PROBLEM SOLVING IN INFANCY - A STUDY OF INFANTS' PERFORMANCE ON TASKS OF SPATIAL MANIPULATION

by

JAMES McKECHNIE

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CONTENTS

				Page
Abstract				i
Chapter 1	- Introduction			1
Chapter 2	- Methods			20
	- Analysis			39
Chapter 3	- Lever task	- (i)	Results	44
		(ii)	Discussion	76
Chapter 4	- Wire task	- (i)	Results	124
		(ii)	Discussion	156
Chapter 5	- Spatial Task	- (i)	Results	178
		(ii)	Discussion	186
Chapter 6	- Relations between tasks			
		(i)	Results	195
		(ii)	Discussion	210
Chapter 7	- Conclusions			220
Appendix 1				226
Appendix 2				227
Appendix 3				228
Appendix 4				230a
Appendix 5				230b
Bibliography				231

ABSTRACT

Children, 12 to 24 months of age, were presented with three tasks: two detour problems and a spatial task. The aim of the study was to assess the performance on each task and to consider the relationship between performance on the two detour problems and the relationship between spatial knowledge and detour ability.

The two detour tasks (the lever task and the bent wire task) shared a common feature in that the object rather than the subject had to be moved in the detour.

The results of the lever task indicated that age, experimental group (three lever designs were used) and the sex of subjects were influential variables. Analysis of the bent-wire data showed that as hypothesised age was the most important variable, accounting for qualitative and quantitative differences in performance.

The results from the detour tasks were discussed with reference to the attainment of skilled behaviour and the relationship between cognitive development and detour ability.

Spatial task results indicated that performance was related to age and that the type of error recorded was also related to the age of the subject.

The hypothesised relationship between the two detour tasks was not supported by the data. Furthermore, the anticipated relationship between detour ability and spatial knowledge failed to emerge.

These results were discussed in relation to the issue of developmental synchrony and the structuralist's view of development.

CHAPTER 1

INTRODUCTION

"Barriers interrupt, delay, or prohibit the attainment of goals or solving problems. They may be fences, screens, parts of interlocking puzzles, or space. Sometimes barriers can be circumvented by taking a detour".

(Davis, 1974)

Problems requiring detour solutions were amongst the first formal tests of behaviour in nonhuman primates and many of these early tests were then adapted for human subjects, particularly young children.

The best example of this early work is that of Köhler (1925) who devised a number of tests that became the standard tasks in investigating this aspect of behaviour.

In a series of experiments, Köhler created a number of problem situations where the simplest and most direct solution was thwarted by introducing a barrier. The task design can be contrasted with some of the earlier work in this area (e.g. Thorndike, 1898) in that the subject was allowed to view all aspects necessary for solution.

Under the title of 'round-about methods', Köhler described tasks whose solution was achieved by circuitous routes. In the first instance, food was placed in front of the subject but direct access was denied by a grill and to obtain the goal the subject must move around the barrier. Köhler demonstrated that apes, a dog and a fifteen-month-old child had little difficulty with this task.

Even when part of the problem was no longer visible, Köhler found that apes could still retrieve the goal. In this case, the food reward was dropped from a room window and the animal must leave the room, and the building, to collect the reward. This task was repeated successfully with a dog as the subject.

A slightly more complex problem involved a suspended, swinging basket, which could not be reached directly. The solution was to move to that part of the room where some scaffolding provided a vantage point from which to catch the basket as it swung past. Once again, Köhler's apes had little difficulty with this task.

The most often quoted of Köhler's experiments are those which involve the use and manipulation of implements. Köhler outlined a number of experiments which demonstrated that his apes were capable of using sticks (or combinations of sticks) to pull food within reach, to retrieve food which is out of reach by using a box for extra height, and to combine both stick and box to retrieve a goal which was unobtainable by using only one implement.

An additional complexity was added to some of these tasks by incorporating the notion of intermediary goals. A typical example of this type of task involved placing a food reward out of direct reach and supplying the subject with a stick which was too short to allow the retrieval of the goal. In order to solve the problem the short stick must be used to catch a larger stick which can then be used to retrieve the food.

These detour tasks with intermediary goals highlighted the individual differences in performance between the apes and also led to the conclusion that as the difficulty of the means to solution increased there was a greater tendency to try more direct paths to solution.

An experiment outlined by Köhler toward the end of 'The Mentality of Apes' draws attention to the limitations in the ape's ability. The problem required the animal to retrieve a food reward which was placed in a three-sided box with the open end facing away from the subject. A stick was supplied to facilitate the retrieval of the goal. However, rather than simply rake the food towards itself, the ape had to push the goal away towards the open end of the box and then pull it towards itself.

In contrast to all the other detour tasks, this particular problem proved to be more difficult. The majority of responses involved direct approaches, raking the food towards themselves even when it collided with the side of the box. Some successes were recorded when the open side of the box was placed at a 90 degree angle to the subject.

Köhler notes that the difficulty in solving this task arises from the fact that the detour does not require the animal to move but rather requires the goal object to be moved in a detour while the animal's position is static. Guillaume and Meyerson (1930) reported that only one of their chimpanzees solved this problem.

Köhler repeated the above task with a twenty-five-month-old child who, like the apes, was capable of making detours with his own body, but the child also failed the task when the detour had to be made by the goal object.

The use of barriers in these tasks resulted in subjects adopting one of two approaches depending on the task. Firstly, the barrier required the subject to move while the goal object remained stationary and secondly, the subject remained stationary while the goal object had to be moved. A further distinction can be made in the latter group since some of the tasks requiring tool use (e.g. a stick or string) required the object to be pulled or raked toward the subject and Kohler's research shows that these tasks were solved by his apes. In contrast, when the goal object had to be moved in a detour away from the subject's body, performance levels declined.

The significance of Köhler's work was not lost on psychologists at the time. Spence (1937) provides a review of animal research that reflects this influence.

For those psychologists interested in development, Kohler's research provided a method of assessing the question of increasing competence in human children.

The central focus of this research was to discover when children could succeed on Köhler's tasks. There was little attention paid to the qualitative differences in performance on the tasks (Alpert, 1928; Brainard, 1930; Harter, 1930; Matheson, 1931; Richardson, 1932; Kellog and Kellog, 1933; Sobel, 1939; McGraw, 1942; Ling, 1946).

The general conclusions from this literature indicated that performance on barrier tasks improved with age and that those subjects who failed on these tasks devoted a greater proportion of their time to primitive reaching. The age of subjects used in the above studies ranged from 7 months, in Richardson's (1932) string-pulling study, to 6 years-of-age in Harter's (1930) study. Sobel (1939) suggested that research into childrens' performance on Köhler's tasks should focus on the age group 18-33 months since this period coincided with quantitative improvements in performance.

The majority of this research failed to look at childrens' performance on tasks where they were required to move the goal object in a detour before retrieving it. One exception to this trend was Brainard (1930), who used his two-and-a-half year old daughter as the main subject in a study replicating many of Köhler's tasks.

Two results are of note from this work. In the suspended basket task, the aim is to follow the rope that is holding the basket up, release it and drop the basket to the ground.

Brainard's daughter had difficulty with this problem. Initially, her attention was drawn toward the goal ignoring the rope, and even when she turned to the rope as a means of solving the task, a problem arose as to which direction the rope should be moved in.

A common behaviour, displayed by Köhler's apes, is to pull the basket directly towards oneself - a strategy which fails since the basket hits the roof. The difficulty arises from the fact that the attachment of the goal to the rope encourages direct action, pulling towards oneself, while the solution requires the awareness that in order to bring the goal closer, one must let it move in the opposite direction.

The second task performance of note concerns the 'open sided box'. Köhler's apes had difficulty in moving the goal object in a detour since they had to move it away before being able to bring it closer. Brainard's daughter, like the apes, persisted in direct solutions, raking the object toward herself despite the fact that the path was blocked. However, after some time had elapsed she succeeded and repeated her success over several trials reflecting some understanding of the problem.

Brainard's results support Köhler's earlier observations of the difficulties created for subjects when the goal object must be moved in a detour. Richardson (1934) supported this argument and introduced a 'new' task to this area, namely a rotating lever.

The problem faced by subjects is that the desired object is placed out of reach and can only be retrieved by rotating the lever it is attached to. Turntables and levers have been used by other researchers, for example, Drescher and Trendelenburg (1927) used a turntable and found orangs, chimpanzees and monkeys capable of solving the problem. Guillaume and Meyerson (1931) used two sticks forming a cross pivoted at the centre and their subjects, chimpanzees, were capable of rotating and retrieving the goal object.

Richardson's lever was of a different design, a straight piece of wood pivoted below its centre. Her results indicate that 42% of the oldest subjects were successful: the study used subjects from 28 to 52 weeks of age. Richardson argued that success was dependent upon age, motivation and emotional development. Furthermore, the behaviour displayed on the lever varied with age; responses influenced by the visual structure of the task were dominant in the younger children's behaviour, e.g. scratching and poking at the lever with older children pulling directly on the lever.

It was suggested by Richardson that the major difficulty posed by the lever task was that subjects were required to move the lever away from themselves in order that the goal object could be brought within reach.

Following a hiatus in the 1950s when the emphasis shifted towards verbal and symbolic tests of problem solving (Duncker, 1959) there has been a re-emergence of interest in barrier tasks.

The use of barriers has once again required subjects to move while the object remains static or alternatively to use some tool that would facilitate retrieval of the goal. A number of studies have investigated the child's reaction to a barrier blocking the path to a goal which has required either a manual or locomotor detour from the subject to retrieve the goal object (Bruner, 1970; Reiser and Heiman, 1982; Reiser, Doxsey, McCarrell and Brooks, 1982; Lockman and Ashmead, 1983; Lockman, 1984; McKenzie and Bigelow, 1986). This research has shown that manual detours are made before locomotor ones (Lockman, 1984) and that manual detours are evident in the latter part of the first year with locomotor detours in evidence in the early part of the child's second year. In addition, there are suggestions that changes in detour ability emerge in the second year. For example, shortest route behaviour is a refinement in detour behaviour that develops in the second year (Reiser and Heiman, 1982) and that some detour tasks are not solved until the end of the child's second year (Reiser et al, 1982).

Fitzpatrick (1978) and Bates, Carlson-Luden and Bretherton (1980) adopted the alternative approach whereby subjects were required to use tools to overcome barriers. The latter study required subjects, 10-11 months-of-age, to retrieve a toy that was out of reach by using a tool, e.g. cloth, string, stick etc. The tool was either in direct contact or in close proximity to the goal and the degree of similarity between the goal object and the tool was manipulated by varying the colour and texture of both items.

The results indicated that primitive tool use involves the knowledge of how two distinct objects can be used to solve a problem. However, the spatial configuration appeared to enhance solution if a link was suggested between tool and goal by having them touching. Willatts (1984) has also considered the influence of spatial configuration between object and support and the effect this has on means-end behaviour.

Fitzpatrick (1978) carried out a more detailed investigation of the skill needed to use tools in the 16-24 month-old-child. Subjects were faced with a number of barrier problems which required the use of a stick or combination of sticks to solve.

The results from this study showed that age was related to success, older subjects having greater success. Furthermore, it was argued that the organisation of skill components was more important than the appearance of any particular skill when considering success on these tasks.

Fitzpatrick had also manipulated the level of frustration within his design with the expectation that it would disrupt performance, but the results did not support this hypothesis. Increased frustration resulted, on subsequent trials, in the more effective use of tools.

While this resurgence of interest in barrier tasks has taken place, Köhler's original finding of the difficulty posed by moving objects in detours rather than the subject themselves, has been neglected. Two exceptions to this trend have been found, namely Koslowski and Bruner (1972) and Davis (1974).

Koslowski and Bruner (1972) adapted Richardson's (1934) lever task resulting in a larger piece of apparatus with the lever mounted on a table, pivoted at the centre and rotating through 360 degrees. Their results demonstrated that age was an important variable in this task. Infants 18 months and over were more capable of solving the problem. However, Koslowski and Bruner were concerned with the qualitative differences in performance as well as the quantitative aspects and they argued that the strategies adopted in this task varied with age.

The youngest subjects (12-14 months) used a greater number of unsuccessful strategies. For example, direct pulling, reaching and moving the lever to and fro. The middle age group (14-16 months) used these strategies as well and in addition, demonstrated an ability to partially rotate the lever. The oldest subjects (16-24 months) used fewer unsuccessful strategies and achieved more rotate and capture solutions.

According to Koslowski and Bruner, an important step in solving this problem is that the infants must combine two pieces of information. Firstly, the effect of their actions on the lever rotation and secondly, the effect of rotation upon the position of the goal object. It is the inability to combine both aspects that results in failure on this task.

Once success is achieved, it is generalised to other similar tasks and lever designs. However, there is no data at present which considers the role that the design of the lever may play in the attainment of success.

The second barrier task which required the movement of the goal object is attributed to Davis (1957; 1974). The bent wire task has been used by Davis and his co-workers in a number of studies. The task involves the removal of some goal object from a wire that consists of a number of 90 degree bends; the complexity of the wire can be varied as can the direction of solution, that is the wire end can be facing toward or away from the subject.

Davis used ten species of primate, including human children, and one non-primate species and the results indicated that while detours may be learned by many species, they display a considerable variation in performance.

The ability of the children to solve these detour tasks is of particular interest. Davis quotes Whitecraft et al (1959) where children ranging from 23 to 58 months of age were tested on the bent wire task. Subjects aged between 36 and 58 months succeeded on all trials and errors were only recorded for the 23-month-old children.

It was further noted that solution times varied markedly across age groups. This was attributed to the facility of older subjects to make and anticipate the appropriate movements for solution. However, it must be noted that no detailed qualitative assessment of the subjects' actions were made; the emphasis was upon quantitative measurement.

The bent wire task was used by Hollis (1962) to test a group of retarded children who were all non-verbal and contestable on standard IQ tests. The performance of these children was found to fall between that of Davis's monkeys and pre-adolescent chimpanzees.

Davis noted that wire complexity influenced performance and also showed that errors and failures increased when the goal object had to be pushed away rather than pulled towards the subject in order that the lure could be removed from the wire.

These two tasks, the rotating lever and the bent wire task, have drawn attention to the difficulty created for subjects by barrier tasks that require the object rather than the subject to be moved in a detour. At present there is no research which would allow us to compare performance on these two tasks since the wire task has not been used on children younger than 23 months-of-age.

The present study will address this issue of comparability between these tasks using a sample of children 12-24 months of age. In addition, attention will be focused on the possible qualitative differences in performance displayed on the wire task and the influence of lever design upon success and failure on the lever task; two issues which have been neglected.

The majority of the pre-1950 investigations of barrier tasks was concerned with the question of whether children could solve the particular task. There were few attempts to address the theoretical issues that performance on these tasks raised or to consider the relationship between performance on these tasks and other aspects of development.

Exceptions to this general pattern did exist. For example, Sobel's (1939) attempt to discover when a how 'insight' developed, given that Köhler (1925) believed that some 'insight-like' process was needed to account for performance on these tasks.

Few researchers have addressed the question of detour behaviour from a developmental and theoretical viewpoint. However, Piaget (1953, 1954) is an exception.

Piaget (1954) proposed that the ability to invent detours was a major hallmark of the final stages of the sensormotor period. The emergence of detour ability is closely linked with the development of spatial knowledge. In particular, the development of reversibility and associativity are relevant to detour understanding. The ability to reverse a displacement and return to a starting point (reversibility) and the ability to reach a given point by alternative routes (associativity) are indicative of an understanding of spatial relationships and are of obvious relevance to detour ability.

It is suggested by Piaget that associativity develops after reversibility and that the former is evident in the stage 5 sensorimotor behaviour of children although limited by the lack of representation resulting in detours that reflect the disappearance path of the object. It is not until stage 6 is attained with the child's ability to represent inter-relationships between objects, with the self represented as an independent object, that these specific limitations are finally overcome.

The relationship between spatial knowledge and detour ability has been noted by Butterworth (1983) and Lockman (1984) produced limited support for this argument. Reiser and Heiman (1982) when investigating shortest route behaviour argued that this behaviour emerged in the second year and proposed that it developed form the child's ability to use a self reference, as opposed to an egocentric reference system reflecting a change in awareness of the general properties of space.

Wishart and Bower (1982) devised a three-cup spatial task which they argued would give a more accurate reflection of the child's understanding of spatial relations. Their results indicated that egocentric errors, while declining, were made by children all through the second year of life and they interpreted this as support for the argument that spatio-temporal identity rules are not attained until the end of the sensorimotor period.

It can be argued that the improved performance on detour tasks reflects the development of spatial knowledge and that the performance on barrier tasks which require the object to be moved in a detour will reflect these changes in spatial awareness.

In addition to proposing a relationship between performance on barrier tasks and the child's concept of space, Piaget has offered a framework within which to consider the qualitative differences in performance that some resarchers have found between age groups (Koslowski and Bruner, 1972).

The transition from secondary circular reactions to tertiary circular reactions implies that the child's behaviour in new and novel situations will vary in the second year of life and the analysis of behaviour in specific barrier tasks may reflect these developments.

While Piaget has provided a framework for understanding detour ability, it must be noted that its applicability has been questioned (e.g. Lockman 1984).

Alternative explanations have been offered to explain the variation in performance on the lever and bent wire tasks. Koslowski and Bruner (1972) have argued that the pattern of results on the lever is a reflection of the process of skill attainment. Similarly, Davis (1974) has proposed that bent wire task results reflect the acquisition of skilled behaviour rather than a sudden learning of the problem solution.

Koslowski and Bruner (1972) have suggested that the subject's analysis of their task will influence performance and Bower (1979a) has argued that the pattern of results reflects the child's awareness of the INRC group properties of the lever task. This is based upon Bower's argument stressing the importance of repetition in development (Bower 1974b, 1976).

Aims and Hypotheses of the Present Study

The aim of the present study is to investigate the performance of children, 12-24 months-of-age, on barrier tasks where the solution requires the manipulation of the goal object through space.

Two tasks, the lever task (Koslowski and Bruner, 1972) and the bent wire task (Davis, 1974) require this type of solution and will be used in the present study. In the case of the bent wire task, this will provide the opportunity to assess 12-24 month infants on this task and will allow a closer investigation of those variables which influence performance on the lever task.

Lever Task

From the work of Koslowski and Bruner (1972) it is hypothesised that age will be a major predictor of performance. Age is expected to be related not only to success on this task but also to reflect qualitative differences in performance.

The assessment of qualitative differences will consider not only actions directed at the lever but also direction of visual gaze during the task - an indicator which Abravnel (1981) has suggested will show developmental changes and which Richardson (1934) and Koslowski and Bruner (1972) noted as a source of information, but did not investigate further.

It is expected that variations in lever design will influence performance levels. The detailed designs are included in the methods section. Guillaume and Meyerson (1931) employed a lever with a cross-strut in their study of chimpanzees and while Koslowski and Bruner (1972) argue that success in their lever task led to generalisation to other similar tasks, there is a lack of detailed information on children's performance on alternative lever designs.

Bent Wire task

Davis (1974) noted that children over 25 months of age did not produce errors on this task. Errors were recorded by subjects aged 23 months of age and to date this has been the youngest sample tested on this task. Since the present sample of children are aged 12-24 months, it is hypothesised that performance will vary with age and that this variation will be reflected in both quantitative and qualitative terms.

Following Davis's (1974) results, it is expected that performance on the wire tasks will reflect various aspects of wire design, that is, wire complexity and whether the solution is 'away' or 'toward' the subject.

Piaget (1954) has proposed that performance on detour tasks is based upon the child's concept of space. Therefore, Wishart and Bower's (1982) three-cup spatial task has been adopted as a means of assessing the subject's understanding of spatial relations.

Spatial Task

Following the consensus of the literature on spatial development, it is hypothesised that age will be a major predictor of performance. In addition, Wishart and Bower (1982) noted that the type of error made on their three-cup spatial task varied with age and it is hypothesised that this pattern will be replicated.

A central tenet of the structuralist's view of development is that performance across tasks will reflect the child's stage of development. This argument would propose that some degree of relationship should exist between performance on the three tasks.

If spatial ability is related to detour developments, this should be reflected in the results. Furthermore, if the qualitative approach to a task reflects the child's stage in development, it can be hypothesised that performance on the lever and wire tasks will reflect this similarity of approach to novel tasks.

CHAPTER 2

(i) METHOD

Design

Infants were assigned to one of three experimental groups on a random basis. All subjects were required to complete three tasks - a spatial task, lever task and a bent-wire task. The spatial task and bent-wire task were constant across experimental groups but the lever task varied. Three lever tasks were used - standard, cross and covered lever.

Within each experimental group, subjects were allocated to one of three groups depending on age. The age groups used were - 12-14 months, 14-18 months and 18-24 months.

Procedure used was the same for each subject regardless of experimental group. A counterbalanced design was employed to neutralise any order effects between the three tasks.

Table 2a outlines the experimental design.

Table 2a - Experimental Design

Experimental Group N=45	Age Group N=15	Lever Task	Bent-wire Task	Spatial Task
Group 1 N = 45	12-14 months 14-18 months 18-24 months	Standard Lever	Wire 1-6 carried out by ALL Subjects	Spatial Task carried out by ALL Subjects
Group 2 N = 45	12-14 months 14-18 months 18-24 months	Cross Lever		
Group 3 N = 45	12-14 months 14-18 months 18-24 months	Covered Lever		

Subjects

One hundred and thirty-five infants participated in the study (Males - 81, Females - 54). The age of subjects ranged from 12 months to 24 months. The mean age within each age group was:

12-14 months	$\bar{x}$ = 13 ; 1
14-18 months	$\bar{x}$ = 16 ; 2
18-24 months	$\bar{x}$ = 21 ; 3

Subjects were recruited from two main sources. Firstly, the Day Nurseries in the Glasgow region and secondly, Mother and Toddler groups in both the Glasgow and Stirling areas. Methods of contacting subjects varied according to the source.

In the case of the Day Nurseries, permission was obtained from the various Strathclyde Regional Offices to visit the Nurseries and seek the co-operation of each Nursery. Once this had been obtained, the parents of each potential subject received a letter asking permission to use their child in the study. A general outline of the study was included in this letter and, if permission was granted, the child was tested 3-4 days later.

Permission to visit Mother and Toddler Groups was obtained from the relevant organiser and contact was made by the experimenter with potential subjects and parents. If the parents indicated their willingness to participate in the study, they were contacted by telephone to arrange the date and time of testing.

Twenty-three infants were excluded from the study due to non-participation in the tasks, refusal to work with the experimenter and, in one instance, illness.

For those subjects found in Day Nurseries, the experimenter spent several days familiarising himself with the children before any attempt was made to carry out the tests. The tests were carried out in the Nursery with a Nursery Nurse present, who was familiar with the child.

Those subjects found in Mother and Toddler Groups were tested with a parent present. Occasionally, parents brought siblings along and every effort was made to exclude these from the test situation.

To counter-balance the possible differences arising from the source of subjects, the experimenter ensured that the various sources were represented within each experimental group.

Experimental Setting

The majority of subjects were tested at Stirling University in a carpeted room with one large desk, two chairs and the experimental equipment. Dimensions of the room were 9 ft by 12 ft (approximately).

A video tape-recorder and monitor were located on the desk and a video camera was positioned at the side of the desk. The experimental apparatus required the use of a purpose-built table (see Apparatus Section) which was positioned against the wall to limit the subject's movement.

When infants were being tested in the Day Nursery setting, a quiet room was obtained and obtrusive furniture was removed. The room was one which would be familiar to the children in the Nursery. The video equipment and experimental apparatus were set up in the most unobtrusive way possible incorporating a similar layout to the above room.

Apparatus

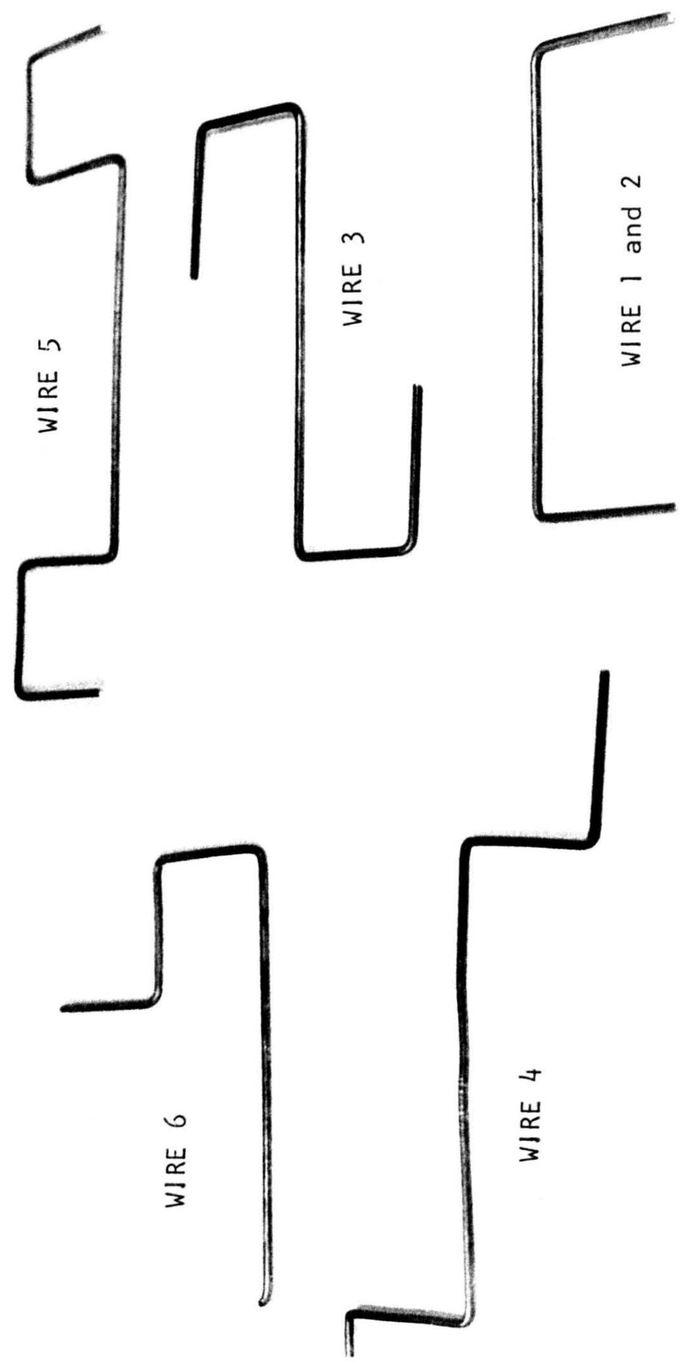
During the test session, the subject was required to tackle three different tasks and the materials employed in each are outlined below.

Spatial Task: This required the table (lever-table with lever removed), three plastic disposable cups and several small dolls which were brightly coloured and approximately 6 cms tall.

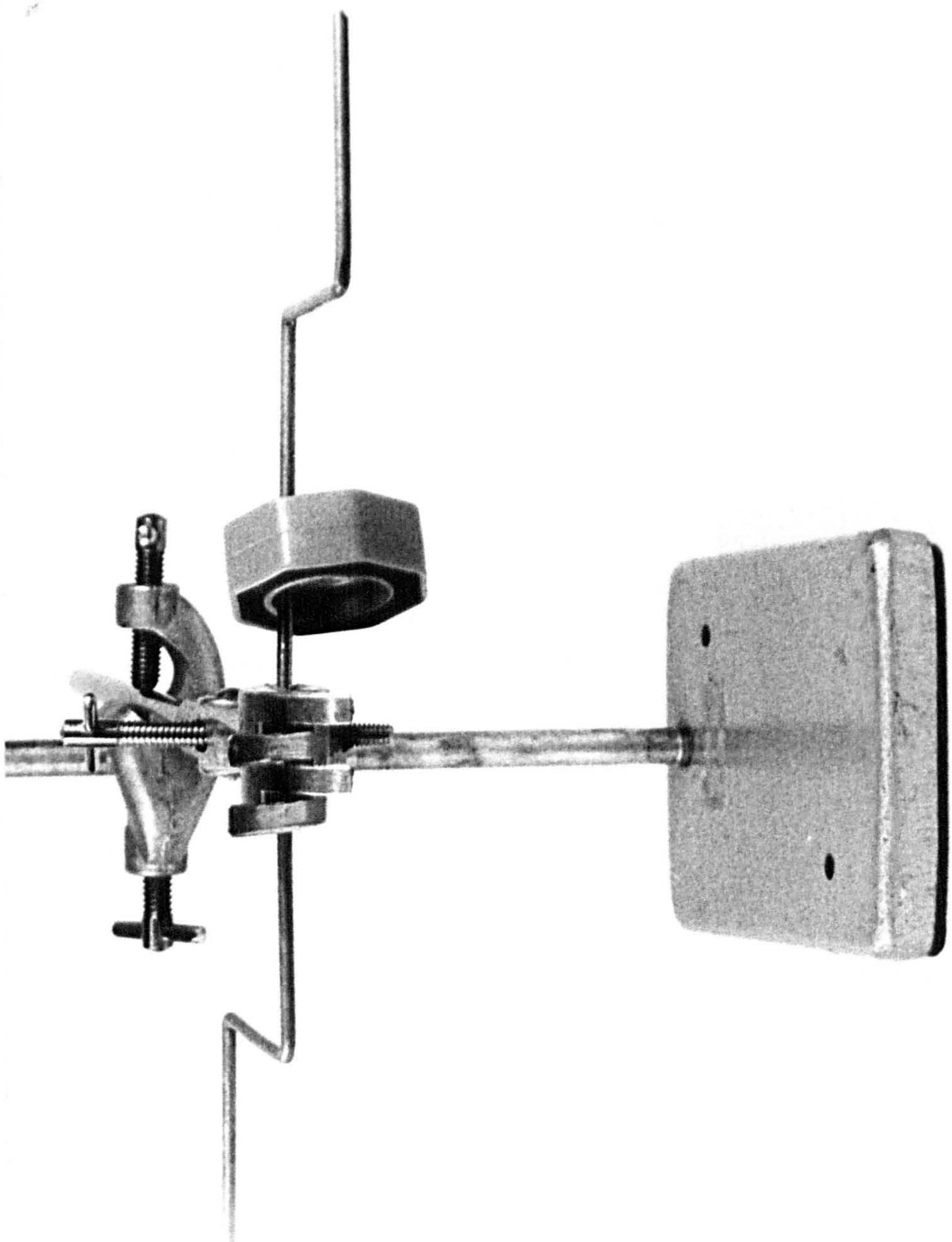
Bent-Wire Barrier Task: The material for this task was adapted from Davis (1974). Six bent-wire shapes were used which varied in terms of complexity, i.e. the number of turns. The photograph shows the six wires used. Dimensions were 15-16 cms. for main centre stretch with each additional section adding 5-5.5 cms. The wires were constructed from a light alloy similar to wire coat-hangers in terms of thickness and texture.

The bent-wires were supported by a standard science stand and clamp and the 'lures' were five brightly-coloured shapes (square, hexagonal, triangle). The shapes were approximately 5 cms. in diameter with a centre hole of approximately 2 cms. This centre hole was small enough to ensure that the lure had to be manipulated around the corners of the wires.

THE BENT-WIRE TASKS



WIRE-TASK READY FOR PRESENTATION TO THE SUBJECT



Lever Task: The spatial and bent-wire tasks were standard for all subjects. However, three lever tasks were used.

<u>Lever Task for Experimental Group 1</u> (Standard Lever)
This design was based upon Koslowski and Bruner's (1972) 'lazy Susan' apparatus. The table top, common to all three levers, was made of wood and measured 91 cms x 91 cms and was mounted on adjustable legs which allowed the height to be set between 38-62 cms depending on the subject's height.

The lever was made of wood and measured 87 cms in length, 9 cms wide and 1 cm thick. This lever was attached to a centre board which measured 41 cms in diameter. The whole construction was attached to the table by a central nut and bolt which allowed the lever to rotate freely.

<u>Lever Task for Experimental Group 2</u> (Cross Lever)
The table detailed above was used but in this case the lever was in the shape of a cross. Each part of the cross was 87.5 cms long, 6 cms wide and 1 cm thick. The cross lever was pivoted at the centre to allow rotation through 360 degrees.

<u>Lever Task for Experimental Group 3</u> (Covered Lever)
Once again, the same table was employed for the base. In this task, the lever from Group 1 was used with two modifications. Firstly, a cover was placed over the lever. This cover had a diameter of 67.5 cms and allowed 9.5/10 cms of lever to protrude at each end. The cover did not interfere with the rotation of the lever. It simply obscured

the centre of the lever.

The second modification involved the attachment of a T-extension on the far end of the lever. Due to the cover stopping contact with the middle section of the lever, some aid had to be provided to help subjects pull the lever end towards them if their reach was not long enough. This extension was 35.5 cms long, 3 cms wide, 1 cm thick and was attached to the main lever with approximately 13 cms protruding from either side.

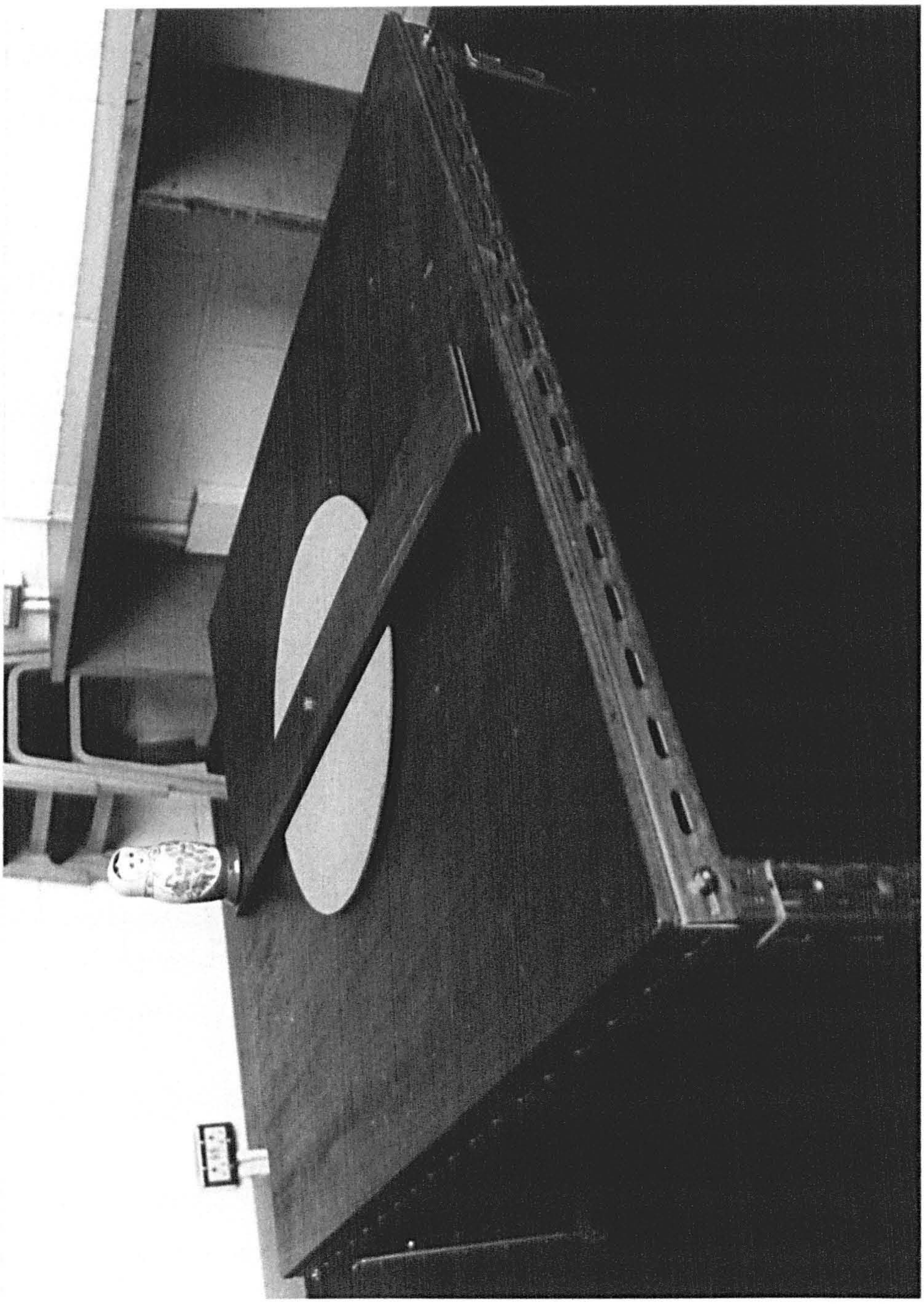
Levers 1, 2 and 3 were all pivoted at the centre by a nut and bolt which allowed them to rotate through 360 degrees. Some hard plastic was used as a washer to stop contact between lever and table top since this would have inhibited rotation.

All of the above descriptions are supplemented by photographs of the apparatus.

In addition to the main apparatus, several toys were used as lures. The dolls for the spatial task and the coloured shapes for the bent-wires have already been mentioned.

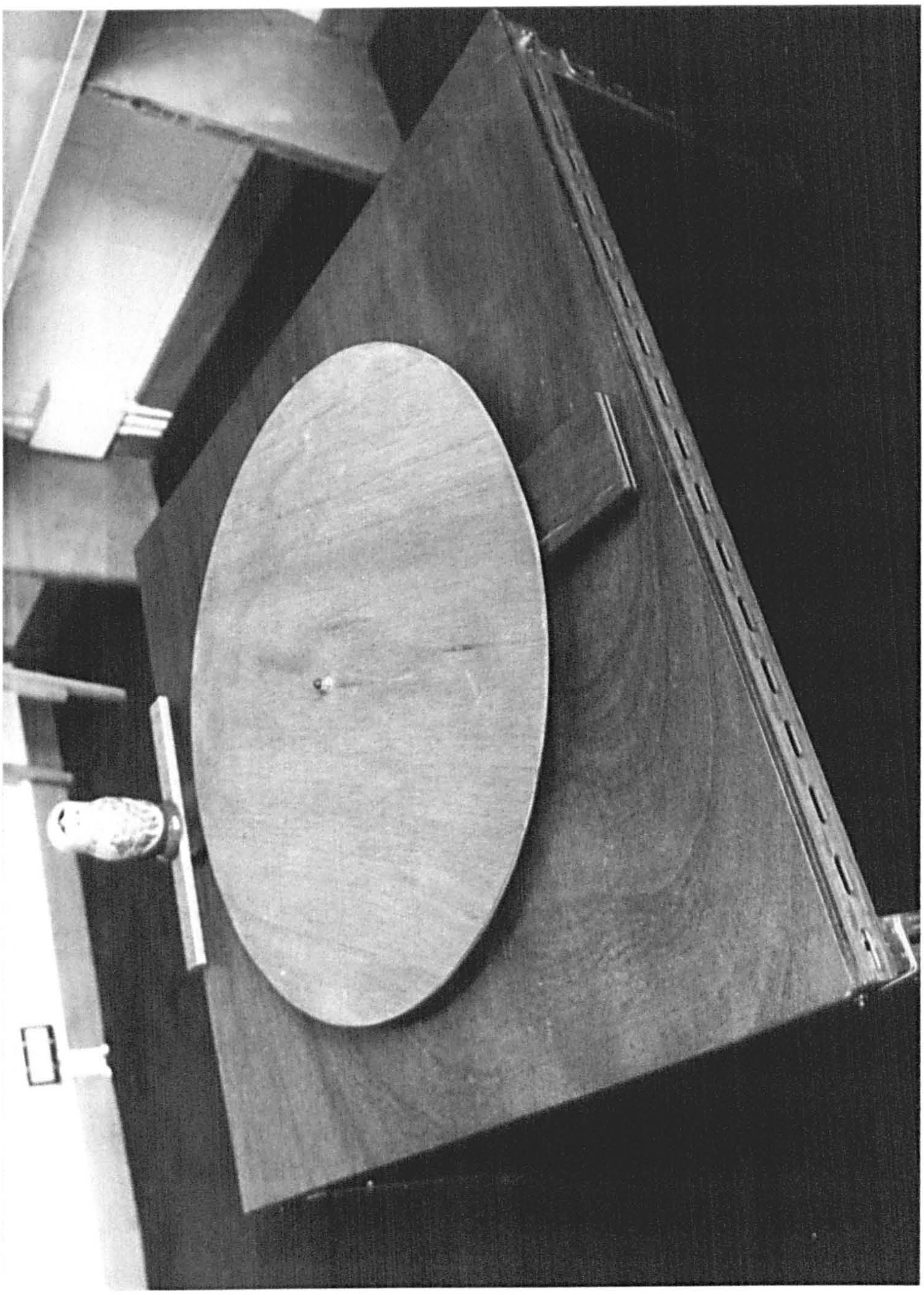
As well as these toys, numerous others were present and used if subjects displayed a preference. These included a set of Russian dolls, small teddy-bear, yellow wooden car and several small furry toys.

THE STANDARD LEVER



THE CROSS LEVER

THE COVERED LEVER



Procedure

On entering the experimental room, some time was allowed for the child to explore the room and the materials that it contained. The experimenter introduced the child to the toys and encouraged the child to play on the table which, at this point, had no lever attached to it.

When some rapport had been established between the experimenter and the child, the experimental tasks were started. Order of presentation was predetermined by a counterbalanced design to neutralise any possible order effects.

The procedure for each of the tasks was as follows:

Spatial Task: This was based upon a procedure outlined by Wishart and Bower (1982) and involved hiding a toy under one of three cups. The subject was then moved resulting in an invisible displacement of the object which involved a change in egocentric position of the object (Figure 2a).

In Wishart and Bower (1982), the subject was seated in an apparatus that allowed the child or the table to be revolved. The present study involved moving the child around a fixed table avoiding the use of any rotating apparatus since this may have influenced performance on the lever task which relied upon a similar movement.

The experimenter and subject started at one end of the table where the subject was shown that there was nothing under each of the cups as it was placed on the table.

The subject was then shown the toy and with the child's attention on the object it was placed under one of the cups. The subject was then lifted around the table to their new position and encouraged to retrieve the toy.

Due to the demands placed on the child of completing three separate tasks, only five trials were carried out. In all five trials, the subject was moved 120° to either the right or left of their starting position. The direction of movement and the cup used to hide the object were pre-determined by the experimental design.

The child's search for the hidden toy was considered successful if the toy was recovered from the correct cup at the first attempt. If the child lifted either of the other cups an error was recorded.

Three categories of error were used. Firstly 'ego error' where an egocentric choice of cup was made and secondly, 'other error' where the third cup was chosen. The third category of error used was termed 'failed', where the subject moved towards a cup but failed to lift it. A maximum of two 'failed' category errors were allowed per child. This latter category was used since the subjects were participating in the task by moving to a specific cup but failed to lift it. In contrast to this, subjects who failed to participate by moving around the table or searching for the object were dropped from the study. In the event of an incorrect response, the experimenter encouraged the child to search under the other cups or the experimenter retrieved the toy drawing the subject's attention to it.

The trial ended when the subject chose a cup or in the case of the 'failed' category trials, when the experimenter considered that the subject was losing interest. In the case of an unsuccessful trial, for example where the child does not move when encouraged to retrieve the toy, the experimenter spent some time (approximately 30 seconds) encouraging the child and then re-ran the trial.

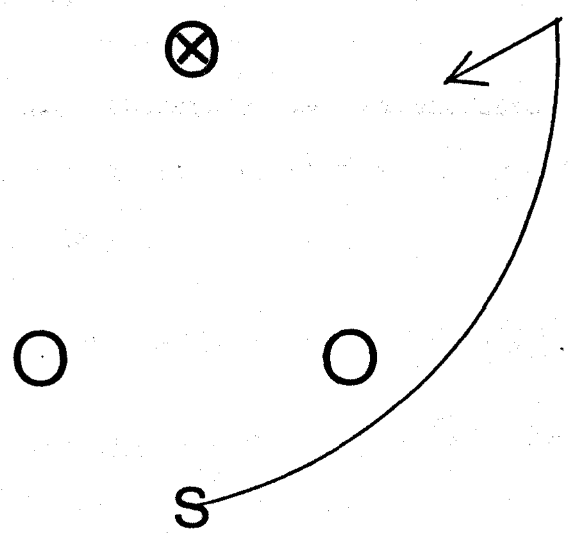


Figure 2a - Three-cup hiding task with subject moved 120°

Bent-Wire Task: Six wire tasks were taken from Davis (1974) and these varied in terms of complexity. The degree of complexity was a reflection of the number of segments that the lure had to be moved in order to remove it from the wire. 'Easy' wire tasks consisted of two segments, 'medium' wire tasks consisted of three segments and 'hard' wire tasks consisted of four segments. Two wire tasks were assigned to each of these categories. In addition to wire complexity, Davis presented tasks on either the left or right of the subject's midline and with the 'open' wire end either facing towards the subject or away from them.

In order that these variables could be included in the present study, the two wires in the 'easy', 'medium' and 'hard' groups were divided to allow one to be presented on the subject's left, the other on the subject's right and one with the 'open' wire end toward the subject and one with 'open' wire end away from the subject.

Each wire could therefore be categorised according to complexity, left or right presentation, or toward or away from subject. (See Table 2b).

Table 2b - Wire Task Categories

Wire	Degree of Difficulty	Direction of 'open' wire end	Left/Right Presentation
1	Easy	Toward	Left
2	Easy	Away	Right
3	Medium	Toward	Right
4	Medium	Away	Left
5	Hard	Away	Right
6	Hard	Toward	Left

Each subject attempted all wire tasks and the order of presentation was randomised. The subject was placed at one end of the table and the science stand holding the bent-wire was placed in front of them. Once the stand and wire were in position, the experimenter showed the lure to the subject and once the child's attention was on the lure, it was placed on the wire. It was possible for the experimenter to place the lure on the wire using his hand to hide the exact movements required. With the lure in position, the subject was encouraged to retrieve it. However, if the child was slow in responding, the experimenter would spin the lure to attract the child's attention to it.

