picture. If time had permitted a more case study approach would have been helpful. Such an approach might have given useful insights with dyslexic pupils where there are likely to be a diversity of factors involved.

In the light of this the following pieces of work could be carried out to extend the work completed within this project:

i. Individual case studies with dyslexics to establish, in detail, their approach to individual arithmetic problems.

ii. A study of which types of diagrams within arithmetic questions are useful and which add to the difficulty of the question.

iii. A study of mathematics anxiety. Establishing which areas of mathematics cause the most anxiety and how this affects performance, particularly for dyslexic pupils.

iv. A comparison of the networks stimulated by aural and visual stimuli.

References

Atkinson, R.L. *et al* (1993) "Introduction to Psychology", Fort Worth: Harcant, Bruce and Jovanovich.

Ashcraft, H.M. (1994) " Human Memory and Cognition", New York: Harper Collins College Publishers.

Ashcraft, H.M *et al* (2001) " On the cognitive consequences of Mathematics Anxiety", in *The Development of Mathematical Skills,* Ed by C. Dolan, Hove UK: Psychology Press.

Ausubel, D.P. (1968) " Educational Psychology a Cognitive View", New York: Holt, Rinehart and Winston.

Baddeley, A. (1986) "A working memory space", London: Oxford University Press.

Bahar, M. (1999) " Investigation of biology students' cognitive structure through word association tests, mind maps and structured communication grids" , PhD Thesis, University of Glasgow.

Bath *et al.* (1986) " The test of Cognitive Style in Mathematics", East Aurora, New York: Slosson Publishers.

Bruner, J.S.J. (1966) " Toward a Theory of Instruction", Cambridge, Mass: Belknap Press of Harvard University.

Buxton, L. (1981) " Do you Panic in Maths?", London: Heinemann.

Case, R. (1985) "Intellectual Development: A Systematic reinterpretation", New York: Academic Press.

Charles, R. and Lester, F. (1984) " Teaching Problem Solving", London: Arnold Publishers.

Chinn *et al*. (2001) " Classroom studies into cognitive style in mathematics for pupils with dyslexia in special education in the Netherlands, Ireland and the UK" , *British Journal of Special Education,* Vol **28** (2), 80 - 85.

Chinn, S.J. and Ashcroft, J.R. (1995) " Mathematics for Dyslexics a Teaching Handbook", London: Whurr Publishers.

Cockcroft Report. (1982) "Mathematics Counts: Report of the Committee of Inquiry into the Teaching of Mathematics in Schools under the Chairmanship of W.H. Cockcroft", London: HMSO.

Collins, C. and Miller, J.C. (1996) " Spelling - Diagnoses and Strategies", in *Dimensions of Dyslexia.* Ed. by Gavin Reid, Edinburgh: Moray House Publications.

Critchley, M and Critchley, E.A. (1978) " Dyslexia Defined", London: Heinemann Publications.

de Bono, E. (1970) " Lateral Thinking: A textbook of Creativity", London: Ward Lock Education Publishers.

Dyslexia Institute. (2000) " The Dyslexia Handbook 2000", Ed by, Smythe I.

Fawcett, A.J. and Nicolson, R.I. (1997) " The Dyslexia Screening Test (DST)", London: The Psychological Corporation.

Flavell, J.H. (1963) " The Developmental Psychology of Jean Piaget", Princeton, N.J: Van Nostrand.

Fisher, R. (1990) "Teaching Children to Think", Oxford: Basil Blackwell.

Gagne (1964) " The Conditions of Learning", New York, Chicago, San Fransisco, Toronto, London: Holt, Rinehart and Winston.

Gathercole, S.E. and Baddeley, A.D. (1996) " The Children's Test of Non - Words Repetition (CNRep)", London.

Goswami, U. (1998) " Cognition and Children", London: Psychology Press.

Hallgren, B. (1950) " Specific Dyslexia (Congenital word blindness) A clinical and Genetic Study", in *Acta Psychiatrica et Neuroloica, Supplementum,* **65**: i- ix, 1- 287.

Harvey, R. (1982) " I Can Keep Going If I Want To: One way of Looking at mathematics", in *Language Teaching and Learning.6.Mathematics,* Ed. by, Harvey, R., Kerslake, D., Shuard, H. and Torbe, M, London: Ward Lock Educational.

Henderson, A. (1989) " Maths and Dyslexics", Llandudno: St.David's College.

Howe, T.V. (1975) " Educational Problems in Writing Chemical Formulae and Equations", MSc. Thesis, University of Glasgow.

Huston, A.M. (1992) " Understanding Dyslexia" Lanham, New York, London: Madison Books.

Johnstone, A.H. and Byrne, M.S. (1987) " Critical Thinking and Science Education", In *Studies in Higher Education,* **12 (3)** , 325 - 39.

Johnstone, A.H. (1997) " Using a Model of Learning to Give Direction to Developments", in *Science Education in the 21st Century,* Ed. by, Thompson,D.L., Aldershot: Arena.

Johnstone, A.H. (1993) " Introduction", in *Creative Problem Solving in Chemistry,* Ed by, Wood, C. and Sleet, R . London: The Royal Society of Chemistry.

Johnstone, A.H. and Selepeng, D. (2001) In *Chemistry education research in practice in Europe.* **2 (1)** 19 - 29.

Johnstone, A.H. (1988) " Meaning Beyond Readability", Guilford: The Southern Examination Board.

Kane, N. and Kane, M. (1979) " Comparison of left and Right Hemisphere Functions" , in *The Gifted Child Quarterly,* **23(1)** 157 - 167.

Kempa, R.F. and Nicholls, C.E.(1983) " Problem Solving Ability and Cognitive Structure - an exploratory Investigation", in *European Journal of Science Education,* **5** (2) 171-184.

Newton, M.J. and Thomson,M.E. (1976) " The Aston Index: A classroom test for screening and diagnosis of language difficulties", Wisbech, Cambs: Learning Development Aids.

Miles,T.R. (1997) " The Bangor test", Wisbech, Cambs: Learning Development Aids.

Miles,T. (1992) " Some Theoretical Considerations", in *Dyslexia and Mathematics,* Ed. by Miles, T.R and Miles,E., London: Routledge.

Miles,T. and Miles, E. (1999) " Dyslexia a Hundred Years On", 2nd Ed, Buckingham, Philadelphia: Open University Press.

Miller, G.A. (1956) "The Magical Number Seven plus of minus two: some limits on our capacity for processing information", in *Psychology Review,* **5**, 98 - 118.

Morgan, W. P. (1896) " A Case Study of Congenital Word Blindness", in *British Medical Journal,* **2***: 1378.*

McGhee, R. (1996) " Formal Assessment", in *Dimensions of Dyslexia,* Ed. by Gavin Reid, Edinburgh, Moray House Publications.

Novak, J. (1978) " An Alternative to Piagetian Psychology for Science and Mathematics Education", in *Studies in Science Education,* **5** ,1 - 30.

Pascual-Leone, "Manual for FIT: Figural Intersections Test", A Group Measure of M-Capacity, Unpublished Manuscript, York University.

Piaget, J. and Inhelder, B. (1969) " The Psychology of the Child", New York: Basic Books.

Pollock, J. and Walker, E. (1994) " Day - To - Day Dyslexia", London, New York: Routledge.

Polya, G. (1962) " Mathematical Discovery", vol **1**. New York: Wiley.

Polya, G. (1957) " How to Solve it: a new aspect of mathematical method", New York: Doubleday Anchor Books.

Reid, G. (1996) " Dyslexia: A Practitioners handbook", Chichester, New York: Wiley.

SEB Standard Grade Arrangements in mathematics (1984).

Sharma, M.C. (1989) " Mathematics Learning Personality", in *Math Notebook.* Vol **7, (Numbers 1 and 2).**

Sharma, M.C. (1989) " Mathematics as a Second language Parts 1 and 2 ", in *Math Notebook.* Vol **4.**

Sharma, M. C. (1990) " Dyslexia, Dyscalculia, and Some Remedial Perspectives for mathematics learning Problems", in *Math Notebook* Vol. **8 (Numbers, 7,8,9,10).**

Singleton, C.H. et al (1996 / 1997) " COPS 1 Cognitive Profiling System. DOS and Windows editions", Newark,NJ: Chameleon Education Systems Ltd.

Smith, S.D. et al. (1983) " Specific reading Disability: Identification of an inherited form through linkage analysis", in *Science.* **219: 1345 - 7**

Smith, S.D. et al. (1991) " Screening for Multiple genes influencing Dyslexia", in *Reading Disabilities : Genetic and neurological Influences,* Ed. by, Pennington, B.F. Dordrecht : Kluwer.

Snowling, M. et al (1996) " Graded Non word Reading Test", Bury St.Edmunds: Thames Valley Test Company.

Stewart, J.S.S. (1989) " Some Genetic aspects of Dyslexia", Paper Delivered at the conference of the Rodin Remediation Academy, Bangor, North Wales, September.

Thomson, M. E. (1991) " Developmental Dyslexia", 3rd Edition. London: Whurr.

Thorndike, E.L. (1912) " Animal Intelligence: Experimental Studies", New York: MacMillan.

Uta, F. (1997) " Brain, Mind and Behaviour", in *Dyslexia Biology Cognition and Intervention,* Ed. by Hulme and Snowling, M. London: Whurr Publishing.

Vingrad, M. (1994) " A Revised Adult Dyslexia Checklist", in *Educare,* **48**: 21 - 23.

Wydell, T.N. (1999) "A Case Study of an English, Japanese Bilingual within mono-lingual Dyslexia", in *Cognition* **70**: 270-305

Yang, M.J. (2000) " Problem Solving in Chemistry at Secondary School", PhD Thesis, University of Glasgow.

List Of Appendices

Appendix A

Figural Intersections Test

Name: ....

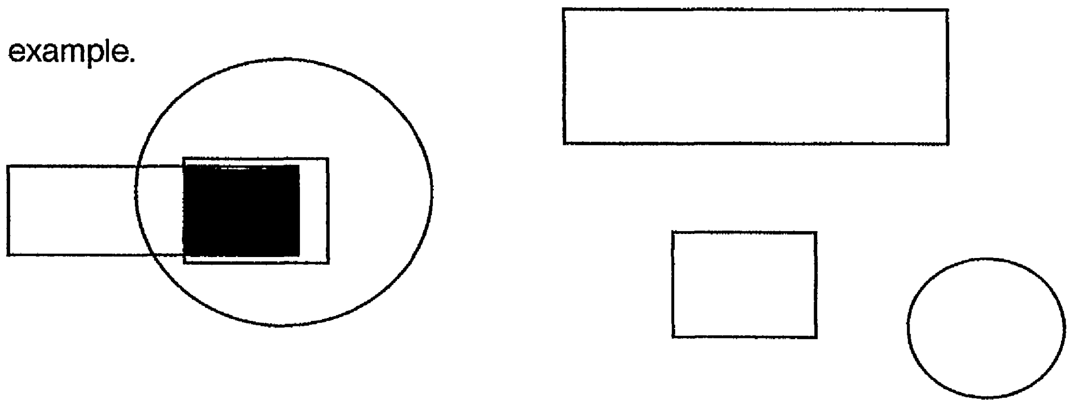
Age: ....

Shape Quiz

To do this quiz you need to :-

1) Look at the shapes on the right hand side of the page .
2) Look at the shape on the left hand side of the page. It is made up of the shapes on the right.
3) Find and shade the area where all the shapes overlap.