Davis (1974) had imposed a time limit on this task of 45 seconds. However, due to the fact that the subjects in the present study were younger than those in previous studies, this time period was extended to 60 seconds.

If the child failed to remove the lure at the end of this period, the experimenter would do so, obscuring the removal with his hand, and allowing the child to play with the lure. If the child successfully retrieved the lure, they were allowed to play with it until the next task was ready for presentation.

Lever Task: Although three lever tasks were used, the procedure was the same in all cases. The table was positioned against the wall to stop subjects moving around one side of the table, and the experimenter was positioned at the other side of the subject in an attempt to limit movement in this direction. It was intended that by limiting the child's movement, attention would be focused upon the lever.

The subject was initially shown the lures, usually the Russian dolls, and when the child was particularly involved with the toy, it was removed and placed on the far end of the lever. The subject was then encouraged to retrieve the toy with the experimenter drawing attention to the lever end closest to the child by gently tapping it up and down.

Five trials were carried out with no fixed time period on any trial. In those instances when the lever had to be moved, e.g. returned to starting point, then every attempt was made to do so without the child attending.

Upon successful completion of a trial, the subject was allowed to play with the toy and if the child was not able to retrieve the toy, the experimenter would do so and allow the child to play with the lure before commencing the next trial.

Failed trials ended when the subject stopped trying to retrieve the goal, e.g. by moving away from the table. The experimenter encouraged the subject to continue by tapping on the lever, pointing at the goal and using verbal encouragement. If this failed to bring the child back to the lever the goal was retrieved by the experimenter.

In all cases at least one attempt was made to encourage the child to return to the task and inspection of video tapes at the end of each day's testing ensured that similar encouragement was given to all subjects.

Parents were instructed not to intervene during the testing of their child. This instruction applied to all experimental tasks.

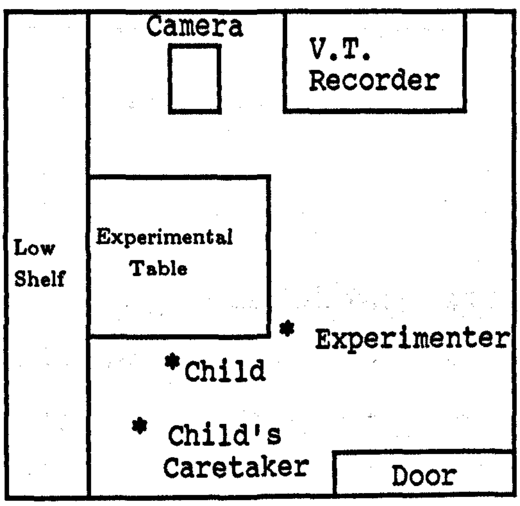


Figure 3a - experimental room layout. During the spatial task the table was moved into the centre of the room and the camera angle was suitably adjusted.

(ii) ANALYSIS OF DATA

Lever Task: The initial analysis used Koslowski and Bruner's (1972) classification of strategies. This required the assignment of subject's lever behaviour to one of five categories. The five categories are listed below.

Strategy 1: Linear Action. This behaviour relies upon direct approach. A variety of behaviours are encompassed in this strategy; direct pulling on lever, direct reaching, lifting lever, moving around to collect object. Also includes some less-common behaviours, e.g. pulling on table, sliding hand along lever.

Strategy 2: Oscillation. The subject moves the lever back and forward across their midline, with the additional limitation that the lever is not moved more than 45 degrees from midline.

Strategy 3: Partial Rotation, comprising of two features. Firstly, the lever is moved more than 45 degrees but less than 90 degrees and then stopped. Secondly, the child does not turn away immediately but rather looks at the results of their efforts.

Strategy 4: Operational Preoccupation. Child is capable of rotating lever but even though these rotations bring goal within reach, it is not retrieved.

Strategy 5: Rotate and Capture. As implied in the name, the child rotates lever and retrieves the toy.

Once the video tape had been analysed in this manner for each trial, a subject profile could be drawn displaying strategies used over all trials (See Appendix 1 for an example). It was then possible to assess subject's ability by:

(a) noting highest strategy achieved on each trial

(b) noting highest strategy achieved over all trials.

The direction of gaze during lever task was also analysed by means of video tape and a simple data-logging programme running on an Apple 11e. The Apple programme allowed a key identifier to indicate a specific gaze. For example, key A would be pressed when the subject was looking at his/her hand on the lever. If gaze was moved to the object, key S was pressed, cancelling the previous key press.

Pressing the first key activated a clock which recorded the duration of the behaviour and the programme also produced a breakdown of gaze direction during a trial in terms of frequency of occurrence, duration of occurrence, total time of any gaze during trial, and the total percentage of trial time spent on any specific gaze. An example of this data print-out is provided in Appendix 2.

Categories used for the analysis of gaze direction were:

Key Label	Gaze signified
A	hand
S	object
D	moving between hand and object
F	looking away
G	at experimenter
H	at mother
J	at lever or lever centre
K	at cross strut (applicable to Group 2)
L	at lever cover (applicable to Group 3)
Y	break, not touching lever.

The above categories were used when the subject was in contact with the lever. In addition to this, a code was used at the end of the trial to signify its outcome:

Key Label	Code
Z	successful use of lever
X	moves around table to collect
C	moves over table to collect
V	lever moved and also moves around to collect.
B	retrieved by experimenter.

The programme, as well as providing a record of gaze direction, also provided solution times for those successful subjects.

Bent-Wire Task: Video taped material was analysed in several ways. Initially, the wire tasks were categorised by following Davis (1974). That is, each of the six trials were classified as

(1) successful - object removed from wire within time period
(2) failed try - attempt to remove object failed, time expired
(3) failed - no attempt to remove object.

If the trial was classified as successful, solution time was noted.

In addition, a behavioural analysis was carried out of subject's response. The Apple 11e programme outlined earlier was used, with the following categories logged.

<u>Key Label</u>	<u>Behaviour</u>
Q	spinning/hitting the object
W	direct pulling on the object
E	pulling the wire/stand
R	to and fro movement of object
T	moved once only and left
Y	manipulating lure around corners
U	moved to end and back again
I	intentional co-ordinated removal of lure
O	accidental removal of lure
P	break, no action on apparatus.

Category P was used when subjects were displaying none of the other behaviours and categories I and O were subjective decisions made by the experimenter in assessing the type of solution achieved.

O, or accidental removal, was defined as removal of the lure which resulted from spinning/hitting, from pulling the wire itself or from removal of the lure when the subject was not attending to it.

I, or intentional solutions, were characterised by the subject attending to the goal object and manoeuvering the lure to the end of the wire and removing it.

Spatial Task: The task was based upon the Wishart and Bower (1982) three-cup spatial task and over the five trials, performance was classified as:

(1) correct where the subject retrieved the goal by lifting the correct cup at the first attempt

(2) error - errors were sub-divided into three:

 (a) ego error, egocentric choice of cup

 (b) other error, where the third cup was chosen

 (c) failed, where the subject moved towards a cup but failed to lift it.

CHAPTER 3

LEVER TASK - RESULTS AND DISCUSSION

(i) RESULTS

The classification of behaviour displayed on this task was based upon Koslowski and Bruner's (1972) five strategies. The behaviour related to each strategy has been outlined in the Methods Section and the five strategies are listed below.

Strategy I	linear action
Strategy II	oscillation
Strategy III	partial rotation
Strategy IV	operational preoccupation
Strategy V	rotate and capture.

The results focused upon three main areas:

(a) The strategies used on the lever task

(b) Successful trials

(c) Gaze direction during lever manipulation.

(a) The Strategies Used

The main concern was with the type of strategies employed by subjects and the number of successes recorded by them. The noted number of successes achieved by each subject was analysed by analysis of variance with age, experimental group and sex as between subject factors and trials as a within subject factor.

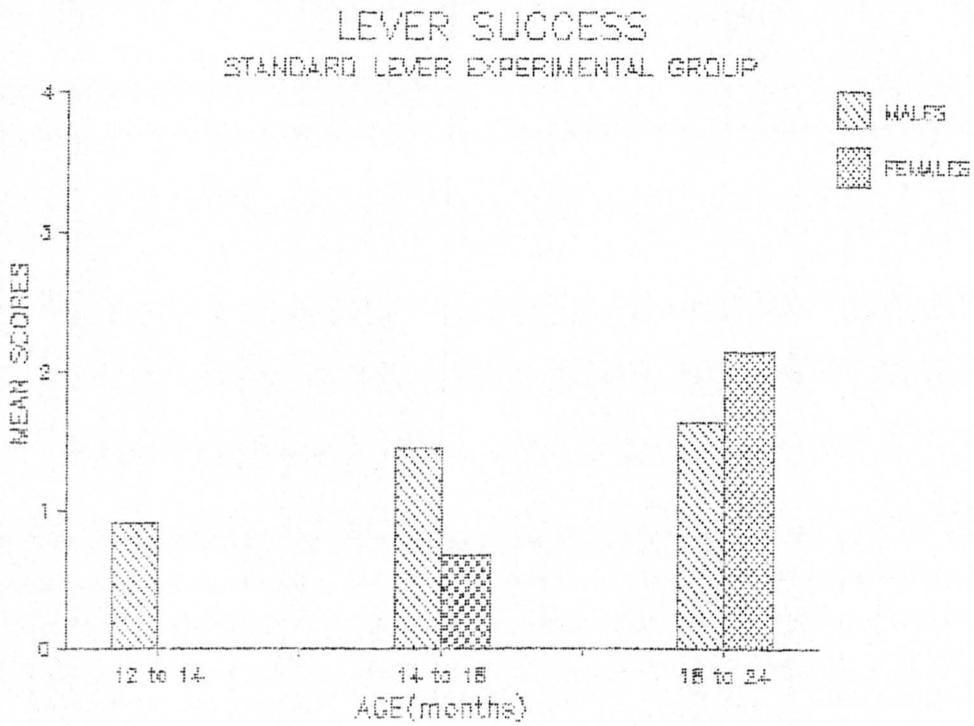
The analysis produced a significant age difference (df, 2, 117; $F = 15.40$; $p < 0.0001$) a significant experimental group effect (df, 2,117; F = 7.72; $p < 0.001$) and sex differences (df, 1, 117; F = 6.00; $p < 0.02$).

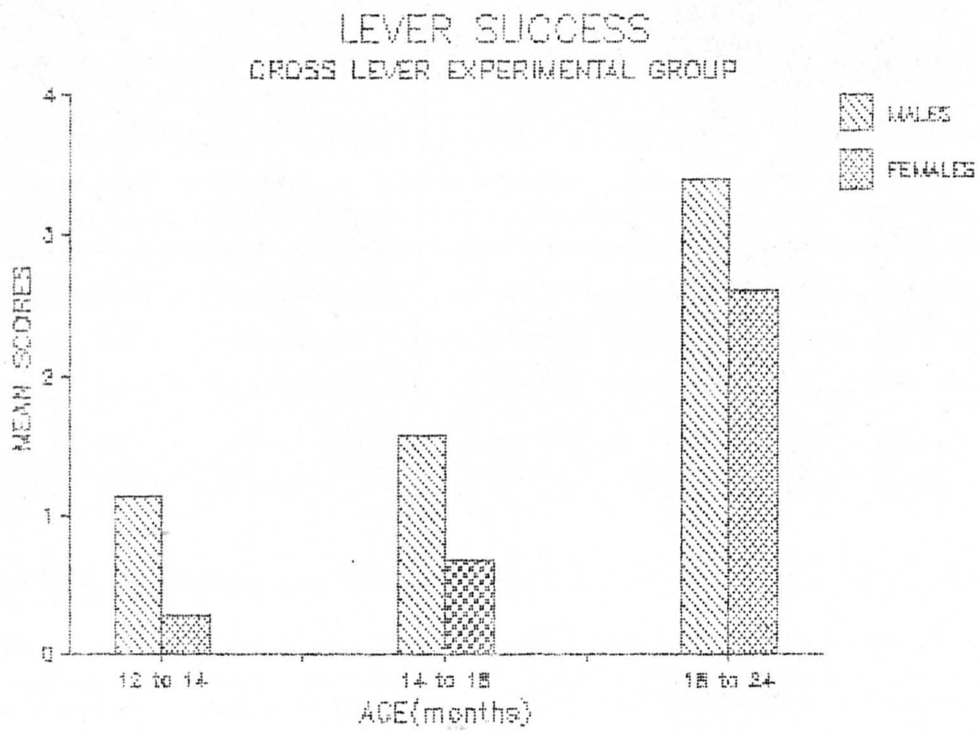
The significant age effect is the result of the superior performance of the older children on this task. The difference in performance between 12-14 and 14-18 month subjects, while indicating the superiority of the older subjects, did not produce a significant difference [t(88) = 1.51; $p > 0.1$, two tailed]. The comparison of the 12-14 month and 18-24 month subjects produced a significant effect [t(88) = 4.98, $p < 0.0001$, two tailed) as did the comparison of 14-18 month and 18-24 month subjects [t(88) = 3.53; $p < 0.001$, two tailed]. These results indicate that the main age effect arises from the contrast of the two youngest age groups with the 18-24 month sample.

The overall age pattern was found within each experimental group (Figure 3a) and of particular note is the failure of the 12-14 and 14-18 month covered lever subjects to achieve any successes: only one other group is in this position, the 12-14 month standard lever females.

Comparisons of age performance within experimental groups indicated that 12-14 month and 14-18 month standard lever subjects' performance was not significantly different [t(28) = 1.98; $p > 0.2$, two tailed] and the 14-18 month and 18-24 month performance also failed to achieve significant levels [t(28) = 1.28; $p > 0.2$, two tailed]. The only significant age comparison in the standard lever group was between the

Figure 3a overleaf


LEVER SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
0
1
2
3
4
12 to 14
14 to 18
18 to 24
AGE(months)


LEVER SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
0
1
2
3
4
12 to 14
14 to 18
18 to 24
AGE(months)

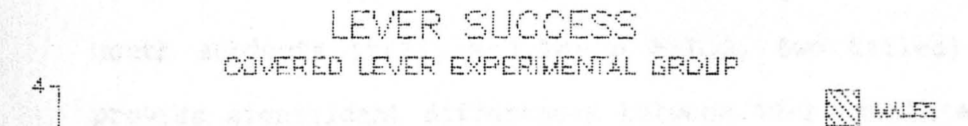


Figure 3a - Lever task success pattern
(mean scores)

12-14 and 18-24 month subjects [$t(28) = 2.27$; $p < 0.05$, two tailed].

Comparison of performance within the cross lever group failed to produce a significant age effect between 12-14 and 14-18 month subjects [$t(28) = 1.18$; $p > 0.2$, two tailed] but did provide significant differences between 12-14 month and 18-24 month subjects [$t(28) = 4.02$; $p < 0.001$, two tailed) and between 14-18 month and 18-24 month subjects [$t(28) = 2.63$; $p < 0.02$, two tailed].

The significant experimental group effect reflects the superior performance of the cross lever group subjects. The cross lever group was shown, by t-test, to be superior to the covered lever group [$t(88) = 3.84$; $p < 0.001$, two tailed] but not the standard lever group [$t(88) = 1.51$; $p > 0.1$, two tailed] and the standard lever group was significantly better than the covered lever group's performance [$t(88) = 2.55$; $p < 0.02$, two tailed]. The major variation in peformance between experimental groups arises from the poor performance of the covered lever group subjects, in particular the 12-14 and 14-18 month subjects' failure to achieve success on this particular lever.

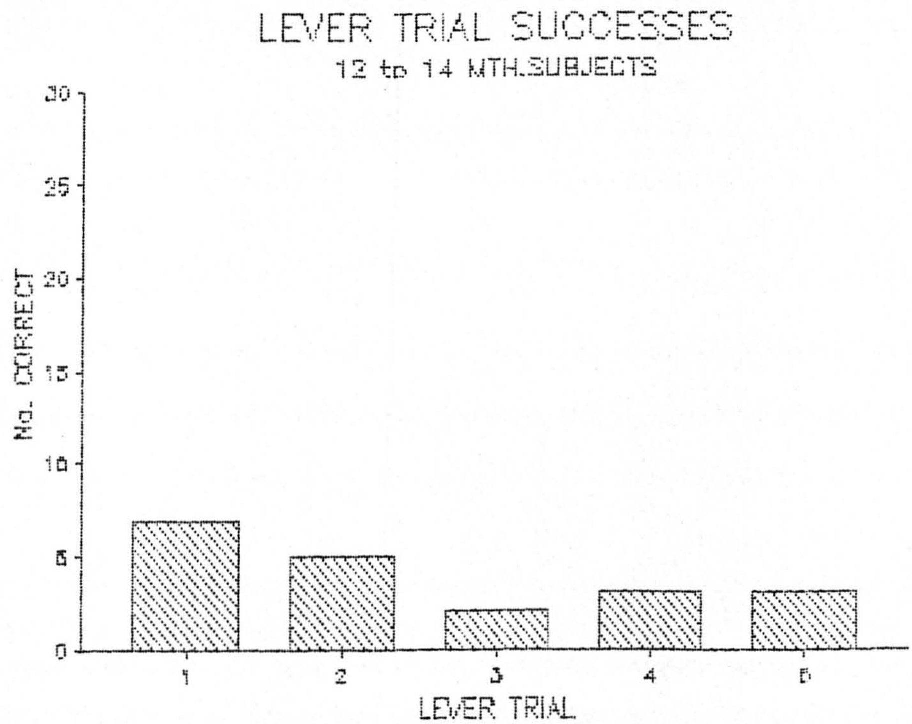
The significant sex effect emphasises the higher number of successes recorded by male ($\bar{x} = 1.43$) compared to female ($\bar{x} = 0.68$) subjects. Figure 3a draws attention to this pattern and to the sole exception, namely the female subjects in the standard lever 18-24 month group. The latter group's performance was not significantly higher than their male counterparts [$t(13) = 0.57$; $p > 0.5$, two tailed]. The only significant male-female difference to emerge within the experimental groups was found in the 18-24 month subjects in the covered lever group where male performance was significantly higher than female subjects [$t(13) = 2.17$; $p < 0.05$, two tailed].

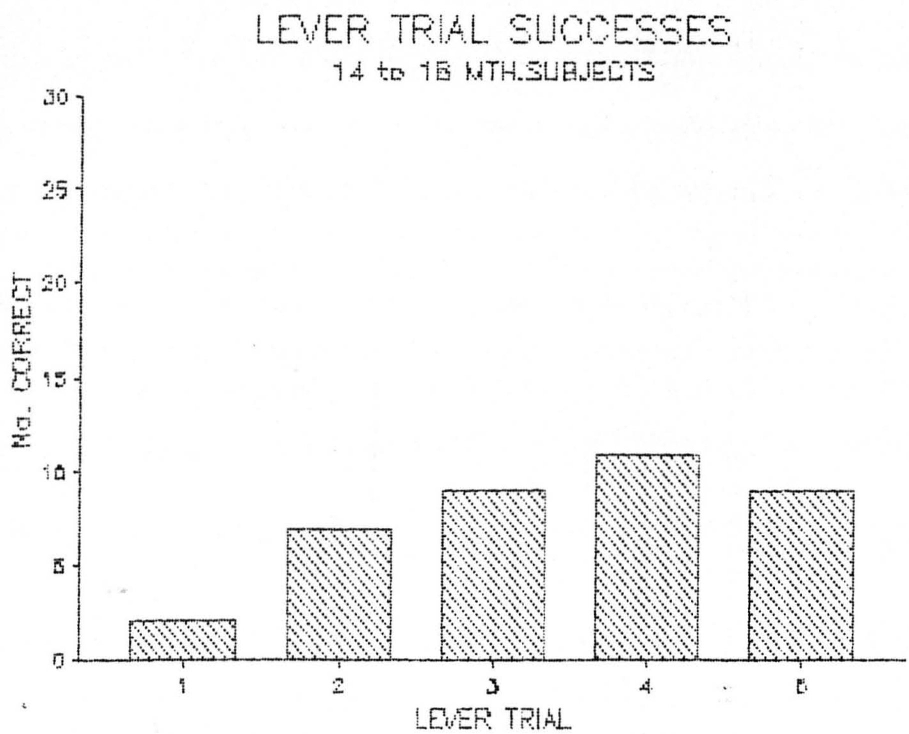
The ANOVA of lever successes also produced a significant trial x age interaction (df, 8, 468; $F = 5.44$; $p < 0.0001$) suggesting that performance varied over the five trials for each age group. Table 3a provides a summary of lever successes on each trial and Figure 3b shows the number of successes per trial for each age group.

<u>Table 3a - Number of Lever Successes on Each Trial</u>

Total Number of Lever Successes					
Trial	Age (mths)	Standard	Cross	Covered	Total
	12 - 14	3	4	0	
Tr 1	14 - 18	1	1	0	20
	18 - 24	2	6	3	
	12 - 14	1	4	0	
Tr 2	14 - 18	2	5	0	25
	18 - 24	3	7	3	
	12 - 14	1	1	0	
Tr 3	14 - 18	4	5	0	34
	18 - 24	7	11	5	
	12 - 14	2	1	0	
Tr 4	14 - 18	6	5	0	36
	18 - 24	7	12	3	
	12 - 14	2	1	0	
Tr 5	14 - 18	4	5	0	38
	18 - 24	9	11	6	

Figure 3b overleaf


LEVER TRIAL SUCCESSES
12 to 14 MTH.SUBJECTS
No. CORRECT
0
5
10
15
20
25
30
1
2
3
4
5
LEVER TRIAL


LEVER TRIAL SUCCESSES
14 to 16 MTH.SUBJECTS
No. CORRECT
0
5
10
15
20
25
30
1
2
3
4
5
LEVER TRIAL

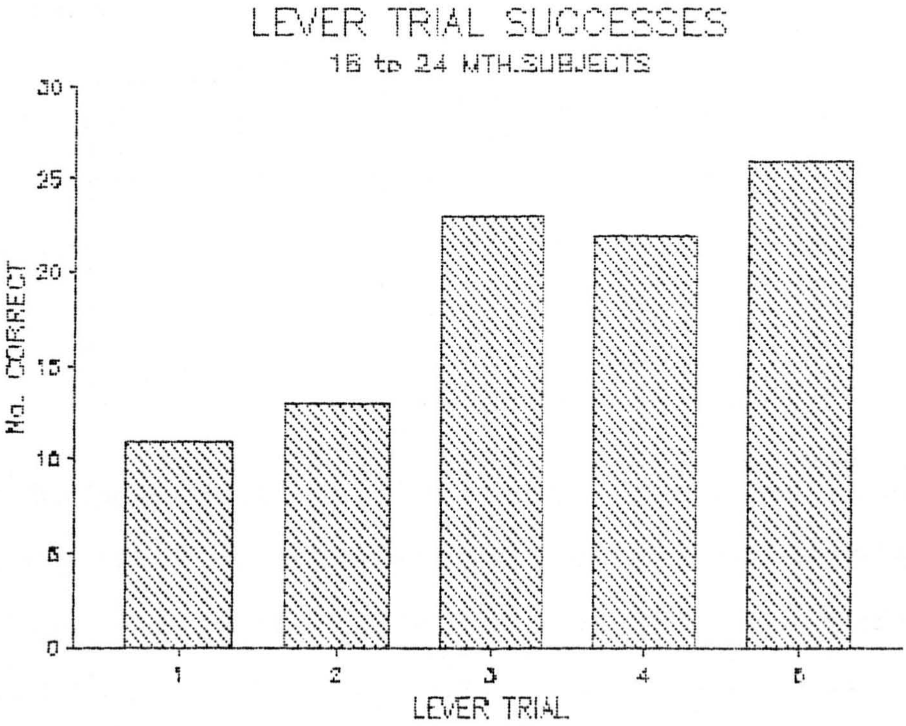


Figure 3b - Number of successes on each lever trial for the three age groups

An ANOVA of success on trial 1, with age, experimental group and sex as factors, produced a significant age effect (df, 2, 117; $F = 3.24$; $p < 0.05$). Table 3b shows the means for that variable and the higher level of success of the 18-24 month group. However, the pattern of results for the 12-14 and 14-18 month subjects is reversed with the younger subjects producing the higher mean score.

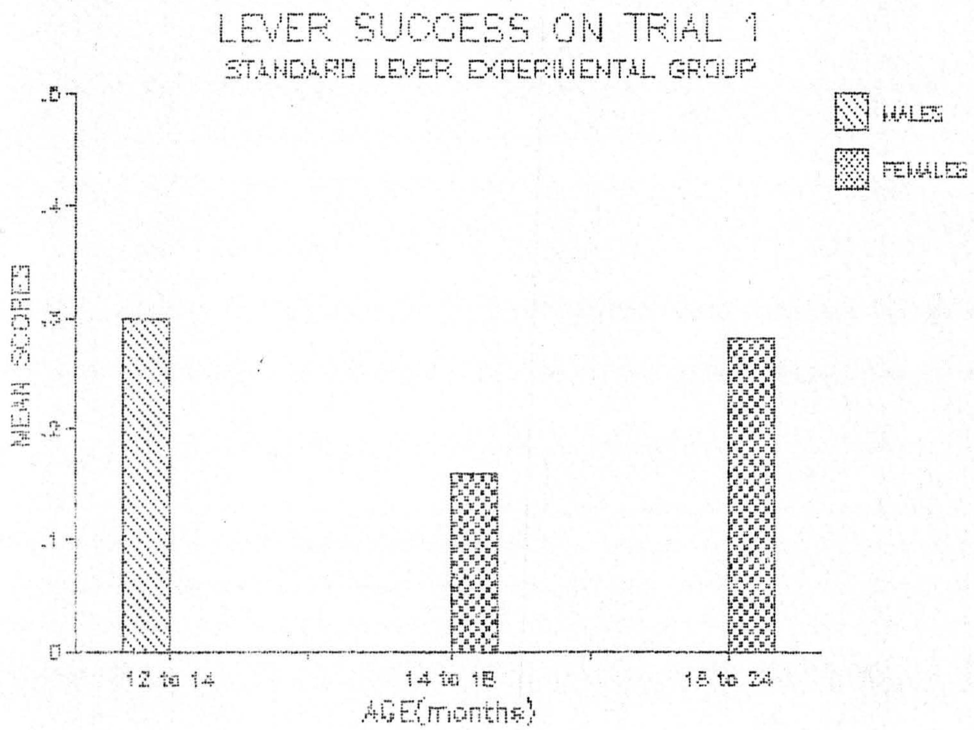
Table 3b - Lever Success on Trial 1 within Age Groups

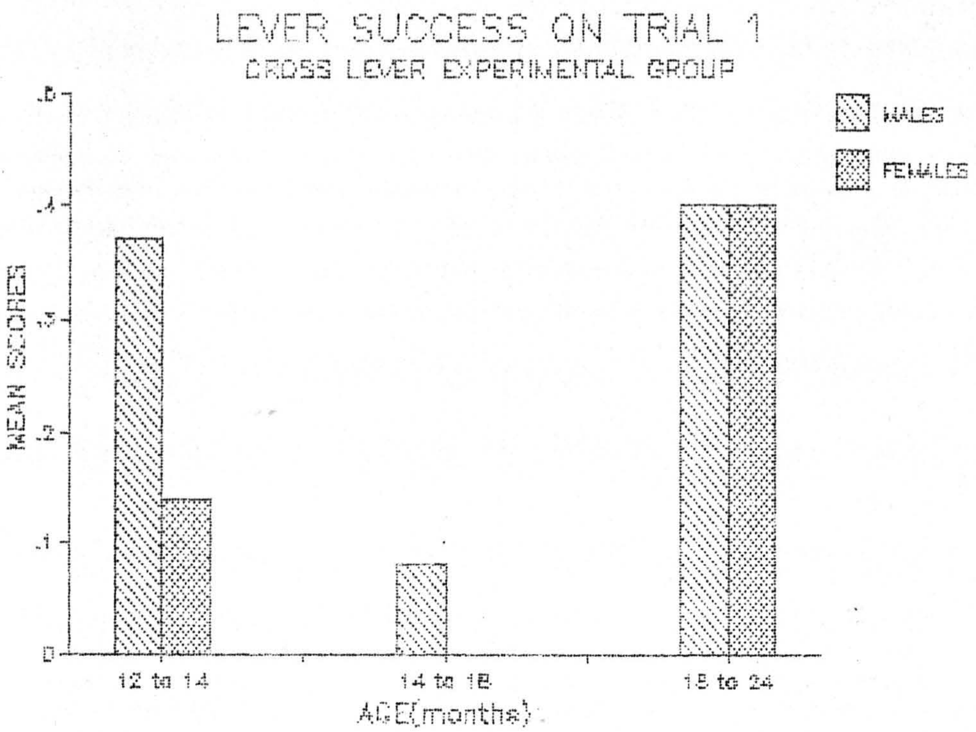
Age (months)	Mean Number of Lever Successes on Trial 1
12 - 14	0.15
14 - 18	0.04
18 - 24	0.24

The performance of the 12-14 month subjects was shown by t-test, not to be significantly higher than the 14-18 month subjects [$t(88) = 1.77$; $p > 0.05$, two tailed]. Figure 3c illustrates the superior performance of the 12-14 month subjects compared to the 14-18 month age group within the standard and cross lever groups, with the exception of the 12-14 month females in the standard lever group. Analysis, by t-test, of this variation within experimental groups failed to produce any significant results.

The analysis of success on trial 2 by means of ANOVA with age, experimental group and sex as factors, failed to produce any significant age differences although a significant

Figure 3c overleaf


LEVER SUCCESS ON TRIAL 1
STANDARD LEVER EXPERIMENTAL GROUP
MEAN SCORES
.5
.4
.3
.2
.1
0
12 to 14
14 to 18
18 to 24
AGE(months)
MALES
FEMALES


LEVER SUCCESS ON TRIAL 1
CROSS LEVER EXPERIMENTAL GROUP
MEAN SCORES
.5
.4
.3
.2
.1
0
12 to 14
14 to 18
18 to 24
AGE(months)
MALES
FEMALES

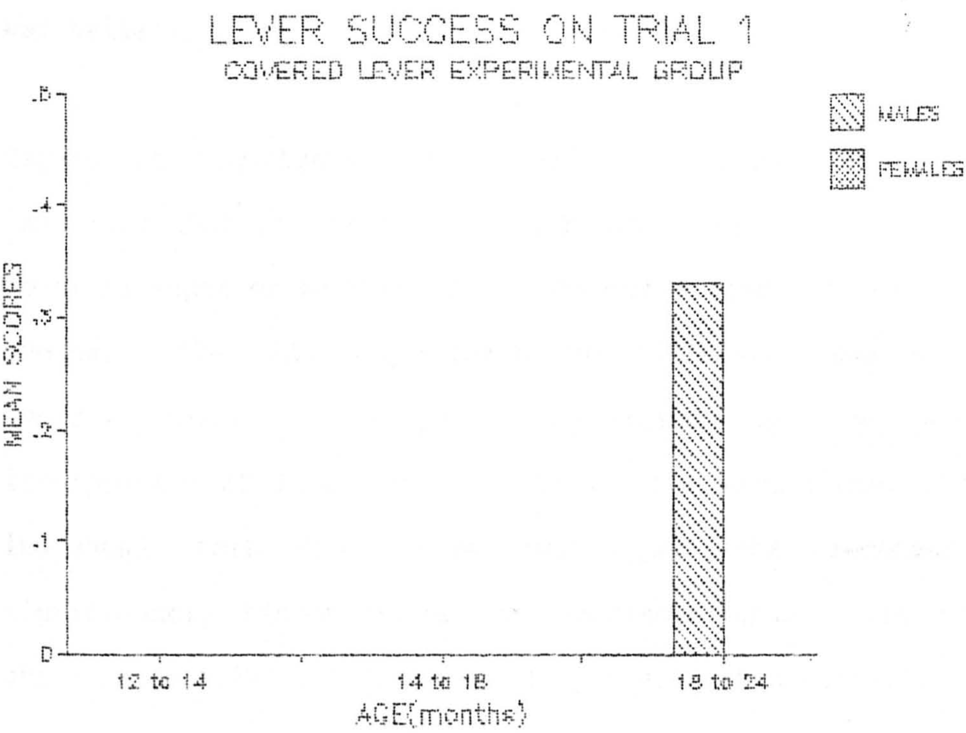
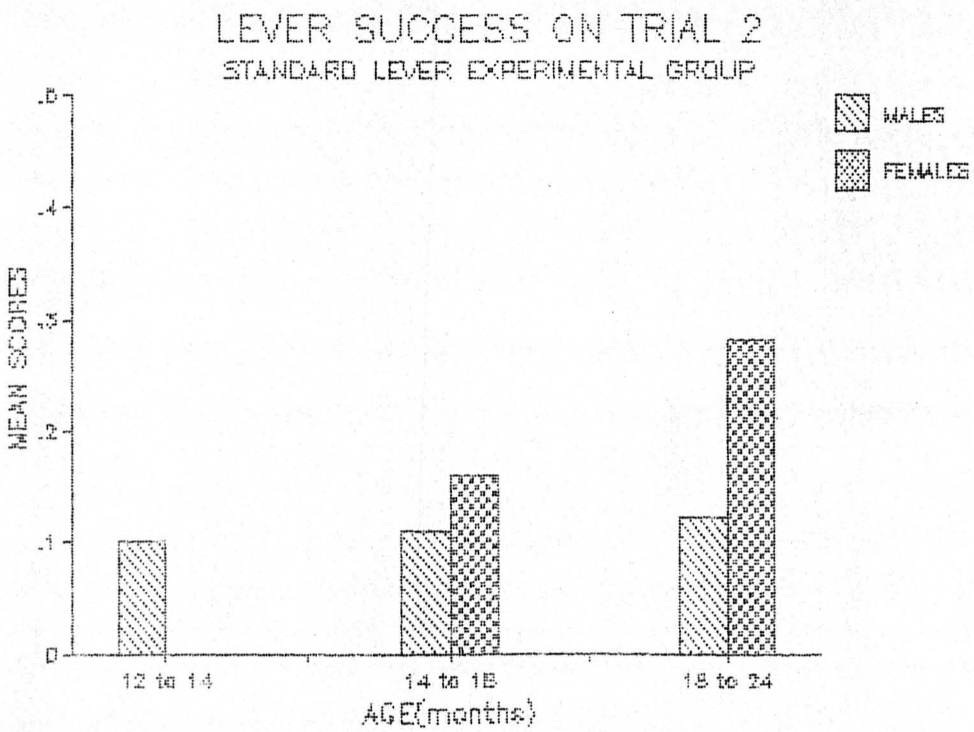


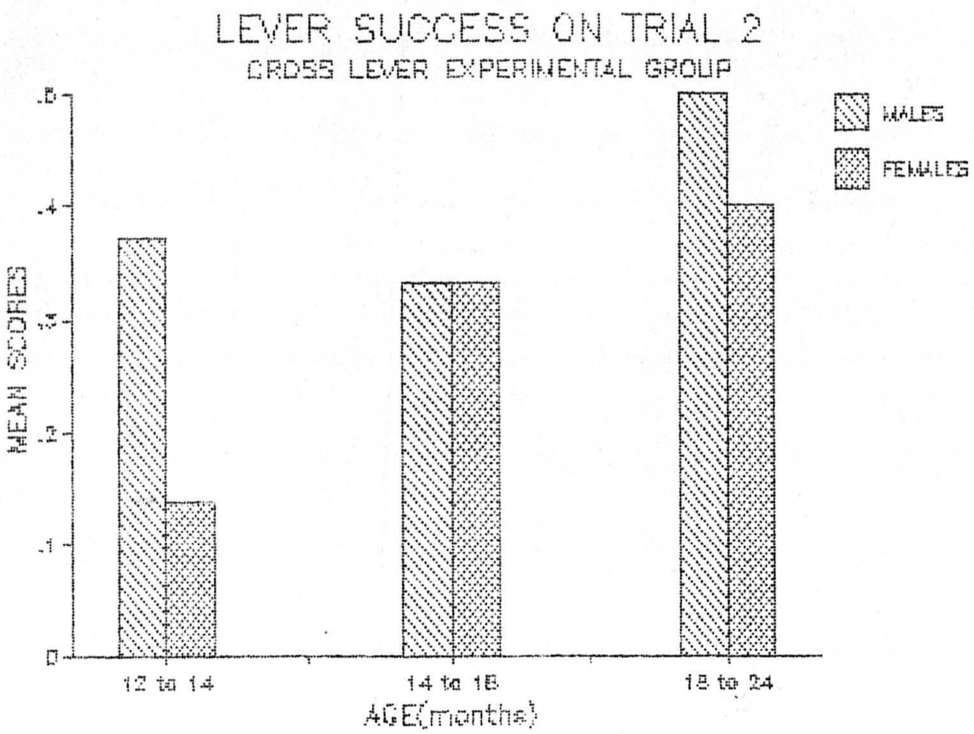
Figure 3c - Lever success on Trial 1 (mean scores) experimental group effect was found (df, 2, 117; $F = 6.24$; $p < 0.01$). The cross lever group performance was shown, by t-test, to be significantly higher than the standard lever group [$t(88) = 2.51$; $p < 0.02$, two tailed] and the covered lever group [$t(88) = 3.55$; $p < 0.001$, two tailed] while the standard lever group's performance was not significantly higher than the covered lever group [$t(88) = 1.05$; $p > 0.2$, two tailed].

Figure 3d highlights this experimental group pattern and indicates that the 18-24 month subjects' performance on this trial is superior to that of the younger subjects in all lever groups. The only significant age difference was at the general level of subjects classified by age alone, irrespective of lever group or sex. The significant result indicated that the 18-24 month subjects recorded a significantly higher number of successes than 12-14 month children on trial 2 [$t(88) = 2.14$; $p < 0.05$, two tailed].

On trial 3, older subject groups' performance was significantly higher than younger subjects (df, 2, 117; $F = 16.09$; $p < 0.0001$) and this was replicated on trial 4 (df, 2, 117; $F = 12.38$; $p < 0.0001$) and trial 5 (df, 2, 117; $F = 20.90$; $p < 0.0001$). Table 3c provides the mean success figures for each age group.

Figure 3d overleaf


LEVER SUCCESS ON TRIAL 2
STANDARD LEVER EXPERIMENTAL GROUP
MEAN SCORES
AGE(months)
12 to 14
14 to 18
18 to 24
MALES
FEMALES
0
.1
.2
.3
.4
.5


LEVER SUCCESS ON TRIAL 2
CROSS LEVER EXPERIMENTAL GROUP
MEAN SCORES
AGE(months)
12 to 14
14 to 18
18 to 24
MALES
FEMALES
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.2
.3
.4
.5

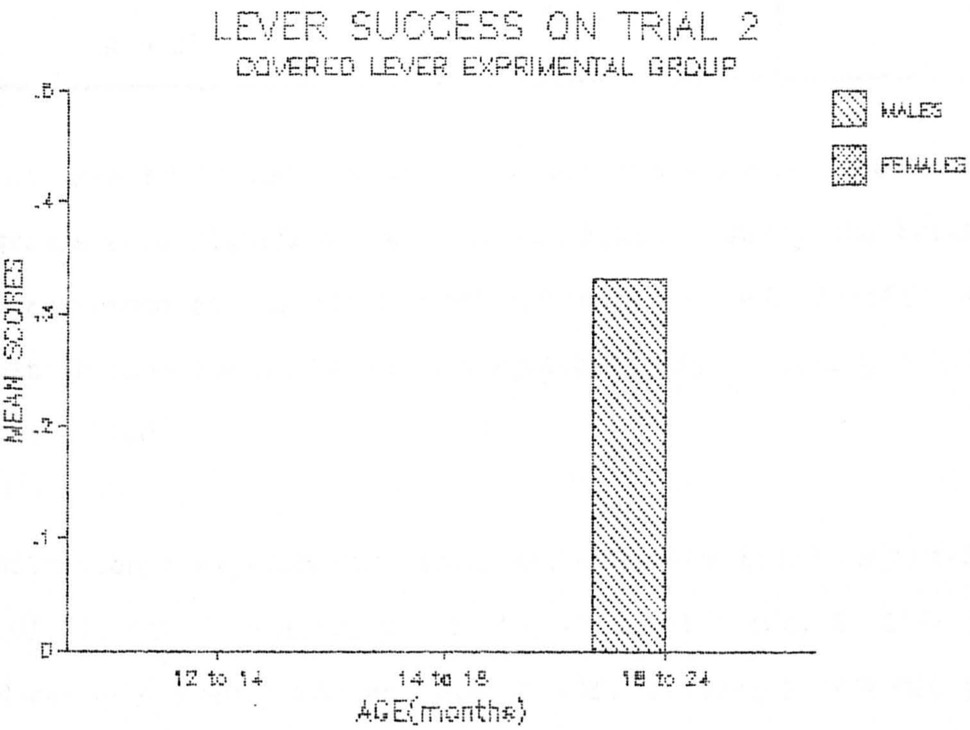


Figure 3d - Lever success on Trial 2 (mean scores)

Table 3c - Lever Success on Trials 3,4 and 5 for each age group

Age (months)	Mean number of successes on lever		
	Trial 3	Trial 4	Trial 5
12 - 14	0.04	0.06	0.06
14 - 18	0.20	0.24	0.20
18 - 24	0.51	0.48	0.58

Analysis by t-test, showed that all comparisons between age groups were significant with one exception, namely the trial 5 performance of the 14-18 month subjects was not significantly better than the 12-14 month subjects [$t(88) = 1.88$; $p > 0.06$, two tailed].

Significant experimental group effects were found on trial 3 (df, 2, 117; $F = 4.12$; $p < 0.05$), on trial 4 (df, 2, 117; $F = 8.44$; $p < 0.001$) and on trial 5 (df, 2, 117; $F = 3.72$; $p < 0.05$). In all of these trials the main experimental group effect is due to the significantly lower performance of the covered lever group in comparison to either the standard or cross groups. Comparisons of the standard and cross lever groups' performance produced no significant differences.

Table 3d - Lever Successes on Trials 3, 4 and 5 for each Experimental Group

Experimental Group	Mean number of successes on lever		
	Trial 3	Trial 4	Trial 5
Standard	0.27	0.32	0.33
Cross	0.38	0.40	0.38
Lever	0.11	0.07	0.13

The final variable, sex, was also found to significantly influence performance on trial 3 (df, 1, 117; $F = 7.22$; $p < 0.01$), trial 4 (df, 1, 117; $F = 5.30$; $p < 0.05$) and on trial 5 (df, 1, 117; $F = 6.33$; $p < 0.05$). In all cases, the performance of male subjects was better than female subjects.

The analysis of success on each trial indicates that the trial x age interaction is the result of the improving performance of the 14-18 and 18-24 month subjects over the five trials, while the 12-14 month subjects' performance is declining.

The analysis of performance on the lever tasks is not only concerned with the level of success achieved but also with the use of the other strategies outlined earlier. Following Koslowski and Bruner, (1972) subjects were classified according to the use of 'low' strategies (i.e. strategies I and II) and 'high' strategies (i.e. strategies III, IV and V) with the implication that a qualitative difference exists between these two categories.

The analysis looked at the number of high and low strategies displayed by subjects over the five lever trials. The ANOVA of high strategy usage showed a significant age effect with older subjects producing a larger number of these strategies (df, 2, 117; $F = 17.51$; $p < 0.0001$) and the cross lever group subjects showed a significantly larger number of these strategies (df, 2, 117; $F = 8.31$; $p < 0.001$). A significant sex effect was also found (df, 1, 117; $F = 10.23$; $p < 0.01$) showing that male subjects recorded a higher number of these strategies.

The analysis of low strategy performance produced the opposite pattern to that found above. A significant age effect was found but in this case the younger subjects produced the significantly higher number of these strategies (df, 2, 117; $F = 13.81$; $p < 0.0001$) while the experimental group differences showed a significantly higher number of low strategies for the covered lever group, with the cross lever group producing the lowest number of this category (df, 2, 117; $F = 8.16$; $p < 0.001$). The significant sex effect indicated that females recorded a significantly higher number of low strategy trials (df, 1, 117; $F = 8.05$; $p < 0.01$).

The procedure of combining strategies into categories may be obscuring the pattern of use of any one strategy, especially since the analysis of success on the lever produced significant age, experimental group and sex effects and this may be influencing the present results. Therefore each strategy was analysed separately by an ANOVA with the five trials as a within subject factor.

Strategy I

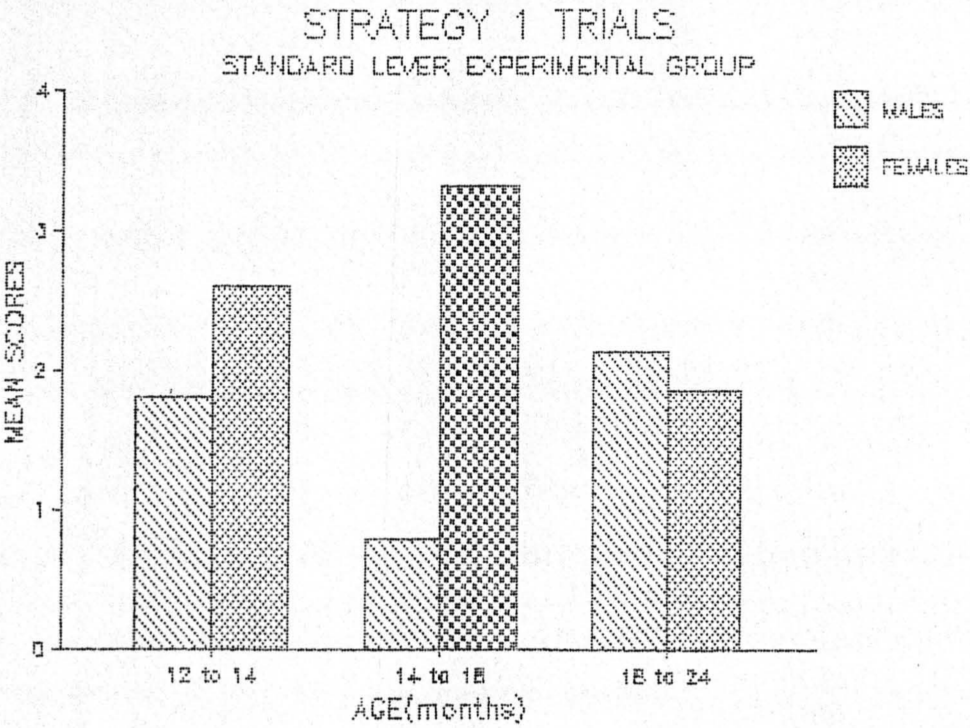
The analysis of trials where strategy I was the highest strategy recorded, was carried out by means of ANOVA with age, experimental group and sex as between subject factors.

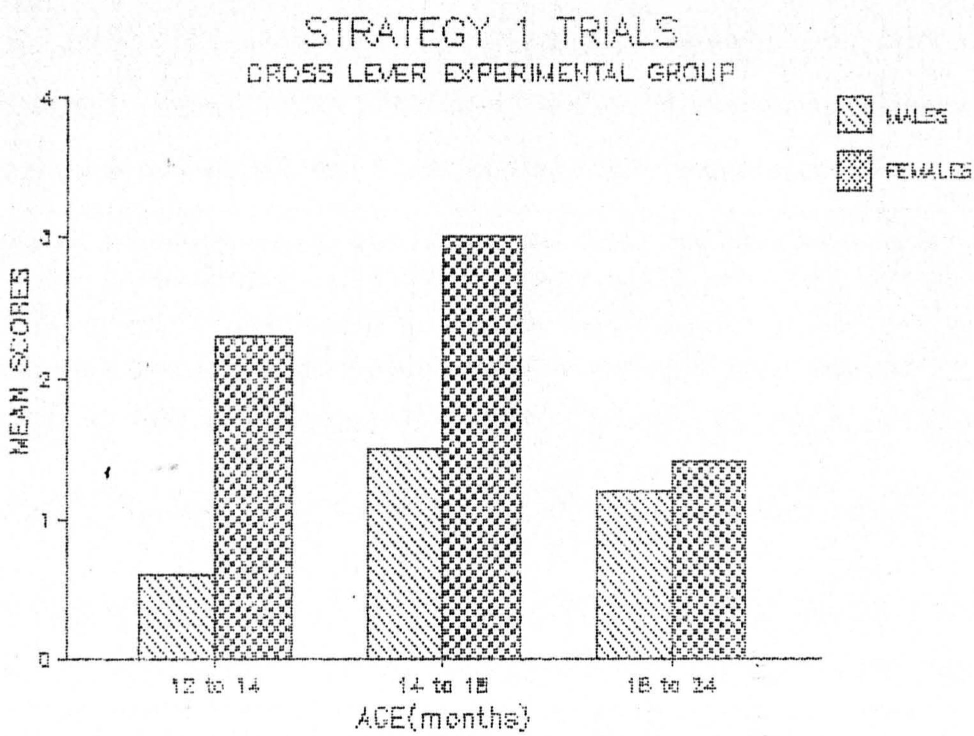
The analysis showed a significantly higher number of strategy I trials were found in the younger subject groups (df, 2, 117; $F = 3.26$; $p < 0.05$) and that females produced a significantly higher number of these trials compared to males (df, 1, 117; $F = 5.19$; $p < 0.03$).

In addition, the analysis produced a significant age x experimental group x sex interaction (df, 4, 117; $F = 2.76$; $p < 0.05$). Figure 3e illustrates the source of this interaction. However detailed analysis (t-test) within each experimental group produced no results which contradicted the age and sex pattern outlined above. In addition, comparison of age group across experimental groups failed to produce any significant results indicating that no significant variation in the use of this strategy was attributable to the various lever groups.

No significant trial effects emerged from the analysis.

Figure 3e overleaf


STRATEGY 1 TRIALS
STANDARD LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
0
1
2
3
4
12 to 14
14 to 18
18 to 24
AGE(months)


STRATEGY 1 TRIALS
CROSS LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
0
1
2
3
4
12 to 14
14 to 18
18 to 24
AGE(months)

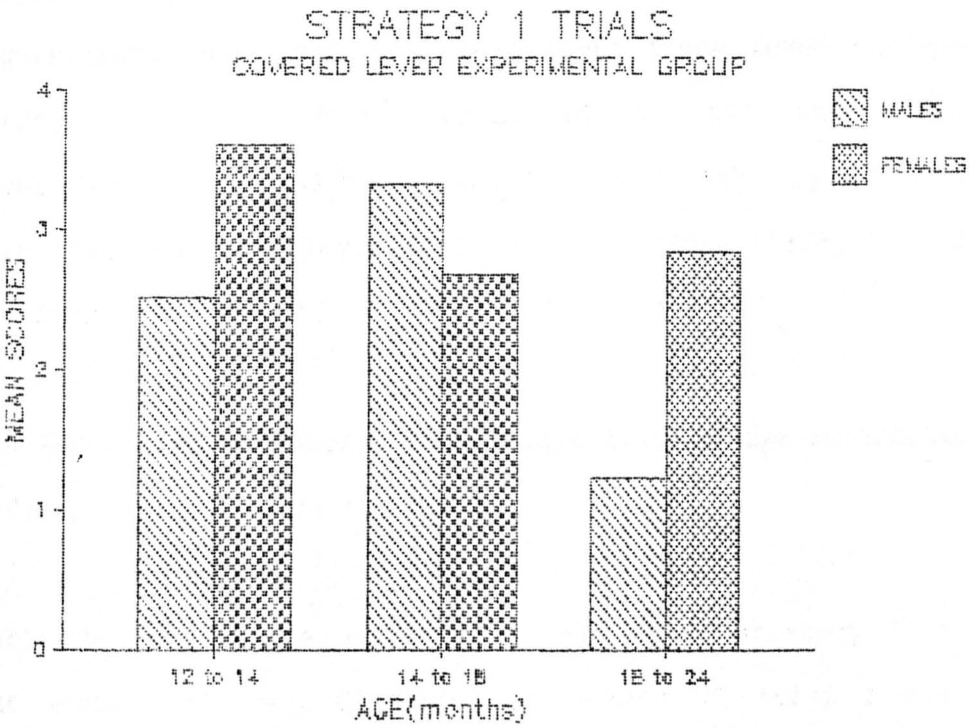


Figure 3e - Lever trials with strategy I as the highest recorded strategy

Strategy II

The ANOVA, with age, experimental group and sex, as between subject factors produced a significant age effect indicating that younger subjects used this strategy more often than older ones (df, 2, 117; $F = 4.89$; $p < 0.01$). In addition, comparison across experimental groups showed that 18-24 month subjects in the standard lever group used this strategy significantly more than the 18-24 month cross lever subjects [$t(28) = 2.21$, $p < 0.05$; two tailed] and that the covered lever 18-24 month subjects used this strategy significantly more than the cross lever 18-24 month subjects [$t(28) = 2.73$; $p < 0.02$, two tailed].

The ANOVA also produced a significant trial x age interaction (df, 8, 468; $F = 3.11$; $p < 0.002$).

Table 3e details the number of trials where strategy II was the highest strategy displayed and ANOVAs of trial 1 and 2 failed to produce any significant results. Analysis of the remaining three trials produced significant age effects, indicating that the 18-24 month subjects had fewer trials where strategy II was the highest strategy used;

trial 3 significant age effect (df,2,117; $F = 6.48$; $p < 0.01$)
trial 4 significant age effect (df,2,117; $F = 5.71$; $p < 0.01$)
trial 5 significant age effect (df,2,117; $F = 4.34$; $p < 0.02$)

Trial 2 failed to produce a significant age effect but did show that on this trial, significant experimental group differences existed (df, 2, 117; $F = 6.22$; $p < 0.01$) and this indicates the highest number of strategy II trials recorded within covered lever groups. Comparison of the standard and covered lever groups on this trial did not produce a significant difference [$t(88) = 1.84$; $p > 0.06$, two tailed].

<u>Table 3e - Trials where Strategy II was the Highest Strategy Displayed</u>

Trial	Age (mths)	Standard	Cross	Covered
Tr 1	12 - 14 14 - 18 18 - 24	3 7 3	1 4 2	4 3 5
Tr 2	12 - 14 14 - 18 18 - 24	4 3 3	3 1 0	6 8 4
Tr 3	12 - 14 14 - 18 18 - 24	5 3 1	6 3 0	5 6 3
Tr 4	12 - 14 14 - 18 18 - 24	7 2 2	5 4 0	6 2 5
Tr 5	12 - 14 14 - 18 18 - 24	6 3 0	4 6 0	4 5 4

<u>Strategy III</u>

The ANOVA for this strategy, with age, experimental group and sex as factors, produced no significant results. Closer inspection of this data revealed a significant difference between 12-14 and 14-18 month subjects [$t(88) = 2.09$; $p < 0.05$, two tailed] with the oldest age group recording a higher number of trials with strategy III as the highest strategy attained. This age group effect was examined within each experimental group with only the standard lever group producing a significant result with the 14-18 month subjects producing a higher number of strategy III trials compared with the 12-14 month subjects [$t(28) = 2.30$; $p < 0.05$, two tailed].

Strategy IV

The ANOVA with age, experimental group and sex as factors produced a significant age effect with 18-24 month subjects recording a significantly higher number of these trials (df, 2, 117; $F = 4.08$; $p < 0.02$). This effect was attributable to the performance of the 18-24 month group since no significant difference on strategy IV trials was found between the 12-14 and 14-18 month subjects.

In addition, a significant sex effect showed that males recorded a higher number of strategy IV trials (df, 1, 117; $F = 6.27$; $p < 0.02$). This result is attributable to the failure of any female subject to record strategy IV as the highest strategy on a trial. This cannot be interpreted as indicating the failure of females to display this strategy. From the individual strategy patterns for each trial, females were found to display this behaviour. However, they ultimately removed the lure from the end of the lever resulting in strategy V as the highest recorded strategy on that trial. The result indicates that it was male subjects who failed to remove the lure from the lever when it was in reach.

Comparison across experimental groups failed to produce any significant results indicating that the type of lever did not influence the number of trials where strategy IV was the highest recorded strategy.

No significant trial effects were found with this analysis.

The analysis of trials culminating in strategy I, II, III or IV emphasises the importance of age as an influential variable on performance. In contrast, experimental group effects were relatively low, strategy II trials providing the exception, and this issue will be returned to in the Discussion.

(b) <u>Successful Trials</u>

The initial analysis focused upon the total number of successes achieved but paid no attention to whether or not subjects attained one or more successes from their five trials. During analysis of the video-tapes, it was noted that successes resulted in surprise reactions from subjects and given Uzgiris and Hunt's (1975) argument regarding the repetition of solutions, the results were analysed to consider this issue.

An ANOVA, with age, experimental group and sex as between subject factors, was carried out on subjects achieving two or more successful trials. A second analysis, using a stricter criteria of three or more successful trials, was also carried out.

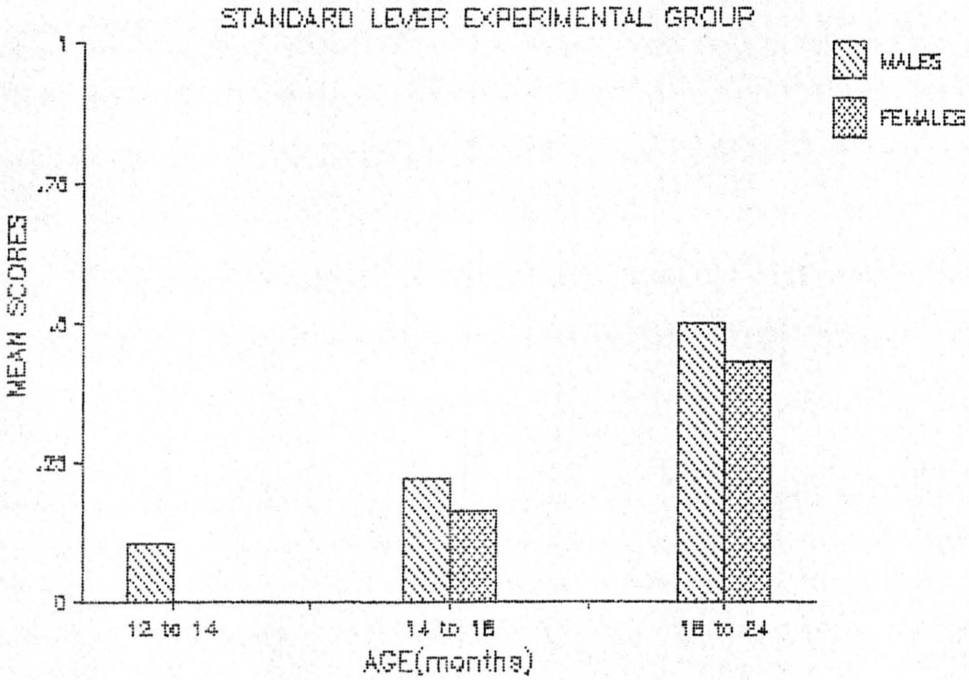
The ANOVA with the imposed criteria of two or more successes showed that the 18-24 month subjects' performance was significantly higher than the 12-14 or 14-18 month groups (df, 2, 117; $F = 16.45$; $p < 0.0001$). This analysis also indicated that subjects in the cross lever group met this criteria significantly more often than the covered or standard lever group with the standard lever performance superior to the covered lever group (df, 2, 117; $F = 9.23$; $p < 0.001$). Finally, the analysis showed that males repeated their successes on the lever trial significantly more often than females (df, 1, 117; $F = 4.79$; $p < 0.05$).

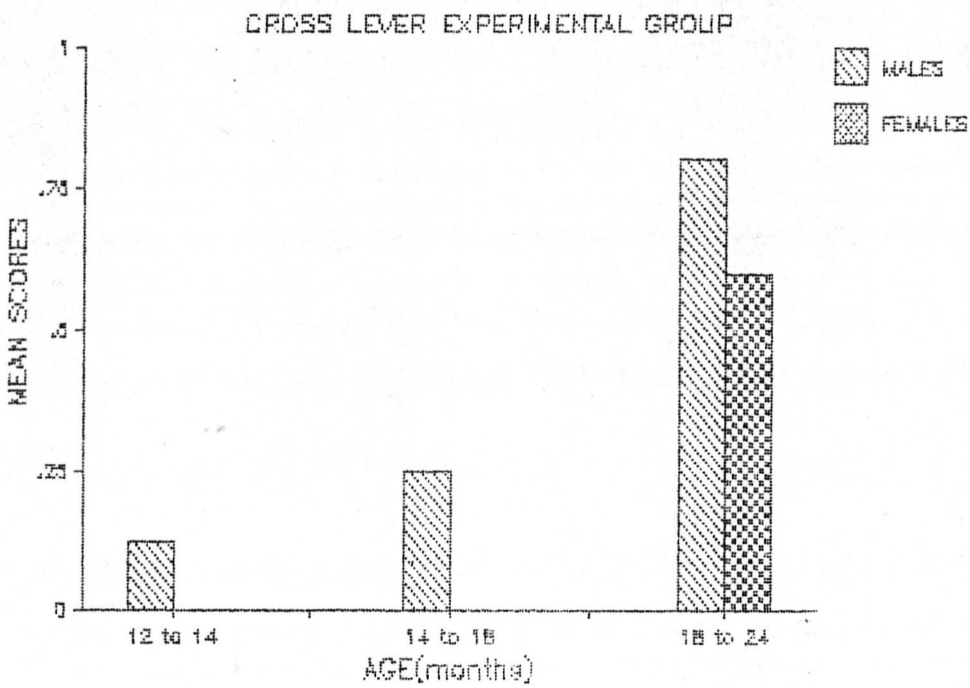
The imposed criteria of three or more successes produced a similar pattern of results to the above. A significant age effect (df, 2, 117; $F = 16.87$; $p < 0.0001$) showed that older subject groups recorded a higher number of repeated successes and the experimental group effect (df, 2, 117; $F = 4.15$; $p < 0.02$) showed that multiple repetitions were more common in the cross lever group and lowest in the covered lever group. The performance of males in meeting this criteria was significantly better than female subjects (df, 1, 117; $F = 4.50$; $p < 0.05$). Figure 3f illustrates the latter set of results.

In considering those subjects who achieve two or more successes on the lever task, the issue of improved performance between the first and last success arises. To assess this aspect of successful performances, the lever solution times were noted for the subject's first and last success. If the subject's performance has improved, then the last success time would be smaller than the first success time. Therefore, for each subject an indicator of improved performance can be established by subtracting the first solution time from the last solution time - if the answer produced is negative, then the subject has improved performance.

The above calculation was carried out for each subject with two or more lever successes, thus providing each child with an indicator of performance improvement. An ANOVA was then carried out to investigate the influence of age, experimental group and sex on this variable.

Figure 3f (overleaf)


STANDARD LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.75
.5
.25
0
MALES
FEMALES
12 to 14
14 to 18
18 to 24
AGE(months)


CROSS LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.75
.5
.25
0
MALES
FEMALES
12 to 14
14 to 18
18 to 24
AGE(months)

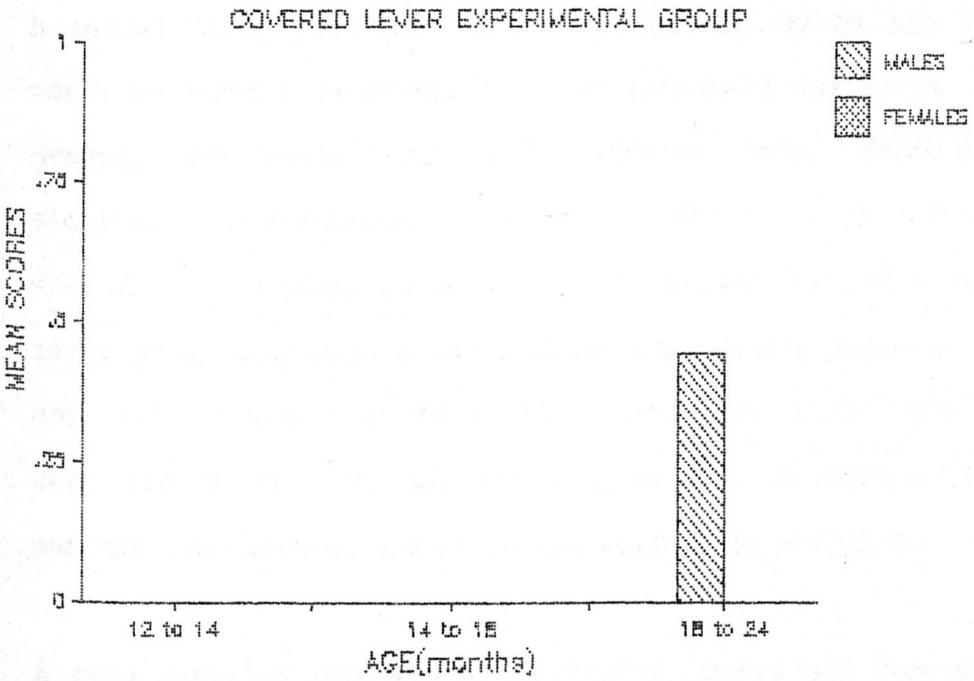


Figure 3f - Subjects with repeated lever success (3+ Criteria)

The first ANOVA of performance improvement used the main terms of age (14-18 month and 18-24 month subjects), sex, and experimental group (standard and cross lever groups). The analysis produced no significant results.

A second ANOVA with main terms age (12-14, 14-18 and 18-24 month subjects), experimental group (standard and cross lever groups) and using only male subject data, produced a significant experimental group effect (df, 1, 19; $F = 5.35$; $p < 0.05$). The mean figure of -13.59 seconds for the standard lever group indicated a significant improvement between first and last success compared to the cross lever group where the mean figure of 1.92 seconds suggested a deterioration in success time between the first and last lever solution.

A more detailed comparison, by t-test, where all age groups and male and female subjects were included, failed to produce any significant results.

Analysis of subjects' first and last solution time independently, failed to produce any significant variation that could be attributed to age, experimental group or sex.

The mean solution time for subjects with two or more successes was also considered. An ANOVA with age (14-18 and 18-24 month subjects), sex and experimental group (standard and cross lever groups) as between subject factors produced a significant age effect (df, 1, 25; $F = 8.01$; $p < 0.01$) with the mean solution time for 18-24 month subjects of 7.58

seconds indicating their significantly faster solutions compared to the 14-18 month subjects with a mean solution time of 22.94 seconds.

A further ANOVA of mean solution times with age (12-14, 14-18 and 18-24 month subjects) and experimental group (standard and cross lever groups) as between subject factors was carried out using only male subjects. Significant age differences were found (df, 2, 19; $F = 3.70$; $p < 0.05$). The mean solution times for the 12-14, 14-18 and 18-24 month subjects were 31.17 seconds, 21.70 seconds and 6.03 seconds, respectively, showing that the older male subjects' solutions were faster than their younger counterparts.

No experimental group or sex differences were found and further analysis (t-test) failed to produce any significant results.

Two final aspects of successful lever trials were considered. Firstly, whether or not lever success was preceeded by the use of a lower strategy. From the individual strategy profiles of each subject, it appeared that some children achieved success without using lower strategies. Lever design has been shown to influence performance in terms of successes achieved and it was decided to consider each experimental group separately. Tables 3f and 3g show the number of successful trials that were or were not preceeded by a lower strategy in the standard and cross lever groups. Due to the lack of success of the 12-14 and 14-18 month subjects in the covered lever group, this analysis was not carried out.

Table 3f - Standard Lever Success and the use of Lower Strategies before Success

	12 - 14 months	14 - 18 months	18 - 24 months
Lower Strategy before success	6	14	7
Success without lower strategy	3	4	21

Table 3g - Cross Lever Successes and the use of Lower Strategies

	12 - 14 months	14 - 18 months	18 - 24 months
Lower Strategy before success	9	10	13
Success without lower strategy	2	11	34

To analyse the data in Table 3 by means of Chi-squared it was necessary to combine the 12-14 and 14-18 month age groups to avoid more than 20% of cells having an expected frequency below 5 (Siegel, 1956).

The results indicate that older subjects were more likely to succeed without using lower strategies on the standard lever group, $x^2 = 13.26$; $p < 0.001$.

Analysis of the cross lever data showed that older subjects were less reliant upon lower strategies on successful trials compared to younger subjects, $x^2 = 11.43$ $p < 0.01$. These results show that younger subjects, irrespective of lever task, relied upon the use of lower strategies in successful trials to a greater degree than the 18-24 month children.

The second and final aspect of the success pattern focused upon the direction of solution. The lever rotated 360° and it was possible to solve the task by pushing the lever to the left or right, the solution can be achieved by two alternative paths. It is possible that subjects may vary in their use of these alternative paths. Therefore, subjects with two or more solutions were classified by age and whether or not the solutions reflected the use of one or both solution paths.

Table 3h - Subjects' Use of One or Both Directions in the Lever Task

	12 - 14 months	14 - 18 months	18 - 24 months
One direction	1	5	16
Both directions	2	7	9

An analysis where 12-14 and 14-18 month groups were combined to meet Siegel's (1956) criteria for Chi-squared failed to produce a significant result, $x^2 = 2.18$; $p > 0.1$, indicating that there was no variation in lever solution direction that was related to age.

(c) Gaze Direction during Lever Manipulation

The analysis considered the direction of visual attention while the subject was in contact with the lever and the measure of comparison was the percentage of lever manipulation time with gaze directed in a specific direction. The most common gaze directions during manipulation of the lever were the subject's hand, the object on the end of the lever and visual attention which moved between hand and object. A number of other categories of visual attention were recorded and these will be returned to.

The initial concern is with the percentage of lever manipulation time spent with gaze directed at the hand, the object or between hand and object. The analysis was carried out on each of the five trials. It should be noted that the t-test analysis in this section compares subjects who display the gaze direction in question and as such are a sub-sample of those children studied.

Percentage of lever manipulation time with gaze on the hand

Trial 1

An ANOVA was carried out with factors age (12-14, 14-18 and 18-24 month subjects), sex and experimental group (standard, cross and covered lever groups). No significant results emerged that were attributable to these factors from this analysis. However, comparison of 12-14 month and 18-24 month subjects produced a significant effect, indicating younger subjects spent a higher percentage of manipulation time displaying this gaze behaviour [$t(46) = 2.37$; $p < 0.05$, two tailed]. A more specific analysis also produced a significant difference between the standard and cross lever groups with standard lever subjects spending more of lever manipulation time looking at their hand [$t(48) = 2.23$; $p < 0.05$, two tailed].

No sex differences were found. However, the ANOVA did produce a significant experimental group x sex interaction (df, 2, 57; $F = 3.30$; $p < 0.05$) and this is attributable to the variation in performance of female subjects between experimental groups.

<u>Trial 2</u>

An ANOVA with factors age (12-14, 14-18 and 18-24 month groups), sex and experimental group (standard, cross and covered lever groups) was carried out and a significant age effect was found (df, 2, 52; $F = 3.30$; $p < 0.05$) and the mean figures indicate that younger subjects spent a higher proportion of lever manipulation time with gaze directed at their hands.

A significant age x experimental group effect was also found (df, 4, 52; $F = 2.56$; $p < 0.05$) and this was attributable to the standard lever condition. The cross and covered lever age groups reflected the age pattern obtained in the ANOVA. However, the standard lever age groups reversed this pattern with the 18-24 month subjects displaying a higher percentage of lever manipulation time looking at their hands. Comparison between age groups within the standard lever group failed to produce any significant results.

Trial 3

An ANOVA with factors age (12-14, 14-18 and 18-24 month subjects), experimental group (standard, cross and covered lever groups) and using only male subjects provided a significant experimental group effect (df, 2, 29; $F = 5.43$; $p < 0.01$) and a significant age x experimental group interaction (df, 4, 29; $F = 4.49$; $p < 0.01$).

The experimental group effect indicates that standard lever subjects spent a higher percentage of lever manipulation time looking at their hand. However, this result was based on data collected from male subjects only.

The analysis (t-test) where male and female subjects were included produced no significant experimental group variation.

The age x experimental group interaction indicates that for the male subjects, the age pattern varies within experimental groups. Within the cross lever group, the highest percentage of time for this gaze was displayed by the 12-14 month and the lowest by the 18-24 month subjects. This pattern was reversed for the standard lever group. A closer inspection of the data, including male and female subjects, produced no significant age differences within the standard lever group. Within the cross lever group, significant differences were found betwen the 12-14 and 14-18 month subjects [$t(15) = 2.50$; $p < 0.05$, two tailed] and the 12-14 and 18-24 month subjects [t(7) = 3.08; p < 0.05, two tailed]. In both instances the younger subjects displayed a higher percentage of time devoted to this specific gaze. The covered lever group 12-14 and 14-18 month subjects also produced a significant age difference with the younger subjects displaying a higher percentage of this gaze [t(11) = 2.52; p < 0.05, two tailed].

Trial 4

A detailed comparison of the percentage of manipulation time spent looking at the hand on the lever was carried out for all age, experimental group and sex combinations with no significant results being found. The analysis of age groups within experimental groups also failed to produce any significant results.

Trial 5

An ANOVA was carried out with age (12-14, 14-18 and 18-24 month subjects), experimental group (standard, cross and covered lever groups) and sex as between subject factors. No significant results emerged, and a more detailed (t-test) analysis of the data failed to produce any significant results.

Percentage of lever manipulation time with gaze on the object

An ANOVA was carried out for each trial and in all cases the factors used in analysis were age (12-14, 14-18 and 18-24 month subjcts), sex and experimental group (standard, cross and covered lever groups). For each trial, a significant age effect emerged.

Trial 1 significant age difference ($df,2,78;F = 4.69;p < 0.05$)

Trial 2 significant age difference ($df,2,77;F = 3.20;p < 0.05$)

Trial 3 significant age difference ($df,2,75;F=10.96;p < 0.001$)

Trial 4 significant age difference ($df,2,75;F=9.28; p < 0.001$)

Trial 5 significant age difference ($df,2,82;F=10.48;P < 0.001$)

The table of the significant variable means indicates that the same pattern of results emerged in all trials. The 18-24 month children spent the greater percentage of lever manipulation time looking at the goal object while the youngest age groups spent a smaller percentage of manipulation time looking at the goal object.

However, all comparisons (t-test) of 12-14 and 14-18 month subjects failed to produce any significant differences, while in contrast, all the t-test comparisons of 12-14 and 18-24 month and 14-18 and 18-24 month subjects produced significant differences. This, along with Table 3n, emphasises that the mean age effect arises from the contrast of the 12-18 month subjects with the 18-24 month subjects.

Table 3i - Mean percentage of lever manipulation time with gaze directed at the goal object

Age (months)	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5
12 - 14	20.65	24.03	24.96	23.24	22.14
14 - 18	21.30	26.51	29.1	30.19	25.08
18 - 24	33.69	42.93	50.06	50.55	47.63

In addition to the above results, the analysis of trial 4 produced a significant experimental group difference (df, 2, 75; $F = 3.65$; $p < 0.05$) and the pattern of means indicates that the cross lever group subjects spent a higher percentage of lever manipulation time with gaze directed at the object ($\bar{x} = 44.63$) while the standard lever group ($\bar{x} = 31.81$) and the covered lever group ($\bar{x} = 25.67$) spent a lower percentage of manipulation time looking at the goal object. The only significant difference found was between the cross and covered lever groups [$t(54) = 2.55$; $p < 0.02$, two tailed].

It should be noted that the age pattern of gaze directed at the goal object repeats the pattern that emerged for success on the lever task, and in addition the experimental group effect on trial 4 is similar to the experimental group effects that emerged for the analysis of success on the lever task. This pattern of results raises the issue of a relationship between this aspect of gaze behaviour and success.

<u>Percentage of lever manipulation time with gaze directed between hand and object</u>

<u>Trial 1</u>

An ANOVA with factors age (12-14, 14-18 and 18-24 month subjects), sex and experimental group (standard, cross and covered lever groups) was carried out and produced a significant effect attributable to sex (df, 1, 43; $F = 5.82$; $p < 0.05$) with males spending a higher percentage of manipulation time with gaze moving between hand and object.

Closer inspection of the results produced a significant difference between 14-18 and 18-24 month subjects with the older subjects displaying the highest percentage of this gaze [$t(37) = 2.13$; $p < 0.05$, two tailed]. In addition, a significant difference emerged between the cross and covered lever groups with the cross lever subjects producing the highest percentage of this gaze [$t(34) = 2.70$; $p < 0.02$, two tailed].

Trial 2

An ANOVA with main terms as above failed to produce any significant results, although a significant difference was found between the cross and covered lever groups with the cross lever subjects displaying the highest percentage of this gaze [$t(33) = 2.54$; $p < 0.02$, two-tailed].

Trials 3, 4 and 5

The analysis of these trials produced only one significant result and that was on trial 5. A significant experimental group difference was found between the cross and covered lever groups with the cross lever subjects producing the highest percentage of this gaze [$t(39) = 2.43$; $p < 0.05$, two tailed].

The 'other' gaze directions

It was noted at the beginning that other directions of gaze had been included in the analysis namely looking at the experimenter, at mother, at lever centre, at cross strut, at the cover and looking away. The analysis of gaze at experimenter, at mother and looking away failed to produce any significant differences between age, sex and experimental group.

The analysis of gaze at lever centre, at cross strut and at cover were only applicable to specific experimental groups, therefore the analysis of this data focused on within group comparisons.

In the standard lever group, gaze at lever centre produced one significant result from the comparison of 12-14 and 18-24 month subjects [$t(12) = 3.69$; $p < 0.01$, two tailed], indicating that older subjects spent a higher percentage of lever trial time looking at lever centre on trial 4.

The analysis of the cross lever group considered gaze at lever centre and gaze at the cross strut. In the case of gaze at lever centre for trial 4, the comparison of 12-14 and 14-18 month subjects produced a significant result [$t(10) = 2.88$; $p < 0.02$, two tailed] indicating that the older subject group spent a higher percentage of lever manipulation time displaying this gaze. This pattern was also found for the 12-14 and 18-24 month subjects on trial 4 as well as with older subjects spending more time on this gaze [$t(6) = 2.71$; $p < 0.05$, two tailed].

Gaze directed at the cross strut produced significant differences on trials 4 and 5. In both cases the comparison of 12-14 month and 18-24 month subjects resulted in the significant difference on trial 4 [$t(6) = 3.87$; $p < 0.01$, two tailed] and on trial 5 [$t(6) = 2.59$; $p < 0.05$, two tailed] and the direction of result indicated that older subjects spent a higher percentage of lever manipulation time displaying this gaze.

Analysis of gaze at the cover produced no significant results.

The analysis of the gaze direction data, especially gaze at the object, indicates a pattern of results which parallels that of success. The obvious question is whether gaze, assessed in terms of the percentage of manipulation time devoted to a specific gaze, is related to success/failure on the lever task.

The correlations (Pearson's r, two-tailed) considered subjects who displayed a particular category of gaze behaviour and correlated the percentage of lever manipulation time displaying this gaze with success/failure on each specific lever trial.

Since the analysis has shown that the three variables of age, experimental group and sex have been related to performance, the correlation analysis focused upon age groups within experimental groups. However, the male-female divide was not made given that this would reduce sample sizes to very small levels.

The correlation tables for the standard, cross and covered lever are presented in full in Appendix 3a, b and c. The focus of this section will be upon the significant correlations.

Standard Lever Group

The correlation analysis produced few significant results. Two significant correlations were found between percentage of manipulation time gazing at the object and success in the 12-14 month sample. On trial 1 (r = 0.7349; n = 12; p = 0.01) and on trial 3 (r = 0.6315; n = 11; p = 0.105) a positive correlation between object gaze and success was found. Only one other significant correlation between these variables was found and that was in the 14-18 month subject group on trial 4 (r = 0.7340; n = 14; p = 0.01) where a positive relationship was indicated.

The only other significant correlation on this analysis was between percentage of lever trial time spent not touching the lever (i.e. breaks). This result indicated a negative correlation between 'breaks' and success for the 14-18 month subjects on trial 4 (r = -0.8173; n = 14; p = 0.01).

No significant correlations were found in the 18-24 month subjects of the standard lever group.

Cross Lever Group

The majority of significant correlations were found between gaze at object and success. In the 12-14 month age group, a significant positive correlation gaze at object and success is found on trial 3 (r = 0.7535; n = 11; p = 0.02). This positive trend in correlation between success and gaze at object is continued in the 14-18 month age group where four out of the five lever trials produce a significant positive correlation:

Trial 1   r = 0.7715; n = 10; p = 0.02

Trial 2   r = 0.6562; n = 14; p = 0.02

Trial 3   r = 0.6586; n = 11; p = 0.05

Trial 5   r = 0.6645; n = 14; p = 0.01

This pattern of positive correlation between object gaze and success was continued in the 18-24 month subject group:

Trial 1   r = 0.6593; n = 11; p = 0.05

Trial 2   r = 0.7233; n = 11; p = 0.02

Trial 4   r = 0.6958; n = 13; p = 0.01

Trial 5   r = 0.6196; n = 12; p = 0.05

A number of other significant correlations were found in this analysis. Within the 12-14 month subject group, significant positive correlations were found between hand-object gaze and success on trial 3 (r = 0.9306; n = 7; p = 0.01) and trial 5 (r = 0.8020; n = 9; p = 0.01), both results indicating that success was correlated with gaze time spent moving between hand and object.

The final area in which significant correlations were found was between 'breaks' in lever manipulation and success. Significant negative correlations between these two variables were found in the 14-18 month subjects on trial 1 (r =

-0.7221; n = 11; p = 0.02) and trial 2 (r = -0.6187; n = 14; p = 0.02) and also in the 18-24 month subjects on trial 1 (r = -0.6940; n = 11; p = 0.02). In all of these cases, the direction of correlation implies that the greater the percentage of lever manipulation time spent in 'breaks', the less likely subjects are to be successful.

Covered Lever Group

Since the present aim is to consider the possible relationship between success and gaze direction, the analysis in this group focused upon the 18-24 month subjects since they were the only ones to record any successes on this lever. Only two significant correlations were found and both produced negative correlations between 'breaks' in manipulation and success in the 18-24 month group. On trial 1 (r = -0.7439; n = 9; p = 0.05) and trial 5 (r = -0.6139; n = 11; p = 0.05), the correlation trend is similar to that found between those variables in the cross and standard lever groups.

The correlation analysis draws attention, not only to the possible relationship between specific gaze direction and success, but also indicates possible experimental group variations.

(ii) DISCUSSION

The main hypothesis proposed that both age and experimental group would be influential in predicting performance on the lever task. While no specific hypothesis was stated for the third variable, sex, the analysis indicated that the sex of the subject influenced performance.

The results for each of these variables will be discussed separately.

Age

The analysis indicates that older subjects record significantly more successes than younger subjects. This age pattern is reflected within each experimental group although the main age effect arises from the contrast in performance of subjects in the 12-18 month range compared to the 18-24 month old subjects. No significant variation in performance was found between the 12-14 month and 14-18 month subjects. However, the mean success figures indicate that the 14-18 month childrens' performance was better than the 12-14 month groups. This does not apply to the covered lever group where neither the 12-14 or 14-18 month old subjects recorded any successes.

Given that the procedure included repetition of trials, it is not surprising that the results indicate an improvement in total successes on subsequent task presentations. The trial x age interaction does indicate that the performance of the 14-18 month and 18-24 month subjects improved over the five trials while the performance of the 12-14 month subjects declined. Repetition or exploration of the task did not improve the 12-14 month subjects' understanding of the task requirements.

The highest success rates for the 12-14 month subjects was recorded on the first trial and may have reflected the subjects' motivation on this early trial which in turn facilitated solution. However, it was a success which was not repeated by all of the subjects involved. Richardson (1934) noted that some subjects followed a successful trial with failure and suggested that this failure may reflect a lack of motivation. Observation of the video tape indicated that subjects were still attempting to retrieve the goal object in subsequent trials and this indirect measure suggests that they were still motivated by the goal; it was the method that was creating the problems.

An alternative explanation of the decline in performance of the 12-14 month subjects is that their mutual successes were accidental. Uzgiris and Hunt (1975) have argued that repetition of the solution to a problem is necessary before one can rule out accidental explanations. The analysis indicated that imposing criteria of 'two or more' or 'three or more' successes showed that repetition of success was significantly more likely in the older subject groups.

Koslowski and Bruner (1972) have argued that it is the younger subjects' reliance upon lower strategies that stops them from succeeding on this task and that claim received support from the analysis of trials ending in 'low' or 'high' strategies. Trials ending in 'low' strategies, strategy I or II, were significantly more likely to be recorded in the younger subject groups.

A closer inspection of the strategies used showed that in the case of strategy I, linear action, significantly more trials where this was the highest strategy recorded were found in the younger age groups. This age pattern was also found for strategy II, oscillation. However, a significant trial and age interaction showed that in the early trials, no age effect was found. In the later trials, namely trials 3, 4 and 5, the significant age effect had emerged indicating that fewer trials ended in this strategy among the older subject groups.

It can be argued that in the earlier trials where all subjects are unfamiliar with the lever that oscillation is a useful strategy when exploring the properties of the lever. The contrast between age groups lies in the ability to move on from this limited strategy toward solution. This result also suggests that the ability to grasp and rotate the lever is present in all age groups but that this skill, while being necessary for success, is not sufficient.

Strategy III, partial rotation, was not frequently recorded. However, age patterns were found indicating that trials where this strategy was the highest recorded, were most common in the 14-18 month age group. Koslowski and Bruner (1972) have suggested that this strategy should be viewed as an intermediary step in solution. It demonstrates the subject's ability to rotate the lever at least 45 degrees and as such is a step beyond oscillation, but still demonstrates a limited understanding of the rotational property of the lever. The 14-18 month subjects' success on the lever falls between the 12-14 and 18-24 month age groups, indicating that this group may be viewed as comprising of subjects whose ability is intermediary and this may provide some support for Koslowski and Bruner's argument.

The superior performance of the 18-24 month old subjects is reflected, not only in the larger number of successes recorded, but also in the number of trials where strategy IV was the highest strategy recorded. This strategy showed that subjects were capable of rotating the lever to the extent that the goal came within reach. However, the subject failed to remove the goal object and rotated the lever away again. Koslowski and Bruner (1972) suggested that this strategy reflected the child's preoccupation with the lever, the goal was forgotten about. Observation of subjects displaying this strategy in the present study indicates that they did not ignore the goal. Instead they appeared preoccupied with their ability to move the goal either toward or away from themselves.

The results support the argument that there was a qualitative difference betwen the age groups in the way that they approached this task. This qualitative difference was also found when considering the successful solutions. There is some evidence to suggest that older subjects were quicker in solving the lever task. One explanation for this is found in the fact that younger subjects were more likely to precede success with a lower strategy, indicating that their route to success involved some degree of trial and error.

Multiple successes were more likely to occur in the older age groups. However, repeated success was recorded to some degree in all age groups. It is possible that the repetition of a success involved the subject repeating the previously successful action pattern and if this were the case, the solution would be in the same direction as previous solutions. The analysis showed that in all age groups, multiple successes involved solutions to both sides of the subject. Those subjects who succeeded more than once, irrespective of age, demonstrated their understanding that the lever rotated in both directions and suggests that repetition of success reflects an understanding of the task (Uzgiris and Hunt, 1975).

The comparison of age group performance within each experimental group supported the pattern of results for strategy use outlined above.. It should be noted, however, that few of the within-group differences reached significant levels.

The analysis of within-group performance also drew attention to the variation in performance between experimental groups, particularly the results of the covered lever subjects.

Experimental Group

Due to the variation in lever design and the subsequent demands placed upon the subjects, it was hypothesised that performance would vary between experimental groups.

Support for this argument was provided by the analysis of total lever successes, where the cross lever group recorded the highest number of successes followed by the standard and covered lever groups. In the latter group's case, the 12-14 and 14-18 month subjects failed to record any successes.

The analysis of lever successes showed that no experimental group differences were found on trial 1, after the first trial experimental group difference were found on trials 2 to 5. The pattern that emerges from this data (cf. Table 3a in Results Section) suggests that success was attained more readily on the cross lever group with a higher number of successes on trial 1, though not significantly, while on trial 2 a significant experimental group difference had emerged indicating the superior performance of the cross lever group. By trial 3, the standard lever group's performance had improved to the extent that the main source of experimental group differences was found in the poor performance of the covered lever group subjects.

A closer inspection of the number of strategy I, II, III or IV trials recorded failed to produce any significant results that were attributable to experimental groups. In the light of the success pattern, this result is surprising. Since the covered lever group were producing fewer successes, the expectation existed that they would have a significant number of trials ending in other strategies. It was only when strategy I and II were combined into the 'low strategy' category that the results showed the covered lever group had significantly more trials ending in these low categories.

Support for the argument that the covered lever group subjects were more likely to record 'low' strategies, was found on trial 2 where a significant result showed that covered lever subjects recorded more trials ending in strategy II compared to the other experimental groups.

The most obvious source of explanation for the above variations in performance is the design of the lever. The fact that significantly more successes were recorded on the cross lever and that this success pattern emerged after the first trial, suggests that this was the easiest, relatively, of the three lever designs.

It can be argued that if subjects used strategy II, oscillation, on this lever, it brought the cross strut within the subject's reach and by moving to the cross strut, it led to the next step of capturing the goal. The cross strut facilitated success by becoming a sub-goal or intermediary step in solution of the task.

In contrast, oscillation of the lever in either the standard or covered lever groups provided no sub-goal to the subject and left them with a larger step between oscillation and success. Some support for this argument comes from the analysis of trials ending in strategy II. The analysis of the total number of trials where strategy II was the highest recorded strategy showed that in the case of 18-24 month subjects, the cross lever group recorded fewer of these trials compared to the standard and covered lever groups. In addition, a similar analysis on trial 2 showed that once again the cross lever group subjects had fewer instances of this trial ending with strategy II.

This pattern can be interpreted as providing some support for the argument that cross lever subjects who displayed strategy II behaviour were more likely to progress to a higher strategy and solution of the task.

Support for the arguments that the cross strut facilitated success, can be found in the analysis of the multiple solution. Children in the cross lever group were more likely to repeat their successes compared to the standard and covered lever groups and repeated success was least likely in this latter group.

While no experimental group differences were found when considering mean solution times, the improvement between first and last solution was greater, for males, in the standard compared to the cross lever group. This latter result indicates that there was greater scope for improvement in the standard lever performance while the cross strut design encouraged optimum solutions, as measured in solution time, on the first successful trial.

If it can be argued that the cross strut facilitated solution on the cross lever, the cover placed over the standard lever impaired performance, most notably in the case of the 12-14 and 14-18 month subjects. The introduction of the cover over the lever may have influenced performance for a number of reasons;

(i) The cover could have distracted the subjects from the lever. It was noted that during covered lever trials, several subjects did attempt to lift or move the cover and in some cases, subjects tried to look under the cover. However, this behaviour did not stop subjects from touching and moving the lever itself.