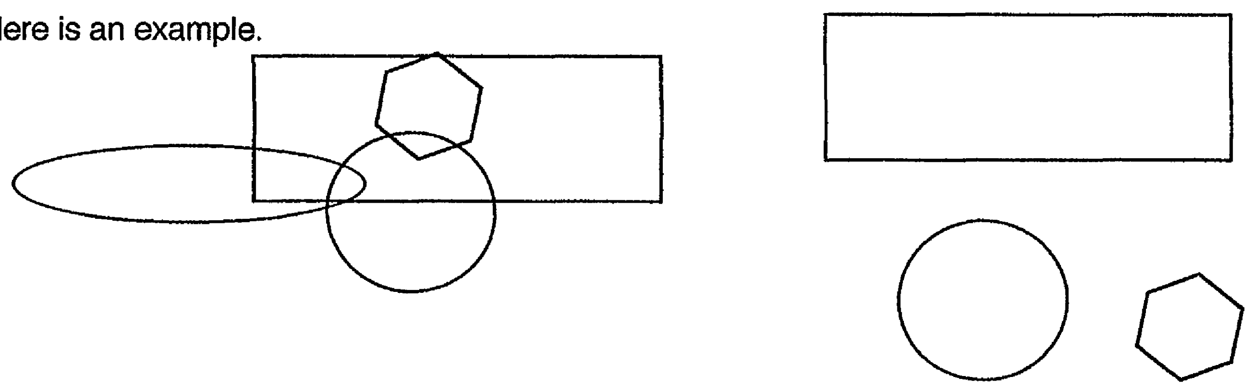
Here is an example.



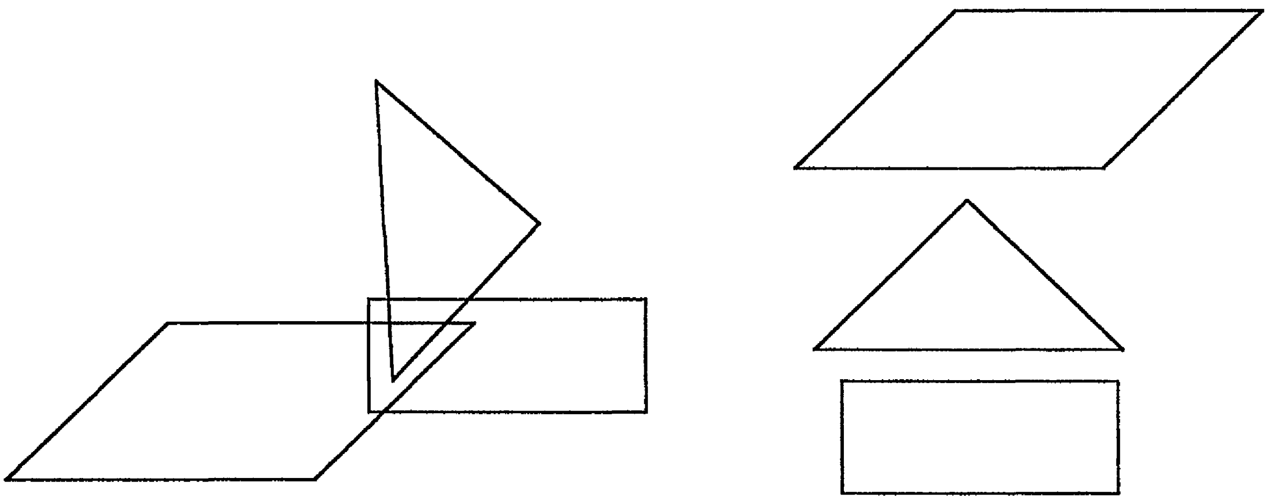
The shapes may be different in size but not in shape.

Sometimes an extra shape will be added to the left hand shape . This is just there to confuse you! You should ignore it.

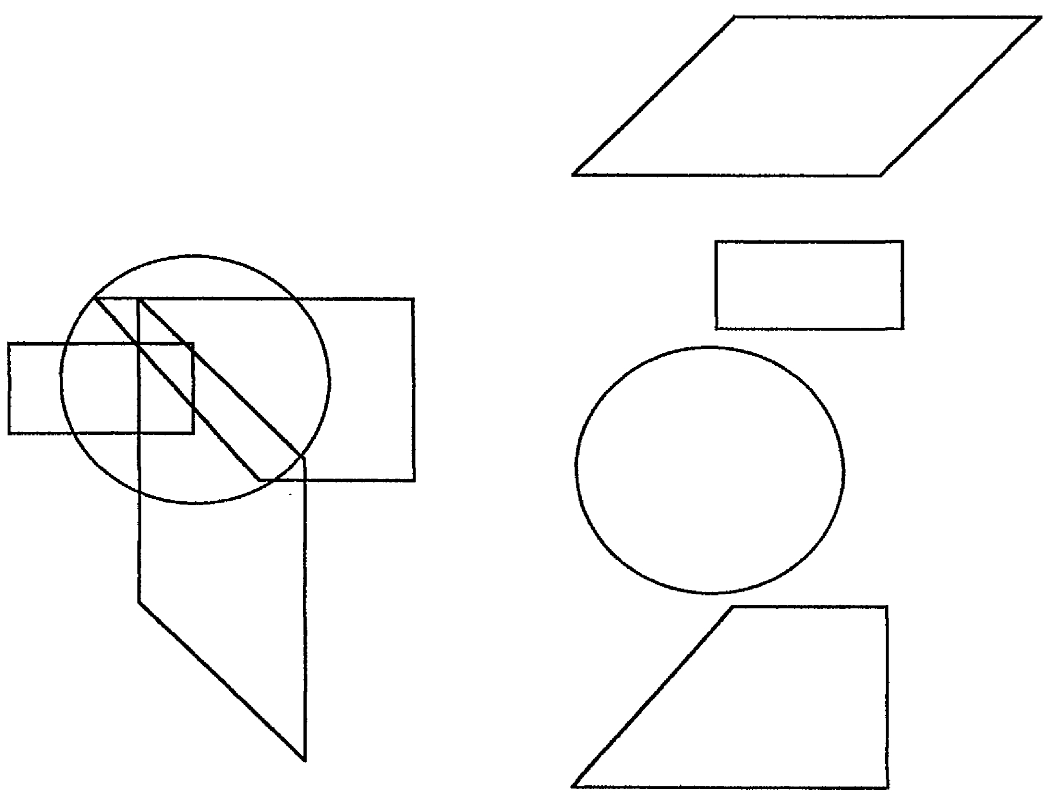
Here is an example.



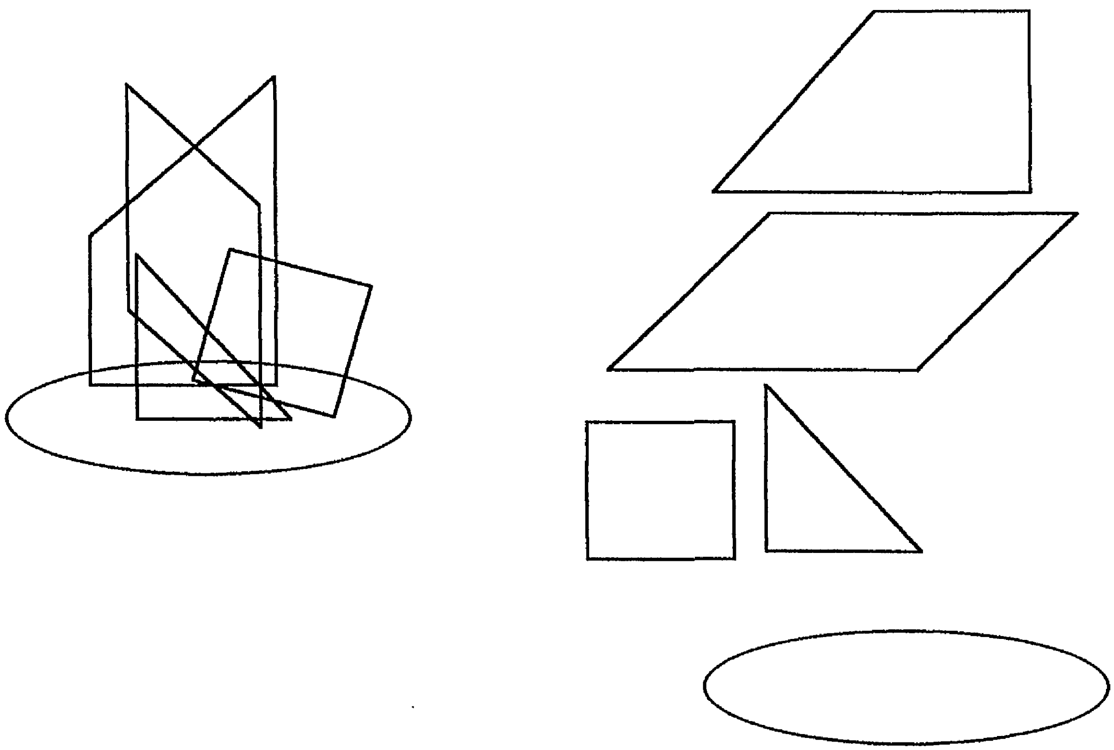
Now try each of these.



2)



3)



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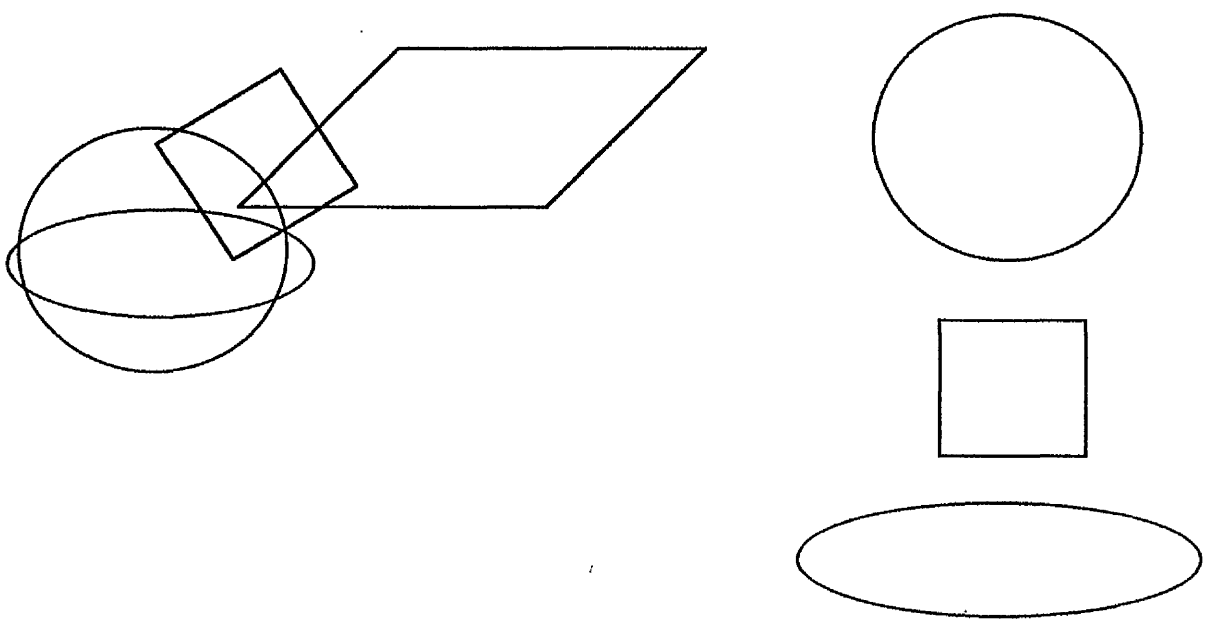
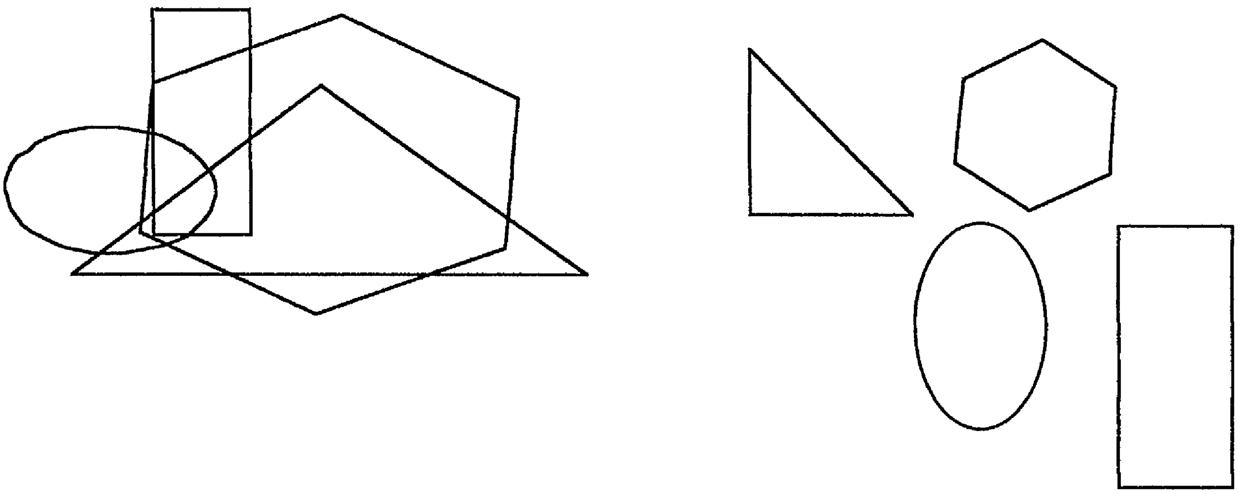