(ii) The introduction of the cover could have made the task mechanically more difficult compared to the standard lever. In the case of the standard lever, subjects were able to use the middle section of the lever to aid rotation. Koslowski and Bruner (1972) had noted this route to success and subjects in the present standard lever group also displayed this type of solution. The introduction of the cover imposes restrictions on the means of achieving a solution. To solve the covered lever task, it is necessary to move the lever 90 degrees. This may involve the child moving to the corner of the table to push the lever end to this position, then to move to the other corner of the table to catch the added T-bar to pull the lever and the goal into reach.

Thus the addition of the cover may impose physical restrictions that reduce the subject's chance of success or which accentuates the need to understand the relation between the two lever ends and this leads to the final explanation of the role of the cover;

(iii) By placing a cover over the standard lever, it may be that information required by the subject, especially the 12-14 and 14-18 month age groups, is being removed.

Before exploring these issues further, influence of the subject's sex on performance will be considered.

<u>Sex</u>

While the analysis of results looked at the possible relationship between sex and lever performance, no significant variation was expected. Previous research on lever tasks, Richardson (1932) and Koslowski and Bruner (1972), had not recorded any difference between male and female subject performance. Fitzpatrick (1978) in a study of tool-using skill in 16-24 month subjects, found some minor sex differences with female subjects displaying less initial exploration and taking longer to get involved in the tasks. Sex differences have also been noted in younger subjects with barrier tasks and tool-using problems [Kramer and Rosenblum

(1978); Bates, Carlson-Luden and Bretherton (1980)].

The present study produced a significant variation in performance attributable to sex. Female subjects did not record as many successes as male subjects and in addition, male subjects were more likely to repeat their successes.

The analysis of success recorded on each trial showed that sex differences did not emerge until trial 3, from which point onwards male performance is significantly superior to that of the female. The analysis also shows that female subjects have significantly more trials where the highest strategy recorded falls in the 'low' strategy category, i.e. strategies I and II.

Analysis of strategy I trials showed that female subjects recorded significantly more trials where strategy I was the highest recorded. The only other significant sex difference was found when analysing strategy IV trials. In this case, males recorded more trials with this as the highest strategy. Females failed to record any trials with strategy IV as the highest trial. It should be emphasised that this does not mean that females failed to display this behaviour but rather that any female subjects displaying strategy IV ultimately removed the goal and thus had the trial classified as strategy V.

One possible explanation for the sex differences in successes on the lever task may be found in Fitzpatrick (1978) claim that female subjects were less exploratory than males on tool-using tasks. If female subjects failed to explore the task and the properties of the lever, they may be less successful. Kramer and Rosenblum (1970) presented subjects with a frustrating barrier task and their results showed that female subjects' capacity to maintain their interest in a frustrating task was lower than males.

In the present study, no difference in interest was noted between the sexes. However, if the task was frustrating, it may have had an alternative effect. Fitzpatrick (1978) noted that frustration on a barrier task may result in a regression effect where subjects resort to more basic strategies. The analysis showed that females had more trials where strategy I was the highest recorded strategy and given that this represented the most basic strategy, it may provide some support for Fitzpatrick's earlier findings.

An alternative explanation for this pattern of results may be that the interaction between the male experimenter and female subjects influenced performance. There was no evidence from the video-taped sessions that this was the case although it remains a possibility.

At a more general level, it has been suggested that the environment and experience of the input may be reflected in intellectual developments and skilled action behaviour (Yarrow, Rubenstem and Pedersen, 1975; Fischer 1980). However, it has been shown that male and female infants experience varies, for example in the types of play activity that they are involved in (Snow, Jacklin and Maccoby, 1983), and that this may be reflected in the infants' approach to new situations. Parke (1981) has noted that mothers and fathers differ in how much exploration they encourage in their infants, with males receiving greater encouragement for this type of behaviour reflecting wider sexual stereotypes. It is possible that the variation in the male and female infants' experience is reflected in their performance on this task.

Previous Research on the Lever Task

Richardson (1934) and Koslowski and Bruner (1972) have investigated infants' performance on the lever task. The results from the two studies are not directly comparable due to variations in terms of subject's age, lever design used, procedural differences and contrasting test environments.

Richardson's work used a sample of 25-52 week old subjects, approximately 7-13 months. The subjects were required to manipulate the lever through the bars of a cot and the lever used was pivoted below the centre.

The pivot position allowed some subjects to rotate the lever by pulling the bar above the pivot point and retrieve the goal object by acting in the same direction as the object was moving. An ability which subjects demonstrate in string problem solving task (Richardson, 1932).

In these circumstances, Richardson found that success before

44 weeks was rare, while performance after this point improved with age. Of those subjects in the oldest age group (52 weeks), 33% recorded successful performances on this task. It should be noted that these results refer to only one of Richardson's experimental conditions, namely where the infant was required to rotate the lever before any demonstration, and this condition corresponds most closely with Koslowski and Bruner's (1972) work.

Richardson's other experimental conditions, such as demonstrating the lever movements for the child, did lead to more successes but Richardson argues that the 40-44 week period was the turning point in performance even when performance in other experimental conditions was considered.

Koslowski and Bruner (1972) did not vary their procedure and focused on Richardson's first condition, presenting the subject with the lever stretching away from them with the goal attached on the far end. This is equivalent to the standard lever design in the present study.

Koslowski and Bruner's work can be contrasted with Richardson's study on several points. Firstly, there was no obstruction between the subject and the lever. Secondly, the age range was extended to include 12-24 month old subjects, and thirdly, the lever was pivoted at the centre, which, due to the size of the lever, prohibited subjects from rotating the lever by pulling on it above the pivot point until they had rotated it part of the way by some other means.

The results obtained complemented Richardson's work, indicating an improvement in performance with age. However, Koslowski and Bruner were concerned, not only with the quantitative variation but also the qualitative aspect of performance and they argued that the quality of the subject's efforts varied with age - a point which Richardson refers to in part of her analysis.

Some limited comparison between these two earlier studies can be made if attention is focused on Richardson's oldest subject group and Koslowski and Bruner's youngest age group, both fall into the 12-14 month range. Richardson's study produced a higher number of successful infants compared to Koslowski and Bruner, 33% and 13% respectively.

These differences may reflect procedural variations between studies or the variation in lever construction and size. It is possible that Richardson's lever, pivoted below the centre and of a much smaller scale, influenced the success rate while Koslowski and Bruner's lever accentuated the need to move one end of the lever (and their hand) in the opposite direction to the goal's movement.

This earlier work in conjunction with the present results demonstrates the ability of infants of this age range to perform on such tasks and supports the hypothesis that age is an important variable when considering performance.

Of the three experimental groups in the present study, the standard lever group can be compared with this earlier research, although procedural variations must be borne in mind. The results from this lever group's performance reflects the earlier work of Koslowski and Bruner, with older subjects recording fewer lower strategy trials and achieving a higher number of successes than their younger counterparts.

In addition, the strategies outlined by these earlier researchers were applicable to the performance of the present subject group. However, the incidence of strategy III was lower in the present work compared to Koslowski and Bruner's (1972) study. One explanation may be in the procedural variations between the experiments. In the present study, subjects displayed strategy III behaviour but were encouraged to continue their efforts and may have moved onto a higher strategy. This may also explain the main point of contrast between the present standard lever group's performance and Koslowski and Bruner's work, namely, that at all age levels, a larger percentage of subjects achieve strategy V status in the present study.

This increase in success levels could also be explained by the major procedural variation between the two studies. Koslowski and Bruner (1972) refer to their trials as lasting approximately 15-20 minutes. However, no detail is given as to whether subjects witnessed lever movements by the experimenter or whether a number of trials wre carried out within this time period. In the present study, five trials were carried out and subject's performance may have been influenced by watching the experimenter move the lever between trials. Richardson (1934) noted that this had some effect on performance and while the present study took steps to minimise this influence, it cannot be completely ruled out.

An alternative explanation for the improved performance of the standard lever group may be in the change of age ranges between the studies. Koslowski and Bruner used three age ranges 12-14, 14-16 and 16-24 months while the present work had age ranges 12-14, 14-18 and 18-24 months. The improved performance of the 14-18 and 18-24 month groups in the present study may reflect this change, although it fails to explain the improvement in the 12-14 month age group.

It can be concluded that while the standard lever group's performance does vary from Koslowski and Bruner's study, the overall trend of results are comparable.

Visual gaze during lever manipulation

The two previous studies in this area have focused upon quantitative and qualitative aspects of performance and in reference to the latter, both studies have suggested that visual gaze may vary between subjects while tackling this problem and this in turn may be related to their performance.

Richardson (1932) refers to 'perceptual attitudes' in describing the difference between subject's focus of attention during a number of string problem tasks. It is suggested by Richardson that subjects attended to varying aspects of the array; the object, the string, the relation between them and this in turn reflected the subject's understanding of the task. For example, a 'trial and error' approach was accompanied by a 'perceptual attitude' where the subject attended to the string and the relation between pulling on it and the object's movement, whereas a solution classified as 'insight' was accompanied by the subject attending to the object as it moved into reach.

Richardson (1934) had also suggested that subjects on the lever task may focus their attention on the goal object and ignore the lever, although her observations did not support this suggestion.

Koslowski and Bruner (1972) have also suggested that visual gaze will reflect the subject's level of performance. Bruner has proposed that performance on the lever task should be viewed as the attainment of a skill. This process involves the acquisition of the component acts (modularisation) and while the individual components are being mastered, attention will focus upon them.

While Richardson (1932, 1934) and Koslowski and Bruner (1972) proposed that gaze direction may provide information in relation to performance, neither study included this in their analysis. The present study hypothesised that gaze differences would be found although no specific arguments were proposed.

The most striking result from the analysis of gaze during lever manipulation showed that on all five trials, the 18-24 month subjects spent more time with gaze directed at the object. The age pattern that emerged for gaze at the hand was not as pronounced although the pattern that emerged showed that the younger age groups spent more of the lever manipulation time with gaze directed at the hand. This age pattern did not emerge in all trials and in some cases, this result was reversed within specific lever groups. For example, on trial 2, the 18-24 month standard lever subjects spent the most time gazing at their hand on the lever.

The analysis of gaze moving between hand and object produced few significant results that were indicative of an age pattern. The exception emerged on trial 1 where the 18-24 month children spent a higher percentage of lever manipulation time with their gaze moving between hand and object compared to the 14-18 month subjects.

The analysis of the other gaze directions produced mixed results when considering age as the main variable. In the case of the 18-24 month subjects in the standard lever group, they spent more time looking at the lever centre when compared with 14-18 month subjects on trial 4. A similar age pattern was found in the cross lever group where 18-24 month old subjects spent more time looking at the cross strut than their 12-14 month counterparts on trials 4 and 5.

Bruner's proposal that during modularisation the component acts will take up the child's attention can be considered in the light of the data. It can be argued that the older subjects, who are also the most successful, spend more of the manipulation time looking at the goal since they have mastered the skill of manipulating the lever. The corollary of this would be that younger subjects would focus attention on other parts of the lever. A degree of support for this is found in the analysis of hand gaze where younger subjects focus more attention on their hand, arguably a more basic component of the skill of rotating the lever. However, this pattern is contradicted by the 18-24 month standard lever group subjects who spend more manipulation time with gaze on the hand compared to their younger counterparts. This latter result will be returned to when considering the experimental group variation.

Richardson (1934) argued that the major difficulty with the lever task was the comprehension of the relationship between hand and object movement. If this is an important element in the solution to the task, the expectation exists that gaze between hand and object may mirror the success pattern that was found. Few significant results were found in this analysis, the only significant result pertaining to subject's age showed that the 18-24 month subjects spent more time on this gaze than the 14-18 month subjects. This pattern could be interpreted as an indication that the 18-24 month subjects, who were the most successful on this task, were not only aware of the relation betwen hand and object movement, but that it may also be related to their success and may reflect the child's understanding of the task requirements.

Laszlo and Bairstow (1985) have argued that perceptual and limb movements illustrate the way that the individual investigates the world and also the way in which it is understood. A similar point is made by Neisser (1976) when proposing that we display cognitive control over our perceptual processes.

Given a novel object, children and adults use their hands and eyes in the process of exploration (Bushnell, 1981) and developmental differences have been found in this process (Abravanel, 1981). Adopting this framework would allow a re-interpretation of the 18-24 month subjects' gaze between hand and object. The fact that they spend more time on this gaze may reflect their knowledge of the relationship between the two elements or at least the knowledge that the solution to the task is based upon this relationship. Similarly, the pattern of results which shows that older subject groups spent more of the lever manipulation time with gaze directed at the lever centre and at the cross strut, may reflect the importance of these areas as sources of information in solving the task.

The issue of whether these gaze directions are related to success will be considered later. For the moment attention will be focused on experimental group differences in visual attention.

While gaze at the object produced a strong age pattern only one trial produced an experimental group effect and this indicated that the cross lever group subjects, the group who recorded the highest number of successes, spent more time with gaze on the object and the covered lever group recorded the lowest amount of lever manipulation time looking at the object. This latter group were the least successful in terms of the number of lever solutions.

Gaze at the hand while manipulating the lever produced mixed results with few experimental group effects. The standard lever group subjects spent more time looking at their hand on the lever than the cross group on the first trial and this pattern was repeated for males on trial 3. Trial 2 produced an age pattern in results which showed younger subjects spending more time looking at their hands. This pattern was only found in the cross and covered lever groups while the standard lever group reversed this pattern.

The experimental group differences for gaze that moved between hand and object were centred upon the cross and covered lever groups. In three of the five trials, the cross lever subjects spent more manipulation time with gaze moving between hand and object when compared to the covered lever group. No significant experimental group differences were found involving the standard lever group. All other gaze direction data failed to produce any experimental group effects.

If gaze direction is interpreted as exploration of the task, it can be argued that the variation in gaze between lever groups reflects the varying demands of the levers.

It was suggested that the covered lever task may have been difficult because the cover itself removed information from the subject. This information could have been about the connection between the lever end and the goal or information about the rotational property of the lever which may have been gained from the lever centre.

Unfortunately, there are no major results to indicate that the covered lever group subjects' gaze patterns were significantly different from the other experimental groups. In terms of gaze moving between hand and object, the cross lever subjects spent significantly more time looking between hand and object than the covered lever subjects. This could indicate that the cover obscured this relationship and would explain the poor quantitative performance of the covered lever group.

The analysis of the other gaze directions provides some support for the argument that the cover removed information that helped subjects solve the lever problem. The cover obscured the pivotal centre and in both the cross and standard lever groups, age patterns or at least one trial indicated that the 12-14 month subjects spent less of the lever trial time with gaze directed at this point. It was this age group which was least successful in both lever groups, while the more successful 18-24 month subjects spent the most time displaying this gaze. Another source of information for the cross lever group was the cross strut and the analysis indicates that on those trials where significant differences were found, it was the older subjects who attended to the cross strut movements.

Interpreting gaze direction as a reflection of exploration of the task indicates that older subjects have a different gaze pattern than younger subjects, for example gaze at the object, and that there is some variation in gaze between experimental groups. The question remains as to whether or not gaze direction is related to success.

The correlation between gaze and success was carried out within each experimental group and the most notable pattern of results shows that in the cross lever group, in both the 14-18 and 18-24 month subjects, gaze at the object was positively correlated with success on four out of five trials. In the 12-14 month group, only one trial produced a significant positive correlation between object gaze and success.

This pattern of results supports the arguments presented earlier that the cross lever as the easiest lever task freed the subject's attention to the extent that they could focus on the goal and its movements for most of the trial time. The fact that this pattern was not present to the same extent in the 12-14 month age group, and that two positive correlations were found between hand-object gaze and success, indicates that this age group required attention to other sources of information while succeeding on this task.

The analysis of the standard and covered lever groups failed to produce any strong pattern of correlations between success and specific gaze directions. Significant positive correlations were found between object gaze and success on a few trials and these were for the 12-14 and 14-18 month standard lever group subjects. The fact that so few significant correlations were found in the standard lever group indicates that attention was directed towards a number of different aspects of the lever by those subjects attaining success.

The correlation between gaze and success in the 12-14 month standard group subjects, rather than the 18-24 month group contradicts expectations. However, an explanation for this could be the type of success that some of the younger subjects recorded. In some cases it was noted that success was the result of subjects pulling directly on the lever with gaze on the object. The child then moved one hand, and the pressure still being exerted by the other hand spun the lever around while the subject looked at the goal; in essence an accidental solution.

No significant correlations were found in the analysis of the covered lever group between gaze and success, thus analysis focused only on the 18-24 month group since they were the only age group to record successes in this task.

The only other significant correlations that emerged were all negative in direction and indicated that breaks in lever contact did not enhance success. A fragmented approach to the lever task, stopping and starting, was more likely to be associated with those that did not succeed. Subjects who succeeded did so with fewer breaks in lever contact and tended to be found in the older age groups in all experimental groups. This group also had superior solution times indicating a well co-ordinated solution strategy.

The correlation between object gaze and success that emerged in the cross lever group indicates the ability of the child to spend more time looking at the object while continuing to manipulate the lever. Millar and Schaffer (1973) have proposed that attending to a goal object while manipulating another object which influences the goal, requires the subject to rely upon stored information or to represent internally the manipulation process. While the present task does not have a distinct separation between the goal object and manipulation, the correlations within the cross lever group indicates that successful subjects need to pay less attention to the manipulation process. However, since this correlation is limited to the cross lever group, the specific lever task demands influence, the extent to which the subject can separate attention between manipulation process and the goal object.

Theoretical Issues

One of the most basic questions regarding this task is the infant's understanding of the relationship between the lever and goal object. The age difference in performance may be reflecting an awareness of the lever and goal. Piaget (1953) has argued that the stage IV infants do not fully understand the use of supports since they would pull on a cloth to retrieve an object that was placed beside rather than upon it. It is possible that the youngest subjects failed to understand the role of the lever as a support and therefore as a means to achieving an end.

Willatts (1984, 1985) has demonstrated that 9-month-old infants have a well-developed understanding of supports and in addition that they are aware of the distinction between the support and the object. This latter point is of particular importance to the child's understanding of the goal-lever relation.

Bower (Bower 1977; Wishart & Bower, 1984) has proposed that by placing one object on top of another object results in the infants viewing the combination as a new entity; the original object by losing one of its boundaries has ceased to be viewed as a separate object. If this is the case, it raises the question of whether or not the subject manipulates the lever as a means of retrieving the goal object, which by being placed on top of the lever has lost its separate identity.

Studies referenced by Schuberth (1983) and Willatts (1985) have demonstrated that by 6 months the object/support distinction can be made and, given the age of the present sample, it can be argued that the goal object maintained its independent identity when placed on the lever.

Bower (1979a) has also argued that infants are not aware that a moving object is the same object when it stops or that a stationary object is the same when it moves. Given that the lever moves the goal object through space, stopping and starting at various points, the subject may be viewing a number of different objects when moving and stationary. If this is the case, it questions the argument that the lever is being manipulated as a means to an end, given that the goal object's identity is not static.

Bower (1979a) has proposed that infants 5 months of age and older view objects as things that can move through space and this results from the object's features assuming importance in defining identity. Accepting Bower's argument would allow us to conclude that in the present study, the age of the subjects implies that they would attribute a static identity to the goal object when moving or stationary. Criticisms of Bower's argument, and the data on which it is based, have been made but there has been no suggestion within them that subjects in the present study's age range should experience difficulty in identifying the goal as it moves (Schuberth, 1983).

Further support for the child's understanding of the lever-goal relation can be found in the approach of many of the youngest subjects to this task, namely to pull directly on the lever. While this is a futile strategy it does indicate an awareness of the lever goal connection. Richardson (1934) also noted this behaviour classifying it as a "good error" since it demonstrated an awareness of the lever-goal relationship.

Results from patterned-string tasks also attend to the fact that infants are capable of comprehending the relationship between two objects (Richardson, 1932; Uzgiris and Hunt, 1975).

The work on patterned-strong tasks and the use of supports has demonstrated that infants are capable of pulling objects towards themselves. Even when there is no direct connection between the object and the means of moving it within reach, infants have been shown to use tools in order to achieve this end (Bates et al, 1980).

Richardson (1934) has argued that the main difficulty with the lever task is that the subject must discover the relationship between the movement of their hand and the movement of the object. It has been argued that the process by which this is attained can be viewed as a developing skill (Koslowski and Bruner, 1972).

The ability to solve the problem reflects the level of organisation of the component parts of this skilled action via the process of 'modularisation'. Each constituent element is mastered and refined and demands less of the child's limited information-processing capacity (Bruner 1970, 1973). The child holding the lid of a box open to retrieve a toy inside is often quoted as an example of skilled activity that reflects the modularisation of the component acts. The unskilled child may repeatedly lift the lid up and down disregarding the toy inside and it is only when this activity can be performed smoothly that it will be combined with the other elements necessary to retrieve the toy (Bruner, 1970).

Failure on the lever task therefore reflects the failure to organise the constituent elements of skilled activity into an appropriate sequence and the present results would suggest that this is closely linked with age. This age pattern is reflected in the analysis of lever successes and in the analysis of highest strategy recorded on each trial. The improvements in performance over the five trials could also be interpreted as support for this argument.

The analysis of mean solution time for successes recorded by the children indicated that the older subjects' solutions were significantly better than their younger counterparts. Interpreting the speed of solution as an indicator of skill shows once again the superiority of the older subject groups. The analysis of the time taken for the first solution that a subject achieved did not produce any significant results. However, the mean solution time for the first success of the 18-24 month group of 16.7 seconds was below that of the 14-18 month subjects (25.8 seconds) and the 12-14 month subjects

(37.2 seconds).

The improvement in solution time between the subject's first and last solution failed to produce any significant age effect and it can be argued that an improvement in skill would have been reflected in this analysis.

Two additional pieces of information may provide some support for the argument of improved technique or skill in older subjects. Firstly, the data shows that it is the older subject groups who are significantly more likely to repeat their successes. The imposed criteria of 'two or more' and 'three or more' successes indicated that it was the 18-24 month group who were recording the highest number of repeated success. This supports the argument that their organisation of the component acts was superior to that of younger subjects. Secondly, the analysis of strategies used on successful trials showed that younger subjects were more likely to use a lower strategy before success, while successful lever trials where no lower strategy was used, were more often recorded in the 18-24 month group. Success without displaying lower strategies implies that subjects are able to recognise that retrieval of the goal is attained by undirectional rotation and that the constituent elements of this skilled action are organised to achieve this end.

The experimental group variation in success on the lever task has already been noted, showing that the cross lever group recorded the highest number of successes and the covered lever group the lowest number.

In addition, the analysis of improvement in solution time between first and last solution showed a significant improvement in the standard lever group performance compared to the cross lever group. An explanation for these results has already been outlined, the demands of the lever task differ and the cross lever, with its subgoal, is not only easier to solve but the improvement between first and last success is less marked since the technique of rotating the lever is not improved upon. In contrast, the standard lever group represents a more difficult task and the means by which solution is achieved, can be refined to a greater extent. It is the scope for improving the technique in rotating the standard lever that explains the significant difference on improved solution time that exists between the standard and cross lever groups.

The performance of the covered lever subjects draws attention to the limitation of viewing this task solely from the perspective of skill attainment. The addition of the cover does not interfere with the basic skill required to solve the task. However, it influences performance to the extent that 12-14 and 14-18 month subjects fail to record any successes and fewer 18-24 month old subjects record successes on this lever compared to the other experimental groups.

The cover did not stop or distract subjects from using the lever but influenced the type of strategy that was used, that is 'low' strategies were most common.

The failure to move beyond these low strategies could be a reflection of the physical restrictions that the cover imposed. For example, the centre board of the standard lever was not available to helping rotation of the lever. This by itself seems to be a poor explanation for the failure of 12-18 month subjects to record any successes on this task.

Koslowski and Bruner (1972) argued that the progression to higher strategies depended upon the subject's level of motivation and the ability to analyse the task.

Richardson (1934) also noted that motivation will influence performance. In her work she found some subjects who recorded one lever success but then failed to repeat it; this was interpreted as reflecting the subject's lack of motivation.

Explaining the results pattern of the covered lever group by arguing that they were less motivated than the other experimental groups implies a bias in the allocation of subjects. Assuming that the subjects were motivated, and their behaviour indicated this, but that this was coupled with a lack of success, it could have led to frustration. It has been demonstrated that frustrated subjects resort to more basic strategies when confronted with a barrier task (Fitzpatrick, 1978) and this may account for the 'low' strategy pattern in this group.

While part of the experimental group variation could be explained by reference to the physical constraints of the covered lever group or the effect of frustration, a third possibility exists. The ability of the child to analyse the task was noted by Koslowski and Bruner (1972) to be an influential factor in progressing to higher strategies. In order to progress, the child must comprehend the relation between its actions and the environment; however, the cover removes vital information. The cover obscures the visual link between the two exposed ends of the lever and it hides the pivotal point of the lever. The visual gaze data showed that covered lever subjects spent less time looking between their hand and object compared to more successful experimental groups.

The loss of information in the covered lever group can be used to explain the experimental group variations in performance by arguing that children in this group had less information about the problem faced. However, the question as to why success was achieved only by the 18-24 month old subjects in the covered lever group must be raised. An explanation based solely on the argument that they were capable of modularising the components acts, seems inadequate given that younger children in other experimental groups demonstrated this ability.

The explanation of results must consider changes that take place in the sescond year that would explain the ability of the 18-24 months to solve this problem, that is to select and apply the correct means for the required end.

Piaget (1953, 1954) has emphasised the cognitive changes associated with the 12-24 month age period and two areas are of particular interest. Firstly, Piaget proposed that the way in which the child explores the environment was marked by the move from primary to tertiary circular reactions and secondly, that the comprehension of detour tasks undergoes a major change in the 12-24 month period.

Koslowski and Bruner (1972) suggest that the child progresses towards higher strategies by interacting with the environment and analaysing the task. However, Piaget would argue that the way the child will approach a specific situation will depend upon the child's level of development.

The fact that the youngest children display significantly more trials that are classified as 'low' strategies and that they have the highest number of strategy I trials reflects the child's application of known means to new situations. Direct pulling is normally a succesful strategy for infants. Therefore it is not surprising to find it applied to the lever task and in previous lever research (Richardson 1934; Koslowski and Bruner, 1972), direct approaches are typical of young infants in manual (Bruner, 1970) and locomotor (Lockman, 1984) detour tasks.

It is only in stage V of the sensorimotor period that infants solve problems that require new approaches. Through tertiary circular reactions, the active trial and error exploration of the environment, solutions are achieved. This is reflected in the analysis of lever task which shows that younger subjects' successes are more likely to be preceeded by lower strategies, indicating a process of experimentation, one effect of which is to increase the time taken for solution and this is supported by the data.

Piaget proposes that it is the stage VI child that invents new means, not by external trial and error but by mental co-ordination of internal representations. Success can be achieved without trial and error although novel situations will require some exploration. In the present study, six cases of success on the first lever trial were recorded without any trial and error; one was recorded in the 14-18 month subject group and the remaining five were recorded in the 18-24 month age group.

From this perspective, the strategies employed on the lever task would reflect the developmental changes which Piaget proposes are typical of the child's exploration of the environment around them. It is this developmental change which accounts for the quantitative and qualitative differences in performance between age groups. In particular, it is the 18-24 month subjects who demonstrate the ability to repeat success on the lever, a criteria which Richardson (1932) and Uzgiris and Hunt (1975) have suggested reflects understanding of the task.

A second measure of understanding, whether or not children with two or more successes used both directions of rotation for success, failed to produce any age effect, indicating that successes in all age groups reflected an awareness that the lever could be rotated in either direction to achieve success.

The second aspect of development in this period concerns detour ability. The lever task can be viewed as a detour (cf Köhler, 1925) and Piaget proposes that the invention of detours is a behaviour associated with stage VI of the sensormotor period. it is at this stage that detours are achieved by previously unseen and unused paths (associativity). Piaget argues that detour ability reflects the ability to represent relations between objects independently of the self and as such is closely linked to the advances in spatial understanding and object concept that are associated with this period.

This view has been challenged by Lockman (1984) who questions the synchrony between spatial understanding and detour behaviour displaying associativity. Lockman failed to find a relationship between stage VI object concept performance and performing detours by previously unseen paths. In fact, associativity was displayed in detour tasks before stage VI object concept performance.

Detour ability has been demonstrated in the latter part of the first year in both manual and locomotor domains (Bruner 1970; Lockman and Ashmead, 1983; Lockman, 1984; McKenzie and

Bigelow, 1986). However, the research on detours has also shown a large variation in performance. McKenzie and Bigelow (1986) propose that the complexity of the task may influence displays of detour ability. For example, Reiser et al (1982) found that it was not until the end of the second year that children could negotiate a maze after seeing the spatial layout.

It can be argued that the lever task is a complex detour problem since it places demands on subjects not found in other tasks, namely, that the object must be moved in the detour and the means of moving the object is by applying force in the direction opposite to that in which the object is moving. Detour tasks traditionally have the object remaining stationary and the subject moving, and while other studies have shown the ability of children to move objects toward themselves (Richardson, 1932; Bates et al 1980) the lever task is unique in requiring children to perform a detour task that violates both of these demonstrated abilities.

It is the combination of the latter two factors which places demands upon the child's understanding of relations between objects and the self and in particular, the ability to represent objects independently of the self. The age pattern in lever performance is therefore reflecting, not only the way in which the child explores the environment, but the child's developing spatial ability and the ability to represent relations between objects and the self. The age pattern of results associated with the covered lever group, where only the 18-24 month subjects succeed, could be reflecting the advanced spatial unerstanding of this age group and the representational ability that Piaget associates with stage VI of the sensorimotor period.

Piaget has made some reference to performance on lever tasks (Piaget, 1978). In a detailed study of children's comprehension of levers, subjects were required to move objects by means of levers. The levers varied in terms of complexity and the children were also required to move the pivot screws and explain or anticipate the effect that this would have.

One of the simplest levers used (lever IV) consisted of one strut with a central pivot, the same basic design as the standard lever. The subjects were required to rotate one end of the lever so that the other end moved an object which was placed beside it. Two major distinctions exist between this and the standard lever. Firstly, the starting position of the lever was the horizontal plane in relation to subjects' body and secondly, the object was placed beside rather than upon the lever.

It was not until 5-7 years that the rotational properties and the relation between hand and lever movement were understood. The present study shows children between 12-24 months solving lever tasks while the above study shows 4-5 year olds experiencing difficulty with this task. There are variations between the tasks and the means of assessment varied in that in Piaget's study, children had to verbally explain their solutions. However, it is suggested that the difficulty of the task was not only in verbally expressing their actions, but the manipulation itself was problematic.

This pattern of repetition is a common one in development and Piaget would refer to it as an instance of vertical decalage (Flavell, 1963). However, the idea of repetition in development has been used to offer an alternative, cognitively based, explanation of the lever task performance.

Bower (1979a) has suggested that success on the lever task is related to the comprehension of the INRC group. The INRC group consists of four transformations, identity (I), negation (N), reciprocal (R) and correlative (C), and is more commonly associated with formal operational thought (Inhelder and Piaget, 1958). Piaget proposes that this cognitive structure is reflected in the adolescents' performance on specific tasks. For example, the see-saw balance task (Inhelder and Piaget, 1958), which demonstrates the negation-reciprocal strategy in problem solving.

The INRC group is closely linked with formal operations since it is argued that this structure emerges from manipulation of the 16 binary propositions (Flavell, 1963). In addition, Flavell (1963) has proposed that the emergence of the INRC group requires a distinction to be made between the 'logical' and 'physical' INRC groups. The former is a sub-achievement of manipulating and inter-relating the 16 binary propositions while the latter reflects the application of the 'logical' INRC to physical problems. For a more detailed explanation of the INRC group and formal operational thought, see Inhelder and Piaget (1958), Flavell (1963), Modgil and Modgil (1976) and Seggie (1978). Research and criticisms of this stage are found in Lovell (1961), Neimark (1970, 1975a, 1975b), Dulit, (1972), Ennis, (1976), Danner and Day, (1977), and Lunzer, (1979). For Bower, the solution of the lever task reflects an understanding of the INRC group which infants demonstrate and which can be interpreted as a precursor to the INRC group associated with adolescence. This is one instance of repetition in development, repetition both literal and formal, which Bower argues are found in behaviours in the physical and cognitive domains (Bower 1974b, 1976, 1979b).

The data showing that older subjects were more successful would be accounted for by their comprehension of the INRC group properties of the task. For Bower, the difficulty of the task is in applying the abstract structure (INRC) to a specific task. The pattern of results showing younger subjects to have fewer solutions, fewer repeated successes and a reliance upon unprofitable strategies are all related to the inability of these children to discard unsuccessful strategies and realise the INRC structure of the situation.

The cross lever group's superior performance can be interpreted by suggesting that the lever structure enhanced the likelihood of subjects becoming aware of the applicability of the INRC structure to the task. In contrast, the covered lever impaired performance by decreasing the subject's ability to comprehend the relevance of the abstract structure to the task. Only the 18-24 month subjects were capable of understanding the task. Bower argues that it is at 18 months and beyond that the task is solved "smoothly ... without trial and error" (Bower 1979a). It will be recalled that only five first trial successes were recorded without any trial and error behaviour in the 18-24 month age range.

While Bower's explanation can be used to explain the age and experimental group results, it does raise other issues. It has already been noted that Piaget viewed the INRC group as a sub-achievement of the 16 binary operations. Leaving aside the validity of this claim, it provides an explanation for the source of this four group. For Bower, the child "must schematize the abstract structure he already has in his head ..." (Bower, 1979a). This draws attention to the contrast between Piaget and Bower.

Piaget views development as a process of conflict where infants acquire S-R solutions to specific situations and if the means to solution fails to succeed when applied to another task, the conflict created will lead to the modification or creation of new schemes that will control behaviour. The level of abstraction that is achieved reflects the experience of the infant, the wider the experience the greater the level of abstraction. Piaget considers that the abstract rules are of necessity formed from the specific experience of the infant.

Bower proposes the reverse of this view, the abstract scheme comes first. The infant is either born with, or quickly acquires, an abstract framework, and this then allows the infant to form S-R solutions to specific tasks. The difficulty faced by the infants on the lever task is in releasing the applicability of the abstract structure (INRC group) to the task. Repetitions in development are viewed as the re-application of the abstract rule to a new situation; in the case of conservation the behavioural conservation of infants precede the verbal conservation of weight (Mounoud and Bower, 1974).

Two issues are of importance to Bower's arguments. Firstly, to demonstrate high level abilities in infants and secondly, to show the link between successive repetitions of behaviours. In both areas, further research is needed. Bower has argued that very young infants display in their behaviour, high levels of cognitive functioning. One example is that of invitation (Meltzoff and Moore, 1977) where neonates have shown the ability to imitate adult facial gestures. While supporting Bower's argument, the data has been questioned and an explanation of the behaviour is still sought (Hayes and Watson 1981; Meltzoff and Moore, 1983a and 1983b).

Bower (1977, 1979a) has also argued that the young infant is aware of object permanence. However, Schuberth (1983) has suggested that the data used by Bower is open to question.

The second important area for Bower's theory is related to the repetition in development and the ability to demonstrate a link betwen successive repetitions. The most successful paradigm for investigating this relationship is the acceleration study (Bower, 1974b). This approach was adopted in an investigation of infants' walking. Neonates 6-days-old display a form of walking which is different from mature walking but consists of the same sequential organisation in time. Bower (1976) argued that if the neonate practises walking at this early phase, acceleration will take place with respect to walking in the later period and research has supported this argument, indicating a causal link between the two phases (Zelazo, Zelazo and Kolb, 1972).

Bower (1974b, 1976) has proposed that repetitions can be observed in a number of areas of development. For example, visually guided reaching, auditory manual co-ordination, as well as repetitions in a number of cognitive areas. This latter group includes the object concept, conservation of weight and the INRC group.

As previously noted, Schuberth (1983) has questioned much of the data concerning the object concept drawing attention to methodological issues and alternative interpretations. With respect to the repetitions of weight conservation and the INRC group, there is relatively little data. Mounoud and Bower (1974) demonstrated the behavioural conservation of weight in infants, proposing that between 6 and 18 months infants develop a sensormotor form of conservation, at 9.5 months infants use the appearance of objects to determine their response. Mounoud and Hauert (1977), using a similar substitution paradigm, found that infants 11-14 months old did not display behaviour conservation. This result raises questions about the developmental pattern of behavioural conservation of weight between 9-18 months and may question the underlying basis on which infants are making their judgements.

In the case of the INRC group, the only reference to repetition of this cognitive structure is Bower's (1979a) proposal that Koslowski and Bruner's (1972) lever task demonstrates the infant's understanding of this four group.

The difficulty in assessing these cognitive repetitions reflects the lack of research which has adopted the acceleration paradigm outlined by Bower. One obvious problem with respect to the INRC group is the time period that separates the two examples of this behaviour. An alternative approach would compare the error patterns and process of acquisition of the INRC group in both cases to ascertain the level of relationship between them; to date this has not been done.

From Piaget's (1978) research, it appears that verbal comprehension and, it is intimated, behavioural success on lever tasks, proves difficult for 4-year-old children. Given the similarity between one of the lever tasks and the present standard lever, the question of whether or not this constitutes a repetition should also be considered.

Piaget and Bower have provided explanations of lever task performance which emphasise the cognitive aspects. Richardson (1934) suggested that the role of maturation and experience should also be considered.

The role of experience has already been mentioned as a potential explanation for the sex differences that were found. However, the question of maturation has not been raised.

Richardson (1934) noted that lever performance improved between 40-44 weeks of age and argued that this was partly a reflection of maturation, specifically physical maturation of subjects' motor skills. The physical immaturity referred to was believed to limit the child's ability to grasp and manipulate the lever through the bars of a cot. In the present study, the youngest subjects were 12 months old and therefore were beyond the age that Richardson was concerned with.

There is some evidence that neural maturation plays a role in the development of detour ability and is also related to changes in spatial knowledge in the second year. Moll and Kuypers (1977) demonstrated that ablated monkeys had difficulty in performing on a visually guided reaching task that involved a detour. Rieser and Heiman (1982) have noted that neural maturation is a possible explanation for the change from egocentric to self-reference spatial knowledge which they believe is found in the second year. The role of experience is raised at a more general level since Rieser and Heiman suggest that the increased locomotor experience of the child can also play a role in this qualitative change in spatial knowledge.

Maturation and experience must therefore be considered as potential explanations for lever task performance.

<u>Summary</u>

The analysis of the data has shown that quantitative and qualitative differences exist between the age groups tested. In addition, the design of the lever and the sex of the subject were found to be influential variables when assessing performance.

A number of alternative explanations were considered. It was proposed that viewing performance as the attainment of a skill would explain the results. However, Koslowski and Bruner's (1972) emphasis on the child's ability to analyse the task and the performance of the covered lever group suggests that the child's cognitive abilities are of importance in predicting performance.

Piaget and Bower present opposing views regarding the process of cognitive development, although both approaches were capable of explaining the data. Bower's position is difficult to evaluate with respect to lever performance and is ultimately tied to an evaluation of his theory of repetitions in development. The Piagetian position provides some grounds for further examination with the emphasis on developmental synchrony; childrens' performance on related tasks should reflect a similar level of ability. It is this latter approach which is developed in later chapters.

It must be noted that at the present time, the role of maturation and experience upon lever task performance cannot be assessed.

CHAPTER 4

WIRE TASK - RESULTS AND DISCUSSION

(i) RESULTS

The results from this task will be presented in three sections:

(a) Wire task performance and the wire categories.

(b) Solution times for wire tasks.

(c) Wire task performance and behaviour categories.

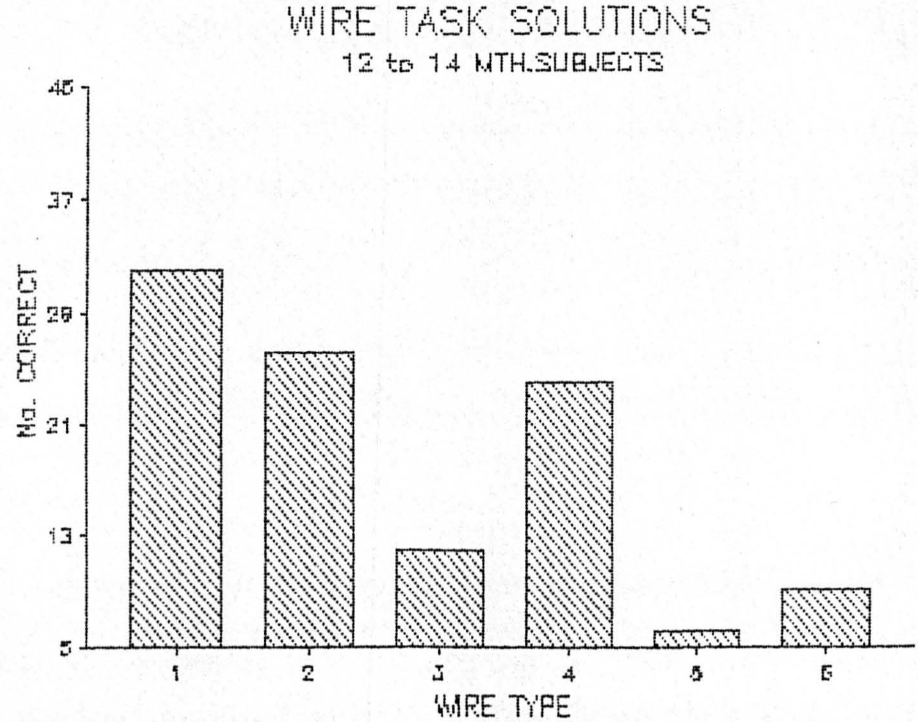
(a) Wire Task Performance and the Wire Categories

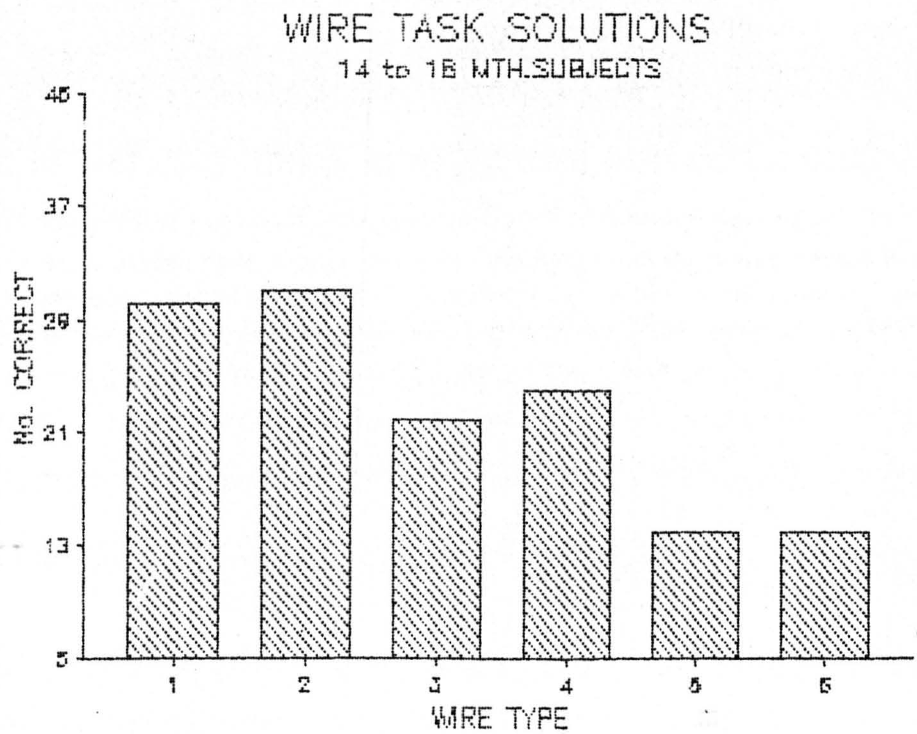
The Methods Chapter drew attention to the sub-categories that were used within the wire tasks, namely, the degree of difficulty, the direction of the 'open' wire end in relation to the subject and left or right presentation. Table 4a summarises this information.

Table 4a - Wire Task Categories

Wire	Degree of Difficulty	Direction of 'open' wire end	Left/Right Presentation
1	Easy	Toward	Left
2	Easy	Away	Right
3	Medium	Toward	Right
4	Medium	Away	Left
5	Hard	Away	Right
6	Hard	Toward	Left

Figure 4a overleaf


WIRE TASK SOLUTIONS
12 to 14 MTH.SUBJECTS
No. CORRECT
45
37
29
21
13
5
1
2
3
4
5
6
WIRE TYPE


WIRE TASK SOLUTIONS
14 to 16 MTH.SUBJECTS
No. CORRECT
45
37
29
21
13
5
1
2
3
4
5
6
WIRE TYPE

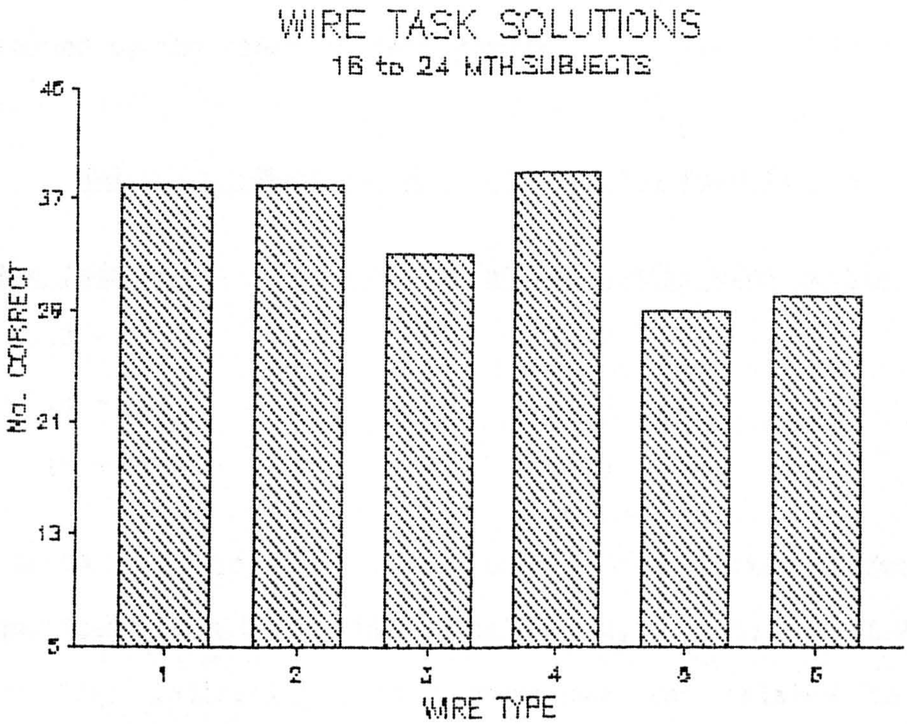


Figure 4a - Number of successes on each wire type for the three age groups.

An analysis of variance, with factors age, experimental group and sex, was carried out on the number of successful trials achieved per subject. The analysis produced a significant age effect (df, 2, 117; $F = 25.22$; $p < 0.0001$) with no notable experimental group or sex effects. Figure 4a and Table 4b indicate that a higher number of successful trials was obtained by the older subject groups.

Table 4b - Mean Number of Successful Wire Trials

Age (months)	Mean Number of Successful Wire Trials
12 - 14	2.42
14 - 18	3.00
18 - 24	4.60

An ANOVA with wire type as a within subject factor produced a significant result for this variable (df, 5, 585; $F = 21.26$; $p < 0.0001$) indicating that performance was related to the design of the wires. In addition, a trial and age interaction was found (df, 10, 585; $F = 1.86$; $p < 0.05$) indicating that some aspect of the wire task, e.g. degree of difficulty, may have influenced performance in the different age groups.

The corollary of the wire task success pattern is that younger subjects produced more errors than their older counterparts. Failure on the wire task was categorised as either 'failed try', where some attempt had been made to remove the lure, and 'failed' where no attempt was made within the allocated time period.

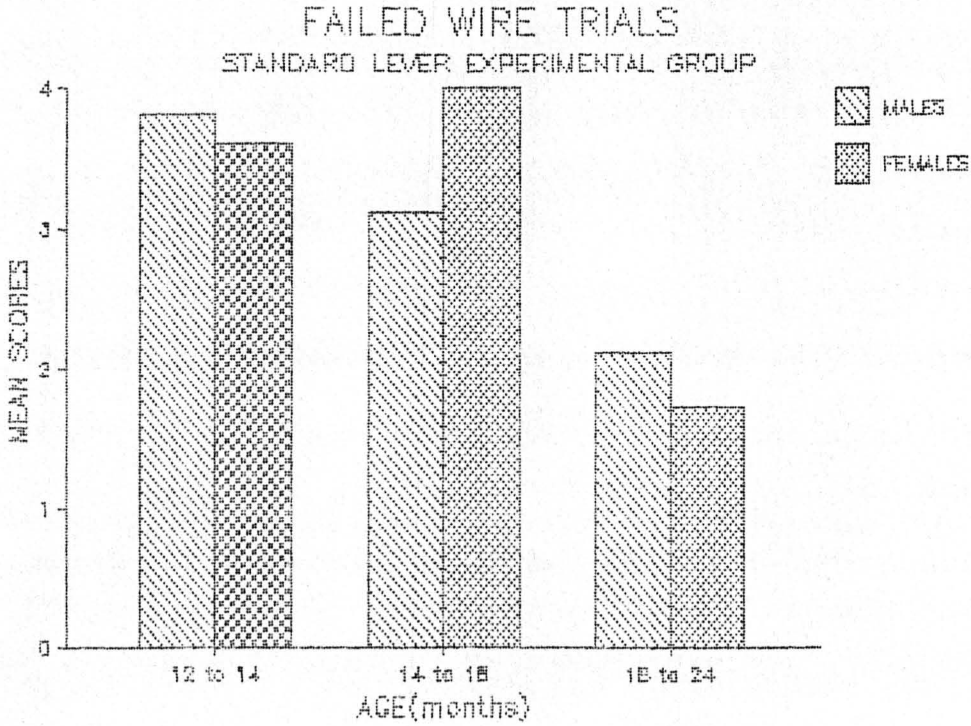
Analysis of variance of the total number of failed trials (i.e. 'failed try' plus 'failed'), 'failed try' and 'failed' trials was carried out with age, experimental group and sex as between subject factors. In all three ANOVAs the only significant result to emerge indicated an age effect on errors on this task.

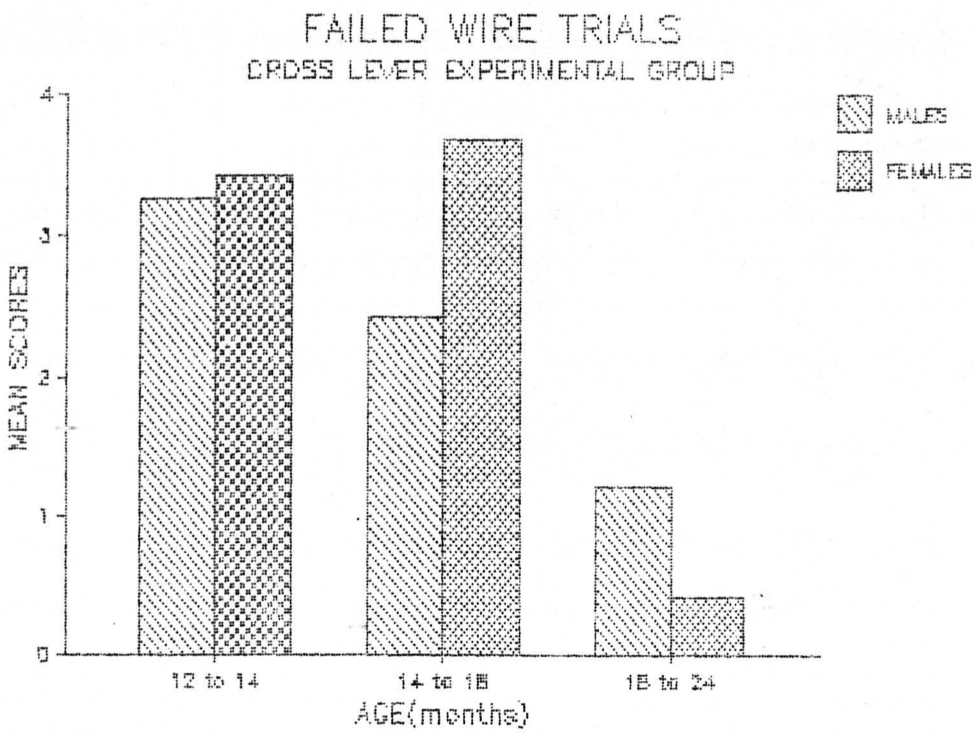
The analysis of total failed trials produced a significant age effect (df, 2, 117; $F = 25.22$; $p < 0.0001$) (Figure 4b) as did the analysis of 'failed try' errors (df, 2, 117; $F = 22.40$; $p < 0.0001$) and 'failed' errors (df, 2, 117; $F = 4.25$; $p < 0.05$). As Table 4c illustrates, in all of these cases a higher mean error score is attained by the youngest age group.

<u>Table 4c - Mean Number of Errors on Wire Tasks</u>

Age (Months)	Wire Task Mean Errors		
	Failed Tasks (Failed Tried and Failed)	Failed Try	Failed
12 - 14	3.58	2.91	0.67
14 - 18	3.00	2.47	0.53
18 - 24	1.40	1.20	0.20

Figure 4b overleaf


FAILED WIRE TRIALS
STANDARD LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
0
1
2
3
4
12 to 14
14 to 18
18 to 24
AGE(months)


FAILED WIRE TRIALS
CROSS LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
0
1
2
3
4
12 to 14
14 to 18
18 to 24
AGE(months)

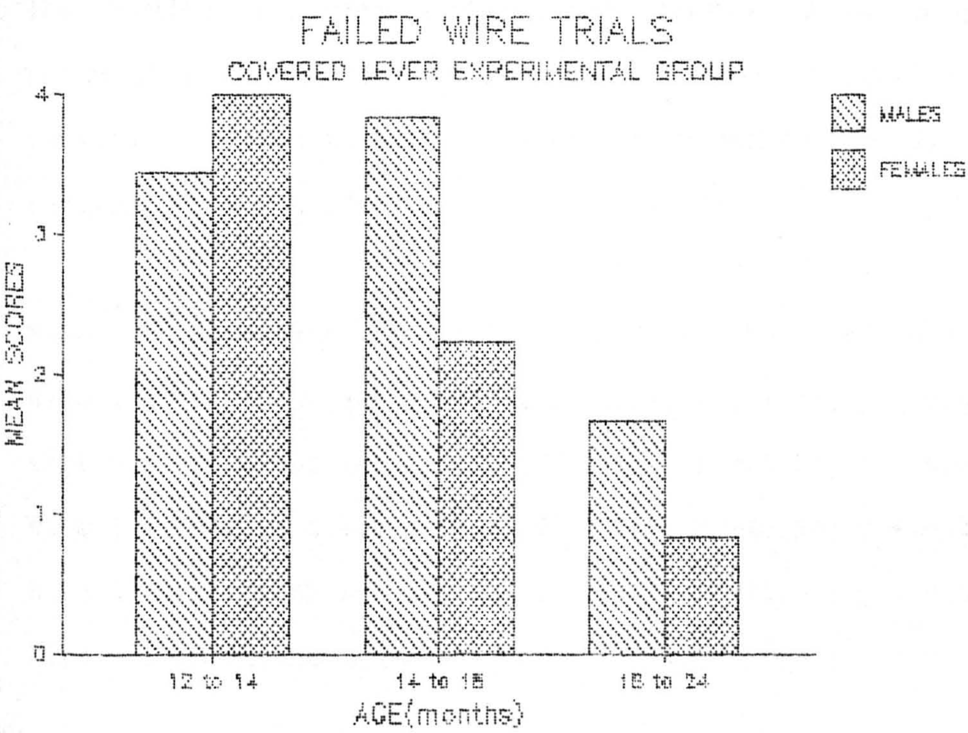


Figure 4b - Failed wire trials (mean scores)

Given the previously noted trial and age interaction that resulted from a repeated measure ANOVA of wire type performance, an assessment of performance on each individual wire was required. For all six wire tasks an ANOVA was carried out on successful performance, with age, experimental group and sex as between subject factors.

The results from this analysis for wires 2, 3, 4, 5 and 6 produced a significant effect for age. Wire 1 provided the exception to this pattern since no age effect emerged from the analysis. The ANOVA results for age were;

Wire 1 No significant age effect (df,2,117; $F = 1.87$; $p > 0.1$)
Wire 2 Significant age effect (df,2,117; $F = 4.31$; $p < 0.05$)
Wire 3 Significant age effect (df,2,117; $F = 11.77$; $p < 0.0001$)
Wire 4 Significant age effect (df,2,117; $F = 10.23$; $p < 0.0001$)
Wire 5 Significant age effect (df,2,117; $F = 16.57$; $p < 0.0001$)
Wire 6 Significant age effect (df,2,117; $F = 14.20$; $p < 0.0001$)

In all of the significant results the pattern of mean scores indicates that 18-24 month subjects' performance was superior to that of the younger subjects. This distinction was not always maintained between the 12-14 and 14-18 month old subjects. For example, on wire 1, the 12-14 month mean performance is superior to that of the 14-18 month group. Table 4d provides a summary of the successful performance on each wire attained by each of the age groups.

Table 4d - Mean Success on Each Wire Task

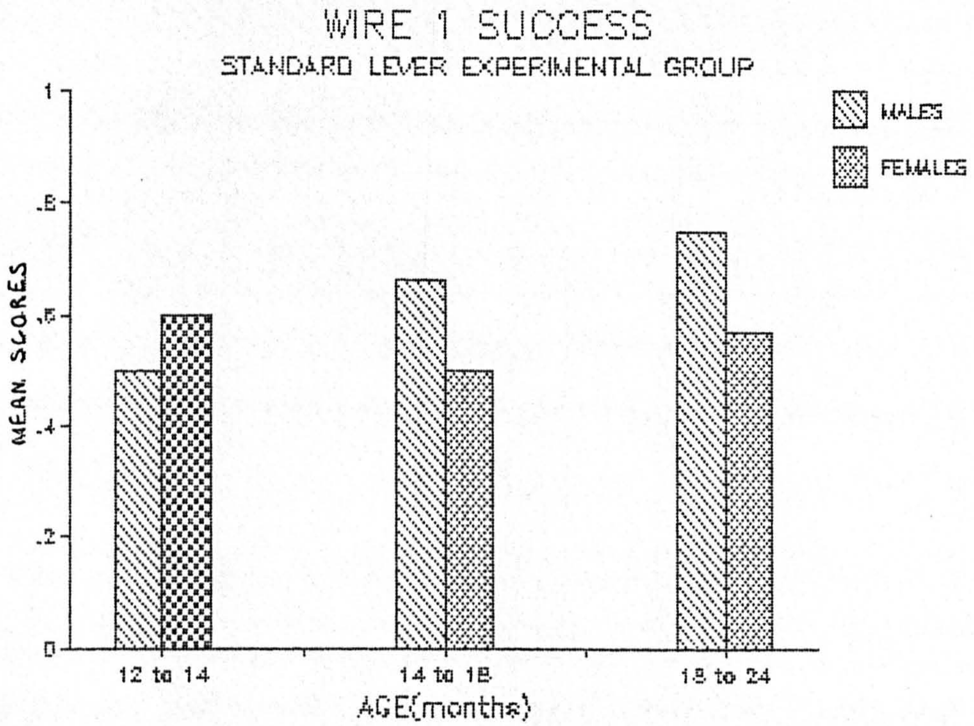
Age (months)	Wire Task Mean Success on Each Wire					
	W1	W2	W3	W4	W5	W6
12 - 14	0.71	0.58	0.27	0.53	0.13	0.20
14 - 18	0.67	0.69	0.49	0.53	0.31	0.31
18 - 24	0.84	0.84	0.73	0.87	0.64	0.67

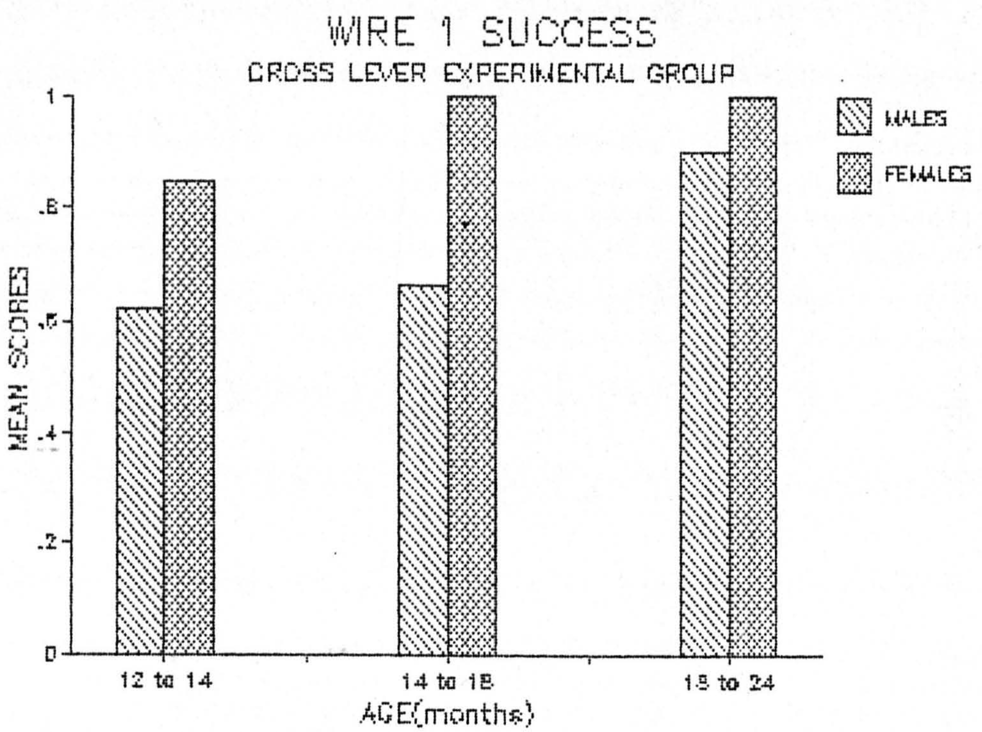
In addition to the age effects that emerged from this analysis, two wire tasks, wire 1 and wire 4, produced significant experimental group effects. The results from wire 1 (df,2,117; $F = 3.85$; $p < 0.05$) indicates that the standard lever group achieved fewer successes on wire 1 than either the cross or covered lever experimental groups. This pattern was repeated on wire 4 where the significant experimental group effect (df,2,117; $F = 3.93$, $p < 0.05$) drew attention to the lower success rate on this task of the standard lever group.

Figures 4c, 4d, 4e, 4f, 4g and 4h represent the performance on each of the wire tasks and in the case of wires 1 and 4 draws attention to the experimental group variation in performance.

These figures highlight the amount of overlap that appears to exist between the performance of the 12-14 and 14-18 month subjects. In a number of instances, the performance of the 12-14 month subjects is superior to that of the 14-18 month

Figure 4c overleaf


WIRE 1 SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE(months)


WIRE 1 SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE(months)

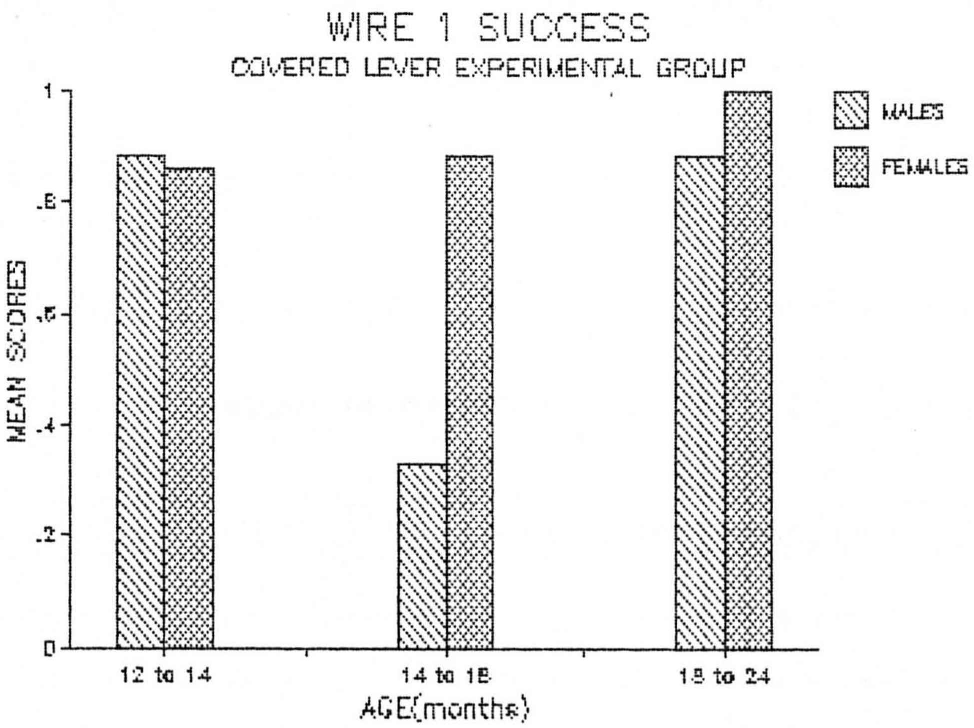
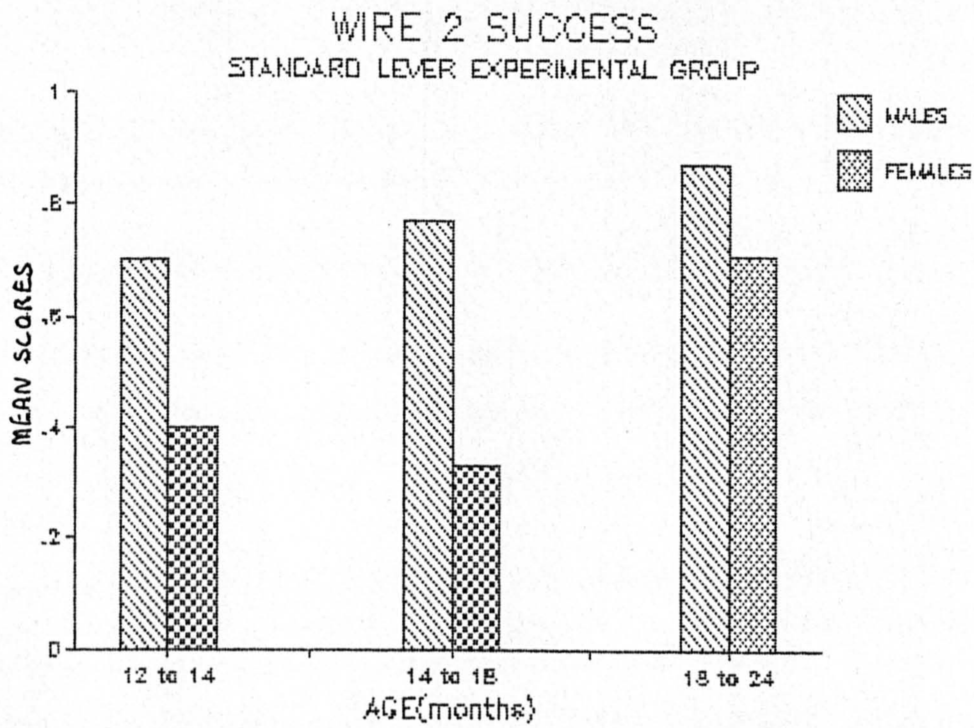
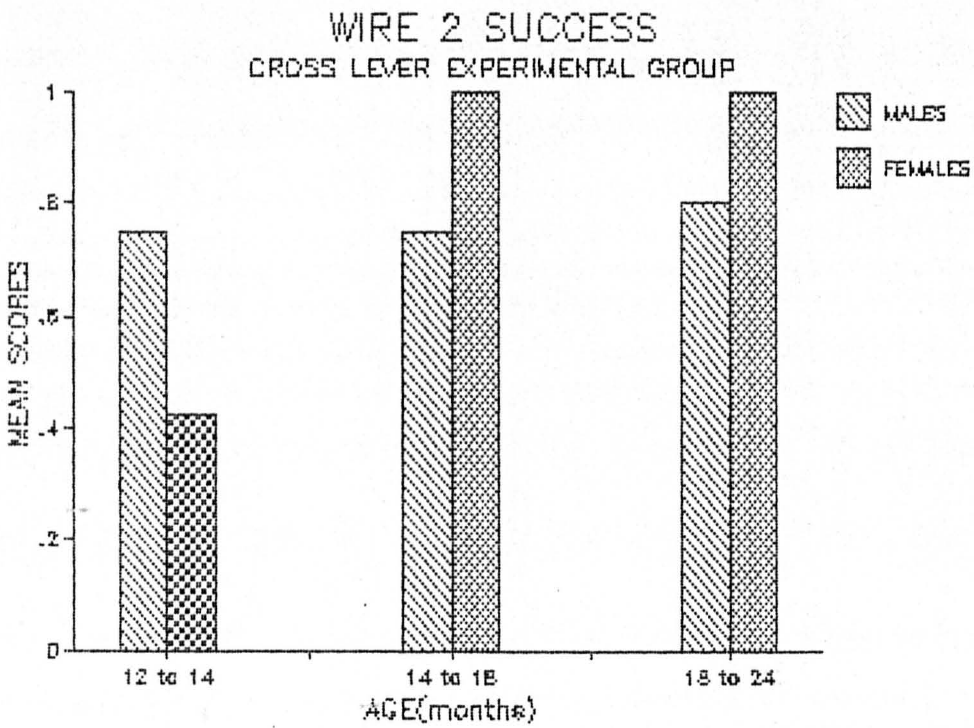


Figure 4c - Success on Wire 1 (mean scores)

Figure 4d overleaf


WIRE 2 SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE(months)
MALES
FEMALES


WIRE 2 SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE(months)
MALES
FEMALES

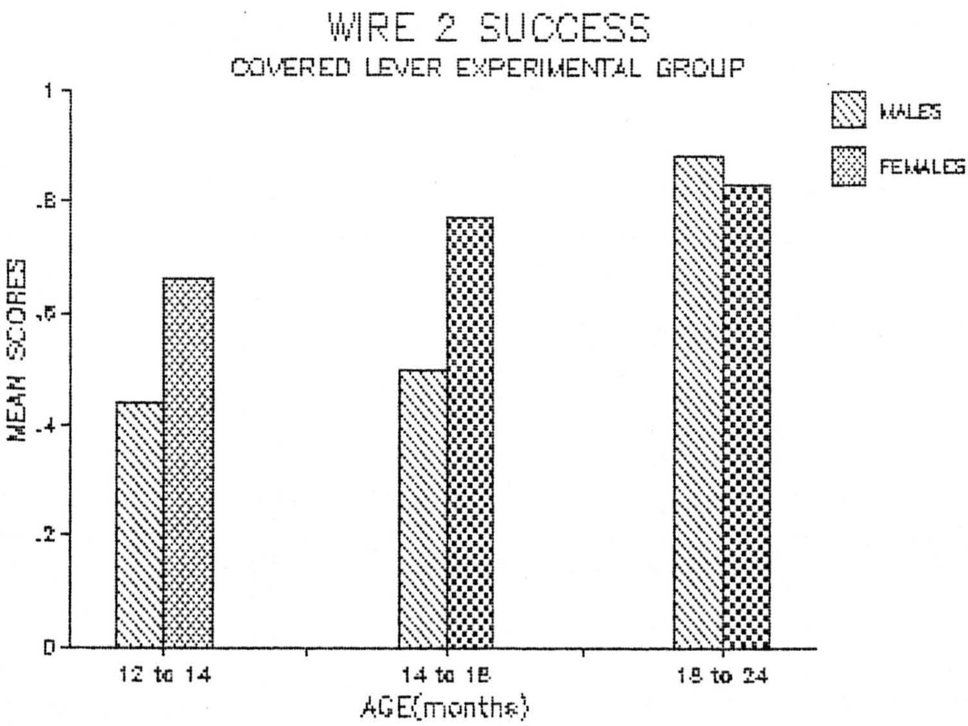
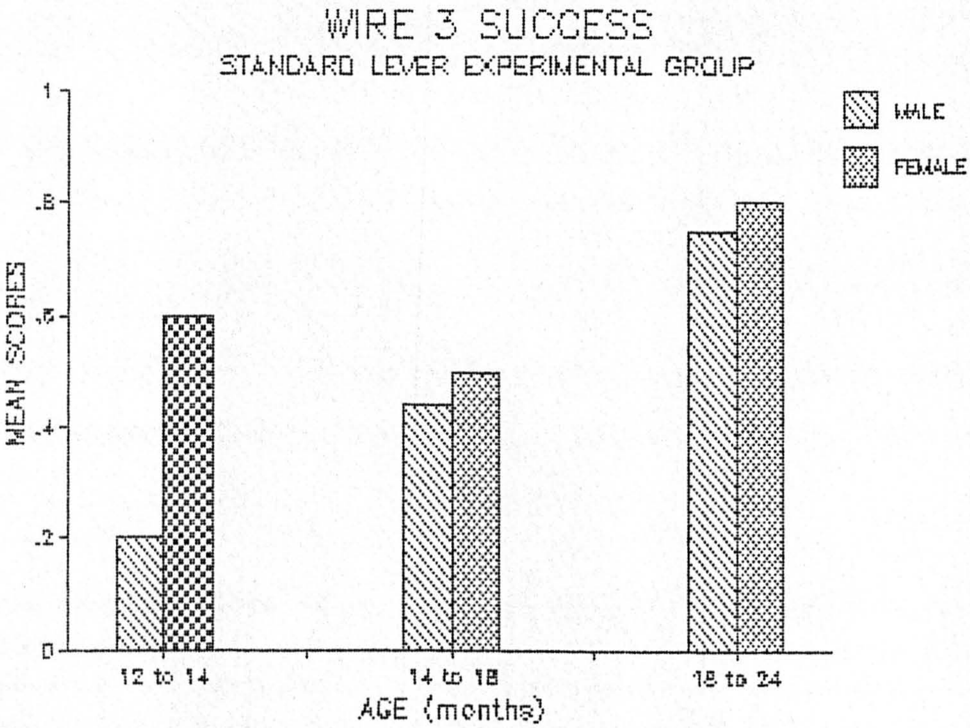
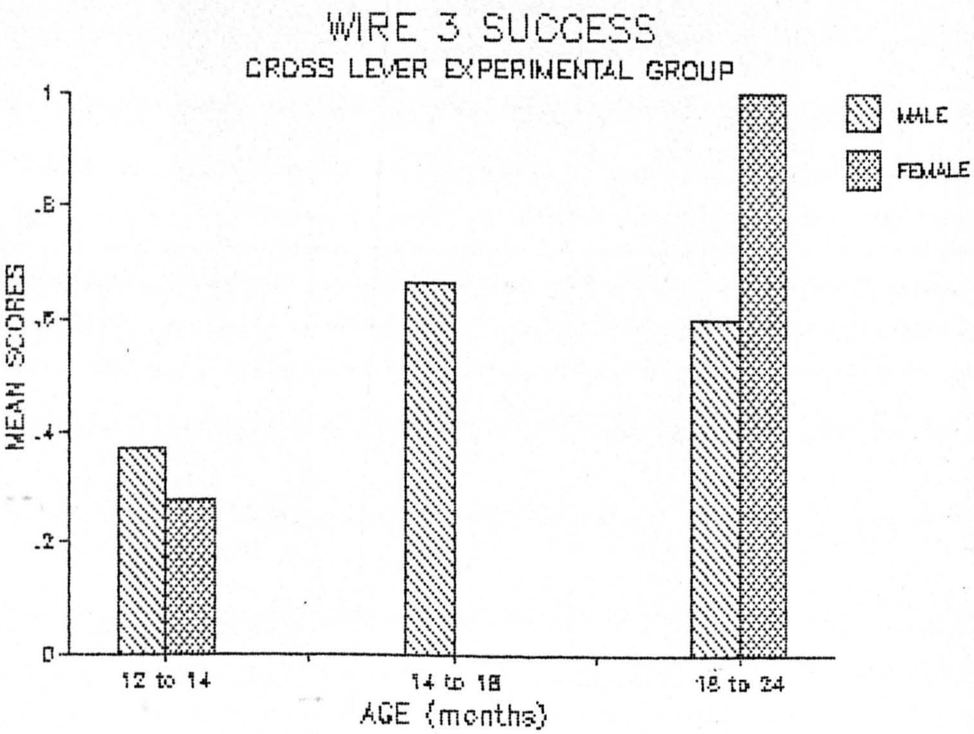


Figure 4d - Success on Wire 2 (mean scores)

Figure 4e overleaf



WIRE 3 SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MALE
FEMALE
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE (months)



WIRE 3 SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MALE
FEMALE
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE (months)

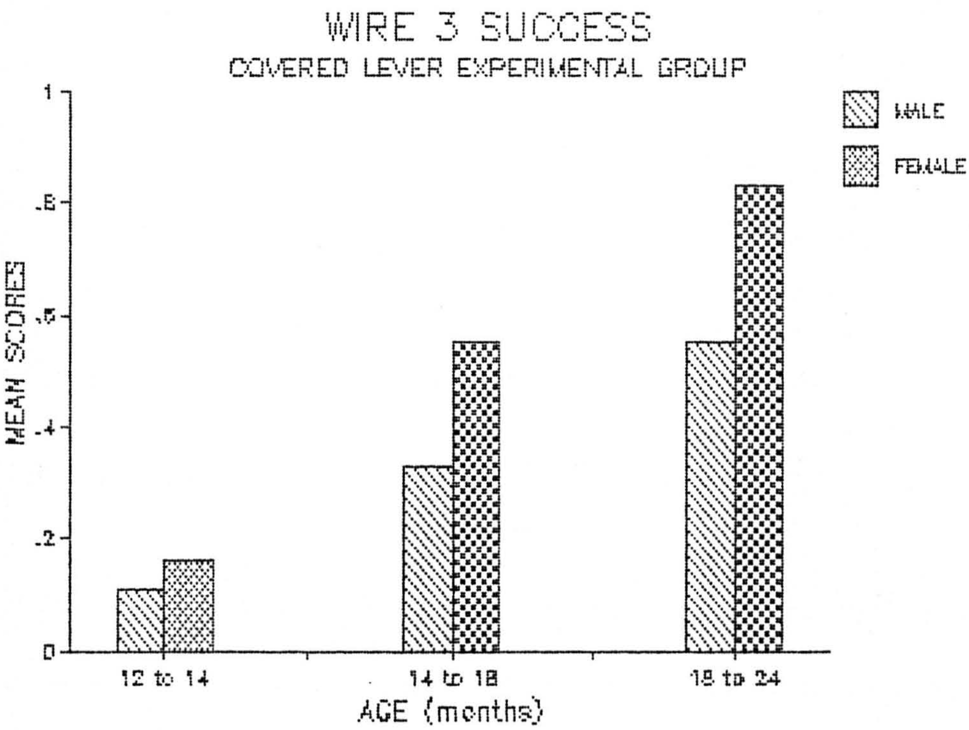
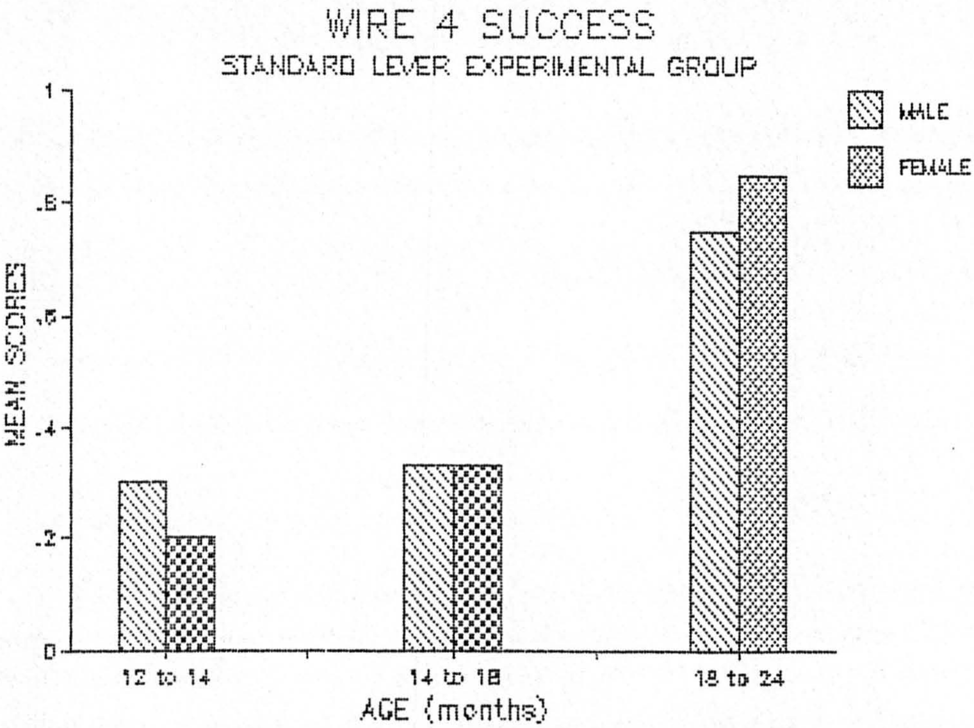
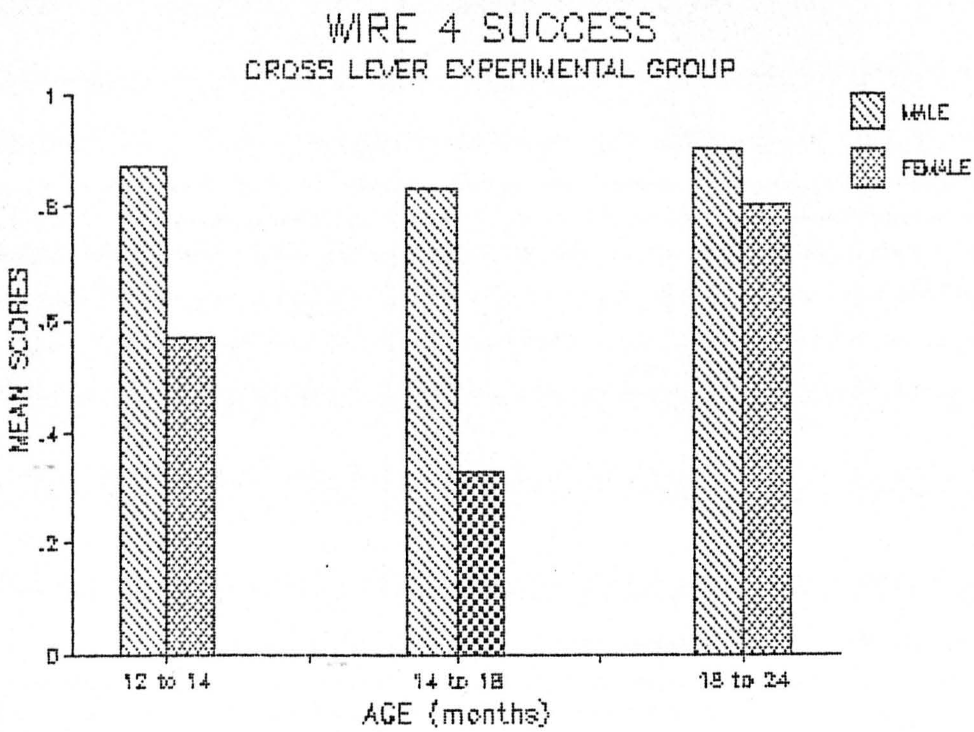


Figure 4e - Success on Wire 3 (mean scores)

Figure 4f overleaf


WIRE 4 SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.8
.6
.4
.2
0
MALE
FEMALE
12 to 14
14 to 18
18 to 24
AGE (months)


WIRE 4 SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.8
.6
.4
.2
0
MALE
FEMALE
12 to 14
14 to 18
18 to 24
AGE (months)

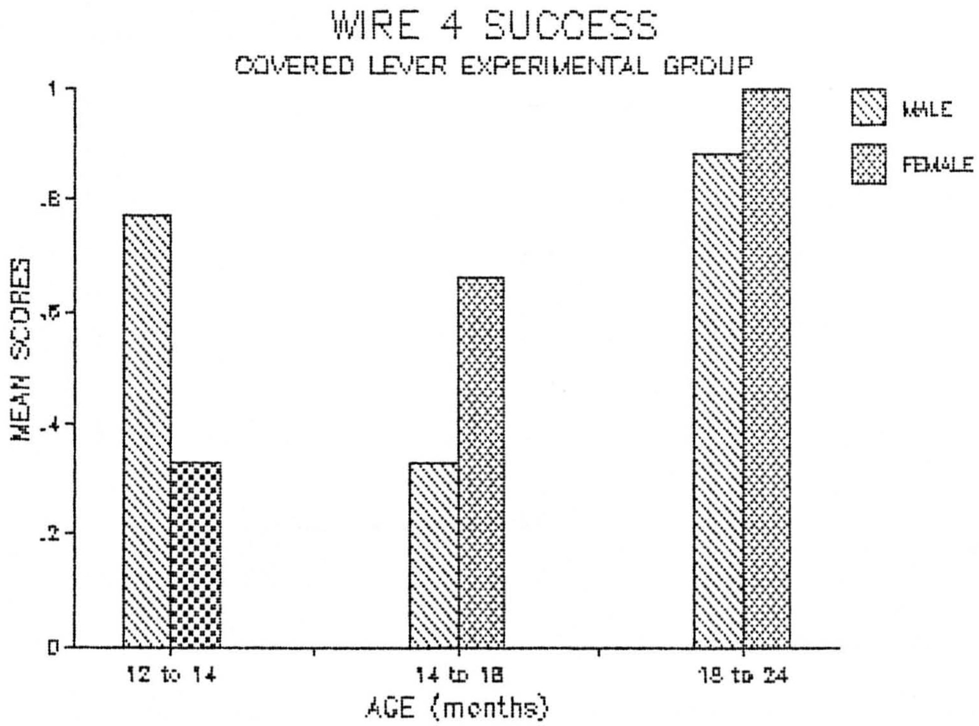
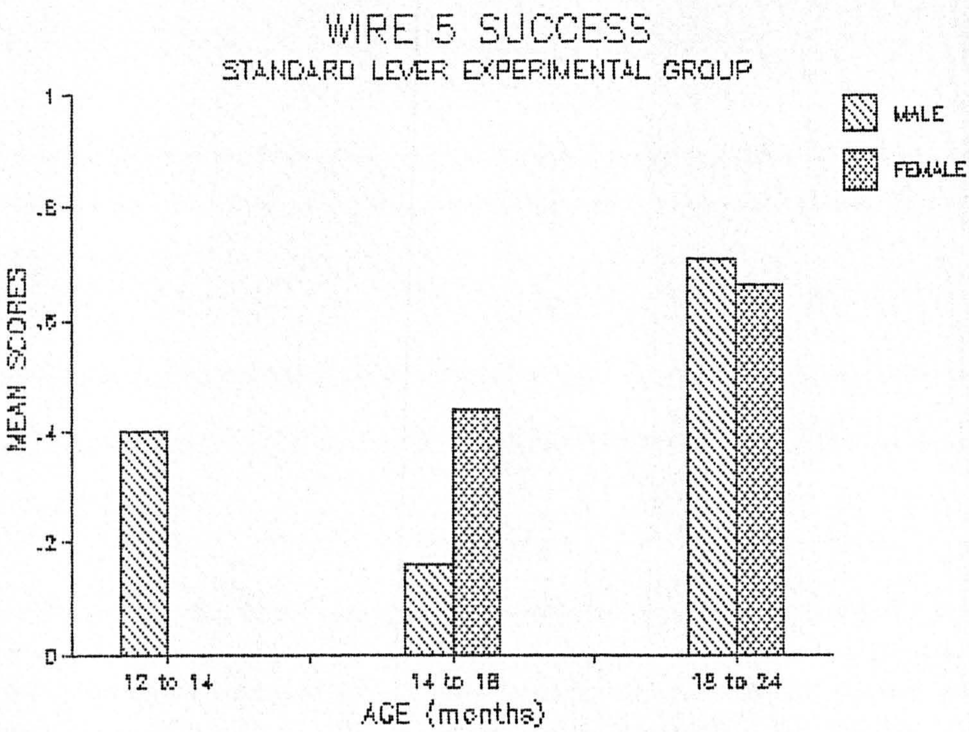
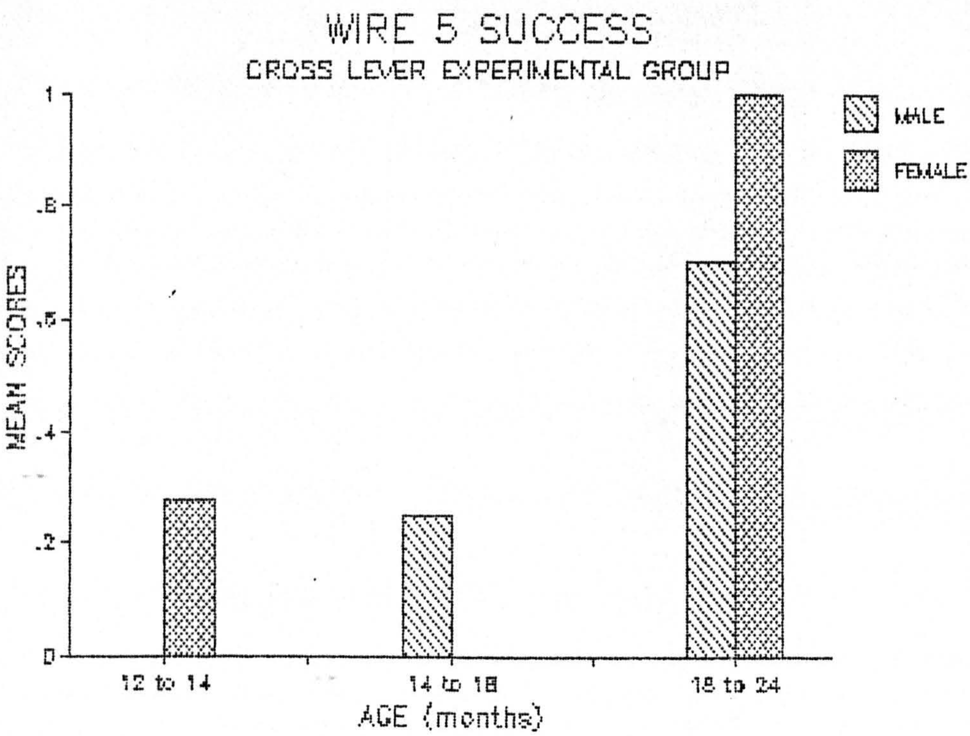


Figure 4f - Success on Wire 4 (mean scores)

Figure 4g overleaf


WIRE 5 SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MALE
FEMALE
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE (months)


WIRE 5 SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MALE
FEMALE
MEAN SCORES
1
.8
.6
.4
.2
0
12 to 14
14 to 18
18 to 24
AGE (months)