5)



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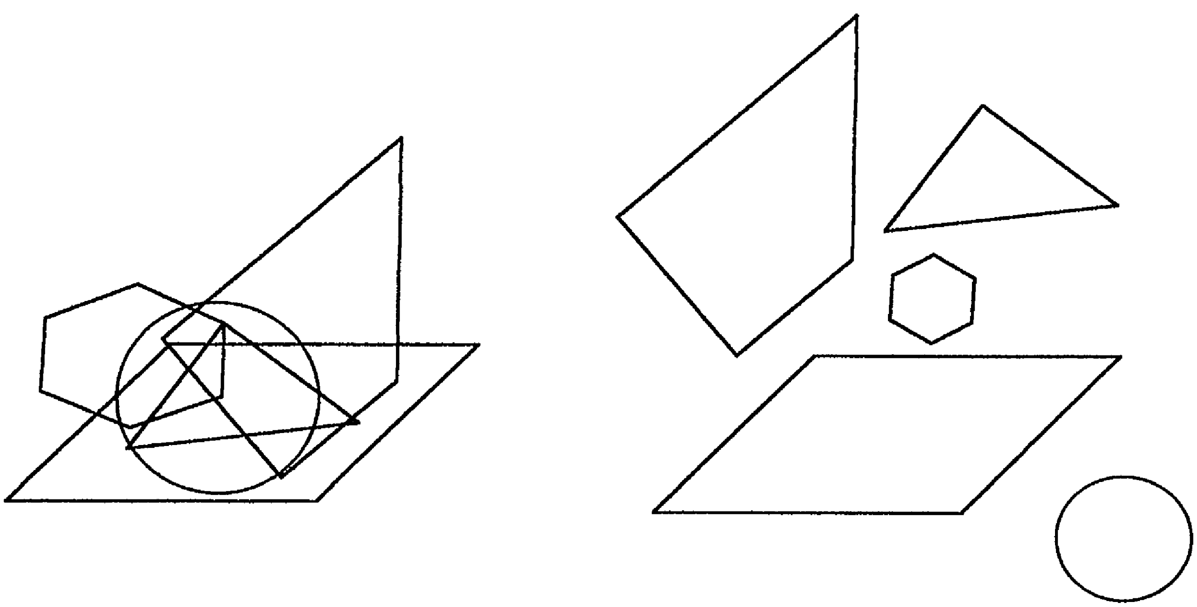

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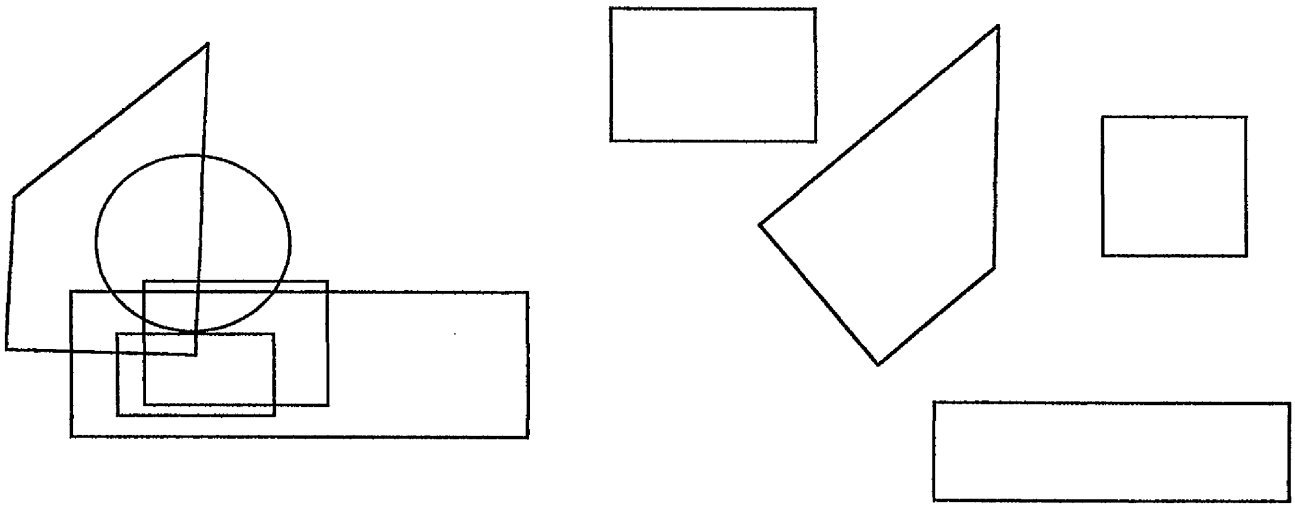
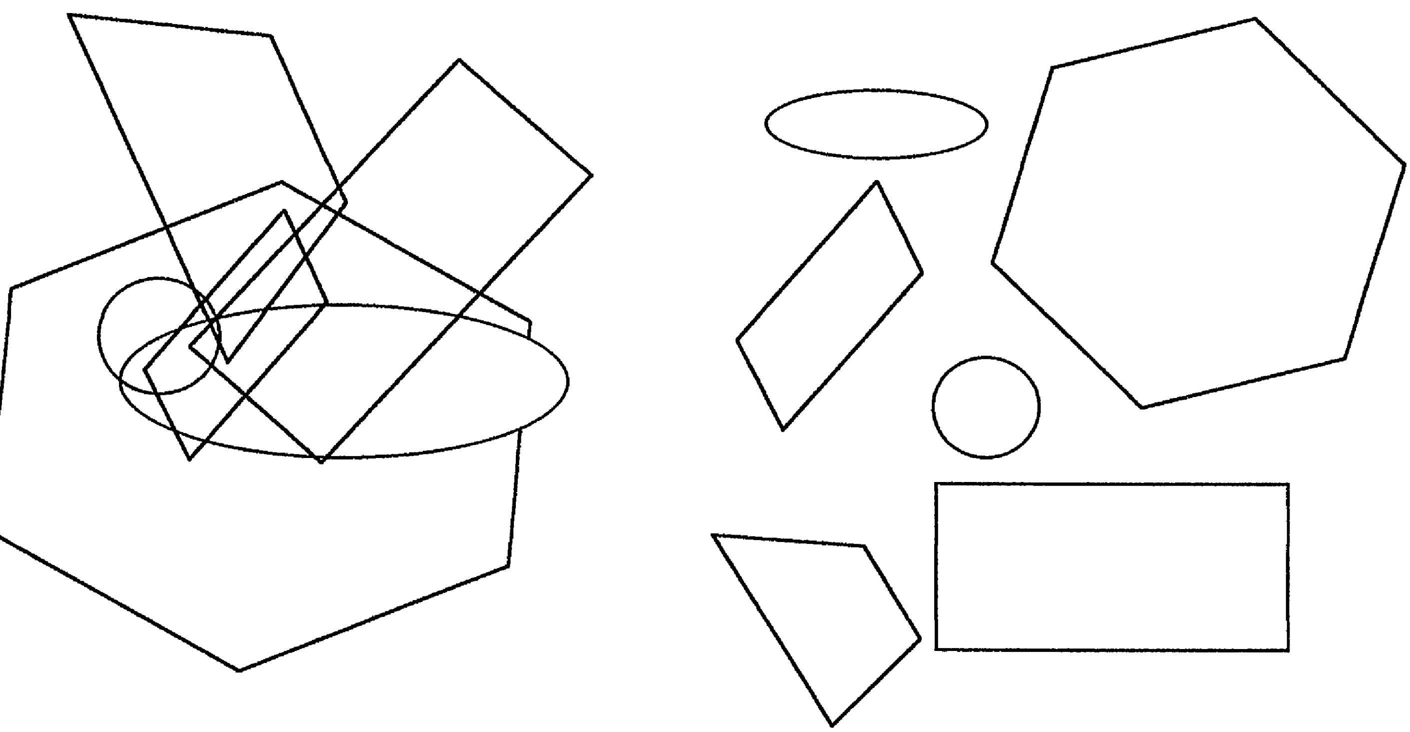


3)



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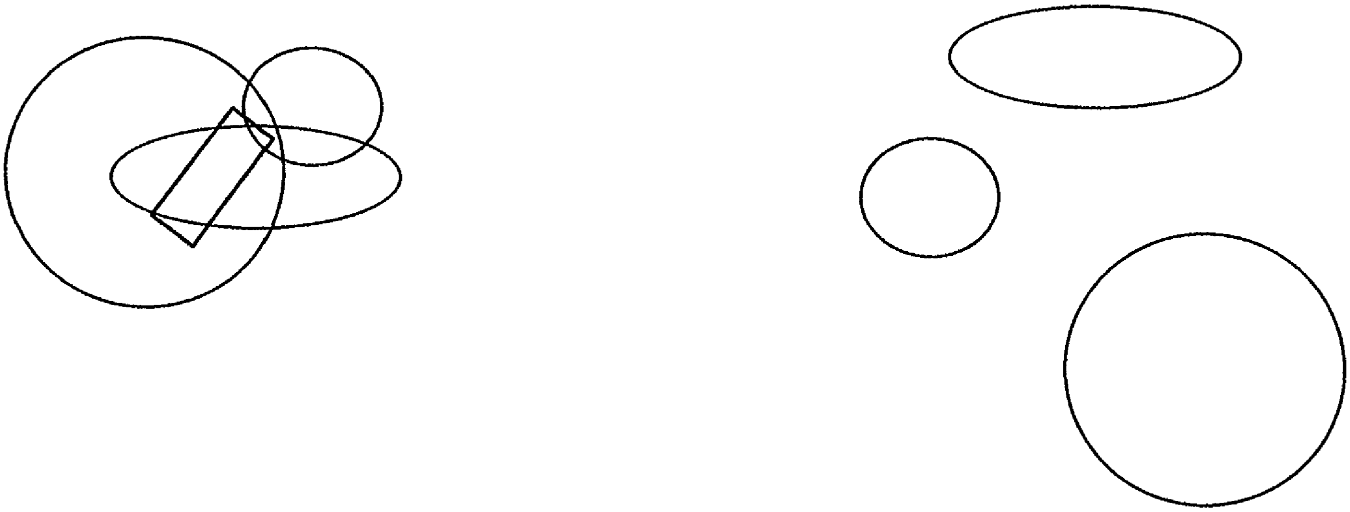
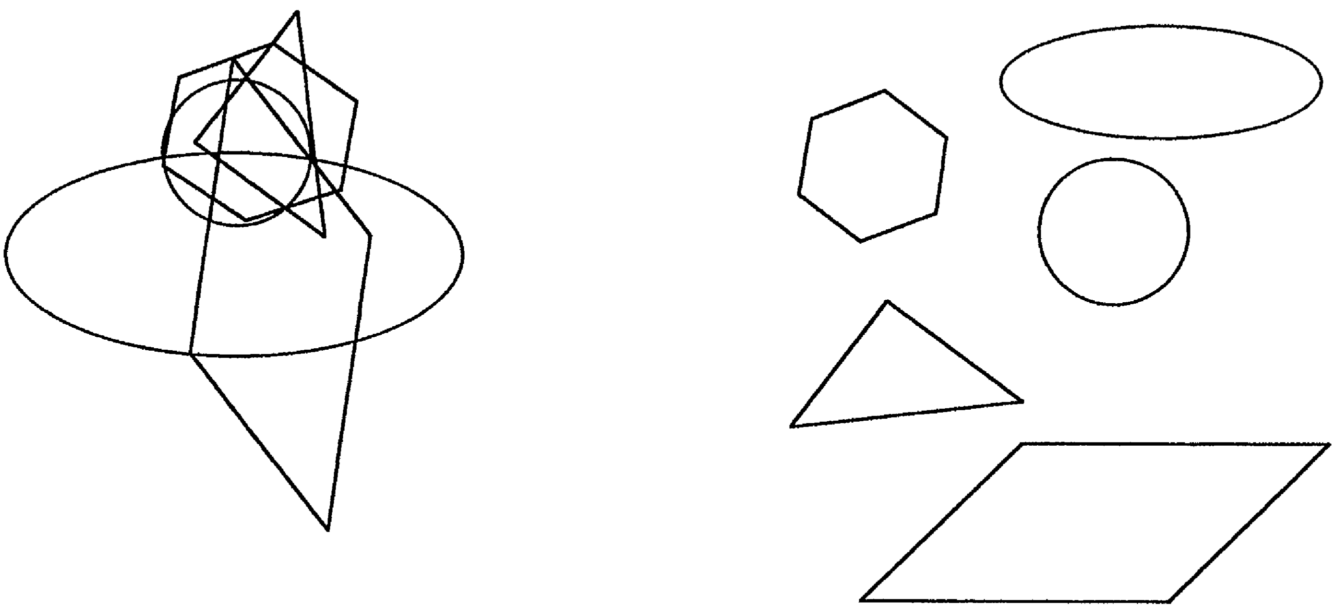