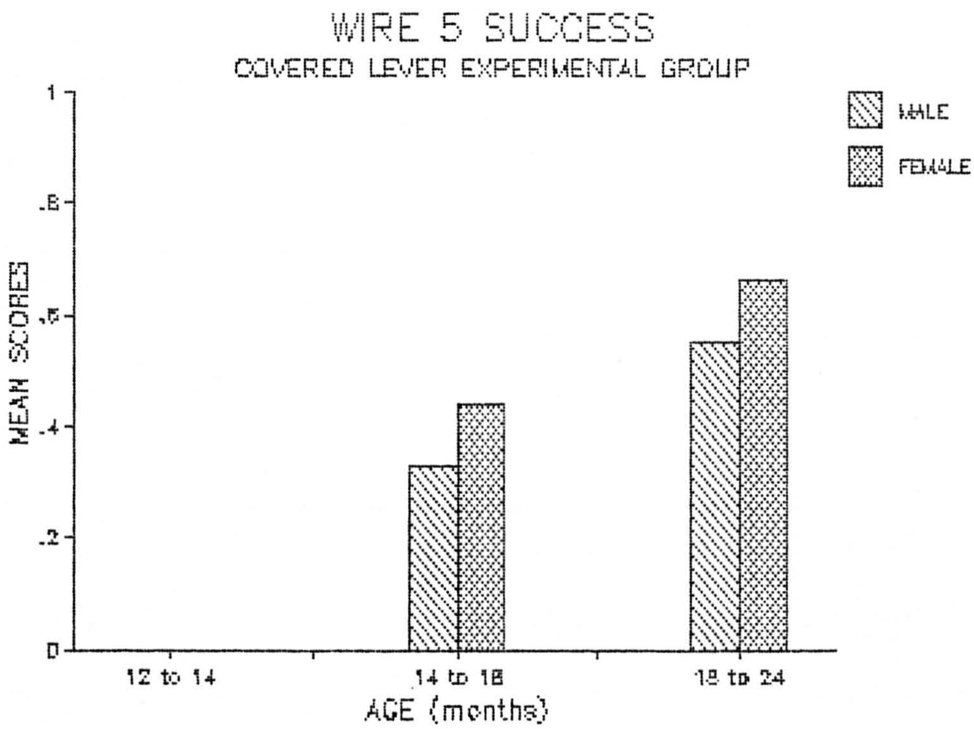
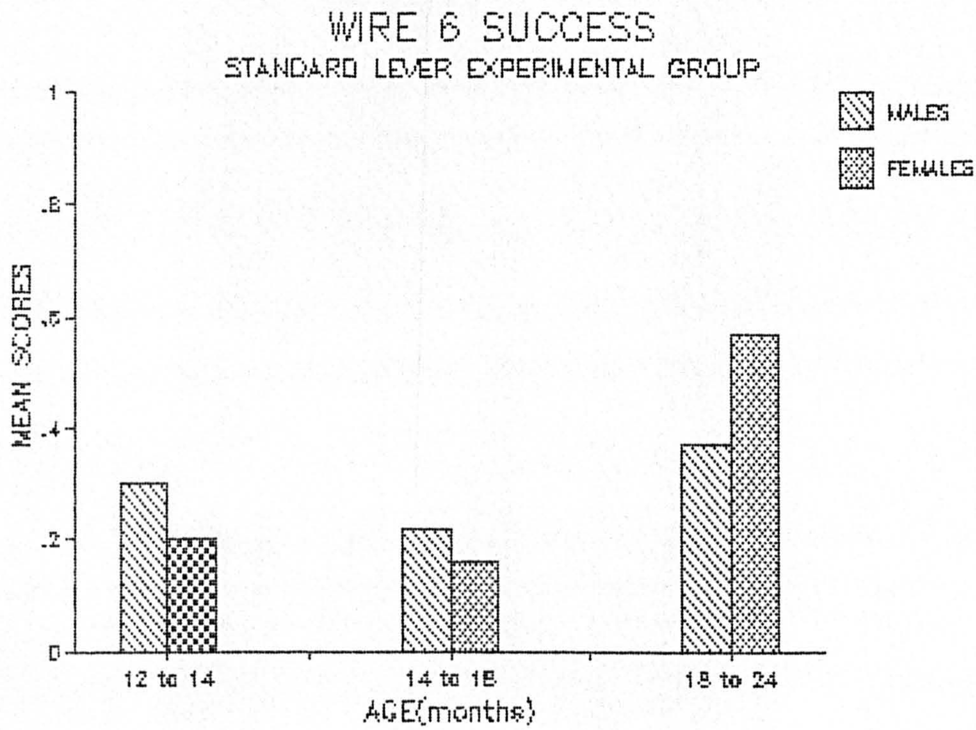
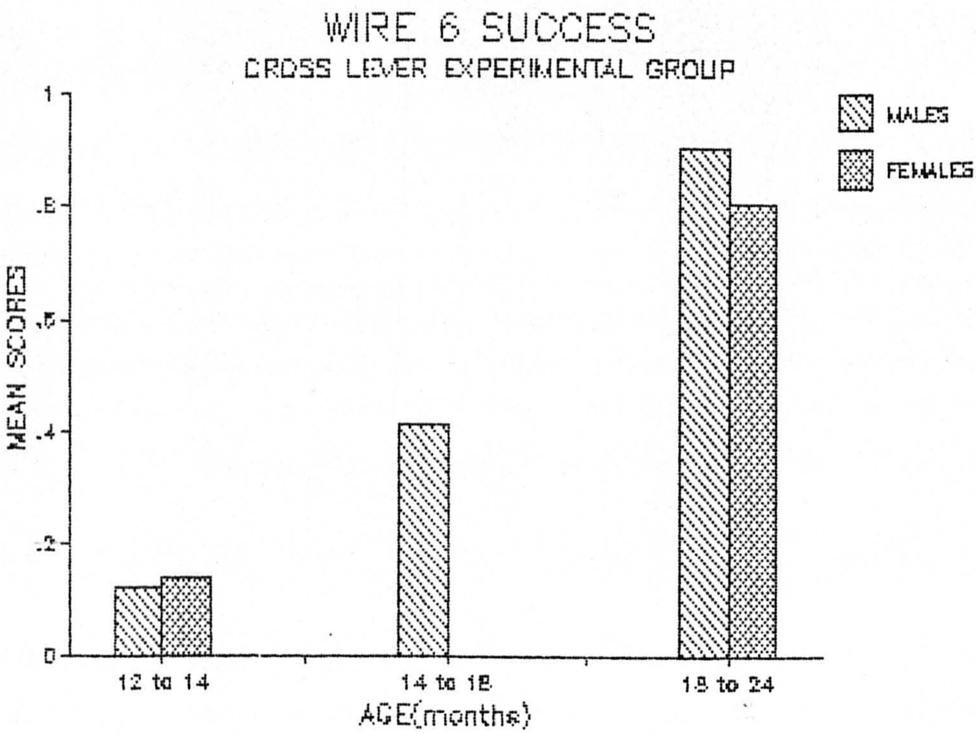


Figure 4g - Success on Wire 5 (mean scores)

Figure 4h overleaf


WIRE 6 SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.8
.6
.4
.2
0
MALES
FEMALES
12 to 14
14 to 18
18 to 24
AGE(months)


WIRE 6 SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MEAN SCORES
1
.8
.6
.4
.2
0
MALES
FEMALES
12 to 14
14 to 18
18 to 24
AGE(months)

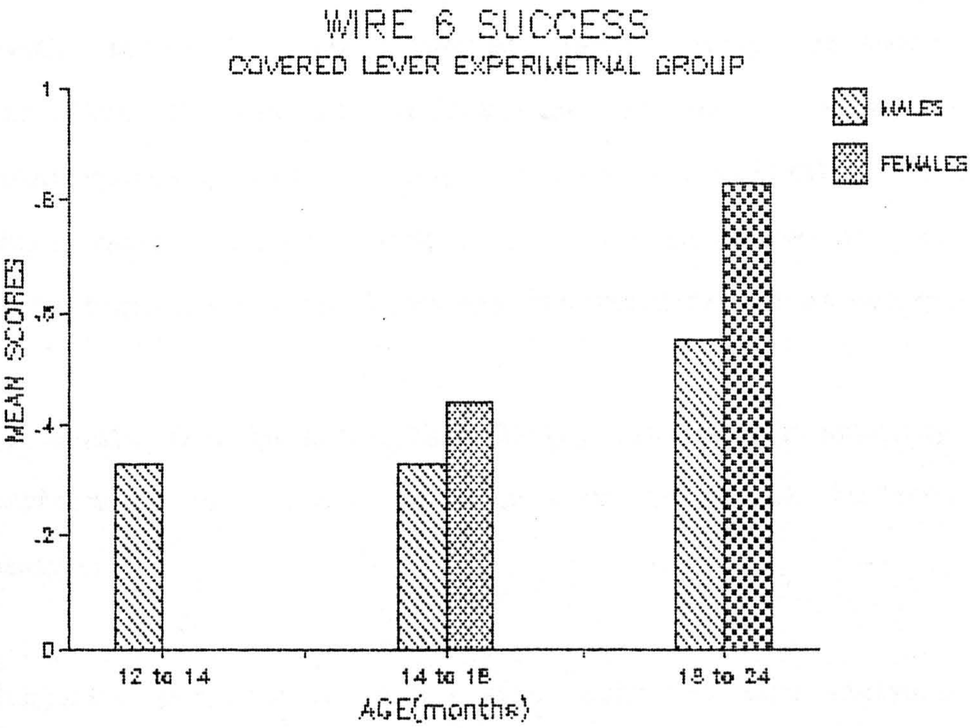


Figure 4h - Success on Wire 6 (mean scores) age group and since this runs counter to the general age trend, demands closer inspection.

Analysis (t-test) of all of these instances of overlap between the 12-14 month and 14-18 month subjects, where the younger subjects' performance appeared superior produced only one significant result and this was on wire 1 where the 12-14 month males in the covered lever group produced a significantly superior performance to their 14-18 month counterparts [$t(13) = 2.55$; $p < 0.05$, two tailed]. In all other cases, including wire 5 where a high degree of overlap in performance was found, no significant differences emerged.

It should also be noted that during this closer scrutiny of performance on wires 1 to 6 no significant sex differences emerged.

Subjects' performance on the wire tasks was also analysed by using the categories outlined in the Methods Section and repeated at the beginning of this section.

Analysis of performance based on degree of difficulty of the wires, that is, 'easy', 'medium' and 'hard' was carried out using an ANOVA with age, experimental group and sex as between subject factors. In all of these categories, a significant age effect was found;

In the 'easy' wire tasks (df, 2, 117; $F = 4.16$; $p < 0.05$)

In the 'medium' wire tasks (df, 2, 117; $F = 18.05$; $p < 0.0001$)

In the 'hard' wire tasks (df, 2, 117; $F = 22.30$; $p < 0.001$).

The ANOVAs for these categories also produced an experimental group effect in the analysis of performance on 'easy' wires (df, 2, 117; $F = 3.25$; $p < 0.05$), reflecting the lower mean success score of the standard lever group ($\bar{x} = 1.26$) compared to the covered and cross lever groups. The latter two groups produced comparable mean scores, the cross lever group ($\bar{x} = 1.55$) and the covered lever group ($\bar{x} = 1.51$).

Inspection of the mean performances in each of these categories (Table 4e) indicates that the 18-24 month subjects' performance was superior to that of the younger subjects and the 12-14 month age group produced the weakest results.

Table 4e - Mean Performance on Wire Tasks According to Degree of Difficulty

Age (months)	Degree of Difficulty of Wire Tasks		
	'Easy'	'Medium'	'Hard'
12 - 14	1.29	0.80	0.33
14 - 18	1.35	1.02	0.62
18 - 24	1.69	1.60	1.31

Furthermore, the above table draws attention to the influence of degree of difficulty upon the subject's performance. An ANOVA with degree of difficulty as a within subject factor produced a significant result (df, 2, 234; $F = 43.68$; $p < 0.0001$) supporting this argument.

In addition, a significant interaction was found between degree of difficulty and age (df, 4, 234; $F = 3.16$; $p < 0.02$) and Table 4e shows that while degree of difficulty influenced performance, the level of success attained in each category varied between age groups.

The previous analysis has shown that degree of difficulty influenced performance on this task; two other wire categories were also used in this study. The first focused upon the presentation of the wire to the left or right of the subject's midline and the second category drew attention to the direction of the 'open' wire end, either toward or away from the subject's body.

ANOVAs were carried out with wire direction and left/right presentation as within subject factors. The analysis showed that wire direction had no effect on performance (df, 1, 117; $F = 0.63$; $p > 0.4$). However, a significant influence was attributed to presentation of the wire to the left or right of the subject (df, 1, 117; $F = 4.62$; $p < 0.05$). Table 4f shows that mean success scores were superior for wires presented to the left of the subject's midline.

Table 4f - Mean Success Scores on Wires Presented to the Right and Left of Midline

Age (months)	Presentation of Wire	
	Left of S's midline	Right of S's midline
12 - 14	1.44	0.98
14 - 18	1.51	1.49
18 - 24	2.38	2.22

While of interest, these results must be interpreted with caution due to the confounding of these variables. Inspection of Table 4a shows that of the wires directed 'away' from the subject, two were presented on the right and one on the left. In contrast, of the wires directed 'toward' the subject, one was presented on the right and two on the left of the subject.

The confounding of these two variables means that the superior performance on wires presented to the left of subjects may be reflecting the fact that out of the three wires in this category, two were directed 'toward' the subject. Similarly, the failure to find a significant result discriminating between wires presented 'away' or 'toward' the subject may be attributable to the confounding of these variables.

(b) Solution Times for Wire Task Success

It has already been noted that the Apple IIe programme used to analyse the data provided solution times for trials, where applicable. In order that these solution times could be considered in more detail, each wire task was analysed individually.

An ANOVA of success time on wire 1 was carried out with age, experimental group and sex as between subject factors. The results indicated a significant age effect (df, 2, 82; $F = 81.53$; $p < 0.001$), with solution times for older subjects being superior to their younger counterparts.

A similar analysis for wire 2 with age, experimental group and sex as factors, produced a significant age effect (df, 2, 77; $F = 3.71$; $p < 0.05$), once again indicating the superiority in speed of solution lying with the older subjects.

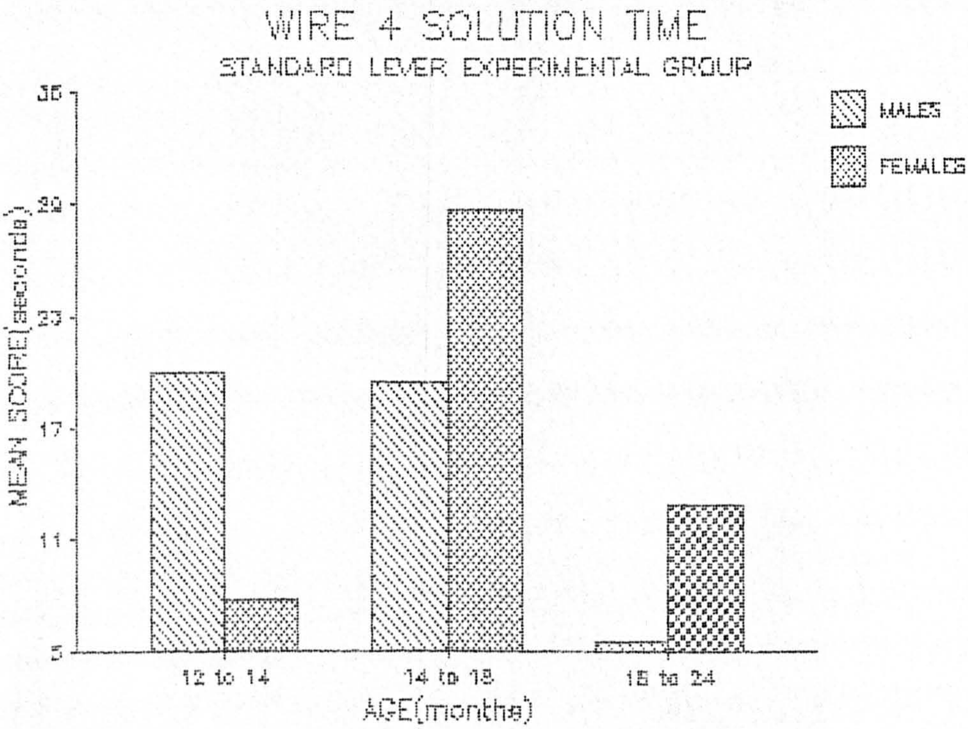
Due to the problem of empty cells, a full ANOVA with all main variables included was not possible for wire 3. A more limited ANOVA with factors age and experimental group was carried out for male subjects producing a significant age effect (df, 2, 28; $F = 9.18$; $p < 0.001$). The age pattern established for wires 1 and 2 was repeated here with the superior mean success time emerging in the older subject groups.

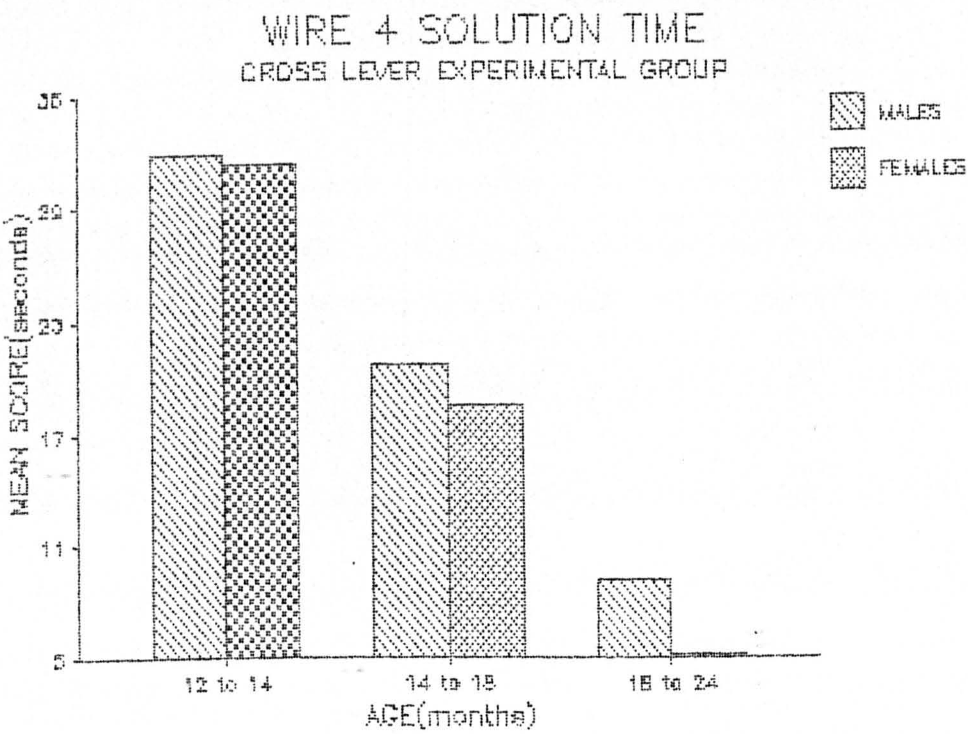
Since the female subjects could not be accommodated in the original ANOVA, a comparison of success times was carried out for all possible age, experimental group and sex combinations. Significant differences were found betwen 12-14 month and 14-18 month subjects [$t(32) = 2.92$; $p < 0.01$, two tailed] and 12-14 month and 18-24 month age groups [$t(43) = 3.56$; $p < 0.001$, two tailed] and the mean solution times indicated that younger subjects took longer to solve wire task 3. No significant difference was found between 14-18 month and 18-24 month subjects although the mean solution time indicates that the oldest age group were faster at solving the wire task. No significant experimental group or sex results were found by the t-test analysis.

On wire 4, it was possible to carry out an ANOVA with age, experimental group and sex as factors. A significant age difference was found (df, 2, 69; $F = 4.85$, $p < 0.05$) and a significant age and experimental group interaction was also found (df, 4, 69; $F = 3.02$; $p < 0.05$). The significant result for age indicated the superior performance in terms of speed of success for the older subjects and from Figure 4i, the age and experimental group co-variation results from the reversal of the positions of the 12-14 month and 14-18 month subjects that occurs between the standard lever group and the cross lever group.

The success time on wire 5 could not be analysed by an ANOVA due to the number of missing cells. To compensate, all possible age, experimental group and sex groupings were

Figure 4i overleaf


WIRE 4 SOLUTION TIME
STANDARD LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORE(seconds)
35
29
23
17
11
5
12 to 14
14 to 18
18 to 24
AGE(months)


WIRE 4 SOLUTION TIME
CROSS LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORE(seconds)
35
29
23
17
11
5
12 to 14
14 to 18
18 to 24
AGE(months)

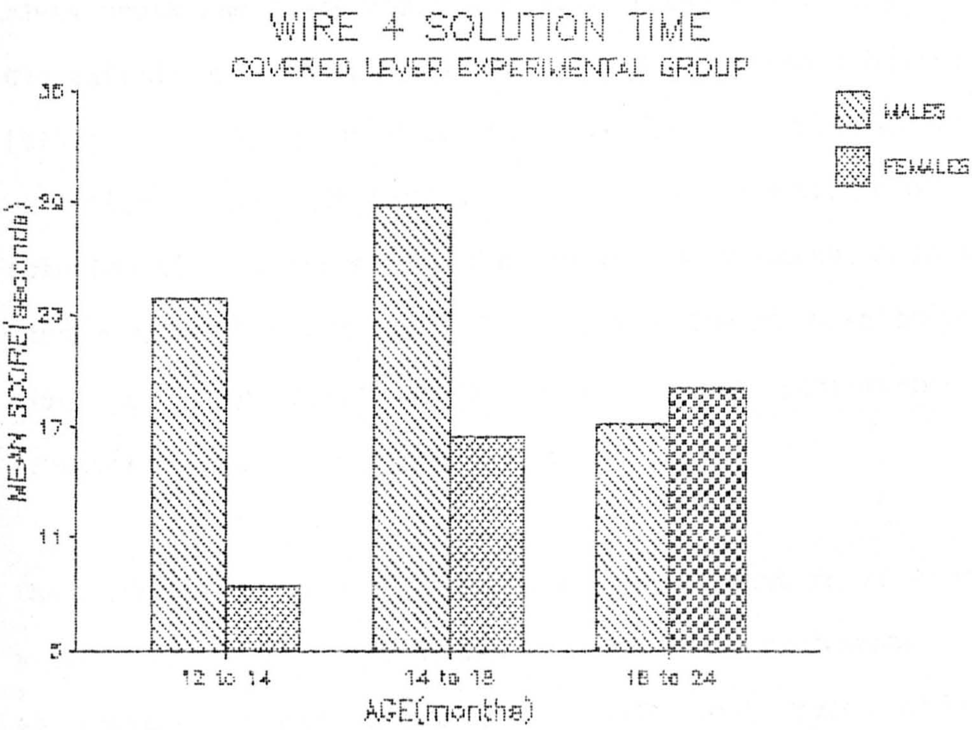


Figure 4i - Wire 4 Solution Time (seconds) analysed by t-tests. No significant experimental group or sex differences were found in this analysis. However, significant age group differences emerged. Comparison of solution times for the 14-18 month and 18-24 month group produced a significant result [$t(41) = 2.28$; $p < 0.05$, two tailed] indicating the solution time for older subjects was superior. No significant differences were found between 12-14 month and 14-18 month subjects [$t(18) = -0.91$; $p > 0.1$, two tailed] or between 12-14 month and 18-24 month subjects [$t(33) = 0.60$; $p > 0.4$, two tailed]. Table 4h draws attention to the fact that on wire task 5 the pattern of mean solution times differs from the previous wire tasks. In this task the 18-24 month group produce the lowest mean solution time, but the 12-14 month subject group performance is superior to the 14-18 month subjects.

The analysis of wire 6 produces a similar pattern to that of wire 5. (Table 4h). An ANOVA with age and experimental group as between subject factors, but with only male subjects, produced a significant variance arising from age (df, 2, 24; $F = 4.69$; $p < 0.05$). However, the mean solution times indicated that the 18-24 month subjects were faster than their counterparts in the other age groups but that the 12-14 month subjects were faster than the 14-18 month age group. When an analysis (t-test) was carried out including the female subjects who solved this wire task, a significant result was found between solution times of the 14-18 month and 18-24 month age groups [$t(42) = 2.39$; $p < 0.05$; two tailed] with the younger subjects producing a slower mean solution time. No other age, experimental group or sex differences were found.

<u>Table 4g - Mean Solution Time in Seconds for All Age Groups</u>

Age (months)	Mean Solution Time for Successful Wire Tasks in Seconds					
	Wire 1	W2	W3	W4	W5	W6
12 - 14	17.96	16.32	27.09	24.97	19.60	21.99
14 - 18	10.68	13.36	15.01	20.74	27.67	31.90
18 - 24	7.09	8.92	12.57	11.89	15.81	19.27

The table draws attention to the age pattern in solution time on wires 1 to 4. Older subjects produce lower mean solution times than younger subjects. On wires 5 and 6, while the 18-24 month group still produce the lowest mean solution time, the youngest age group, 12-14 month, provide a lower mean solution time than the 14-18 month group.

Table 4g also draws attention to another pattern in solution time that the previous analysis does not point out, namely that in the case of 14-18 month and 18-24 month subjects, the mean solution time increases from wire 1 through to wire 6, bearing in mind that this reflects the increasing complexity of the wire tasks. The 12-14 month subjects produce a more variable pattern of mean solution times. One possible explanation for this pattern in the 12-14 month subjects, may lie in the behaviours displayed by the specific age groups when tackling these tasks.

(c) <u>Wire Task Performance and Behaviour Categories</u>

Up until this point, the analysis of wire task performance has focused upon the quantitative data. However, the analysis of subjects' performance on this task included a qualitative component as well, namely the type of behaviour displayed by subjects during performance. In addition to this, subjects' successful performance on the wire tasks was categorised by the experimenter as 'accidental' or 'intentional'. The basis of this classification was briefly outlined in the Methods Section.

Analysis of variance was carried out on the number of successes that were categorised as 'intentional' or 'accidental' and in both ANOVAs, between subject factors were age, experimental group and sex.

The analysis of 'intentional' successes produced a significant age effect (df, 2, 117; $F = 41.82$; $p < 0.0001$) as did the analysis of 'accidental' successes (df, 2, 117; $F = 6.34$; $p < 0.01$). Table 4h presents the mean number of 'intentional' and 'accidental' successes in each age group and it can be seen that, while the number of 'intentional' wire solutions increases with age, the number of 'accidental' solutions declines.

Table 4h - Mean Scores in 'Intentional' and 'Accidental' Wire Successes

Age (months)	Category of Wire Success	
	'Intentional'	'Accidental'
12 - 14	0.53	1.82
14 - 18	1.49	1.40
18 - 24	3.47	0.87

Since classification of success as either 'intentional' or 'accidental' was based upon the behaviours displayed by the subject, a more detailed analysis of behaviour was expected to elaborate the qualitative differences between subjects' performance.

Analysis of subjects' behaviour during the wire task focused upon the frequency of behaviours displayed. The initial analysis summated the frequency of behaviours for all six wire tasks for each subject and an analysis of variance was carried out with factors age, experimental group and sex.

Significant results were obtained for the following behaviours:

(a) Spinning/Hitting the Lure: The ANOVA produced a significant age effect (df, 2, 103; $F = 9.01$; $p < 0.001$) and Table 4i contains the mean frequencies for this behaviour in each age group, indicating that it was more prevalent among the youngest subjects.

(b) **To and Fro Movement of the Lure:** A significant age difference was found (df, 2, 86; $F = 4.82$; $p < 0.02$). The pattern of mean frequencies in each age group (Table 4i) indicates that this behaviour was most common in the 14-18 month group and fewer occurrences were noted in the 12-14 month age group.

(c) **Corners, manipulating lure around the bends on the wire:** Once again significant age effect emerged from the ANOVA (df, 2, 85; $F = 22.56$; $p < 0.0001$). Table 4i shows that this behaviour was more common in the older subject groups.

(d) **Breaks, the number of breaks in behaviour during the task:** The ANOVA produced a significant age effect (df, 2, 110; $F = 13.04$; $p < 0.0001$) and Table 4i indicates that breaks in behaviour were more common among younger age groups.

Analysis of the other behaviour categories produced mixed results. In the case of 'direct pulling' on the lure, the ANOVA produced no significant effects for age, experimental group or sex. While an ANOVA of 'pulling on the wire' failed to produce any variance attributable to the main factors i.e. age, experimental group or sex, a significant co-variation between experimental group and sex (df, 2, 90; $F = 2.31$; $p < 0.05$) was found.

Two other categories, 'move once' and 'play' had very low frequencies of occurrence, limiting the analysis. 'Play' behaviour was not recorded for any subject and 'move once' occurred rarely. T-test analysis of frequency of 'move once' behaviour produced no significant age, experimental group or sex differences.

<u>Table 4i - Mean Frequency of Behaviour Categories on Wire Tasks</u>

Age (months)	Mean Frequency of Behaviour Categories					
	Spinning/ Hitting	To & Fro	Corners	Breaks	Direct Pull on Line	Pulling Wire
12 - 14	11.23	2.37	1.72	19.70	11.88	6.21
14 - 18	7.56	4.11	4.19	15.93	15.59	4.22
18 - 24	6.00	3.49	6.28	11.17	15.83	3.03

From the above analysis, it can be argued that different age groups display different behaviours on the wire tasks. However, the question arises as to the possible relationship between behaviours displayed and success on the task. To consider this possibility, a number of scattergrams were plotted which indicated a potential relationship between frequency of behaviours and success. (Scattergrams for 'moved once' and 'play' wire behaviours showed no relationship between these behaviours and success and no correlations were carried out.) A number of Pearson 'r' correlations were carried out where behaviour frequencies, the total frequency overall six trials for each subject, were correlated with the total number of wire successes, total 'intentional' wire success and total 'accidental' successes achieved per subject. The analysis was concerned with whether particular behaviours were related to success on the task and therefore subjects who achieved no successes were excluded from the analysis.

A correlation analysis (Pearsons 'r', two tailed) was carried out for each of the three factors, age (Table 4j), experimental groups (Table 4k) and sex (Table 4l). These tables are to be found at the end of this data chapter. A number of significant correlations were obtained although in many cases the correlations were not particularly strong.

From Table 4j where subjects are categorised according to age, a variation in correlation pattern was noted for spinning/hitting behaviour. In the 12-14 month age group, this behaviour is positively correlated with total success ($r = 0.351$; $n = 40$; $p = 0.05$, two tailed) and with total intentional success ($r = 0.574$; $n = 18$; $p = 0.02$, two tailed). In contrast to this, the 18-24 month subjects produce a negative correlation between this behaviour and total success ($r = -0.457$; $n = 42$; $p = 0.01$, two tailed) and for total 'intentional' successes as well ($r = -0.624$; $n = 41$; $p = 0.001$, two tailed). In addition, the 14-18 month group produce a negative correlation between spinning/hitting and total intentional success ($r = -0.441$; $n = 29$; $p = 0.05$, two tailed).

The positive correlation between spinning/hitting and 'intentional' successes for the 12-14 month age group does raise a question about the qualitative assessment of 'intentional' and 'accidental' successes made by the experimenter, after all spinning/hitting the lure was an indicator of 'accidental' success. A possible explanation may be that while 12-14 month subjects used spinning/hitting of the lure to move it along the wire, the final removal of the lure may have been carried out in a more controlled 'intentional' manner resulting in a classification of the success as 'intentional' but achieved by a behaviour more strongly related to 'accidental' successes.

Pulling directly on the lure is negatively correlated with total success ($r = 0.462$; $n = 42$; $p = 0.01$, two tailed) and 'intentional' successes ($r = 0.590$; $n = 41$; $p = 0.001$, two tailed) for the 18-24 month subjects. No significant correlations were found for the 14-18 month or 12-14 month age groups. Similarly, pulling on the wire produced significant correlations only in the 18-24 month group. Negative correlations emerged between wire pulling and total success ($r = -0.405$; $n = 42$; $p = 0.01$, two tailed) and 'intentional' success ($r = -0.564$; $n = 41$; $p = 0.001$, two tailed).

Moving the lure backwards and forwards, i.e. to and fro, produced a negative correlation between this behaviour and total success in the 18-24 month group (r = -0.402; n = 42; p = 0.01, two tailed) but a positive correlation between this behaviour and 'intentional' successes in the 12-14 month age group (r = 0.482; n = 18; p = 0.05, two tailed).

The manipulation of the lure around the corners of the wire tasks produced significant correlations in all age groups. In the 12-14 month group, this behaviour is positively correlated with total successes (r = 0.355; n = 40; p = 0.05, two tailed) and this pattern is repeated in the 14-18 month group (r = 0.576; n = 40; p = 0.001, two tailed) and the 18-24 month group (r = 0.748; n = 42; p = 0.001, two tailed). It would appear that the more successes achieved the more of this behaviour that is recorded, a rather obvious conclusion. However, manipulation of the lure around the corners indicates a degree of control that would lead to 'intentional' successes and in the case of the 14-18 month (r = 0.683; n = 29; p = 0.001, two tailed) and the 18-24 month group (r = 0.761; n = 41; p = 0.01, two tailed) this relationship is found. In addition, the 18-24 month group produces a negative correlation between this behaviour and 'accidental' successes (r = -0.613; n = 20; p = 0.01, two tailed).

Table 4j also indicates that the number of breaks that the subject took in their attempts to remove the lure from the wire was correlated with success. In the 18-24 month group, breaks in behaviour were negatively correlated with total successes (r = 0.651; n = 42; p = 0.001, two tailed) and 'intentional' success (r = -0.799; n = 41; p = 0.001, two tailed). It could be argued that in this age group, the higher the number of solutions, the fewer the breaks in solving the task, indicating a controlled and directed strategy. This is contrasted with the 18-24 month group who attain accidental successes, in this case a positive correlation between breaks and accidental success emerges ($r = 0.497$; $n = 20$; $p = 0.05$, two tailed).

In the 14-18 month group, a negative correlation emerges between breaks in behaviour and 'intentional' successes ($r = -0.353$; $n = 29$; $p = 0.05$, two tailed). This contrasts with the 12-14 month group where intentional success and behaviour 'breaks' are positively correlated ($r = 0.625$; $n = 18$; $p = 0.01$, two tailed), possibly indicative of a more fragmented approach to success in the younger age group.

Table 4k draws attention to the experimental groups and the possible variation in performance between them. The previous ANOVAs produced no experimental group effects on the behaviours produced and this supports the expectation that the lever task, and in particular the type of lever task, should have no influence on wire task performance. This expectation was supported by the fact that few points of contrast emerged between experimental groups in this analysis.

For all lever groups breaks in wire task behaviour was significantly negatively correlated with total success and 'intentional' successes, while in all lever groups manipulation around corners on the wire task was positively correlated with total success and total 'intentional' successes. Table 4k provides the detailed information on the strength and significance levels of these correlations.

The points of contrast that emerge between the experimental groups focuses on the strength of correlation obtained and whether or not these correlations attain significantly acceptable levels. For example, the correlation between spinning/hitting and total success is negatively correlated in all groups, due to the influence of the oldest age groups in all experimental groups, but only reaches significantly acceptable levels in the cross and covered lever groups.

The behaviour of directly pulling on the lure produced some variation in correlation across lever groups. In the cross lever group, direct line pulling and 'intentional' success was negatively correlated ($r = -0.386$; $n = 33$; $p = 0.05$, two tailed) while the other two experimental groups failed to produce significant results. However, the covered lever group produced a significant correlation between direct lure pulling and accidental successes ($r = 0.486$; $n = 32$; $p = 0.01$, two tailed).

The problem in interpreting correlations based upon experimental groups is that each group contains three age groups, which it has already been determined, vary in their use of these behaviours. However, it is of interest to note the similarity in correlation patterns between the experimental groups.

Table 41 presents the results of a correlation analysis based on the variable of sex. The ANOVAs on behaviour frequency produced no effect attributable to this variable and the correlation tables for male and female subjects, irrespective of experimental group and age, are in fact remarkably similar. The points of contrast between these two groups of subjects arises from the strength of correlations achieved and in the relationship between success on the wire task and direct lure pulling. It is only in the male sample that direct pulling on the lure is significantly negatively correlated with intentional successes ($r = -0.419$; $n = 51$; $p = 0.01$, two tailed) while it is only in the female sample that direct pulling on the lure is positively correlated with 'accidental' successes ($r = 0.363$; $n = 51$; $p = 0.05$, two tailed). Once again, interpretation of these correlations must be tempered with the knowledge that age and experimental group are not catered for in this analysis.

The similarity between experimental group correlation and betwen male-female correlation tends to direct attention towards age as the major influence on the relationship between behaviour frequencies on the wire task and successes achieved. To explore the influence of age on these correlation patterns a stage further, a more specific analysis was undertaken to look at the three age groups within each experimental group (Table 4m, 4n and 4p). These tables are at the end of this data chapter.

It should be noted that at this level of specificity, the number of subjects in each group can become very small. This produces a problem of interpreting the results. If the correlations are significant or non-significant, generalisations from these sample sizes must be extremely tentative. Given this caveat, the correlations of success on wire tasks and behaviour frequencies were examined for each age group within the experimental groups.

The main point of interest was whether the correlation patterns established at the general level of analysis were also apparent at this more specific level. In the standard lever group, no significant correlations were found in the 12-14 month age group, and the problem of sample size is apparent in the 'intentional' successes group where n = 3. The correlation between manipulation around corners and total success levels is significantly correlated in the 14-18 month age group (r = 0.550; n = 14; p = 0.05, two tailed) and this reflects the pattern of results established at the general level. Table 4m indicates that in the 18-24 month group, a significant negative correlation emerges between spinning/hitting the lure and total intentional success. It is also shown that manipulation around corners is positively correlated with total success and total intentional successes and that 'breaks' in behaviour are negatively correlated with intention successes. All of these results were found at the general level of analysis for this age group.

Table 4n focuses upon the cross lever group and the age groups within it and some points of contrast emerge between this group's correlation results and the general level results. In the 12-14 month group, direct pulling on the lure and total 'intentional' success is positively correlated ($r = 0.706$; $n = 8$; $p = 0.05$, two tailed) and pulling on the wire behaviour is negatively correlated with 'intentional successes' ($r = 0.829$; $n = 8$; $p = 0.02$, two tailed). The contrast between this specific level of analysis and the general level of analysis for 12-14 month subjects is that while in Table 4j and 4n the direction of correlation is the same for both categories, it is only at the specific level of 12-14 month subjects within the cross lever group that significance is achieved.

A similar contrast is found in the 14-18 month cross group subjects where spinning/hitting is positively correlated with 'accidental' successes ($r = 0.799$; $n = 7$; $p = 0.05$, two tailed). While this direction of correlation is similar to that found in Table 4j it is only at this level that significant results were obtained. This pattern is also found in the 18-24 month sample with direct pulling on the lure and accidental successes significantly correlated at the specific level ($r = 0.746$; $n = 8$; $p = 0.05$, two tailed) but while the direction of correlation is matched at the general level, the strength of correlation is not significant.

All of the other significant correlations that are found in Table 4n reflect the patterns established at the general level.

The final experimental group, the covered lever (Table 4p), produces a similar pattern to the above, in that the majority of the significant correlations that were found in all three age groups reflect correlation patterns that were established at the general level of age group analysis. An exception to this pattern is found in the 12-14 month subjects in the covered lever group who produce a significant correlation between breaks in behaviour and total successes ($r = 0.763$; $n = 13$; $p = 0.01$, two tailed) while at the general level of analysis, this pattern was not established.

Overall it can be argued that this specific level of analysis produced correlation patterns that were established previously at the more general level and subsequently provides added support for these relationships.

<u>Key for Tables 4j, 4k, 4l, 4m, 4n and 4p</u>

SPI	Spinning/hitting
DIP	Direct pulling on lure
PUW	Pulling wire
TOF	To and fro
COR	Moving around corners
PLA	Play
BRK	Breaks

The Significance Levels for these tables are:

* 0.05 ** 0.02 *** 0.01 **** 0.0001

All two tailed tests.

Table 4j - Correlations between wire success categories and behaviour frequencies for each age group

Age Group 12 - 14 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 40	* 0.351	0.305	-0.196	0.300		* 0.355		0.058
Total Intentional Success n = 18	** 0.574	0.414	-0.111	* 0.482		0.382		*** 0.625
Total Accidental Success n = 39	0.201	0.202	-0.033	0.012		0.019		-0.107

Age Group 14 - 18 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 40	-0.171	-0.200	-0.155	0.206		*** 0.576		-0.301
Total Intentional Success n = 29	* 0.441	-0.260	0.029	0.267		**** 0.631		* 0.353
Total Accidental Success n = 29	0.167	0.132	0.162	0.071		-0.079		0.038

Age Group 18 - 24 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 42	*** -0.457	*** -0.462	*** -0.405	*** -0.402		**** 0.748		**** -0.651
Total Intentional Success n = 41	**** -0.624	**** -0.590	**** -0.564	-0.218		**** 0.761		**** -0.799
Total Accidental Success n = 20	0.206	0.366	0.320	-0.261		*** -0.613		* 0.497

Table 4k - Correlations between wire success categories and behaviour frequencies for each experimental group

Standard Lever Group

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 40	-0.175	-0.176	* -0.335	-0.053		**** -0.652		* -0.333
Total Intentional Success n = 26	*** -0.598	-0.392	-0.311	0.001		**** 0.731		*** -0.585
Total Accidental Success n = 27	0.360	0.117	0.084	-0.156		-0.210		0.254

Cross Lever Group

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 43	*** -0.422	-0.228	*** -0.443	0.152		**** 0.739		**** -0.660
Total Intentional Success n = 33	**** -0.619	* -0.386	** -0.421	0.179		**** 0.740		**** -0.700
Total Accidental Success n = 29	0.352	-0.011	0.115	-0.208		-0.310		0.100

Covered Lever Group

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 39	** -0.408	0.151	** -0.402	0.234		**** 0.748		*** -0.514
Total Intentional Success n = 29	*** -0.514	-0.264	* -0.415	0.055		**** 0.859		**** -0.617
Total Accidental Success n = 32	-0.108	*** 0.486	0.066	0.247		-0.023		-0.032

Table 41 - Correlations between wire success categories and behaviour frequencies for males and females

MALE

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 72	* -0.233	-0.142	**** -0.425	0.167		**** 0.675		**** -0.509
Total Intentional Success n = 51	**** -0.614	*** -0.419	*** -0.388	0.094		**** 0.679		**** 0.617
Total Accidental Success n = 52	0.261	0.066	-0.003	-0.099		-0.110		-0.057

FEMALE

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 50	**** -0.501	-0.009	* -0.324	0.067		**** 0.777		**** -0.499
Total Intentional Success n = 37	**** -0.523	-0.270	** -0.384	0.0701		**** 0.850		**** -0.665
Total Accidental Success n = 36	0.030	* 0.363	0.277	0.105		-0.286		0.338

Table 4m - Correlations between wire success categories and behaviour frequencies for each age group within standard lever group

Age Group 12 - 14 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 12	0.439	0.290	-0.388	0.339		0.267		-0.144
Total Intentional Success n = 3								
Total Accidental Success n = 12	0.478	0.289	-0.212	0.257		0.084		-0.002

Age Group 14 - 18 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 14	0.242	0.230	-0.304	0.020		* 0.550		0.119
Total Intentional Success n = 9	-0.299	0.197	-0.244	0.569		0.488		-0.352
Total Accidental Success n = 11	0.417	0.055	0.532	-0.273		-0.227		0.454

Age Group 18 - 24 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 14	-0.408	-0.406	-0.196	-0.404		*** 0.724		-0.336
Total Intentional Success n = 14	** -0.613	-0.473	-0.531	-0.082		**** 0.871		** -0.656
Total Accidental Success n = 4	0.874	0.339	0.154	-0.613		-0.629		0.908

Table 4n - Correlation between wire success categories and behaviour frequencies for each age group within cross lever group

Age Group 12 - 14 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 15	0.000	0.424	-0.178	0.259		0.431		-0.150
Total Intentional Success n = 8	0.238	* 0.706	** -0.829	0.610		0.516		0.424
Total Accidental Success n = 14	0.271	0.157	0.071	-0.160		0.107		-0.147

Age Group 14 - 18 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 14	-0.249	-0.414	-0.210	0.062		* 0.563		-0.504
Total Intentional Success n = 11	-0.585	-0.362	0.044	0.375		0.512		-0.459
Total Accidental Success n = 7	* 0.799	-0.610	-0.080	-0.273		-0.183		-0.428

Age Group 18 - 24 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 14	-0.438	**** -0.880	-0.393	-0.495		*** 0.699		**** -0.890
Total Intentional Success n = 14	* -0.574	**** -0.878	-0.448	-0.285		*** 0.698		**** -0.935
Total Accidental Success n = 8	0.082	* 0.746	0.220	0.009		** -0.807		*** 0.838

Table 4p - Correlations between wire success categories and behaviour frequencies for each age group within the covered lever group

Age Group 12 - 14 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 13	0.540	0.176	0.235	0.356		0.412		*** 0.763
Total Intentional Success n = 7	* 0.829	0.328	0.481	0.611		0.713		** 0.862
Total Accidental Success n = 13	0.075	-0.037	0.362	-0.184		-0.337		0.269

Age Group 14 - 18 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 12	-0.284	0.311	-0.068	0.365		0.530		-0.177
Total Intentional Success n = 9	-0.333	-0.351	0.060	0.382		**** 0.952		-0.273
Total Accidental Success n = 11	-0.119	0.515	0.136	0.296		-0.048		0.108

Age Group 18 - 24 months

	SPI	DIP	PUW	TUF	MOV	COR	PLA	BRK
Total Success n = 14	*** -0.732	-0.439	* -0.552	-0.443		**** 0.815		**** -0.811
Total Intentional Success n = 13	**** -0.844	-0.506	** -0.671	-0.338		**** 0.829		**** -0.821
Total Accidental Success n = 8	0.272	0.491	0.344	-0.180		-0.453		0.159

(ii) DISCUSSION

The main hypothesis for this task suggested that performance, assessed on quantitative and qualitative terms, would be influenced by age.