10)



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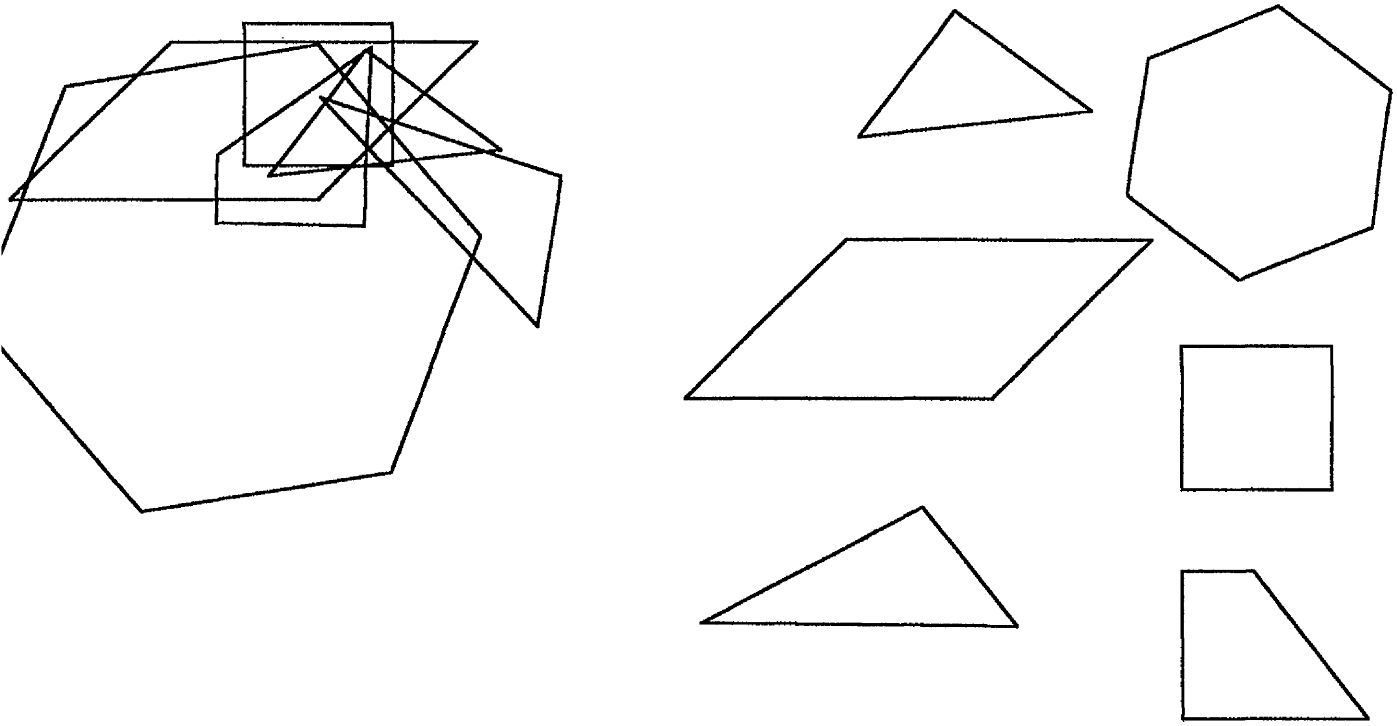
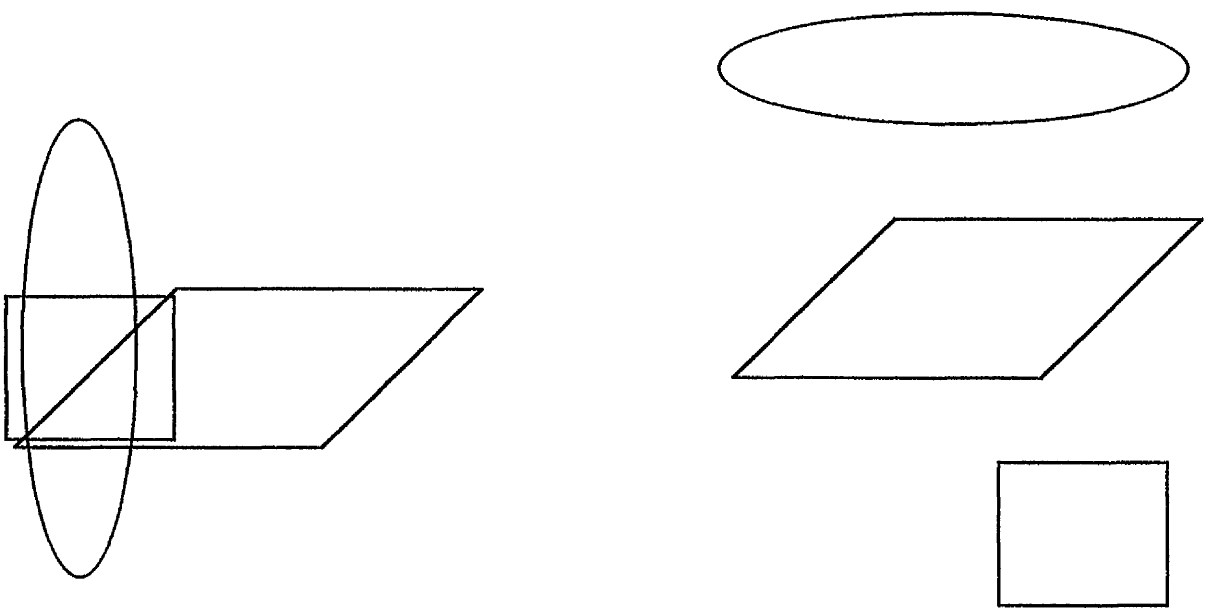


12)



Appendix B

Word Network Questionnaire

Name:

Age: ________

Addition

____

____

____

____

____

____

____

____

____

____

Subtraction

Multiplication

Division

Equals

Appendix C

Symbol Network Questionnaire

Name: ____________________

Age: __________

+

addition

product

sum of

total

minus

add up

share

increase

more than

and

decrease

plus

subtraction

decrease

total

subtract

square

take away

difference

less than

how many

minus

equals

X

multiplication

times

square

split

sum

power

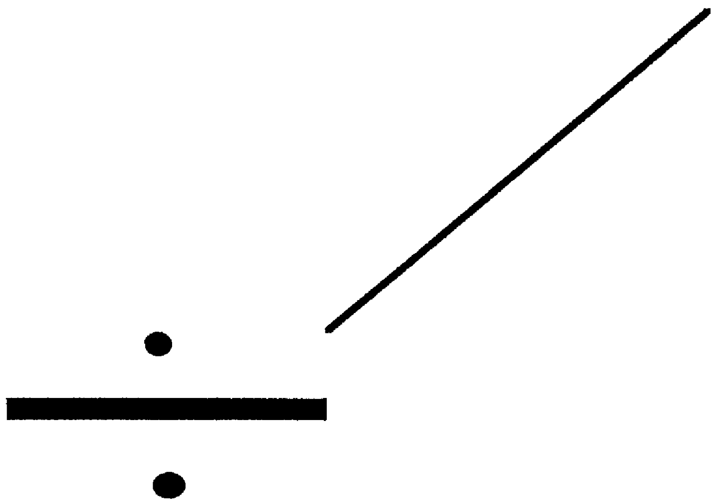
means

product

of

increase

multiply



division

product

split

means

group

share

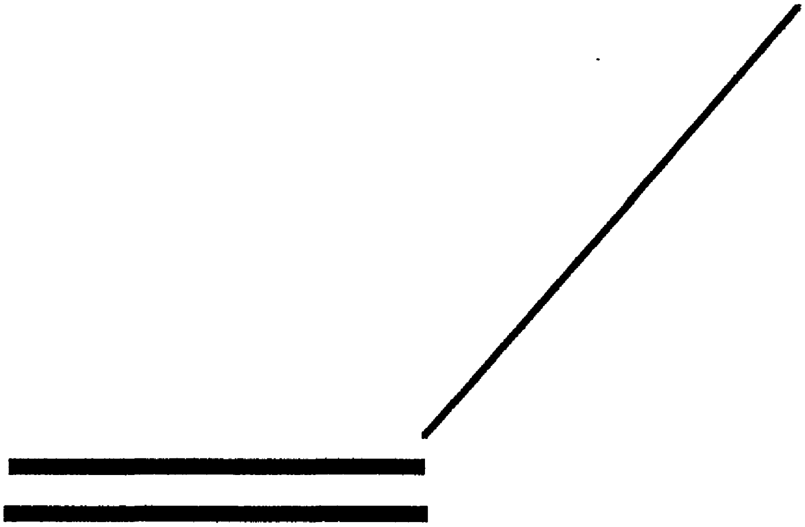
sum of

how many

power

and

divide



equals

take away

increase

same as

means

will be

divide

is

represents

total

answer is

Appendix D

Arithmetic Booklets

Name: ....

Age: ....

- Please answer as many questions as you can.
- Try to write down as much working out as you can.
- Please write your answers on the question paper.

Centre for Science Education
University of Glasgow

(1) Jimmy had 320 stamps.
He was given 49 for his Birthday.

How many does he now have?

(10) Jane bought 375cm of ribbon.
She cut it into 5 equal pieces.

How long is each piece?

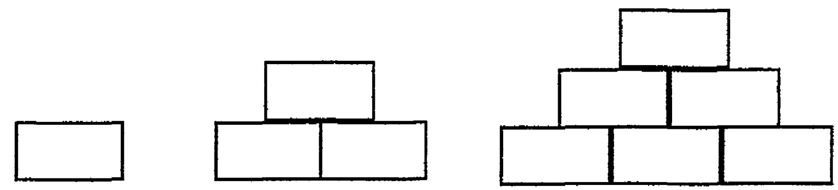
(3) A video stand has 6 shelves.
Each shelf has 4 sections and each section can hold 3 videos.

How many videos can the stand hold altogether?

(8) What would the next two numbers be in the following sequence,

1,3,6,10, , ,

This number sequence can be used to build a display of boxes in a shop window.

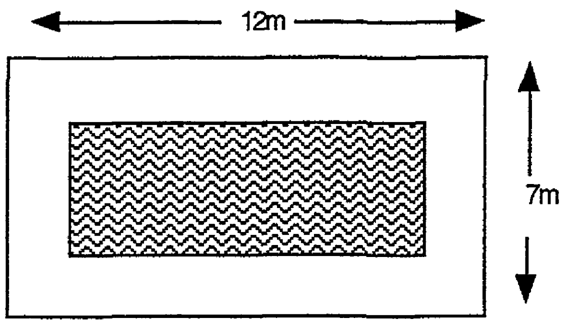


1 3 6

What would the display look like if 10 boxes were used?

(5) The diagram on the below shows a swimming pool.
Around the pool there is a path.
The path is one metre wide.

Find the area of the path.



(6) 80 people came to a party.

42 of them only enjoyed Pepsi.
26 of them only enjoyed Coca - cola.

How many did not enjoy either?

(7) Tom had 196 jelly babies.
He ate 29 while watching T.V.

How many does he have left?

(4) A fruit seller had two baskets of oranges.

One basket had 476 oranges and the other had 298.
During the day 577 oranges were sold.

How many oranges are left?

(9) The lunch menu at the local cafe reads as follows.

Starters	Main courses	Desserts
Soup	Burger	Ice Cream
Melon	Fish	Jelly

If you had to eat a two course meal how many different meals could you possibly have?

(2) Susan has 90p pocket money. She went to the sweet shop and bought the following :-

A bar of chocolate for 50p.

A sherbet dip for 15p.

And 2 toffees at 2p each.

How much did she spend altogether ?

Name: ....

Age: ....

- Please answer as many questions as you can.
- Try to write down as much working out as you can.
- Please write your answers on the question paper.

Centre for Science Education
University of Glasgow

(1) Jimmy had 320 stamps.
He was given 49 for his Birthday.

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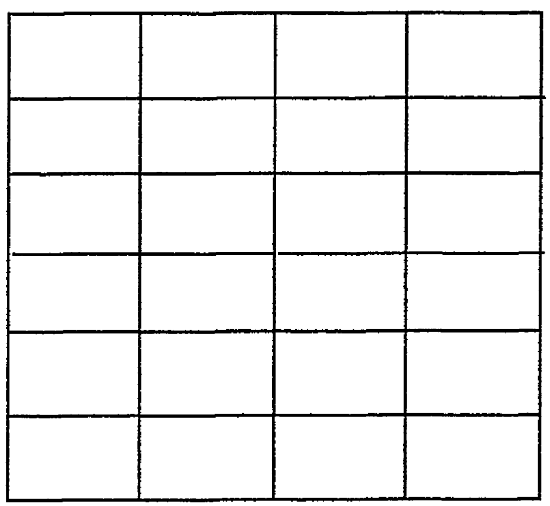

(8) What would the next two numbers be in the following sequence,

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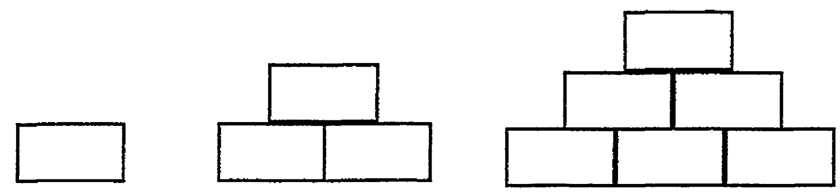
This number sequence can be used to build a display of boxes in a shop window.



1 3 6

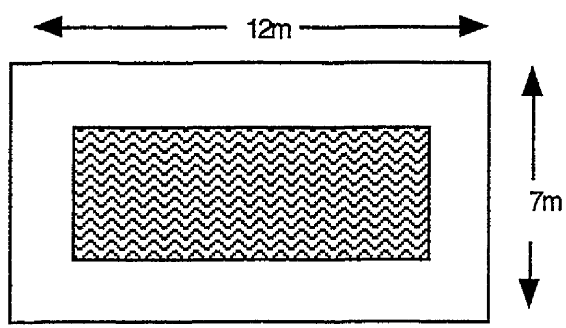
What would the display look like if 10 boxes were used?

If 55 boxes were used how many rows would there be in the display?

(5) The diagram on the below shows a swimming pool.

Around the pool there is a path.
The path is one meter wide.

Find the area of the path.



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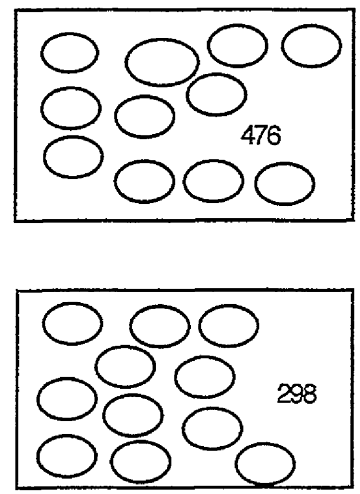

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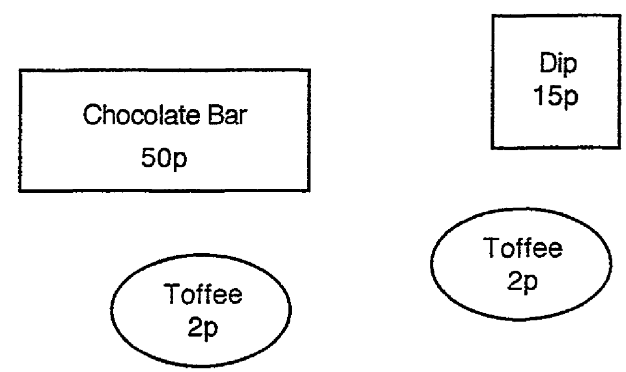
(2) Susan has 90p pocket money. She went to the sweet shop and bought the following :-

A bar of chocolate for 50p.

A sherbet dip for 15p.

And 2 toffees at 2p each.

How much did she spend altogether ?



Appendix E

Results from the Arithmetic Booklets

Key for the "General Data' section

Column	Number	Meaning
School	1/2/3/4/5/6/7	Number allocated to school of pupil
Dyslexia	0	Non-dyslexic
	1	Dyslexic
WMS	3/4/5/6/	Working memory space of each child
	?	Working memory space unknown
Test	0	Pink Booklet
	1	White Booklet

Key for the 'Test Questions' section.

Number	Meaning
0	Wrong Answer
1	Correct Answer
2	8a correct, 8b wrong
3	8a wrong, 8b correct

Key for the ' Method Section'.

Number	Meaning
0	Incorrect method used
1	Correct method used.
2	No method shown

Key for the 'Diagram' section.

Number	Meaning
0	No diagram used
1	Diagram used

Results for the Arithmetic Booklets and Working Memory Space.

General Data							Tes Questions											Method										Diagram									
Pupil	Age	M/F	Sch	Dys	VM	Tes	1	2	3	4	5	6	7	8	9	10	Tota	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	#
1	9	M	1	0	?	0	1	0	0	0	0	0	1	1	0	0	**4**	1	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0
2	9	M	1	0	4	0	1	1	1	1	0	1	0	0	0	0	**5**	1	1	1	1	0	1	1	0	2	1	0	0	0	0	0	0	0	1	0	0
3	9	M	1	0	?	0	1	0	1	1	0	1	1	3	0	0	**6**	1	0	1	1	2	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
4	9	M	1	0	5	0	1	0	1	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	1	0	0	1	0	0
5	9	M	1	0	5	0	1	1	1	1	0	0	1	3	0	0	**8**	1	1	1	1	2	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0
6	9	M	1	0	4	0	1	1	1	1	0	1	1	2	1	1	**9**	1	1	1	1	2	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
7	10	M	1	0	4	0	1	1	0	1	0	1	1	0	0	0	**5**	1	1	2	1	2	1	1	0	2	0	0	0	1	0	0	0	0	0	0	0
8	10	M	1	0	5	0	0	1	1	1	0	1	1	0	1	1	**7**	0	1	1	1	0	0	1	2	1	1	0	0	1	0	0	0	0	1	0	0
9	10	M	1	0	4	0	1	1	1	1	0	1	1	2	0	1	**8**	0	0	1	1	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
10	10	M	1	0	4	0	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
11	10	M	1	0	4	1	1	0	1	0	0	0	0	1	0	1	**5**	1	2	1	2	0	2	2	1	2	1	0	0	0	0	0	0	0	1	0	0
12	10	M	1	0	4	1	1	0	0	1	0	0	1	1	0	1	**6**	1	1	2	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
13	10	M	1	0	?	1	1	1	1	1	0	1	1	0	0	1	**7**	1	1	1	1	2	1	1	2	1	1	0	0	0	0	0	0	0	1	0	0
14	10	M	1	0	?	1	1	0	1	1	0	1	1	2	0	1	**7**	1	2	1	1	2	1	1	2	2	1	0	0	1	0	0	0	0	0	0	0
15	10	M	1	0	4	1	0	1	0	1	0	1	1	3	1	1	**7**	0	1	2	1	2	1	1	2	1	1	0	0	0	0	1	0	0	1	0	0
16	10	M	1	0	4	1	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
17	10	M	1	0	4	1	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
18	11	M	1	0	3	1	1	1	1	0	0	1	1	1	0	1	**8**	1	1	1	1	2	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
19	11	M	1	0	5	1	1	0	1	1	0	1	1	1	0	1	**8**	1	2	1	1	0	0	1	1	2	1	0	0	0	0	1	0	0	1	0	0
20	9	M	1	1	4	0	1	1	0	0	0	1	1	1	0	1	**7**	1	1	2	0	2	1	1	1	0	1	0	0	1	0	0	0	0	1	0	1
21	10	M	1	1	4	0	0	0	0	0	0	0	0	0	0	0	**0**	1	0	0	0	0	0	1	0	2	0	0	0	0	0	1	0	0	0	0	0
22	10	M	1	1	4	0	1	1	0	0	0	0	0	1	0	0	**4**	1	1	2	0	0	2	0	1	2	0	0	0	0	0	0	0	0	1	0	0
23	10	M	1	1	?	0	1	1	0	0	0	0	1	3	0	0	**4**	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0
24	10	M	1	1	5	0	1	1	1	0	0	0	1	0	0	1	**5**	1	1	1	1	2	2	1	1	2	1	0	0	0	0	0	0	0	0	0	0
25	11	M	1	1	?	1	1	1	1	0	0	0	0	0	0	0	**3**	1	1	1	1	0	0	1	0	2	2	0	0	0	0	0	0	0	0	0	0
26	11	M	1	1	5	1	1	1	1	0	0	0	1	0	0	0	**4**	1	1	1	0	0	0	1	1	2	0	0	0	0	0	0	0	0	1	0	0

Results for the Arithmetic Booklets and Working Memory Space.