The hypothesised quantitative differences between the age groups is supported by the analysis of total successes on this task. The 18-24 month subjects produce the highest mean success score ($\bar{x}$ = 4.60) while the 12-14 month group produce the lowest ($\bar{x}$ = 2.42). Further support for this age effect comes from the analysis of failed trials. Failure on the wire tasks was categorised as either 'failed try', where an attempt was made to remove the lure in the time available, and 'failed', where no attempt was made to remove the lure.

Analysis based on the total number of failed trials (i.e. 'failed try' category plus 'failed') and consideration of the errors within the 'failed try' and 'failed' categories indicated that subjects produced more errors in all three categories.

These results, while emphasising the influence of age in performance, also draw attention to the fact that even the oldest children found these tasks difficult and subsequently recorded errors on them. This supports Davis's (1974) claim that as the age of subjects declines, the error pattern starts to increase. Davis noted that 3-5 year old children recorded no errors when faced with these tasks but children aged 23-25 months made two or more errors in their attempts to solve the wire tasks. It should be borne in mind that Davis used the wire tasks in a study of cross-species learning abilities and that the wire tasks, (a total of forty wires were used), were presented on more than one occasion to each subject.

The errors recorded by the 23-25 month old children were made during the first presentation of these tasks and were corrected on subsequent trials. This earlier study does draw attention to the fact that errors started to appear in performance at the end of the second year and, given that the present study used a sample of 12-24 month subjects - an age group not previously tested on this task - errors were expected in their performance.

The higher error rates present in the younger children's performance cannot be explained by suggesting that they failed to attempt the task. The analysis of errors indicates that the majority of errors fell into the 'failed try' category suggesting that the children attended to, and were motivated to participate in the task. This latter point receives some support from Davis (1974) where it was noted that few of the species tested failed to participate in this type of task.

The analysis of the wire task performance also showed that wire type was an influential variable and the significant age and wire type interaction drew attention to the relationship between performance on the various wires and the subject's age. To investigate this further, the analysis of performance on each individual wire was carried out and the significant effect of age on performance was found on wires 2, 3, 4, 5 and 6, indicating the superior performance of older children compared to their younger counterparts. Wire 1 provided the exception to this pattern with the 12-14 month children's performance overtaking the 14-18 month group. Similarly, on wire 4, no clear pattern of performance emerged between the 12-14 month and 14-18 month groups.

Wires 1 and 4 produced better than expected performances from the 12-14 month subjects, and it will be argued at a later stage that this improved performance was due to a combination of the strategies used by these subjects and the physical characteristics of these wires.

The analysis of performance on each individual wire also drew attention to the amount of overlap between the performance of the 12-14 month and 14-18 month subjects within each experimental group. The pattern that emerges indicates that the 18-24 month children produce the greatest number of successes on all wires. However, the distinction between the performance of the 12-14 and 14-18 month children was not always clear. The analysis of the performance of these two younger groups reinforced this impression and leads to the suggestion that the main distinction in performance is between the 12-14 month and 18-24 month children.

The analysis of success on each wire also produced experimental group effects on wires 1 and 4. In both cases, the results indicate that lower performance levels were achieved by the standard lever group. Experimental group effects were not anticipated on this task and, given that the distinction between these groups was based on the lever task design, it would suggest that performance on the wire tasks was influenced by the type of lever the subjects faced. The results from the lever task analysis indicated that the three lures varied in terms of degree of difficulty and one suggestion may be that subjects' motivation on the wire task was influenced by their success/failure on the lever task. If this was the case, one would expect the covered lever group to have produced the lower wire task results since the majority of subjects failed that lever task. In addition, the possible influence that success/failure on any one task may have had upon another task was compensated for by the counterbalanced presentation order of the three main tasks. A more plausible explanation for the experimental group effect is that it is a reflection of the cross sectional design. This is reinforced by the fact that detailed scrutiny of the results for wires 2, 3, 5 and 6 failed to produce any experimental group differences.

No mention has been made of the final variable, sex. The reason for this is that the sex of the subject has not shown itself to be an influential variable on wire task performance. A review of the research on this task (Davis, 1974) made no mention of any sex differences in performance and the present study supports this conclusion.

One of the main findings that emerges from previous research, is that the degree of wire complexity is a major factor in influencing performance (Davis, McDowell and Nissen, 1957; Whitecraft, Cobb and Davis, 1975; Hollis, 1962). The research indicates that as the number of segments increases, success rates decline. This pattern was found for a number of species including a sample of 23-25 month old children.

The present results support this conclusion. The categorisation of wires as 'easy', 'medium' and 'hard', reflecting the number of segments in each wire, indicated that not only did older children produce superior success rates in each category, but that for all age groups, the move from 'easy' to 'hard' wires resulted in a decline in mean success scores. The analysis of performance on each individual wire reinforced this point with a pattern of lower mean success scores as one moves from wire 1 through to wire 6 (see Table 4d in Results Section). This is also supported by the analysis which showed that wire type was an influential factor when considering performance. Table 4d demonstrates this point but also draws attention to some variation in performance within these categories. The major variation arises in the 'medium' wire category, i.e. wires 3 and 4, where performance for all age groups is superior on wire 4 and this is particularly the case for the 12-14 month subjects.

The explanation of this variation in performance within the 'medium' difficulty category, may be a reflection of other aspects of the wire patterns or, particularly in the case of the 12-14 month group, the strategies employed by the subjects. In the 12-14 month subjects, the dominant behaviour was that of spinning/hitting the lure and this approach is more likely to lead to success on wire 4 than wire 3 because of the variation in design of these two wires.

The distinguishing feature between wire 3 and 4 is the direction of the third segment of the wire. In the case of wire 3, this is directed towards the stand holding the wire, compared to wire 4 where the third segment is directed away from the centre of the stand. Hollis (1962) found that retarded children, chimpanzees and monkeys were less successful on wire tasks where the third segment is directed towards the centre. Therefore, one explanation for the variation in performance in the 'medium' category may be that, while wires 3 and 4 share the same number of segments, the direction of the final segment influences performance.

The influence of the direction of the third segment can also be considered on wires 5 and 6 and in this case it does not produce such a variation in performance. For this reason, it can be argued that the superior performance on wire 4, particularly for the 12-14 month group, reflects the fact that the dominant strategy of that group on this task was more likely to influence success due to the 'open' design of the wire.

The wires varied, not only in terms of degree of difficulty, but also in terms of whether they were presented to the left or right of the subject's midline. The possible effect of left/right presentation was investigated by Davis et al (1957) and Hollis (1962), the former with primates and the latter with mentally retarded children. In both cases, there was no variation in performance that was attributable to this feature.

The present study, in analysing successes on wires presented to left or right, found that in both categories, the age of subjects influenced performance, with older children achieving more successes in both categories. There was, however, some variation in mean scores for left and right presentations. In the case of the 12-14 month group, higher mean success scores were recorded for wires presented on the left, while in the 18-24 month group, higher mean success scores emerged for wires presented on the right.

It is difficult to attribute the variation in performance that has been found to the left/right presentation variable, since each wire varied in more than one dimension. For example, while wire 1 and 2 were similar in terms of number of segments on the wire, they varied in that one was presented to the left and one to the right. In addition, wire 1 had the 'open' wire end facing toward the subject and wire 2 had the 'open' wire end facing away from the subject. Any variation in performance on wire 1 and 2 could be due to left or right presentation or a combination of these factors. It can be argued that in the case of the 12-14 month age group, the superior performance in left presentation wires was influenced by the fact that wire 4 was presented on the left and inflated the success score of left-presented wires. The superior performance on wire 4 may have been due to the fact that it was presented on the left but it is equally possible that, given the design of this wire and the strategies adopted by this group, they would have been equally successful if the wire had been on the right of their midline.

This type of explanation cannot be used to explain the superior performance of 18-24 month subjects on wire positioned to the right of their midline, since there is no specific wire on which 18-24 month subjects' performance is markedly superior in comparison to the corresponding left presentation wire.

Previous research has failed to indicate any performance variation attributable to left-right presentation and the present study, while raising the possibility that there may be some effect attributable to this variable, cannot reach any firm conclusions due to the small number of trials and the possible influence of compounding variables. It would, however, suggest that some more detailed research of this task is required to tease out the possible influence of this variable on performance.

It was hypothesised that the final aspect of pattern variation would influence performance, namely the direction of the wire 'away' or 'toward' the subject. Previous research (Davis, 1974) argued that a greater number of errors were created on wires that required subjects to manipulate the lure away from their bodies. This was such a strong influence on performance in the cross species studies that Davis and Leary commented "...*It would appear that pushing food away becomes more probable if S's position on the phyletic scale is higher, and it is likely that this was an important component of an emerging skill in tool using*" (Davis 1974).

There are no records of childrens' error patterns on 'away' and 'toward' tasks, only Hollis's (1962) study of mentally retarded children where he noted that they produced more errors in the 'away' trials, but there would appear to be a parallel between the difficulty of pushing the lure 'away' in the wire task and the problem of pushing the lure 'away' from the obstacle in Köhler's (1925) problem. While phylogenetic differences may be found in this ability, it is also arguable that ontogenetic variation will also be found. The 3-5 year old children in Davis (1974) solved the tasks with no errors and no distinction between 'away' and 'toward' wire tasks. When does this ability first emerge?

The present study failed to show any distinction between performances on away or toward wire tasks. It is possible that this distinction had no influence on subjects' performance. They were either capable or not capable of solving the wire task, irrespective of whether this involved moving the lure away or toward their own bodies. The implication of this is that the wire task may be reflecting the subjects' ability to perform detours irrespective of the direction of this detour, or alternatively that the task is reflecting manipulatory skills which, once attained, can be applied to wire tasks regardless of the direction of movement.

The major difficulty in accepting any of these arguments is that there is a large amount of data detailed in Davis (1974) which shows a number of species having difficulty with this aspect of pattern direction. Therefore, it may be the case that the present study has failed to show any effect attributable to this aspect of the wire tasks because so few tasks were used in the present study, and performance on certain wires, e.g. wire 4, may have been influenced by other factors which would have the effect of inflating the success rate on 'away' wires. In addition, the problem of confounding wire direction and left/right presentation was raised in the analysis section and this may be influencing the results obtained.

This aspect of the wire tasks requires a more detailed study since it would provide valuable information in the area of cross species comparison and may shed some light into the development of detour ability in young infants.

One last aspect of quantitative performance was considered in the present study, namely solution time. Davis (1974) with the human subjects in his study ranging from 2-5 years of age, found an improvement in performance time related to age. The older children solved the problems more quickly and it was argued that this reflected the older child's ability to make the correct movements with few errors. The general pattern of results from the present analysis supports Davis's claim about the superior performance, measured in speed of success, of the older children. Table 4g emphasised this point by showing that in every wire task, the 18-24 month subjects produce the fastest mean solution times.

This pattern is continued when comparing the 14-18 month group with the 12-14 month on wires 1 to 4 but on wires 5 and 6, the younger group produce the superior mean success times, although on wire 5 this was not a significant difference. Davis's interpretation of these variations in solution time would lead us to believe that on wires 5 and 6, the 12-14 month subjects made fewer errors than the 14-18 month group when solving the task. The main problem with this claim is that it was not based upon any qualitative analysis of the behaviour of the subject's performance. It is possible that the superior solution times of the 12-14 month subjects are not the results of an awareness of the correct movements but rather reflect the use of a strategy employed by the younger subjects which produced a faster solution time but one that is achieved by an inferior means. This would lead us to a consideration of the qualitative differences in performance which have been mentioned at various points in the Discussion. Before doing this, the solution time data (Table 4g) provides some support for our arguments about the influence of the degree of wire complexity on performance. From the table, it can be noted that as wire complexity increases, the solution times also increase in the 14-18 month and 18-24 month groups of children, indicating not only that the children find these tasks more difficult, reflected in the lower success rates, but those that can solve the tasks, take longer to do so.

The fact that this pattern is not found in the 12-14 month group draws our attention to the qualitative aspects of the analysis.

The first indication of the qualitative differences in performance between age groups, emerged from the analysis of total 'intentional' and 'accidental' successes. This classification was based upon the behaviours which resulted in removal of the lure. A goal-directed, co-ordinated approach where the subject attended to the lure and displayed manipulatory skills in manoeuvering the lure around the corners of the wire, resulted in a classification of 'intentional' success. In contrast, those subjects who paid little attention to the effect of their behaviours on the lure, who failed to manoeuvre the lure along and around the wires, and who in some cases showed surpassed reactions when the lure dropped from the wire, had their successes classified as 'accidental'. The distinction that was being emphasised was the contrasting approach to the task.

The analysis of these contrasting approaches indicated that older subjects displayed more 'intentional' successes and fewer 'accidental' successes, while the younger subjects reversed this pattern with more 'accidental' and fewer 'intentional' successes. It can be argued that, while all age groups managed to record success on the wire tasks, the means by which the removal of the lure was attained varied between age groups. This claim is reinforced when the analysis of specific behaviour frequencies is recalled. From these results, younger subjects relied more on spinning/hitting the lure, they showed significantly lower incidences of manipulating the lure around corners, they had a more fragmented approach to the task in that they had a larger number of breaks in behaviour and they showed a lower incidence of moving the lure to and fro. While all of these behaviour categories produced significant age differences, the behaviours classified as 'direct pulling on the lure' and 'pulling on the wire' failed to produce significant differences between age groups. In the case of direct lure pulling, the mean frequency data indicates that all age groups displayed this behaviour with the highest occurrence in the 14-18 and 18-24 month groups. Pulling directly on the wire, from the mean frequency data, was more common among the younger subjects.

From the results, the main variable that was related to the behaviour displayed was age. Experimental group and sex were not noted as influential factors. Furthermore, the analysis indicates that the behaviour cateagories were correlated with success on the wire tasks. In the 18-24 month group, the 'direct' strategies, e.g. spinning/hitting, direct pulling, pulling the wire, were all negatively correlated with total success rates and with total 'intentional' successes. Those subjects in this age group who were achieving successes on the wire task were relying on other strategies. The argument proposed is that they were manipulating the lure along the wire and some support for this comes from the positive correlations between manipulating the lure around corners and total successes. Further credibility is given to this claim by the positive correlation between manoeuvering around corners and 'intentional' successes, and the negative correlation between this behaviour and 'accidental' successes.

However, manipulation of the lure by itself does not ensure success. To and fro behaviour involved moving the lure backwards and forwards along the wire and by definition, this would involve moving the lure toward and away from the open end of the wire. Therefore, manipulation of the lure had to be accompanied by an awareness that the lure movements had to be undirectional, toward the 'open' end of the wire. The fact that in the 18-24 month subject group, a negative correlation was found between to and fro movement and success, would indicate that those subjects achieving high success rates on the wires were aware of the need for this directed movement if the lure was to be removed from the wire.

In contrast, the 12-14 month and 14-18 month groups produced fewer significant correlations, indicating a reliance on a wider base of behaviours to achieve success. In the 14-18 month group, spinning/hitting is negatively correlated with total 'intentional' successes, while manipulating around corners is positively correlated with total successes and total intentional successes, patterns which were found in the oldest age group of children, indicating a more directed approach to the task.

The 12-14 month group of children are the only ones to produce a positive correlation between spinning/hitting and total success. It can be argued that in this youngest group, where this behaviour was more prominent, it was the dominant strategy used in achieving success that worked particularly well on wires 1 and 4. A positive correlation was also found between this behaviour and 'intentional' success and from the explanation of intentional successes above, this would appear to be a contradiction in the classification of successes. However, it is possible that while this strategy was used to achieve movement of the lure, the final removal had a more controlled quality resulting in the retrieval of the lure being classed as 'intentional'.

The manipulation of the lure to and fro on the wire is positively correlated with 'intentional' success in this age group. It is possible that this behaviour is exploratory. It demonstrates the ability of this youngest age group to manipulate the lure, and also indicates a lack of awareness in relating the lure movements to the 'open' end of the wire. Another interpretation of this movement is that it indicates a trial and error approach to the task, one that contrasts with the 18-24 month children where this trial and error approach is not used by those achieving high success rates on the wire tasks.

One last point of contrast between the three age groups emerges from this correlation data. The oldest children produce negative correlations between breaks in behaviour and success, both total success and intentional success, but produce a positive correlation between breaks in behaviour and 'accidental' success. The 14-18 month group produces a negative correlation between breaks in behaviour and 'intentional' success while the youngest group of subjects produces a positive correlation between these two categories.

It can be argued that within the 14-18 month and 18-24 month age groups, those subjects achieving high 'intentional' rates of success carried out the task in a well-organised fashion. There was little stopping and starting of the task. This is supported by the success time data which indicates older children achieve faster solution times. In contrast, the younger subjects' approach to the task was more fragmented, there were a lot of breaks in behaviour and they subsequently took longer to succeed, a pattern often related to trial and error behaviour. While this is mainly the case in the youngest age groups, some of the older children who recorded 'accidental' successes also approached the task in a fragmented manner with a larger number of breaks in behaviour.

The pattern that emerges from this qualitative analysis of behaviour on the wire tasks is that the older children achieve a higher number of 'intentional' successes and that they do this by using behaviours that are appropriate to the task.

They avoid using behaviours which would reduce the possibility of success. The younger subjects record a lower level of success on the wire tasks and of those successes achieved, a higher number are classified as 'accidental'. The reason for this pattern is the reliance by younger children on more direct strategies. They record a higher frequency of these behaviours and produce positive correlation between these behaviours and success on the wire tasks.

A number of other studies have indicated that children, when faced with problem-solving tasks, adopt direct approaches in their initial attempts to solve the task (Kohler, 1925; Richardson 1932, 1934; Koslowski and Bruner, 1972; Fitzpatrick, 1978) and previous work on the wire tasks has indicated that spinning/hitting the lure is a common strategy (Hollis, 1962).

One possible explanation for the high frequency of spinning/hitting the lure may be in the child's previous experience. Unlike the lever task, the bent-wire task cannot be regarded as totally novel. Many children have cot toys which hang across their cots and they are encouraged to hit and spin the toys which are suspended before them. This previous experience, coupled with the fact that the experimenter did spin the lure to attract the infant's attention, may have influenced the amount of this behaviour recorded. However, this does not explain why older children, who displayed this behaviour as well, changed their strategies to more appropriate ones. The results indicate a quantitative and qualitative change in performance with age and that the approach to the task is related to success.

One explanation for the performance variation on this task would be to suggest that it is reflecting the development of manipulatory skill. The wire task, in differentiating between those children that can manipulate the lure and the improvement that takes place in performance across the three age groups, is a reflection of the superior motor skills of the older children. Davis (1974) has argued that while motor skill must play a part in this task, it does not explain all of the variation in performance found in this task.

In the present study, the manipulatory skills necessary to solve the task were displayed at all age levels and the experimenter noted many younger subjects demonstrating the ability to move the lure along the wire but then abandoning this strategy in favour of spinning/hitting the lure. If this task is simply a reflection of motor skills, the underlying skill in solving any of the tasks is the same yet if the degree of wire complexity influenced performance levels, subjects would solve one task but fail on another.

The argument that this task is reflecting manipulatory skills could lead us to the expectation of an improvement in performance over the six trials as subjects learn or refine the relevant skill. Figure 4j shows the pattern of successes over the six trials irrespective of the actual wire in each trial. For each of the three age groups, there is no pattern

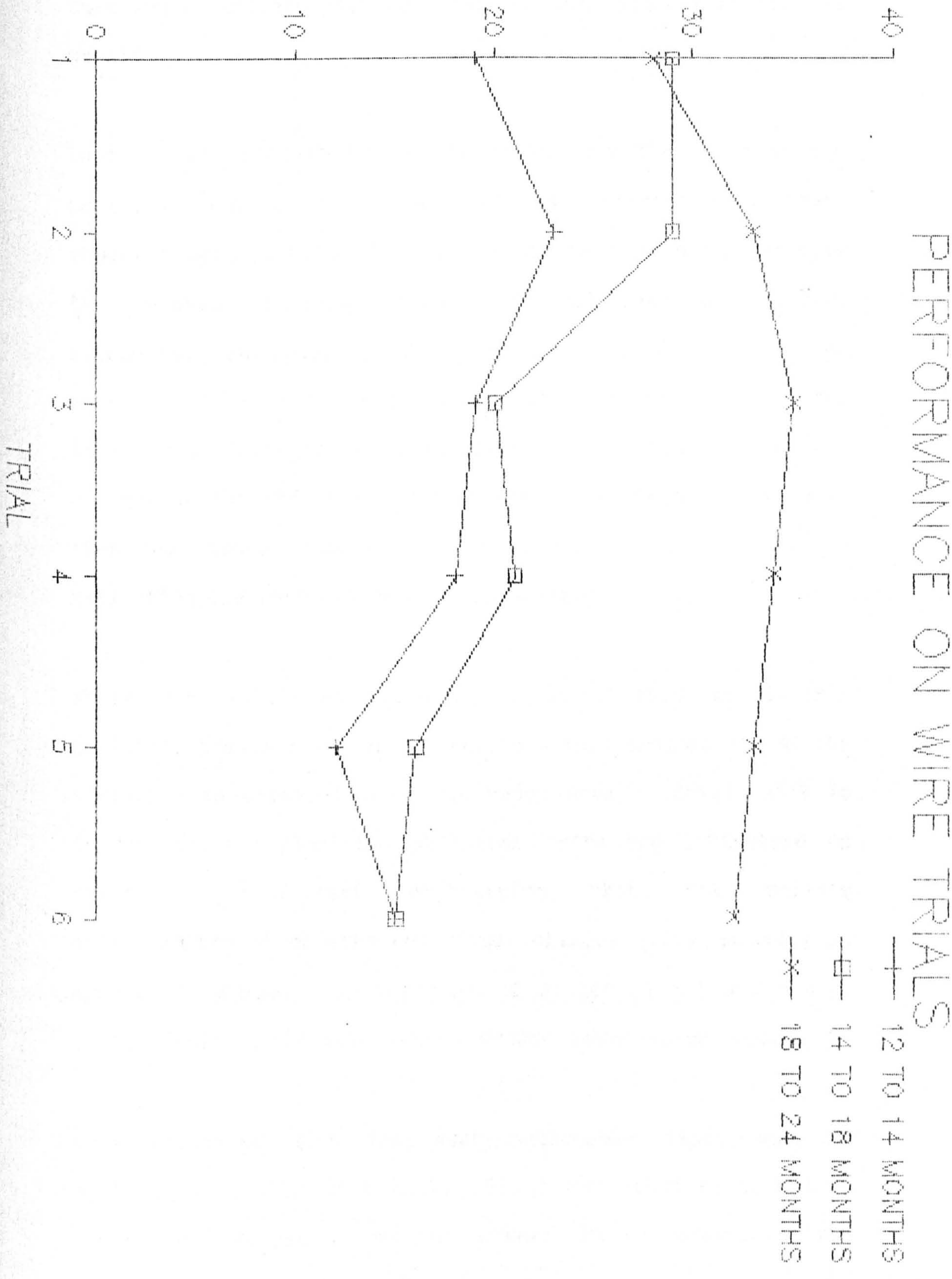


Figure 4j - Number of successes on each wire trial that would indicate that any learning took place over the six trials.

Davis (1974) suggested that the reason why the 3-5 year old children produced error-free tasks was a reflection of their superior perceptual abilities. They were able to perceive the demands of this detour task and make the correct movements. Furthermore, since the 23-25 month old children were the first to be recorded producing errors on this task, it would indicate that the ability to solve this detour task emerges at the end of the second year. If this is the case, then the present sample of 12-24 month old subjects may be reflecting the development of this ability.

While motor skills are improving throughout this period, this in itself does not appear to provide a full explanation of the variation in performance. The major area of development is in the child's cognitive abilities, with the literature on cognitive development emphasising that the child's understanding of objects and plans, changes quite markedly at around 18 months. In the case of Piaget (1953) and Bruner (1973), this is the culmination of the sensorimotor period.

This coincides with the most noticeable improvement in performance on the wire tasks and it was noted earlier that there was a degree of overlap between the performance of the 12-14 month and 14-18 month age groups.

Focusing upon the cognitive changes that take place in the second year, the transition from stage IV to stage VI would, according to Piaget (1954), explain the child's increasing ability to deal with these detour tasks. In addition, the qualitative changes in performance that have been noted may reflect the move from secondary circular reactions to tertiary circular reactions and culminating in the child's ability to represent action internally.

The reliance of younger subjects on spinning/hitting the lure could be interpreted as the child applying a familiar action to a new situation. This has been found to be a common strategy in many problem solving situations (Richardson, 1932; Köhler, 1925; Koslowski and Bruner, 1972; Fitzpatrick, 1978).

It is possible that the child is directing their behaviour towards a goal and demonstrating intentionality of action but that the means are not sufficient to attain success on a consistent basis. The move to stage V and the tertiary circular reactions associated with this stage allows the child to discover new means through active experimentation. This experimentation is often displayed in trial and error patterns of behaviour. Uzgiris and Hunt (1975), in discussing means-end tasks drew a distinction between successes achieved by trial and error and those achieved by "insight". An indication of trial and error behaviour on this task may be found in the to and fro manipulation of the lure. The frequency of this behaviour is highest in the 14-18 month group of children and is positively correlated with success in the 12-14 month subjects, while in the 18-24 month subjects, this behaviour is negatively correlated with 'intentional' and total successes.

Finally, the transition from stage V to stage VI of the sensorimotor period is marked by the child's ability to discover new means by internal representation or it may be viewed as the external experimentation of stage V now taking place internally, prior to action. Uzgiris and Hunt (1975) argued that examples of this were to be found in solutions to novel tasks that took place without any overt trial and error. The present study did not use this approach when analysing the data. However, from inspection of the behaviour patterns, the majority of successes that took place without trial and error on this task were found in the 18-24 month old subject group. This tentative conclusion would need to be supported by further experiments on this task.

The relationship between breaks in behaviour and success may indicate that trial and error behaviour was not common amongst those 14-18 month and 18-24 month subjects who achieved increasing numbers of intentional successes. The underlying assumption was that trial and error behaviour would be marked by a fragmented approach to the task and if this assumption is accepted, it would also explain the variation in solution times that were found.

By focusing upon the cognitive changes that take place in the sensorimotor period, it is possible to argue that performance on these wire tasks reflects the child's understanding of the task. It may also explain why 3-year-old children make no errors on this task (Davis 1974).

The wire tasks had not been used on a group of subjects in this age range before. However, these tasks are capable of distinguishing between the three age groups in question in both a qualitative and quantitative sense. The main hypothesis regarding an age pattern in performance was supported, although the expected variation in performance on 'away' and 'toward' wires was not found. In addition, some variation in performance emerged from the presentation of wires to the right or left of the subject's midline and this was not expected from previous results.

These results suggest that this task has some value in our understanding of development but the present study, due to the small number of trials used, has failed to clarify all of the wire variables which may influence performance. There is a need, therefore, for a more detailed study to consider which of the variables, outlined by Davis (1974), influence performance within this age range of children.

CHAPTER 5

SPATIAL TASK - RESULTS AND DISCUSSION

(i) RESULTS

An analysis of variance was carried out on the number of successful trials per subject. Age (12-14 months, 14-18 months and 18-24 months), experimental group (standard, cross and covered lever groups) and sex were the between subject factors.

The analysis produced significant age differences (df, 2, 107; $F = 25.81$; $p < 0.0001$) and inspection of the significant variable means indicated that the 18-24 month subjects had the highest mean score and the 12-14 month age the lowest mean score (see Table 5a).

Table 5a - Mean number of spatial task successes in each age group

Significant Variable Means

Age Group	Mean Spatial Task Success
12-14 months	2.32
14-18 months	3.12
18-24 months	3.81

A total of 10 subjects failed to record any successful trials; 5 in the 12-14 month age group, 3 in the 14-18 month age group and 2 in the 18-24 month sample.

In addition, the analysis of variance produced a significant age/experimental group interaction (df, 4, 107; $F = 4.01$; $p < 0.01$). Figure 5a provides some elaboration of the analysis of variance results and gives some indication of the age/experimental group effect.

From the graph it can be seen that the age effect for successful responses is most prominent in the standard lever group. While the cross and covered lever groups support this age pattern, they produce a less marked difference between age group performance.

Comparison of age group differences in performance within experimental groups accentuates this point, with the standard lever group producing significant results for all age comparisons on spatial task success. The t-test analysis compared those subjects with one or more spatial task successes and produced the following results:

Comparison of age groups within the standard lever group:

12-14 month and 14-18 month groups:

$t(22) = 2.34$; $p < 0.05$; two tailed

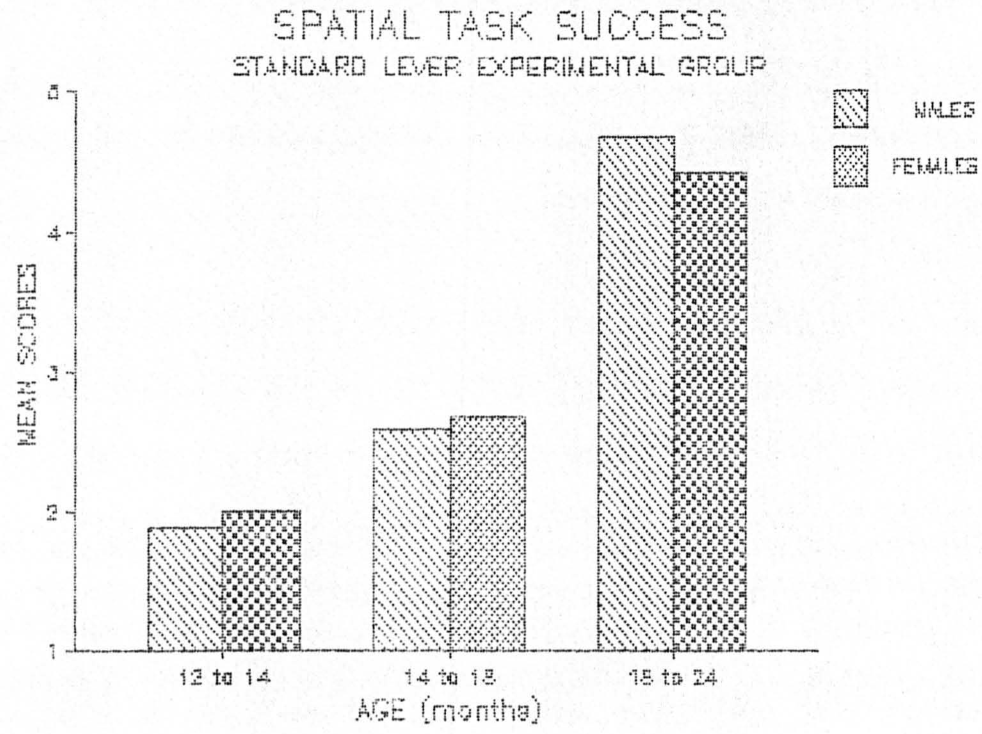
12-14 month and 18-24 month groups:

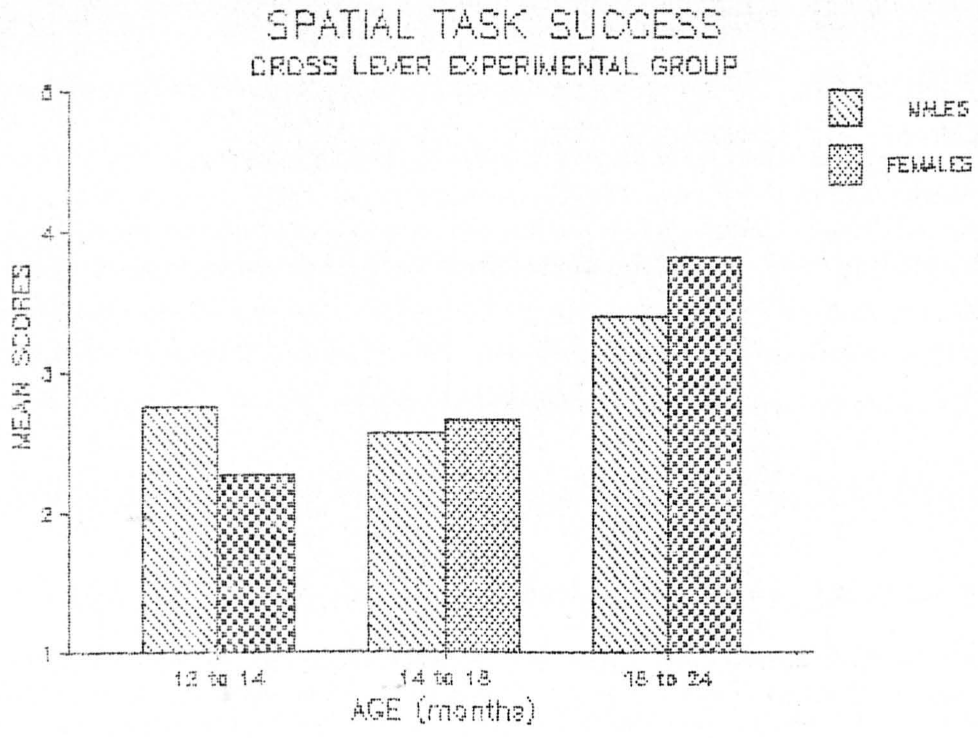
$t(22) = 10.55$; $p < 0.0001$; two tailed

14-18 month and 18-24 month groups:

$t(24) = 7.48$; $p < 0.0001$; two tailed.

Figure 5a overleaf


SPATIAL TASK SUCCESS
STANDARD LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
1
2
3
4
5
12 to 14
14 to 18
18 to 24
AGE (months)


SPATIAL TASK SUCCESS
CROSS LEVER EXPERIMENTAL GROUP
MALES
FEMALES
MEAN SCORES
1
2
3
4
5
12 to 14
14 to 18
18 to 24
AGE (months)

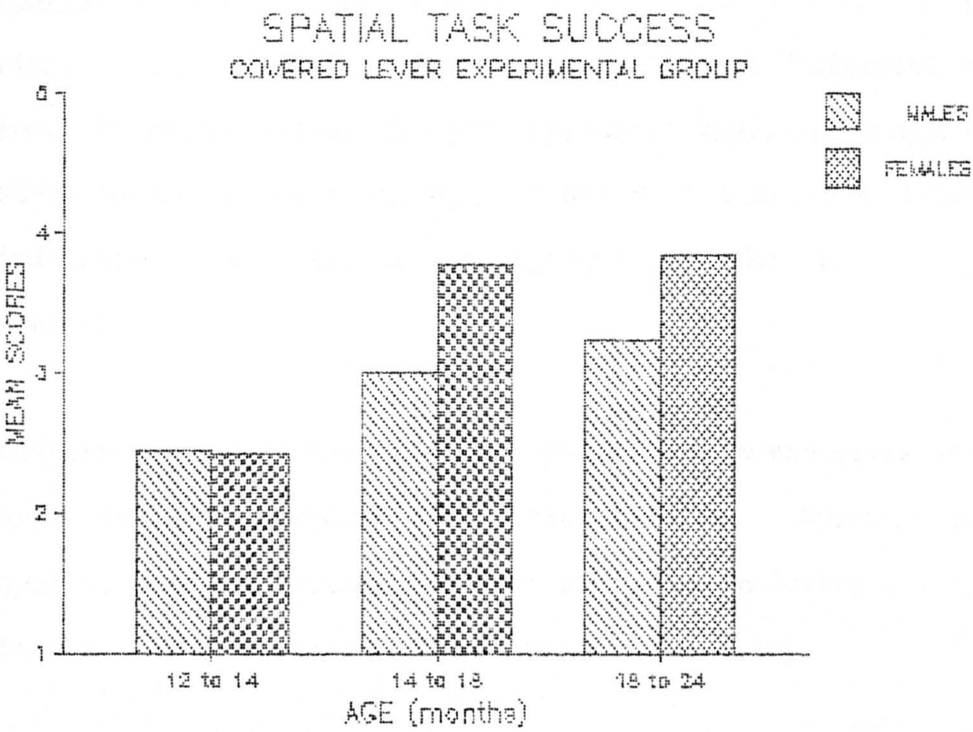


Figure 5a - Spatial task success (mean scores)

In all of the above, older subjects produced a higher number of successful trials.

A similar analysis, comparing those subjects with one or more spatial task successes, was carried out for the age groups within the cross lever group. A significant difference was found to exist between the performance of the 12-14 month and 18-24 month subjects [$t(28) = 2.87$; $p < 0.01$, two tailed] indicating the superior performance of the 18-24 month subjects.

Comparison between the other age groups within the cross lever group failed to produce significant results. However, mean spatial task performance for each age group indicates a trend that follows the overall ANOVA pattern (Table 5b).

Table 5b - Mean Number of Spatial Task Successes within each experimental group

Age (months)	Standard Lever Group	Cross Lever Group	Covered Lever Group
12-14	1.40	2.53	2.27
14-18	2.27	3.27	3.20
18-24	3.93	3.53	3.47

Within the covered lever group a significant result was obtained when comparing 12-14 month and 18-24 month subjects' successes on this task [$t(26) = 2.82$; $p < 0.01$, two tailed], indicating the superior performance of older subjects on this task. Inspection of the age group mean performance results (Table 5b) indicates the general trend of higher success rates within the older subject groups.

Table 5c provides a breakdown of the results for all categories of response on this task for the whole sample irrespective of experimental group. The number of successful trials (i.e. correct responses) reinforces the previous ANOVA results while the error patterns that emerge would appear to indicate an age pattern.

Table 5c - Spatial Task Results for Age Groups

Category of Spatial Task Response	Number of responses for each category (5 trials per subject)		
	12-14 month	14-18 month	18-24 month
Correct	93	131	164
Egocentric	30	26	15
Other	64	49	26
Fail	38	19	20

	12-14 months	14-18 months	18-24 months
No. of Ss making egocentric errors	20	18	15
No. of Ss making 'Other' errors	38	28	17

Figure 5b illustrates the pattern of results for each age group in all categories of response to the spatial task.

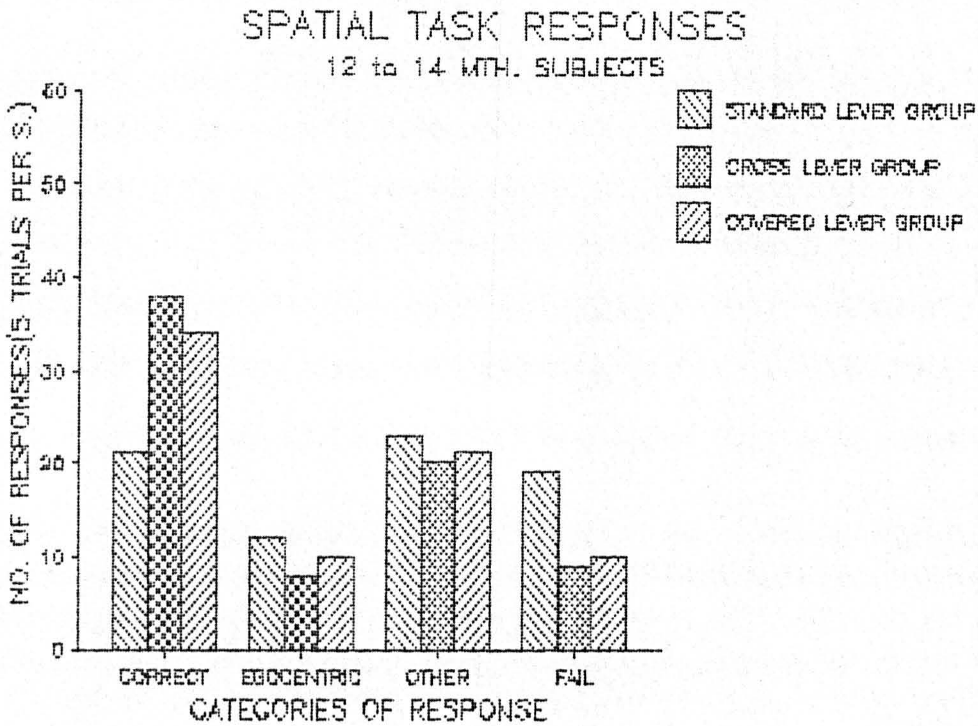
It was noted earlier that the ANOVA produced a significant age/experimental group interaction and Figure 5b illustrates this in greater detail. Of particular interest is the variation in performance of subjects who are in the same age group but in a different experimental group. For example, from Figure 5b the number of correct responses recorded by the 12-14 month standard lever subjects is lower than that recorded by the 12-14 month cross lever subjects and covered lever subjects. A closer analysis of the latter variation in performance failed to produce any significant results.

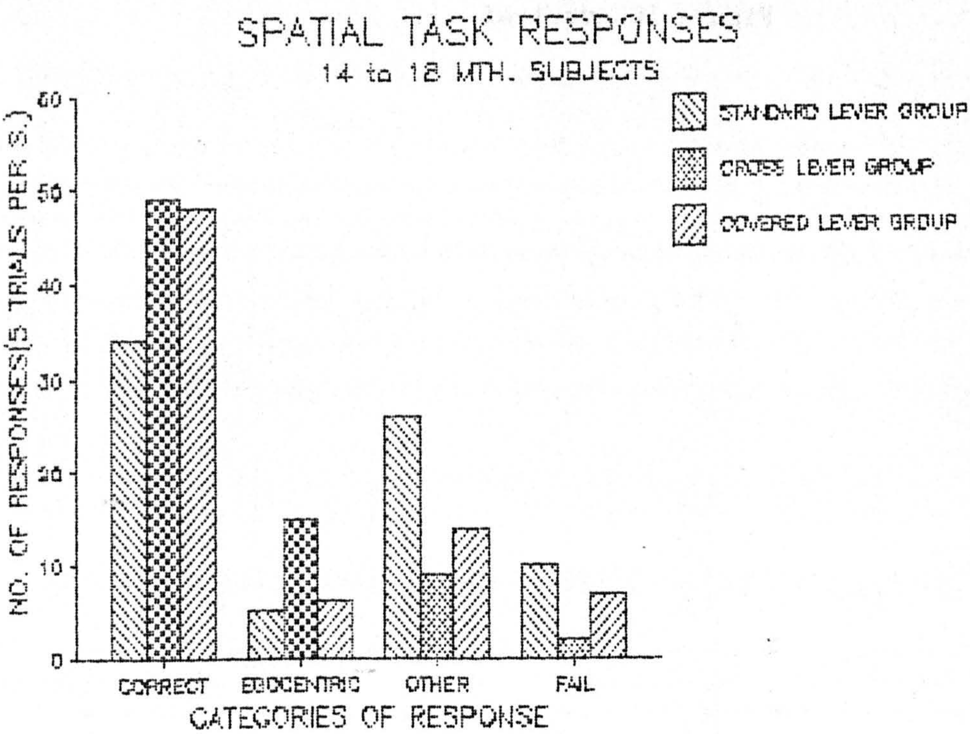
Analysis of these differences in correct responses between the 14-18 month standard lever subjects and the 14-18 month covered lever subjects did produce a significant difference [$t(25) = 2.33$; $p < 0.05$, tow tailed] showing that a larger number of correct responses were recorded in the covered lever group.

Similarly, the comparison of the 18-24 month standard lever subjects and the 18-24 month cross lever subjects' performance produced a significant difference [$t(21.7) = 3.53$; $p < 0.01$, two tailed]. A further comparison of the 18-24 month subjects in the standard and covered lever groups also produced a significant result [$t(19.7) = 3.16$; $p < 0.01$, two tailed] and in both cases the standard lever 18-24 month subjects produced significantly more correct responses.

In both of these analyses the test for equality of variance (Levene test) was significant and the BMDP Manual (1981) advises the use of t-tests where the variance of each group is

Figure 5b overleaf


SPATIAL TASK RESPONSES
12 to 14 MTH. SUBJECTS
NO. OF RESPONSES(5 TRIALS PER S.)
STANDARD LEVER GROUP
CROSS LEVER GROUP
COVERED LEVER GROUP
CORRECT
EGOCENTRIC
OTHER
FAIL
CATEGORIES OF RESPONSE


SPATIAL TASK RESPONSES
14 to 18 MTH. SUBJECTS
NO. OF RESPONSES(5 TRIALS PER S.)
STANDARD LEVER GROUP
CROSS LEVER GROUP
COVERED LEVER GROUP
CORRECT
EGOCENTRIC
OTHER
FAIL
CATEGORIES OF RESPONSE

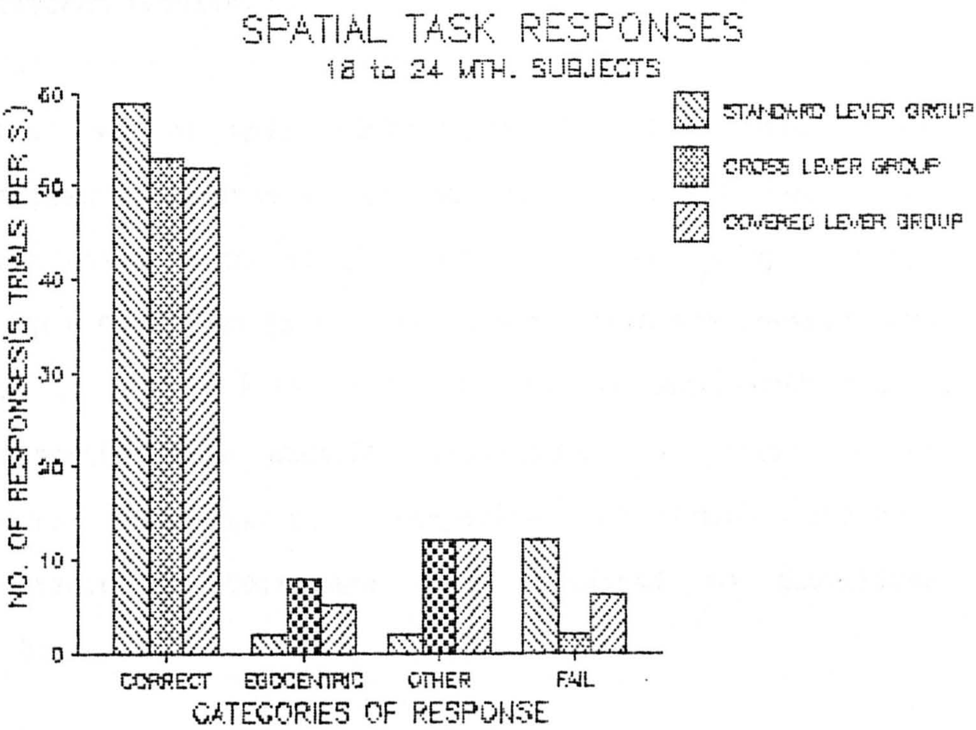


Figure 5b - Spatial task responses - total scores in each category estimated separately. The degrees of freedom are approximated in this analysis. (BMDP, 1981, p.96).