27	11	F	2	0	5	0	1	1	0	0	0	1	1	2	0	1	**6**	1	1	1	1	0	1	1	1	2	1	0	0	1	0	0	0	0	1	0	0
28	11	F	2	0	5	0	1	1	1	0	0	1	1	1	0	1	**7**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	1	0	0	1	0	0
29	11	M	2	0	3	0	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	1	0	1	0	1	0
30	11	M	2	0	5	0	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	1
31	11	M	2	0	4	0	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	1	0	0	1	0	0
32	12	M	2	0	4	0	1	0	0	1	0	1	1	1	0	1	**7**	1	2	2	1	2	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
33	12	M	2	0	4	0	1	0	1	0	0	1	1	1	0	1	**7**	1	2	1	2	2	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
34	12	M	2	0	6	0	1	0	1	1	0	1	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
35	12	M	2	0	5	0	0	1	1	1	0	1	1	1	1	1	**9**	0	1	1	1	2	1	1	1	1	1	0	0	0	0	1	0	0	1	0	0
36	12	F	2	0	5	0	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
37	12	F	2	0	4	0	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
38	12	F	2	0	5	0	1	1	1	1	1	1	1	1	1	1	**10**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1	0	
39	13	F	2	0	?	0	1	0	0	1	0	1	1	2	0	1	**6**	1	1	0	1	1	1	1	0	1	1	0	0	0	0	1	0	0	1	0	0
40	11	F	2	0	4	1	1	0	0	1	0	0	0	2	0	0	**4**	1	1	2	1	2	0	1	1	2	2	0	0	1	0	0	0	0	0	0	0
41	11	M	2	0	3	1	1	1	1	1	0	0	1	1	0	1	**7**	1	1	1	1	2	0	1	1	2	1	0	0	1	0	0	0	0	1	0	0
42	11	F	2	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	2	1	0	0	1	0	0	0	0	1	0	0
43	11	M	2	0	3	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	2	1	1	1	2	1	0	0	0	0	0	0	0	1	0	1
44	12	F	2	0	3	1	1	1	0	0	0	1	1	1	0	1	**7**	1	1	0	0	0	1	1	1	1	1	0	0	1	0	1	0	0	1	0	0
45	12	M	2	0	5	1	1	1	1	1	0	0	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	2	0	0	0	0	0	0	0	1	0	0
46	13	M	2	0	5	1	1	0	1	0	0	1	0	1	0	1	**6**	1	2	1	2	2	1	2	1	2	1	0	0	0	0	0	0	0	1	0	0
47	13	M	2	0	5	1	0	0	1	1	0	1	1	1	0	1	**7**	0	1	1	1	0	1	1	2	2	1	0	0	0	0	1	0	0	1	0	1
48	13	M	2	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	1	0	0	1	0	0
49	11	F	2	1	5	0	1	1	0	1	0	0	1	3	0	0	**5**	1	1	0	1	0	0	1	0	0	1	0	0	0	1	0	0	1	1	0	0
50	12	M	2	1	5	0	1	1	0	0	0	1	1	1	1	0	**7**	1	1	2	2	0	1	1	1	1	2	0	0	1	0	1	0	0	1	0	0
51	12	M	2	1	5	1	1	1	0	1	0	1	1	3	0	1	**7**	1	1	0	1	0	1	1	0	2	1	0	0	1	0	0	0	0	1	0	0
52	12	M	2	1	?	1	1	1	1	0	0	1	1	2	0	1	**7**	1	1	1	1	0	1	1	1	2	1	0	0	1	0	0	0	0	0	0	0
53	12	F	2	1	5	1	1	1	0	1	0	1	1	1	0	1	**8**	1	1	0	1	0	1	1	1	1	1	0	0	1	0	1	0	0	1	0	0
54	10	M	3	0	4	0	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
55	10	F	3	0	?	0	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0

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56	10	M	3	0	4	0	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0
57	11	F	3	0	4	0	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
58	11	F	3	0	5	0	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	1	1	0	0	1	0	1
59	11	M	3	0	4	0	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	2	1	0	0	0	0	1	0	0	1	0	0
60	11	M	3	0	5	0	1	1	1	1	1	1	1	3	1	1	**10**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
61	11	F	3	0	5	0	1	1	1	1	1	1	1	1	1	1	**11**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1	0	0
62	11	F	3	0	3	0	1	1	1	1	1	1	1	1	1	1	**11**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
63	12	F	3	0	5	0	1	1	1	0	1	1	0	1	0	1	**8**	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
64	12	M	3	0	3	0	1	1	1	0	1	1	1	3	0	1	**8**	1	1	1	1	1	1	1	1	2	1	0	0	0	0	1	0	0	1	0	0
65	12	F	3	0	5	0	1	1	1	1	1	1	1	1	1	1	**11**	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	0	1	0	0
66	10	M	3	0	4	1	1	1	1	1	0	1	1	0	0	1	**7**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
67	10	M	3	0	3	1	1	0	1	1	0	1	1	3	0	1	**7**	1	2	1	1	0	1	1	1	2	1	0	0	0	0	1	0	0	1	0	0
68	10	M	3	0	4	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
69	10	M	3	0	?	1	1	1	1	1	0	1	1	3	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
70	11	M	3	0	?	1	1	1	0	1	0	1	1	2	0	1	**7**	1	1	2	1	2	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
71	11	M	3	0	5	1	1	1	1	0	0	1	1	1	0	1	**8**	1	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
72	11	F	3	0	3	1	1	1	0	1	0	1	1	1	0	1	**8**	1	1	0	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
73	11	F	3	0	4	1	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
74	11	F	3	0	3	1	1	1	1	1	1	1	1	1	1	1	**11**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0
75	12	F	3	0	4	1	1	1	0	1	1	1	0	1	0	1	**8**	1	1	0	1	1	1	1	1	2	1	0	0	1	0	0	0	0	1	0	0
76	12	M	3	0	5	1	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
77	12	M	3	0	?	1	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	2	1	0	0	1	0	0	1	0	1	0	0
78	12	F	3	0	4	1	1	1	1	1	1	1	1	2	1	1	**10**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1	0	0
79	11	M	3	1	3	0	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	1	0	1	0	0
80	10	M	4	0	?	0	0	1	0	0	0	1	0	0	0	0	**2**	0	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
81	10	M	4	0	4	0	1	0	0	1	0	0	1	1	1	0	**6**	1	0	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
82	10	F	4	0	4	0	1	1	0	1	0	1	1	0	0	1	**6**	1	1	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1
83	10	M	4	0	5	0	1	1	0	1	0	1	1	1	0	0	**7**	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
84	10	F	4	0	5	0	1	1	1	1	0	1	1	1	0	0	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0

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85	10	M	4	0	3	0	1	1	1	0	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
86	10	F	4	0	6	0	1	0	1	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
87	10	F	4	0	?	0	1	1	1	0	0	1	1	2	1	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0
88	10	M	4	0	5	0	1	0	1	1	0	1	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
89	10	F	4	0	5	0	1	1	1	1	0	1	1	2	1	1	**9**	1	1	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0
90	10	F	4	0	5	0	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
91	11	M	4	0	5	0	1	0	0	0	0	0	0	1	0	0	**3**	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0
92	11	M	4	0	5	0	1	1	1	0	0	1	0	0	0	0	**4**	1	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
93	11	F	4	0	5	0	1	0	1	1	0	1	1	0	0	1	**6**	1	0	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0
94	11	F	4	0	5	0	1	1	0	1	0	1	0	2	0	1	**6**	1	1	0	1	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
95	11	F	4	0	5	0	1	0	0	1	0	1	1	1	0	1	**7**	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1
96	11	M	4	0	5	0	1	1	1	1	0	1	1	0	0	1	**7**	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0
97	11	M	4	0	4	0	1	1	0	1	0	1	1	1	0	1	**8**	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
98	11	M	4	0	5	0	1	1	1	1	0	1	1	1	0	0	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0
99	11	F	4	0	5	0	1	1	1	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
100	11	F	4	0	6	0	1	1	1	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1
101	11	M	4	0	U	0	1	1	1	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
102	11	F	4	0	5	0	1	1	1	0	1	1	1	1	1	0	**9**	1	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1
103	11	F	4	0	5	0	1	1	1	0	0	1	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
104	11	M	4	0	5	0	1	1	1	1	0	1	0	1	1	1	**9**	1	1	1	1	0	1	0	1	1	1	0	0	0	0	0	0	0	1	0	0
105	11	M	4	0	?	0	0	1	1	1	0	1	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
106	11	F	4	0	5	0	1	1	1	1	0	1	1	2	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
107	10	F	4	0	?	1	1	1	1	1	0	1	1	0	0	0	**6**	1	1	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
108	10	F	4	0	4	1	1	0	1	1	0	1	1	2	0	1	**7**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
109	10	F	4	0	?	1	1	1	0	1	0	1	1	3	0	1	**7**	1	1	0	1	0	1	1	0	1	1	0	0	0	0	0	0	0	1	1	0
110	10	M	4	0	?	1	1	1	1	1	0	1	1	3	0	0	**7**	1	1	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	1	1	0
111	10	M	4	0	?	1	1	1	1	1	0	1	1	3	1	0	**8**	1	1	1	1	0	1	1	0	1	0	0	0	1	0	0	0	0	1	0	0
112	10	M	4	0	4	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
113	10	F	4	0	4	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1

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114	10	F	4	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
115	10	F	4	0	5	1	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
116	10	F	4	0	6	1	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	1	0	0	1	0	0
117	11	M	4	0	5	1	0	1	0	1	0	1	1	1	0	0	**6**	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1
118	11	M	4	0	3?	1	0	1	1	1	0	0	1	1	0	0	**6**	1	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	1
119	11	F	4	0	5	1	1	1	0	1	0	1	1	1	0	1	**8**	1	1	0	1	0	1	1	1	1	1	0	0	1	0	0	1	0	1	0	0
120	11	F	4	0	4	1	1	1	1	1	0	1	1	2	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
121	11	M	4	0	5	1	1	1	1	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	0	1	0	0	0	0	0	1	0	0	0	0
122	11	M	4	0	5	1	1	0	1	1	0	1	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
123	11	F	4	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
124	11	F	4	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0
125	11	M	4	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0
126	11	F	4	0	4	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1
127	11	M	4	0	4	1	1	1	1	0	0	1	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0
128	11	F	4	0	5	1	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
129	11	F	4	0	5	1	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	1	1	0	0
130	11	F	5	0	6	0	1	0	1	1	0	1	1	1	1	1	**9**	1	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
131	9	M	5	0	6	0	1	1	0	1	0	1	1	2	0	1	**7**	1	1	2	1	2	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
132	10	M	5	0	5	0	1	0	0	0	0	0	1	1	0	1	**5**	1	1	0	1	2	2	1	1	0	1	0	0	0	0	0	0	0	1	0	0
133	10	M	5	0	5	·0	0	0	1	0	0	1	1	1	0	0	**5**	1	1	1	1	0	1	1	1	2	2	0	0	0	0	1	0	0	1	0	1
134	10	M	5	0	5	0	1	1	1	0	0	1	1	3	0	1	**5**	1	1	1	1	0	1	1	0	1	1	0	0	1	0	1	0	0	1	0	0
135	10	F	5	0	?	0	1	0	0	1	0	1	1	2	0	1	**6**	1	2	2	1	2	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
136	10	M	5	0	4	0	1	1	0	0	0	1	1	3	0	1	**6**	1	1	2	0	2	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
137	10	M	5	0	5	0	1	1	1	1	0	1	0	3	0	0	**6**	1	1	1	1	2	1	2	0	2	2	0	0	0	0	0	0	0	1	0	0
138	10	M	5	0	4	0	1	1	0	1	0	1	0	3	0	1	**6**	1	1	0	1	2	1	2	2	2	1	0	0	0	0	0	0	0	1	0	1
139	10	M	5	0	5	0	1	0	0	1	0	1	1	2	0	1	**6**	1	2	2	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
140	10	F	5	0	5	0	0	1	1	1	0	1	1	1	0	0	**7**	0	1	1	1	2	1	1	1	0	2	0	0	0	0	0	0	0	1	0	0
141	10	M	5	0	5	0	1	1	0	1	0	1	1	3	0	1	**7**	1	1	1	1	2	1	1	2	1	1	0	0	0	0	0	0	0	1	0	0
142	10	M	5	0	5	0	1	0	1	1	0	1	1	3	0	1	**7**	1	1	1	1	2	1	1	2	0	1	0	0	0	0	0	0	0	1	0	0

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143	10	F	5	0	4	0	1	1	0	1	0	1	1	1	0	1	**8**	1	1	2	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
144	10	F	5	0	5	0	0	1	1	1	0	1	1	1	0	1	**8**	0	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
145	10	M	5	0	4	0	1	0	1	1	0	1	1	1	0	1	**8**	1	2	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
146	10	M	5	0	5	0	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1	0	1
147	11	F	5	0	?	0	1	0	0	0	0	1	0	1	0	1	**5**	1	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0
148	11	F	5	0	4	0	1	0	0	1	0	1	1	2	0	1	**6**	1	1	2	1	0	1	1	1	2	1	0	0	1	0	0	0	0	1	0	0
149	11	F	5	0	4	0	0	1	1	1	0	1	1	0	0	1	**6**	0	1	1	1	2	1	1	0	1	1	0	0	0	0	0	0	0	1	0	1
150	11	M	5	0	3	0	1	1	0	0	0	1	1	3	0	1	**6**	1	1	0	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
151	11	M	5	0	3	0	1	1	1	1	0	0	1	1	0	0	**7**	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0
152	11	F	5	0	4	0	1	1	0	1	0	1	1	3	0	1	**7**	1	1	2	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	1
153	11	M	5	0	5	0	1	1	1	1	0	0	1	3	0	1	**7**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
154	11	F	5	0	4	0	1	1	1	1	0	1	1	2	0	1	**8**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
155	11	F	5	0	5	0	1	0	1	1	1	1	1	3	0	1	**8**	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0
156	11	M	5	0	4	0	1	1	1	1	0	1	1	3	0	1	**8**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
157	11	M	5	0	?	0	1	1	1	1	0	1	1	3	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
158	11	F	5	0	?	0	1	1	1	1	0	1	1	2	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1
159	10	M	5	0	5	0	1	0	1	1	0	1	1	1	1	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
160	9	F	5	0	3	1	1	1	1	0	0	0	1	3	0	0	**5**	1	1	1	0	2	1	1	0	0	2	0	0	1	0	0	0	0	1	0	0
161	10	F	5	0	5	1	0	0	0	0	0	0	0	0	0	0	**0**	1	1	2	1	2	0	2	0	2	2	0	0	0	0	0	0	0	1	0	0
162	10	M	5	0	?	1	0	0	0	0	0	0	0	0	0	0	**0**	1	1	2	0	2	0	1	2	1	2	0	0	0	0	0	0	0	0	0	0
163	10	F	5	0	5	1	1	1	0	0	0	0	0	1	0	1	**5**	1	1	2	1	2	2	2	1	2	1	0	0	0	0	0	0	0	1	0	0
164	10	F	5	0	4	1	0	1	0	0	0	0	1	1	0	1	**5**	1	1	0	0	0	1	1	1	2	1	0	0	0	0	1	0	0	1	0	0
165	10	F	5	0	?	1	1	0	1	0	0	1	1	0	0	1	**5**	1	0	1	0	0	1	1	0	2	1	0	0	0	0	0	0	0	1	0	1
166	10	M	5	0	4	1	1	1	1	1	0	0	0	0	0	1	**5**	1	1	1	1	0	0	0	0	2	1	0	0	1	0	1	0	0	1	0	0
167	10	F	5	0	5	1	1	1	0	1	0	1	0	3	0	0	**5**	1	1	2	1	2	1	2	0	2	2	0	0	0	0	0	0	0	1	0	0
168	10	M	5	0	5	1	0	1	0	1	0	1	1	1	0	0	**6**	0	1	2	1	0	1	1	1	0	2	0	0	0	0	0	0	0	1	0	1
169	10	M	5	0	5	1	1	1	0	1	0	0	1	2	0	1	**6**	1	1	2	1	2	2	1	1	0	1	0	0	0	0	0	0	0	1	0	0
170	10	F	5	0	4	1	1	1	0	1	0	0	1	1	0	1	**7**	1	1	2	1	2	0	1	1	2	1	0	0	0	0	0	0	0	1	0	1
171	10	F	5	0	4	1	1	1	1	0	0	0	1	1	0	1	**7**	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0

Results for the Arithmetic Booklets and Working Memory Space.

172	10	M	5	0	4	1	1	1	1	0	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
173	10	F	5	0	4	1	1	1	0	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0
174	10	F	5	0	6	1	1	1	1	1	0	1	1	3	0	1	**8**	1	1	1	1	0	1	1	2	1	1	0	0	0	0	0	0	0		0	0
175	10	M	5	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	2	1	1	1	2	1	0	0	0	0	0	0	0	1	0	1
176	11	M	5	0	5	1	1	1	0	0	0	1	1	2	0	0	**5**	1	1	2	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1
177	11	M	5	0	5	1	1	1	0	0	0	1	0	1	0	1	**6**	1	1	2	2	2	1	2	1	0	1	0	0	0	0	0	0	0	1	0	1
178	11	F	5	0	5	1	1	1	1	1	0	1	1	2	0	0	**7**	1	1	1	1	0	1	1	1	0	1	0	0	1	0	0	0	0	1	0	0
179	11	M	5	0	5	1	1	1	1	0	1	1	0	2	0	1	**7**	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
180	11	M	5	0	4	1	1	1	1	1	1	0	1	2	0	0	**7**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
181	11	F	5	0	5	1	1	1	0	1	0	1	1	2	0	1	**7**	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
182	11	F	5	0	?	1	1	1	1	1	0	1	1	2	1	0	**8**	1	1	1	1	0	1	1	1	1	2	0	0	0	0	0	0	0	1	0	0
183	11	F	5	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
184	11	M	5	0	4	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	0	2	0	0	0	0	1	0	0	1	0	0
185	11	M	5	0	4	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
186	11	F	5	0	5	1	1	1	1	1	0	1	1	1	0	1	**9**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
187	11	F	5	0	4	1	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1
188	11	F	5	1	4	1	1	1	0	1	0	1	1	0	0	0	**5**	1	1	0	1	0	1	1	0	0	2	0	0	1	0	0	0	0	1	0	0
189	11	M	6	1	4	0	1	1	0	0	0	1	1	3	1	1	**7**	2	2	2	2	2	2	2	1	2	2	0	0	0	0	0	0	0	1	0	0
190	11	F	6	1	6	0	1	0	1	1	1	1	1	1	1	1	**10**	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
191	12	M	6	1	5	1	1	0	0	1	1	0	0	2	0	0	**4**	2	0	0	2	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1
192	13	M	6	1	4	1	0	0	1	0	1	1	1	1	0	1	**7**	0	0	1	0	1	1	1	1	0	1	0	0	1	0	1	0	0	1	0	1
193	11	F	7	0	5	0	1	1	0	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
194	12	F	7	0	5	0	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0
195	12	F	7	0	5	0	1	1	1	1	1	0	1	1	1	1	**10**	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	0	0	1	0	0
196	12	F	7	0	5	0	1	1	1	1	0	1	1	1	1	1	**10**	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
197	11	F	7	0	5	0	1	0	0	0	0	1	1	1	0	1	**5**	1	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0
198	11	F	7	0	5	1	1	1	0	0	0	1	1	1	0	1	**7**	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0
199	11	F	7	0	3	1	1	1	0	1	0	1	1	2	0	1	**7**	1	1	0	1	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
200	11	F	7	0	4	1	1	1	1	1	1	1	1	1	0	1	**10**	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	1	0

Results for the Arithmetic Booklets and Working Memory Space.

201	12	F	7	0	3	1	1	1	0	1	0	1	1	3	0	0	**6**	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	0	1	1	0
202	12	F	7	0	5	1	1	1	0	1	0	1	1	1	0	1	**8**	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0
203	12	f	7	0	3	1	1	1	0	1	0	1	1	1	0	1	**8**	1	1	1	1	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0
204	11	F	7	1	5	0	1	1	0	1	0	1	1	1	0	1	**8**	1	0	1	1	0	1	0	1	0	1	0	0	1	0	0	0	0	1	0	0
205	12	F	7	1	?	0	1	0	0	1	0	1	1	1	0	1	**7**	1	1	0	1	0	1	1	1	0	1	0	0	1	0	0	0	0	1	0	0
206	12	F	7	1	3	1	1	1	0	1	0	1	1	1	0	0	**7**	1	1	0	1	0	1	1	1	0	1	0	0	1	0	0	0	0	1	0	0
207	12	F	7	1	6	1	1	1	0	1	0	1	1	1	1	0	**8**	1	1	0	1	0	1	1	1	1	1	0	1	1	1	0	0	0	1	0	1

Appendix F

Results for Word and Symbol Questionnaires grouped by Age

Number of pupils within each age group.

Age	Number
9	9
10	74
11	89
12	30

Results for the Word Questionnaire grouped by Age.

Results for the word 'Addition' , grouped by age

Age	Add	Sum	Plus	Altogether	Total	Increase	And	Put On	Build Up	More Than	Product	All
9	9	6	8	1	7		3					
10	69	33	51	24	29	22	2	1	1			
11	74	26	58	20	20	8	9	3		7	8	1
12	18	6	4	10	5	1	2					

Results for the word'Subtraction' , grouped by age

Age	Take Away	Minus	Subtract	Decrease	Difference	Take Off	How Many more	How many left	Deduct	Lower	Less	From
9	9	9	6		8							
10	67	49	50	22	23	10	15	2	2			
11	79	43	37	8	13		2			1	4	1
12	20	7	7	1	1							

Results for the word 'Multiplication', grouped by age

Age	Times	Multiply	Product	Of	Groups Of	Double	Squared Number	By	Cubed	Long Mult	Power	Adding	Tripling	More Than	Sum Of
9	9	8		1		1									
10	63	60	12	1	14		1								
11	77	51	17	1	1	2	6	1	3	1	2	1	1	2	3
12	16	9	2	8											

Results for the word 'Division', grouped by age

Age	Divide	Group	Share	Split	Smaller Pieces	Fraction	Separate	Sets	How Many	Simplify	Goes Into	Less	Decrease	Quotient	Average
9	8	1	1	1		1	2		1					1	
10	65	6	26	5					6		16				1
11	65	1	11		5	2	1	1	13		13	2	6		
12	12	1	1	1	1	2	2	1	2	1	1				

Results for the word' Equals', grouped by age

Age	Answer	Total	The same	Together	Makes	Comes to	Find	How Much	Equal	Sum of	Final	Is	Means	Added Up	Equivalent	Result	Final
9	4	2	2	1	3												
10	26	26	17	5	33	4	1					8					
11	49	16	11	7	32	2	2	2	11	4	6	6	1	2	1		
12	14	6	3						2		2					3	1

Results for the Symbol Questionnaire Grouped by Age.

Results for the symbol'+' , grouped by age

Age	Product	Sum	Total	Add Up	Increase	More	And	Plus
9	3	8	6	9	7	4	6	9
10	6	46	34	67	51	22	39	70
11	13	35	24	80	41	14	35	76
12	0	7	5	20	16	6	11	20

Results for the symbol '-', grouped by age

Age	Decrease	Subtract	Square	Take Away	Difference	Less Than	How Many	Minus
9	9	9		9	9	8		9
10	63	70	2	70	47	60	4	64
11	66	78	2	79	50	43	1	74
12	18	21	1	21	8	12		21

Results for the symbol 'x', grouped by age

Age	Times	Square	Split	Sum	Power	Means	Product	Of	Increase	Multiply
9	9		1	2			5		4	9
10	70	27	1	13	11	1	39	9	26	70
11	81	12		15	12	2	56	10	34	81
12	21	4		5	7	1	11	5	12	21

Results for the symbol ' ÷', grouped by age

Age	Product	Split	Means	Group	Share	Sum Of	How Many	Power	And	Divide
9	2	7	0	2	5	0	1	2	0	9
10	6	50	2	41	67	2	15	4	1	72
11	4	54	2	35	73	6	22	5	4	81
12	3	18	0	6	15	2	2	0	0	21

Results for the symbol ' =', grouped by age

Age	Take Away	Same As	Means	Will be	Divide	Is	Repreasents	Total	Answer is
9		4	3	9		7	4	6	9
10	4	20	37	55	1	56	27	52	70
11	4	26	45	64	1	66	32	69	79
12		7	11	16		15	12	19	21

Appendix G

Results for the Word and Symbol Questionnaires grouped by Working Memory Space

Number of pupils within each working memory space group.

WMS	Number
3	17
4	53
5	83
6	7

Results for the Word Questionnaire grouped by Workning Memory Space.

Results for the word 'Addition' , grouped by WMS

WMS	Add	Sum	Plus	Altogether	Total	Increase	And	Put On	Build Up	More Than	Product	All	Of	How Many	Amount		
3	13	7	6	5	3		2						1				
4	52	21	42	14	15	10	7	1	1	5	6			2	2		
5	70	32	47	29	25	9	3			3	4			1			
6	6	1	3	2	4	1	1						1				

Results for the word'Subtraction' , grouped by WMS

WMS	Take Away	Minus	Subtract	Decrease	Difference	Take Off	How Many more	How many left	Deduct	Lower	Less	From	Count Down	Sum of	Least	Left over	
3	14	7	9	1	5		1				1	1					
4	53	36	35	12	14	5	5		1		2	1			1	1	
5	75	40	37	9	18	3	9				1		1	2			
6	6	3	3	2	2		1		1								

Results for the word 'Multiplication', grouped by WMS

WMS	Times	Multiply	Product	Of	Groups Of	Double	Squared Number	By	Cubed	Long Mult	Power	Adding	Tripling	More Than	Sum Of	Total	Increase
3	13	8	2	1	1	2	3	2	1		1		2	1	1	1	1
4	52	41	6	1	2	2	3		1		1	1	1		1		
5	69	52	17	1	8		5								4		
6	5	5	2														

Results for the word 'Division', grouped by WMS

WMS	Divide	Group	Share	Split	Smaller Pieces	Fraction	Separate	Sets	How Many	Simplify	Goes Into	Less	Decrease	Quotient	Average	Half	Quarter
3	12	1	2			1	1		1		3	1			1		
4	51	2	14	3	6		1	1	5					1	1	1	1
5	63	6	10	3	5	1	2	1	12		22		3		1		
6	6		3						2								

Results for the word' Equals', grouped by WMS

WMS	Answer	Total	The same	Together	Makes	Comes to	Find	How Much	Equal	Sum of	Final	Is	Means	Added Up	Equivalent	Result	Similar
3	8	3	2		4						1	2				1	
4	26	18	6	6	24	3	1	2	14	1						1	
5	41	18	13	10	30	3			18	3	7	5			1	2	
6	4	2	2		2			1									1

Results for the Symbol Questionnaire grouped by Working Memory Space.

Results for the symbol'+' , grouped by WMS										
WMS	Product	Sum	Total	Add Up	Increase	More	And	Plus		
3	3	7	6	15	10	4	6	15		
4	8	32	19	59	41	17	29	53		
5	8	36	26	74	49	17	43	75		
6	1	4	3	6	4	3	3	6		
Results for the symbol '-', grouped byWMS										
WMS	Decrease	Subtract	Square	Take Away	Difference	Less Than	How Many	Minus		
3	13	14		17	8	10	1	17		
4	47	53	2	54	39	40	2	51		
5	68	80	1	80	46	50	2	74		
6	5	6		5	4	4	4	15		
Results for the symbol 'x', grouped by WMS										
WMS	Times	Square	Split	Sum	Power	Means	Product	Of	Increase	Multiply
3	17	3		2	4		11	3	5	17
4	53	13		14	9	1	30	8	22	53
5	80	17	1	15	14		50	10	31	79
6	6	3				1	3		3	6
Results for the symbol ' ÷', grouped byWMS										
WMS	Product	Split	Means	Group	Share	Sum Of	How Many	Power	And	Divide
3	1	1	10	8	13	2	3	2		17
4	6	39		27	50	4	15	5	3	50
5	5	56	2	35	69	3	18	4	1	80
6		4		3	5		1			6
Results for the symbol ' =', grouped byWMS										
WMS	Take Away	Same As	Means	Will be	Divide	Is	Repreasents	Total	Answer is	
3	1	4	12	14		11	5	13	17	
4	2	18	33	41		45	22	44	53	
5	3	22	40	61	1	68	33	64	80	
6		4	5	6		4	3	5	6	

Appendix H

Results from the Word and Symbol Questionnaires for the Dyslexic group

Number of Pupils within each age group

Age	Number
10	4
11	7
12	8

Number of Pupils within each working memory space group

WMS	Number
3	2
4	5
5	8
6	2

Results for the Word Questionnaires grouped by Age.

Results for the word 'Addition' , grouped by age

Age	Add	Sum	Plus	Altogether	Total	Increase	To	Times	More Than	Jion
10	2	2	2	2			1	1		
11	4	2	4		1					1
12	6	2	2	3	1	1			1	

Results for the word'Subtraction' , grouped by age

Age	Take Away	Minus	Subtract	Decrease	Less	Reduce	Less Than	Split	Shorten
10	3	2						1	
11	7	6	2						
12	8		2	1	1	1	1		1

Results for the word 'Multiplication', grouped by age

Age	Times	Multiply	Product	Square	By	Add	Number Of
10	2	2				1	1
11	7	3	1	1			1
12	6	2			1	1	

Results for the word 'Division', grouped by age

Age	Divide	Group	Share	Split	Into	Of	Square Root	Reduce
10	1		1	1	1			
11	5				2	1	1	
12	5	1		1	1			1

Results for the word' Equals', grouped by age

Age	Answer	Total	The same	Together	Makes	Is	Find	Ends Up	Same As	Result	Means	Is
10	2				1			1				
11	1		1		2	1	1	1	1			1
12	4	2		2	1	1			2	2	1	1

Results for the Symbol Questionnaires grouped by Age.

Results for the symbol'+' , grouped by age										
Age	Product	Sum	Total	Add Up	Increase	More	And	Plus		
10		3	1	4	2	1	2	4		
11	1	3	3	7	3	1	4	7		
12				6	7	1	3	8		
Results for the symbol '-', grouped by age										
Age	Decrease	Subtract	Minus	Take Away	Difference	Less Than	Equals			
10	3	3	2	4	1	4				
11	6	7	6	7	1	4	1			
12	7	7	6	8		5				
Results for the symbol 'x', grouped by age										
Age	Times	Square	Split	Sum	Power	Means	Product	Of	Increase	Multiply
10	4						1	1		4
11	7	2			2		3	1	2	7
12	8	1	1	3	1	1	2		5	7
Results for the symbol ' ÷', grouped by age										
Age	Divide	Split	Means	Group	Share	Sum Of	How Many			
10	4	1		2	4		1			
11	7	4			4	1	2			
12	8	7	1	3	4		1			
Results for the symbol ' =', grouped by age										
Age	Answer is	Same As	Means	Will be	Total	Is	Repreasents			
10	4	1	3	3	2	3				
11	7	3	5	4	6	7	2			
12	8	3	4	3	7	3	5			

Results for the Word Questionnaires Grouped by Working Memory Space.

Results for the word 'addition', grouped by WMS

WMS	Product	Sum	Total	Add Up	Adding	Together	And	Plus	Multiplication	Dividing	Sentence	Times	Join
3		1	1	2	1			1					
4	1	2		3	2	2	1	3	1	1			
5		4		4	3	2		3	1		1	2	
6				1				1					1

Results for the word 'subtraction', grouped byWMS

WMS	Adding	Subtract	Reduce	Take Away	Difference	Less	How Many	Minus	Times	Shorten	Split
3		2		2				1			
4		2		4	1			4			
5	1	1	1	8		1		2	1	1	1
6		1		2				1			

Results for the word 'multiplication', grouped by WMS

WMS	Times	Square	By	Deduce	Product	Division	Quotient	Of	Multiply
3	2		1						2
4	4			1		1			3
5	6						1		1
6	1	1			1	1		1	

Results for the word 'division', grouped byWMS

WMS	Root	Split	Of	Reduce	Share	Into	Split	Quotient	By	Divide
3									1	2
4					1		1	1		4
5			1	1		3				3
6	1									2

Results for the word ' equals', grouped byWMS

WMS	Altogether	Same As	Means	Answer	Add	Even	Ends Up	Total	Result	To Be	Find
3		1						1		1	
4	1			3	1	1	1	1			
5	2	1		4				1	2		1
6		1	1								

Results for the Symbol Questionnaire grouped by Working Memory Space

Results for the symbol '+' , grouped by WMS

WMS	Add	Sum	Plus	Altogether	Total	And
3	2	1	1		1	
4	4	2	3	2		1
5	5	4	2	2		
6	1					

Results for the symbol ' -' , grouped by WMS

WMS	Take Away	Minus	Subtract	Decrease	Difference	Reduce	Less
3	2	1	2				
4	4	4	2		1		
5	8	3				1	1
6	2	1	1				

Results for the symbol 'x' , grouped by WMS

WMS	Times	Multiply	Product	Of	Add	Squaer
3	2	2				
4	4	3			1	
5	7	1		1		
6	1	1	1			1

Results for the symbol '÷', grouped by WMS

WMS	Divide	By	Share	Split	By	Quotient	Reduce	Into	Of	Square root
3	2	1			1					
4	4		1	1		1				
5	4						1	3	1	
6	2									1

Results for the symbol '=', grouped by WMS

WMS	Answer	Total	The same	Together	Makes	To be	Find	Ends Up	Is	Result
3		1	1			1				
4	3	1		1				1		
5	4	1	1	2	2		1	1		2
6			1						2	

Appendix I

Set of instructions which was left with staff after initial discussions.

Many thanks for your help.

Questionnaire 1 (green) :- Each page should be completed in 1 minute.Words and phrases which mean the same as the title word should be written. Spelling is not important, as long as I can figure it out.

Questionnaire 2 (yellow) :- Each page should be completed in 30 seconds. A line between each word which means the same as the symbol is required. No ruler needed.

Shape quiz (white) :- Each page should be completed in 30 seconds. The area of overlap is the only area which should be shaded.

Booklets (white,pink):-Half of the children should do a white booklet while the others do the pink.This division should be random and not based on age or ability. They should do the booklet at their own pace and show as much working as possible.

Please emphasise to the children that it is how they do maths problems that we are looking at - not whether the answer is correct or not. Therefore this work is not a test and that as we are looking at how they work it should be all their own work.

Appendix J

Full Results from the Statistical Analysis

The programme used for all of the statistical analysis was the SPSS Inc. This programme was many functions but only two of them were used during this project: the t-test and the correlation function.

t - Tests

This test was used to compare two sets of unrelated data to see if the average of the groups is significantly different. That is, the difference between them is due to an outside factor and not just a natural fluctuation between the two averages.

Two t-tests were done, the first compared the average mark gained by the dyslexic group with that gained by the non-dyslexic group. A full result from the test is given below in table **J.1**.

Table J.1 results from the t-test for average marks

Variable	Number of cases	Mean	Standard Deviation
Marks for dyslexics	21	6.0	2.324
Marks for non-dyslexics	185	7.7	1.891

t-value = -3.71

two tail significance = **0. 0001 (p< 0.01%)**

The second t-test compared the average results for the white booklet with those of the pink booklet. A full result is given in table **J.2**.

Table J.2 results from the t-test for pink and white booklets (que. 2,3,4 and 10)

Variable	Number of Cases	Mean	Standard Deviation
Marks for Pink	109	3.00	1.1
Marks for White	98	3.04	1

t-value = **-0.55**

two tail significance = **0.586** (not significant)

Correlation Tests

Correlation looks for a relationship between an outcome and a known factor. In this case a relationship between overall success and age was investigated, as well as, the relationship between working memory space and overall success. That of working memory space and success in individual questions was also carried out. Thus three sets of correlation tests were completed. Of course, correlation does not imply causality.

The first correlation done was that of overall success (total mark within the test) and age and this gave the following result, table **J.3**.

Table J.3 Correlation results

Age	Total
Number in sample	185
Correlation Coefficient	0.24
P	0.001

This has significance at less than **0.1%**.

The second correlation was done with the results for the pink and white booklets and working memory space and produced the following results, table **J.4**.

Table J.4 Correlation Results

WMS	Total (pink)
Number in Sample	98
Correlation Coefficient	0.02
P	0.857
WMS	**Total (white)**
Number in Sample	73
Correlation Coefficient	-0.02
P	0.882

Neither of these results is significant.

The third set of correlations looked at each question individually and working memory space and gave the results shown in table **J.5**.

Table J.5 Correlation Results (158 in sample)

Question Number	Correlation Coefficient	P
1	-0.08	0.301
2	-0.09	0.228
3	0.42	0.596
4	0.08	0.322
5	-0.06	0.42
6	0.10	0.19
7	-0.56	0.482
8a	0.04	0.642
8b	-0.05	0.559
9	0.11	0.169
10	-0.06	0.446

None of these results are of significance.