The ANOVA carried out on correct responses did not indicate any sex differences in performance. However, between group comparisons of male and female subjects did produce some significant results.

In the case of male subjects in the 18-24 month group, significant differences in successful trials were found between males in the standard and cross lever group ($t [14] = 2.94$, $p < 0.05$, two tailed) and the standard and covered lever groups ($t [13] = 2.75$, $p < 0.05$, two tailed), both results demonstrating the superior performance of males in the standard lever group. Comparison of female subjects' performance in this age group produced no significant results.

The male subjects in the 12-14 month age group produced significant differences in successful performance when comparison of the standard and cross lever groups was carried out ($t [14] = 2.26$, $p < 0.05$, two tailed) and the results indicate that males in the cross lever group were more successful on this task.

The only significant difference to emerge between female subjects was found in the 14-18 month age group when comparisons between the standard and covered lever groups indicated that females in the covered lever group produced more successful trials ($t[12] = 2.34$, $p < 0.05$, two tailed).

It was noted earlier when inspecting Table 5c that the error patterns varied between age groups. In both the egocentric and 'other' error categories the younger subjects produced more errors than older subjects. Figure 5b draws attention to this pattern within each experimental group. The pattern for egocentric and 'other' errors in the standard and covered lever groups follows the established trend, namely younger subjects producing a larger number of both types of error.

The cross lever group, while broadly following this pattern, does vary somewhat, with the 14-18 month age group producing more egocentric errors than the 12-14 month group and the 18-24 month subjects producing more 'other' errors compared to the 14-18 month age group.

In all cases the number of failed trials was highest for the 12-14 month age group while the 14-18 month and 18-24 month subjects recorded fewer failed trials and produced little variation between these two age groups.

Analysis of variance of the error patterns was hampered by the problem of empty cells. However, age differences in error patterns emerged when subjects were categorised by age irrespective of experimental group. At this level, significant differences were found for egocentric errors between 12-14 month and 18-24 month subjects who had at least one such error recorded [$t(33) = 2.62$; $p < 0.02$, two tailed].

A significant difference was also found between the 14-18 month and 18-24 month age grups [$t(31) = 2.37$; $p < 0.05$, two tailed]. In both cases the 18-24 month subjects produced fewer egocentric errors.

Further analysis of this material was hampered by low error rates (e.g. in the standard lever group 18-24 month subjects, $n = 2$ for egocentric errors). However, where it was possible to compare experimental group performance no significant results emerged.

An analysis of error patterns between age groups within each of the experimental groups was also hampered by low error rates, but where analysis was possible no significant results were found.

(ii) DISCUSSION

Piaget (1954) proposed that one of the major changes in the second year of the sensorimotor period was the child's developing spatial knowledge. The transition from stage IV through to stage VI is highlighted by the understanding of reversibility and associativity, which in turn are at the root of the explanation for the emergence of detour behaviours. Piaget's proposal draws attention to the relationship between the development of detour ability and spatial knowledge in general and provides the rationale for the present study's interest in the child's spatial performance.

The task used in the assessment of the child's spatial knowledge was adapted from Wishart and Bower (1982) and required the child to recover a hidden toy from under one of three cups after the relative position of subject and toy had been changed by moving the child. This allowed the subject's performance to be categorised as; correct (solution), egocentric (response failed to allow for relative change of position), other (where the response was to search under the third cup) and failed (where the child moved towards a cup but did not search under it).

The main analysis of results for correct responses, indicated that successful responses were recorded in all age groups but in addition, performance improved as age increased. The analysis also draws attention to the variation of this result between experimental groups (Figure 5a) and the results of age group comparisons within experimental groups indicated that the strongest age trend in successful performances was to be found in the standard lever experimental group. The cross and covered lever groups did not produce the same consistency of significant results although the trend of results in these latter two groups were always in the expected direction.

This pattern of successful performance supports the initial hypothesis and falls in line with the general development of spatial ability (Piaget 1954), and in itself is not surprising. However, the error patterns that were found in the analysis, raise a number of interesting issues.

As in Wishart and Bower (1982) all age groups produced both egocentric and 'other' errors and in addition, the fourth category of failed trials was also present in all age groups. The error pattern that emerged indicated that younger subjects produced a greater number of these errors than their older counterparts.

In the case of the 12-14 month group, the number of egocentric and 'other' errors is marginally greater than the successes achieved by this group and while the 14-18 month and 18-24 month age groups do not have such high error rates a notable number of trials were still producing errors (33% for the 14-18 month subjects; 18% for the 18-24 month age group). From Table 5c, the number of subjects who made errors can be noted and it cannot be argued that these errors were being produced by a small minority of subjects. Furthermore, the variation in performance on this task, particularly in the younger subject groups, was such that the same subject recorded correct, egocentric and other responses amongst their five trials.

Within experimental groups, the pattern of errors found in the overall sample was maintained, the exception arising in the cross lever group where the 14-18 month subjects recorded more egocentric errors than the 12-14 month age group and the 18-24 month subjects produced a higher number of 'other' errors compared to the 14-18 month age group. Neither difference proved to be significant.

It was noted earlier that statistical comparison of error patterns within experimental groups was hampered by low error rates. However, at the general age level of analysis, irrespective of experimental group or sex, significant differences in egocentric errors were found between the age groups, emphasising the familiar pattern that younger subjects produced more egocentric errors than older subject groups.

The analysis of results produced a significant age/experimental group interaction and from the more detailed comparison between experimental groups, differences were found in performance for the same age group of subjects across experimental groups. These effects were not anticipated since subjects were assigned to experimental groups on a random basis and the type of lever task performed by the subject was not expected to influence performance on this task.

These effects demonstrate the difficulty of sampling an infant population with confidence and constitute a tribute to the great individual variation of cognitive 'characters' in the population.

The factors in the analysis of results were age, experimental group and sex. While the first two have been shown to have influenced the results, the last variable, sex, does not appear to have played any role in distinguishing between subjects' performance. It should be emphasised that the sex of the subject was not expected to influence performance but Figure 5a does draw attention to some male-female differences in performance. Under closer scrutiny, none of these differences turned out to be significant.

The main point of contrast between the present results and the earlier work of Wishart and Bower (1982) is to be found in the pattern of Other errors recorded.

The present study has noted a higher incidence of Other errors and has shown that this category of error is greater than the recorded Egocentric errors for all age groups. This pattern contradicts Wishart and Bower's (1982) results.

The present results indicate that Other errors are dominant in all age groups and that this pattern is found in each experimental group, although the cross lever experimental group deviates slightly from this pattern.

It is possible that the procedural changes introduced in this study have in turn introduced an experimental artefact which has inflated this category of response.

The procedure in the present study involved moving the child 120° around from their original position at the table and then encouraging them to retrieve the object. The time delay between the child being moved and search for the object was kept to a minimum as the excessive delay in Bremner and Bryant (1977) and Bremner (1978a) may have influenced performance. Wishart and Bower's study used a rotating table and chair device that allowed the table or child to be moved and when the infant was allowed to search for the object, they reached from their seated position to the desired cup.

The present study had avoided the use of this type of apparatus since it was based upon rotation, the same movement that is the source of solution for the lever task and it was felt that the inclusion of a rotating device in the spatial task may interfere with performance in the lever task and vice versa.

Once the child had been moved and encouraged to search the child's path to the Egocentric cup resulted in them passing the Other cup. It is therefore possible that the child was distracted by the closer cup on the path actually traversed and lifted it creating an Other error.

If this effect did occur the net result would be to inflate the number of Other errors and at the same time deflate the number of Egocentric errors. While this is an important point in the example outlined above, it influences the category of error and does not detract from the infant's failure to solve the task.

In explaining the success of infants or this task, it could be argued that it reflects an understanding of spatial relations. However, alternative explanations are possible. One such explanation is that the child solved the task, not by relying upon cognitive ability, but rather by perceptual means. They watched the cup that was covering the toy as they were moved around the table. Due to the static camera, it was not possible to record subject's gaze during movement in any systematic fashion. However, on those trials where it was possible to note subject's gaze during movement, subjects either failed to focus attention on the relevant cup or searched under a different cup from the one they were attending to. These observations were of a very occasional nature and their reliability is questionable. Wishart and Bower, on the other hand, explored this possibility more systemtically by retesting a small sample of their subjects while using a screen to prevent visual tracking of the relevant cup. These results indicated that a cognitive explanation of performance on this task was more likely.

An alternative explanation for success on this task could be that the infants who succeeded were using landmarks in the room to solve the task. In the last few years, there has been a growing body of literature that has focused on the ability of the infant at the end of the first year to use landmarks (Acredelo 1978; Acredelo and Evans 1980; Presson and Ihrig 1982; Keating, McKenzie and Day 1986; Meuwissen and McKenzie 1987), indicating the role of visual information on the infant's ability to locate objects in space.

The test room in the present study provided the subject with a number of landmarks - the window, the door, the video equipment and the presence of another adult who remained stationary during the test. All of these could have been used by the subject to help locate the object.

However, the presence of landmarks does not mean that they will be used and if they are, some indication of this may be found in the infant's behaviour. For example, if the object is hidden under the cup nearest the video equpment and the infant notes this, once they have been moved they would relocate the relevant cup by checking with the position of the video equipment. Observation of the subjcts during the trials and on video tape after the trials, failed to provide any support for the idea that subjects were using this type of information.

Alternatively, if landmarks were used by subjects to succeed in this task, why is there such a large variation in subject's performance across the five trials? This variation is particularly noticeable in the 12-14 month age group where the same subject records a combination of successful trials, egocentric errors and other errors over five trials. It is only in the 18-24 month age group that a degree of consistency emerges in performance. If landmarks were being used by subjects, it is arguable that a more consistent pattern of results would emerge.

Finally, support for the argument that the use of landmarks does not explain success on this task is to be found in Wishart and Bower (1982). In their study, the room used for testing had a minimal number of possible cues present and they recorded no use of these landmarks during testing.

It was noted earlier that the age pattern of successful responses on this task was not particularly surprising and indicates qualitative advances in the infant's spatial knowledge in the second year of life. These advances have been noted by other resarchers. Keating, McKenzie and Day (1986) argued that it was not until the second year that infants could successfully locate objects without landmarks, by relying on an inferential strategy. Reiser and Heiman (1982) suggested that while detour behaviours can be observed early in the second year, the more sophisticated detour strategy of 'shortest route' does not emerge until later on in the second year as the child develops a self reference system indicating an awareness of the general properties of space. McKenzie and Bigelow (1986) provide some support for shortest route detour behaviour emerging later in the second year.

However, the fact that infants in the latter part of the second year are still producing errors, suggests that the three cup task is particularly difficult and furthermore may provide some support for Wishart and Bower's (1982) argument that the infant's understanding of relations between objects and between self and object does not emerge fully until they have a stable object identity, as indicated by the attainment of the stage VI object permanence task. Unfortunately, no data was collected on the infant's performance on stage IV or VI object permanence tasks. Therefore it cannot be stated that stage VI infants were still making egocentric errors although Wishart and Bower (1982) did show this to be the case.

CHAPTER 6

RESULTS AND DISCUSSION

(i) RESULTS

Age has been shown to be a major influence when reviewing performance on each task. Figures 6a, 6b and 6c show the mean performance levels for each task for the three age groups within each experimental group and emphasises the improvement in performance associated with age.

To investigate the relationship between performance on each of the tasks, a correlation analysis (Pearson's 'r') was carried out focusing upon each age group within the experimental groups. Tables 6a, 6b and 6c (which are at the end of this Results Section) represent a summary of this analysis and attention will focus upon three main aspects:

(i) lever task - wire task correlations
(ii) lever task - spatial task correlations
(iii) wire task - spatial task correlations.

(i) Lever task - Wire task correlations

Within all experimental groups, a positive correlation emerged between lever and wire task performance for all age groups. The exception to this pattern were the 12-14 and 14-18 month old subjects in the covered lever group reflecting their failure to record any successes on the lever task. While the correlation trend was positive, only one result attained a significantly acceptable level, namely the 14-18 month

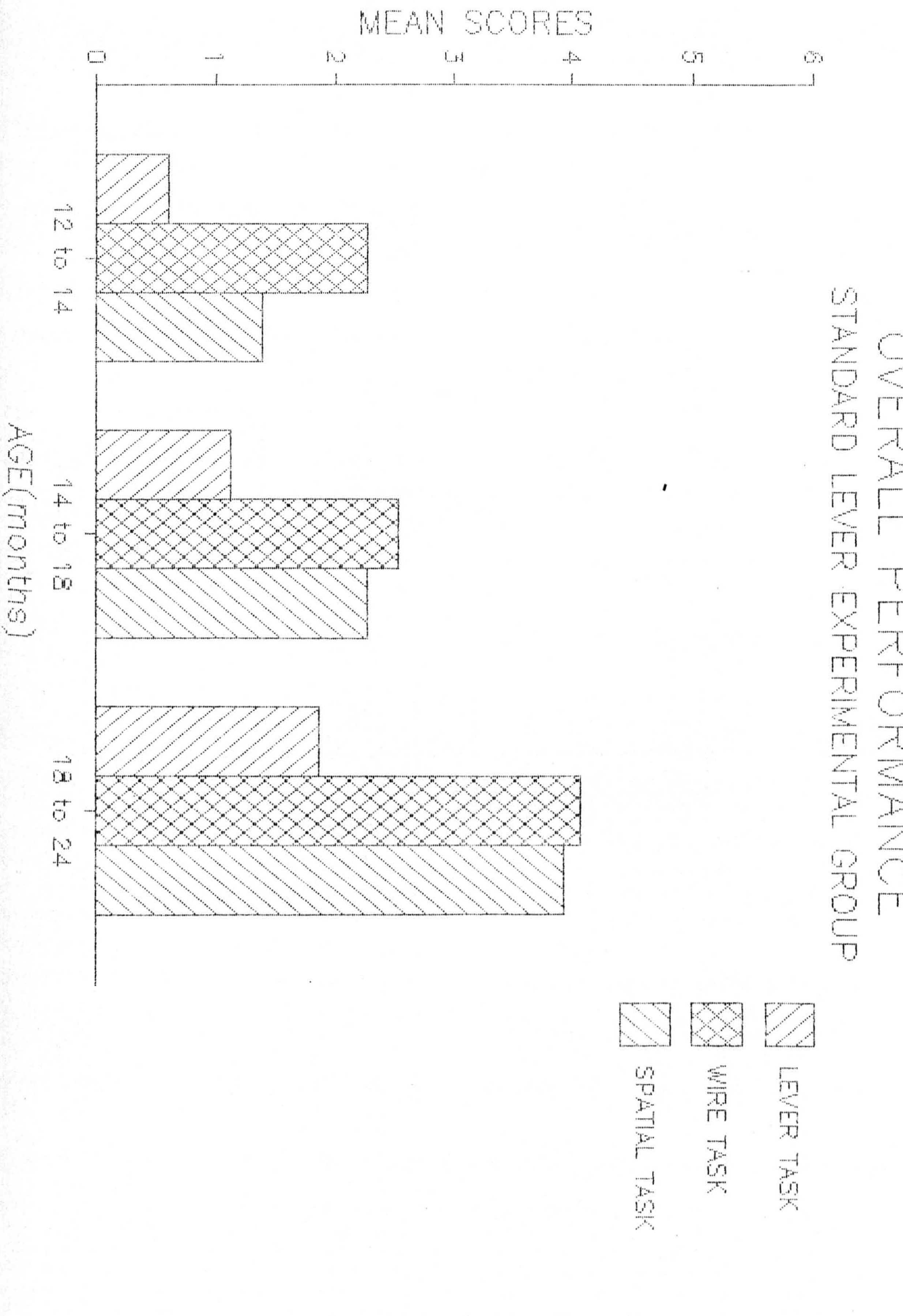


Figure 6a - Overall performance (mean scores) standard lever group

Figure 6b - Overall performance (mean scores) cross lever group

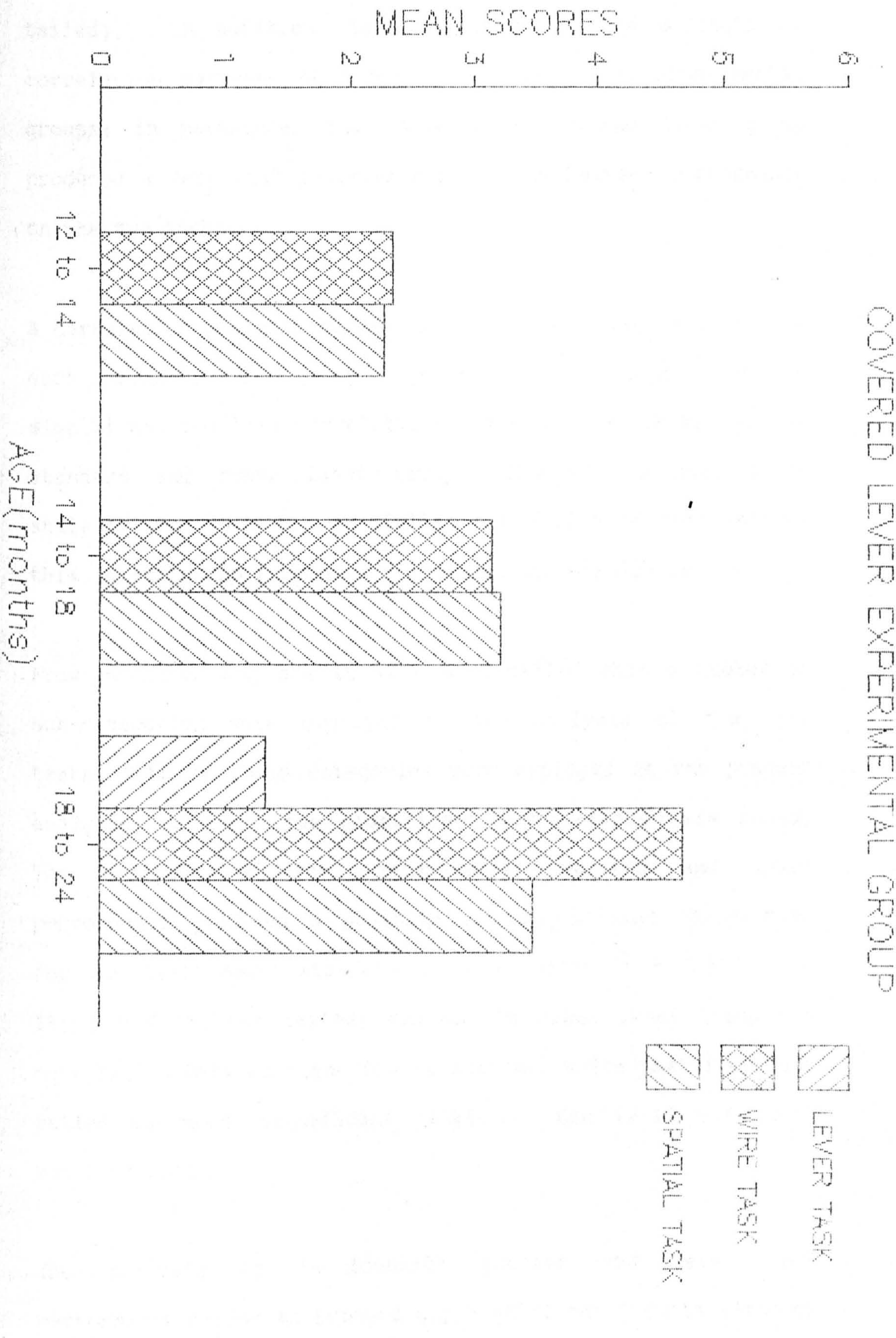


Figure 6c - Overall performance (mean scores) covered lever group standard lever subjects ($r = 0.649$; $n = 15$; $p = 0.01$, two tailed). In addition, some variation in the strength of correlation between the tasks was found across experimental groups; in particular the 18-24 month covered lever group produced a very weak positive correlation between performance on the two tasks.

A correlation analysis between lever and wire task success for each experimental group ignoring age groups produced significant positive correlations between these tasks for the standard and cross lever groups. However, a correlation analysis where age was partialled out failed to substantiate this relationship (Appendix 5 provides correlation results).

From previous chapters it will be recalled that a number of sub-categories were employed in the analysis of the wire tasks. Both of these categories were employed in the present analysis; however, few significant correlations were found. The analysis of the 'intentional' success and lever performance produced a positive and significant correlation for the 12-14 month standard lever subjects ($r = 0.558$; $n = 15$; $p = 0.05$, two tailed) and on the cross lever group the correlation between these two categories, while positive, just failed to reach significant levels in the 12-14 and 14-18 month groups.

The analysis of 'accidental' success and lever task performance failed to produce any significant results although in the case of the 14-18 and 18-24 month cross lever subjects, negative correlations were found which were just below acceptable levels.

The correlation trend indicates that 'intentional' success had a stronger, positive relationship with lever performance when compared to 'accidental' success, where the correlations were negative in many cases. The exception to this trend was the 14-18 month standard lever subjects where the correlation from both categories of wire success were comparable.

Correlating the number of wire successes where the wire faced 'toward' or 'away' from the subject with lever performance produced only one significant correlation for the 14-18 month standard lever subjects. The number of 'away' successes was positively correlated with lever success ($r = 0.544$; $n = 15$; $p = 0.05$, two tailed). Examination of the results failed to suggest any trends in the correlation.

(ii) <u>Lever task - Spatial task correlations</u>

Tables 6a, 6b and 6c show that no significant relationships were found between performance levels on these two tasks. The correlation results are all relatively weak. However, there is some experimental group variation in the direction of the correlation.

In the standard lever group, all age groups produced a positive correlation between spatial task and lever performance. In contrast to this, the cross lever group analysis resulted in negative correlations for all age groups and this pattern was continued in the covered lever group where the 18-24 month subjects, the only ones to record lever successes, produced a negative correlation between these two tasks.

The most notable result from this analysis is the lack of any significant relationship between subjects' performance on these two tasks.

(iii) <u>Wire task - Spatial task correlations</u>

The analysis of the relationship between wire task performance and spatial task performance produced only one significant correlation. A positive correlation was found between performance on these tasks for the 14-18 month subjects in the covered lever group ($r = 0.515$; $n = 15$; $p = 0.05$, two tailed).

The correlation figures do indicate some experimental group variations. In the standard lever group, performance on the wire and spatial tasks is negatively correlated, with the 12-14 month age group result just following below significantly acceptable levels. The cross lever group in contrast produced a positive correlation trend between these two tasks and the covered lever group reflects both of these trends with a positive correlation for the 12-14 and 14-18 month subjects and a negative trend for the 18-24 month subjects.

Focusing attention upon the wire sub-categories fails to improve the number of significantly acceptable results. Analysis of the relationship between 'intentional' wire success and spatial task performance failed to produce any significant results, while the analysis based on 'accidental' wire success produced one significant negative correlation for the 12-14 month standard lever subjects ($r = -0.618$; $n = 15$; $p = 0.02$, two tailed).

The analysis of 'away' and 'toward' wire success with spatial task performance produced two significant correlations. In the 12-14 month standard lever subjects, a negative correlation was found between 'away' wire task successes and spatial task success ($r = -0.515$; $n = 15$; $p = 0.05$, two tailed) while the 14-18 month covered lever subjects produced a positive correlation between 'toward' wire success and spatial task success ($r = 0.583$; $n = 15$; $p = 0.05$, two tailed). No discernable correlation trends were evident.

The results from this analysis failed to show any strong relationship between performance on these tasks.

From an inspection of Tables 6a, 6b and 6c, it can be seen that the largest number of significant correlations are found between wire task performance and the sub-categories of the wire task. These correlations are of interest in the light of earlier analysis of wire task performance.

The earlier analysis of wire task results showed that an age pattern existed when looking at 'intentional' and 'accidental' successes with older subjects recording more 'intentional' successes. The correlations between total wire success and 'intentional/accidental' success provides support for these earlier conclusions.

In both the standard and cross lever groups, significant positive correlations are found between 'accidental' success and total wire performance for the 12-14 month subjects. In contrast, the 14-18 and 18-24 month subjects in both groups produce a significant and positive correlation between 'intentional' success and total wire success. This pattern changes in the covered lever group where the 12-14 and 14-18 month subjects produce significant positive correlations for both 'intentional' and 'accidental' successes when correlated with total wire performance. Covered lever 18-24 month subjects produced a positive correlation between 'intentional' success and total wire success.

These results support the argument that younger subjects' successes are more likely to be classified as 'accidental' while 18-24 month subjects' successes are comprised of 'intentional' successes.

No distinction was found between performance on the 'away/toward' wires in the earlier analysis and correlation results show that for every age group 'away' and 'toward' successes are positively correlated with total success. The lack of variation in the correlation results indicates that this sub-category of the wire tasks had no influence on performance.

Performance on Individual Wires

The six wire tasks varied in terms of complexity, direction of solution and presentation to the left or right of the subject's midline. It is possible that performance on one or two specific wires is related to success on the lever and spatial task.

To consider this, an analysis was carried out where success-failure on each wire was correlated with performance on the other two tasks. Tables 6d, 6e and 6f provide a summary of this data and are to be found at the end of the Results Section.

The three main areas of concern are:

(i) Lever and wire task correlations - only two significantly acceptable correlations were found in this category. In the 14-18 month standard lever group, performance on wire 2 was positively correlated with lever task performance (r = 0.680; n = 15; p = 0.01, two tailed) while the 12-14 month cross lever subjects produced a positive correlation between wire 6 performance and lever task results (r = 0.689, n = 15; p = 0.01, two tailed).

The results failed to identify a consistent relationship between performance on any one wire task with lever task performance.

(ii) Spatial and wire task correlations - within this category, few significant correlations were found.

Performance on wire 1 was positively correlated with spatial task performance for the 12-14 and 14-18 month covered lever subjects. However, this result was not replicated in the other experimental group results.

The only other significant result was recorded in the standard lever group where a negative correlation was found between wire 5 and spatial task performance for the 12-14 month subjects.

The analysis failed to show a relationship between a specific wire task and spatial task performance that was consistent across experimental groups.

(iii) **'Intentional/Accidental' wire success and wire task correlations** - the results from this analysis draw attention to the age pattern in performance on the wire tasks. This is most notable in the standard lever group where success on specific wires is positively correlated with 'accidental' successes for the 12-14 month subjects while the correlations in the 18-24 month groups are with 'intentional' successes.

These results which are supported to some extent by the results of the cross and covered lever groups reinforce the qualitative differences in performance on the wire tasks which have been outlined in earlier chapters.

The correlation results from both analyses failed to identify a strong and consistent relationship between performance on the three tasks; the implications and possible explanations for these results will be discussed in the next section.

Qualitative relations between lever and wire task performance

To consider the relationship between the strategies displayed on the lever and wire tasks, a correlation analysis was carried out between the number of 'low' and 'high' strategies used on the lever trials and the number of 'accidental' and 'intentional' wire successes.

This analysis was carried out for each age group within the three lever conditions. Two significant correlations emerged. In the cross lever 18-24 month subjects, a significant correlation was found between the number of 'low' lever strategies and 'accidental' wire successes ($r = 0.52$; $n = 15$; $p = 0.05$, two tailed). The second significant correlation was found in the 14-18 month covered lever subject group, where the number of 'low' strategies correlated significantly with 'accidental' wire successes, but in this case a negative correlation was found ($r = -0.567$; $n = 15$; $p = 0.05$, two tailed).

A more detailed analysis correlated the highest strategy recorded on each lever trial with total 'accidental' and 'intentional' wire successes.

Within the standard lever group only one significant result was recorded on trial 1 for the 12-14 month age group. The significant correlation was found between lever strategy level and 'intentional' wire successes ($r = 0.537$; $n = 15$; $p = 0.05$, two tailed).

The cross lever group produced three significant correlations. In the 14-18 month age group, a significant correlation emerged between lever strategy level and 'intentional' wire successes on trial 1 ($r = 0.515$; $n = 15$; $p = 0.05$, two tailed) and on trial 5 a significant correlation between strategy level and 'accidental' wire success ($r = -0.564$; $n = 15$; $p = 0.05$, two tailed). In the 18-24 month group, a significant correlation was found between strategy level and 'accidental' wire success on trial 4 ($r = -0.664$; $n = 15$; $p = 0.02$, two tailed).

The covered lever group produced only two correlations of note. The first significant result was found in the 12-14 month subject group on trial 4 where the relationship between lever strategy level and 'intentional' wire successes produced a positive correlation ($r = 0.578$; $n = 15$; $p = 0.05$, two tailed). The second significant result was found in the 14-18 month group on trial 3 where the correlation between the strategy level used on the lever and 'accidental' wire success produced a positive correlation ($r = 0.647$; $n = 15$; $p = 0.01$, two tailed).

While representing only a limited analysis of this aspect of the wire and lever task behaviours, the results do not indicate a strong relationship between the strategies used on each task.

Table 6a - Correlations between Task Performance
Standard Lever Group

12-14 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires	0.244				
Spatial	0.355	-0.481			
Intentional	* 0.558	0.424	0.371		
Accidental	0.118	**** 0.971	** -0.618	0.196	
Away	0.348	**** 0.888	* -0.515	0.301	**** 0.883
Toward	0.100	**** 0.905	-0.354	0.453	**** 0.861

14-18 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires	*** 0.649				
Spatial	0.027	-0.168			
Intentional	0.331	** 0.625	0.182		
Accidental	0.335	0.378	-0.403	-0.486	
Away	* 0.544	**** 0.769	-0.026	0.441	0.339
Toward	0.411	*** 0.708	-0.232	0.487	0.214

18-24 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires	0.246				
Spatial	0.132	-0.018			
Intentional	0.202	**** 0.819	0.113		
Accidental	0.042	0.174	-0.222	-0.422	
Away	0.136	**** 0.921	-0.104	*** 0.748	0.171
Toward	0.315	**** 0.927	-0.066	**** 0.765	0.152

Table 6b - Correlations between Task Performance
Cross Lever Group

12-14 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires	0.371				
Spatial	-0.109	0.254			
Intentional	0.464	0.292	0.013		
Accidental	-0.070	** 0.606	0.205	* -0.583	
Away	0.089	* 0.564	0.342	-0.023	0.498
Toward	0.380	**** 0.776	0.046	0.370	0.351

14-18 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires	0.194				
Spatial	-0.155	0.081			
Intentional	0.419	** 0.635	-0.253		
Accidental	-0.430	0.233	0.325	-0.330	
Away	0.134	**** 0.949	0.004	*** 0.697	0.210
Toward	0.224	**** 0.977	0.128	** 0.556	0.235

18-24 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires	0.178				
Spatial	-0.270	0.311			
Intentional	0.123	* 0.568	-0.124		
Accidental	-0.487	-0.479	-0.068	* -0.563	
Away	0.178	*** 0.702	0.322	0.199	0.092
Toward	0.047	** 0.601	0.071	* 0.565	**** 0.769

Table 6c - Correlations between Task Performance
Covered Lever Group

12-14 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires					
Spatial		0.328			
Intentional		* 0.585	0.165		
Accidental		* 0.531	0.087	-0.053	
Away		**** 0.763	0.200	0.284	0.394
Toward		**** 0.784	0.305	** 0.614	0.428

14-18 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires					
Spatial		* 0.515			
Intentional		*** 0.721	0.306		
Accidental		*** 0.692	0.425	0.000	
Away		**** 0.928	0.377	*** 0.646	*** 0.667
Toward		**** 0.895	* 0.583	*** 0.673	* 0.591

18-24 month (N = 15)

	Lever	Wires	Spatial	Intentional	Accidental
Lever					
Wires	0.041				
Spatial	-0.293	-0.348			
Intentional	0.189	** 0.613	0.028		
Accidental	-0.047	-0.195	-0.320	* -0.547	
Away	0.135	**** 0.864	-0.421	0.471	-0.053
Toward	-0.056	**** 0.882	-0.195	** 0.596	-0.281

Table 6d - Correlations based on performance of success-failure on each wire

Standard Lever Group

12-14 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1	0.340	-0.084	0.467	0.478
2	0.282	-0.324	0.068	* 0.570
3	-0.112	-0.179	0.353	* 0.525
4	0.432	0.047	0.452	0.368
5	-0.048	** -0.718	0.075	**** 0.764
6	-0.048	-0.479	0.075	**** 0.764

14-18 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1	0.180	-0.259	0.341	0.126
2	*** 0.680	-0.259	0.021	*** 0.759
3	0.497	-0.134	0.062	* 0.580
4	0.242	-0.095	* 0.554	-0.350
5	0.034	0.316	0.221	0.175
6	-0.049	0.037	0.444	-0.465

18-24 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1	0.113	0.351	** 0.600	-0.123
2	0.060	0.027	0.373	0.262
3	0.259	0.027	* 0.543	0.262
4	-0.040	-0.165	** 0.628	-0.029
5	0.245	-0.086	** 0.631	0.140
6	0.315	-0.221	* 0.526	0.210

Significance levels two-tailed Pearsons 'r'

*	0.05
**	0.02
***	0.01
****	0.001

Table 6e - Correlations based on performance of success-failure on each wire

Cross Lever Group

12-14 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1	-0.358	0.193	-0.013	0.281
2	0.253	0.492	0.070	0.087
3	0.365	0.053	0.427	0.203
4	-0.007	-0.147	-0.013	0.281
5	-0.023	-0.014	-0.118	0.239
6	*** 0.689	-0.236	0.135	0.028

14-18 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1	0.325	0.008	0.366	0.255
2	-0.180	-0.028	0.154	0.398
3	0.144	0.098	* 0.516	0.146
4	0.325	0.008	0.443	-0.082
5	0.080	0.028	*** 0.701	0.099
6	0.084	0.199	0.459	0.175

18-24 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1	0.019	-0.130	0.252	-0.136
2	-0.079	0.423	0.164	0.150
3	-0.038	0.178	0.411	* -0.556
4	0.459	0.013	0.370	-0.259
5	0.036	0.278	-0.052	0.278
6	0.136	0.013	0.473	*** -0.669

Significance levels	*	0.05
two-tailed	**	0.02
Pearsons 'r'	***	0.01
	****	0.001

Table 6f - Correlations based on performance of success-failure on each wire

Covered Lever Group

12-14 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1		*** 0.706	0.300	0.396
2		0.264	0.410	0.316
3		0.035	0.376	0.218
4		0.024	0.000	0.256
5				
6		-0.060	* 0.575	0.278

14-18 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1		** 0.619	0.418	* 0.560
2		0.469	0.508	* 0.560
3		0.423	*** 0.734	0.123
4		0.282	*** 0.705	* 0.582
5		0.267	* 0.517	*** 0.647
6		0.267	0.345	*** 0.647

18-24 month (N = 15)

Wire	Lever	Spatial	Intentional	Accidental
1	0.048	-0.124	-0.107	0.240
2	-0.141	-0.524	0.115	0.353
3	-0.025	-0.082	** 0.634	-0.374
4	0.192	0.108	0.388	-0.184
5	0.220	-0.379	0.492	-0.238
6	-0.101	-0.205	0.502	-0.262

Significance levels	*	0.05
two-tailed	**	0.02
Pearsons 'r'	***	0.01
	****	0.001

(ii) <u>DISCUSSION</u>

The most notable result to emerge from this analysis is the lack of significant correlations between performance on the three tasks. It was hypothesised that performance on the lever and wire task would be positively correlated and that the ability to perform successfully on both of these tasks would be related to the child's spatial knowledge, reflected in their performance on the spatial task.

The proposed relationship between the lever and the wire task is based upon a common feature of both tasks, namely that they are detour tasks (Koslowski and Bruner, 1972; Davis, 1974). The lever and wire task differ from the traditional detour tasks of reaching (Bruner, 1970) or locomotor detours (McKenzie and Bigelow, 1986) where the goal object is retrieved by the subject moving in relation to a stationary object. In contrast the lever and wire tasks require the subject to move the goal object around a detour in order to retrieve it.

The independent analysis of the lever and wire task results indicated that a similar age trend was found in both sets of results, older subjects recording a higher number of successes. This age trend was not confined to the quantitative aspects of performance but also emerged from the qualitative analysis of both tasks. While these results suggest a parallel in performance, the correlation analysis failed to support this hypothesis.

In only one case was a significant positive correlation found between lever and wire task performance, the 14-18 month standard lever group. It was noted in the qualitative analysis of wire performance that the 14-18 month subjects had the highest frequency of 'to and fro' behaviour and it was suggested that this may reflect the age group's approach to the exploration of novel tasks. The positive correlation may reflect the application of trial and error strategies to both tasks.

This explanation is weakened by the fact that the significant correlation was found only in the standard lever group. It has been argued that the cross lever, with its sub-goal, was more likely to be solved by a trial and error approach. However, the correlation between wire and lever performance for this experimental group was not significant.

Performance on the wire task was also considered to have reflected qualitative differences in successful trials. The categories of 'intentional' and 'accidental' wire success have already been discussed and correlations based upon these sub-categories failed to produce any strong support for a relationship between either category and lever performance.

Kohler (1925), Richardson (1934) and Davis (1974) have all emphasised the difficulty of performing detour tasks that involve moving objects away from the self before retrieving them. The wire task included sub-categories of wires where solution involved moving the lure toward or away from the subject's body while the lever required subjects to push the lever away from themselves in order that the goal could be brought within reach. The analysis considered the argument that a closer relationship existed between performance on wires categorised as 'away' and the lever task.

Once again, this analysis failed to produce any consistent pattern of relationship with only one positive correlation.

The more detailed analysis of success/failure on each specific wire and its relationship with lever performance failed to show that any particular wire was related to the subject's lever results.

While few significant correlations were found, those that did emerge are all in the hypothesised direction. However, the lack of consistent results requires some consideration.

The assumption of comparability of the detour tasks may be invalid. While the tasks may share the common factor of a detour, the procedure by which that detour is carried out is a point of contrast between the two tasks.

Davis (1974) noted that the bent wire task was unique in that the manipulandum, discrimmandum and reinforcement are the same object - the lure. In contrast, the lever task requires the use of an intermediary rod, the lever, to achieve success. The lack of correlation between the tasks may reflect this distinction. In the bent wire task, subjects are receiving direct feedback from their actions when their hand is on the lure and this coincides with the main focus of attention. With the lever subjects, visual attention must be directed towards their hand on the lever or on the movements of the lure. The gaze data from the lever analysis indicated that subjects varied in terms of what they attended to - older infants spent more of the trial time attending to the goal and its movements while there was some evidence to suggest that younger subjects attended to other sources of information, for example, their hand on the lever.

It was also noted that the uniqueness of each task may not be comparable. There is a parallel between the wire task and mobiles suspended horizontally across prams and playpens and a child's previous experience on such toys may influence their approach to the wire task.

These variations between the tasks could have a net effect of increasing performance levels on the wire task. It is evident that higher mean scores of success were achieved on the wire task (Figure 6a) and the lack of significant correlations indicates that some subjects were recording wire successes without achieving lever task success. In the covered lever group, 12-14 and 14-18 month old subjects failed to record any lever successes but did record wire task success. This may be a reflection of the increased demands of the covered lever task. However, subjects in the other experimental groups recorded wire success without achieving lever task successes.

The lack of synchrony between these two detour tasks could be attributed to the different task requirements. Detour ability does not emerge as an all-or-nothing ability. Piaget argues that it is demonstrated in the behaviour of stage 5 children but with certain limitations. For example, the alternate route needs to be immediately perceptible. It is only in stage 6 that these limitations are overcome with the development of the ability to represent relationships between objects.

Lockman (1984) has shown that detour ability develops across domains at different rates. He noted that the ability to solve reading detours emerged before the capacity to solve locomotor detours.

Within specific domains the type of task influences the display of detour ability. In the area of locomotor detours the ability to move around a barrier is apparent in the latter part of the first year (Lockman and Ashmead, 1983). However, shortest-route detour behaviour does not emerge until the second year (McKenzie and Bigelow, 1986; Reiser and Heiman, 1982) and certain locomotor detour tasks are not solved until the end of the second year (Reiser et al, 1982).

Thus asynchrony in locomotor detours demonstrates that while tasks may share a common basis, caution must be exercised in assuming the equivalence of tasks in assessing any ability (Corrigan, 1979).

The analysis of the relationship between spatial task performance and wire/lever performance proved to be fruitless. No strong support for the hypothesised relationship was found.

Piaget (1952, 1954) has proposed that the child's development of spatial knowledge is related to their ability to either reverse a displacement or to use one of several alternative paths to a given goal, both of which are closely linked with the child's detour ability. It is not until the end of the sensorimotor period that the child is credited with an objective understanding of space; until then the egocentric nature of the child's thought limits the capacity to take account of an object's movement and limits the child's understanding of alternative paths in detour problems, that is, associativity (Flavell, 1963).

The decline in egocentric responding should therefore accompany an improvement in performance on detour tasks. Previous research has shown some relationship between spatial knowledge and detour ability. Infants have been shown to solve a stage IV object concept task before being able to carry out a reading detour task where the goal was placed behind a transparent barrier (Lockman, 1984; Butterworth, 1983). The ability to solve a stage IV object task indicates for Piaget the establishment of a simple objective group. It also demonstrates reversibility, a property relevant to the solution of detours.

This data demonstrates that it is not the awareness of an object's existence behind a barrier which stops the child from retrieving the goal. Rather it is the fact that the child must comprehend the spatial relationship between the objects before being able to retrieve it. The development of spatial knowledge has also been related to the development of shortest route behaviour in the second year (Reiser and Heiman, 1982).

The spatial task in the present study was used to consider the childs' spatial understanding and the results, with some minor variations, supported the work of Wishart and Bower (1982) and indicates a decline in errors for older children. However, the results of the correlation analysis produced no support for the argument that improved performance on the spatial task would be related to improved detour performance.

In the case of the lever and spatial task performance, no significant correlations were found. The analysis of wire task and spatial performance produced only one positive correlation betwen the tasks and this was found in the 14-18 month covered lever subject group.

Examination of the correlations using the sub-categories of the wire task did not improve the overall results. The category of intentional/accidental success produced one significant negative correlation between accidental success and spatial task performance for the 12-14 month standard lever group indicating that success between these two categories was not related.

The wire category of 'away/toward' produced two significant correlations. Firstly, a negative correlation between 'away' wire successes and spatial task success for the 12-14 month standard lever subjects and secondly, a positive correlation between 'toward' wire successes and spatial performance for the 14-18 month covered lever subjects.

It has been argued that movement away from the self requires a more objective understanding of space, therefore a positive correlation between 'away' wire success and spatial task success would be anticipated. The fact that the results contradict this expectation could be a reflection of the failure overall to find any distinction between performance on away/toward wire tasks.

The individual correlation of success/failure on each wire failed to provide any strong support for the relationship between performance on any specific wire and spatial task performance.

The failure to find some degree of synchrony between performance on the three tasks is disappointing given the pattern of results that were found when considering each task independently.

In the discussion of the lever task results it was proposed that one way of discriminating between the cognitive explanation of Piaget and Bower for the results would be to consider the relationship between lever performance and other related tasks. The structuralist's argument that the various items within a stage develop concurrently reflecting the generality of the underlying structures, results in the belief that behaviour on specific tasks will reflect the child's stage of development (Flavell, 1971). The lack of any significant relationship between detour ability and spatial knowledge weakens this argument.

Lockmein (1984) also investigated the relationship between detour ability and spatial knowledge proposed by Piaget. The results provided limited support for Piaget's claims and in particular failed to find the proposed relationship between the development of associativity in the spatial and detour domains.

These results, along with others (Uzgiris and Hunt, 1975; Kopp, O'Connor and Finger, 1975) have resulted in Fischer (1980) arguing that in development, synchrony is the exception and unevenness in development is the rule. In a similar vein, Gopink and Meltzoff (1984) in their study of the relationship between language development and cognitive development proposed that abilities which require the same conceptual level may develop in sequence rather than concurrently.

The approach outlined above would explain the present study's failure to find a relationship between the tasks by suggesting that few relationships should be expected, unevenness or decalage in development, is the norm.

Alternatively, it may be argued that the assumption that any measure of detour ability will be related to spatial knowledge is wrong. Corrigan (1979) has argued that this is a major weakness in the structuralist's position and it has already been suggested that the two detour tasks were not comparable in certain areas and that this could explain the lack of relationship between the tasks. Adopting this perspective would suggest that the lack of relationship between the detour and spatial tasks may be a reflection of the tasks chosen to assess performance in these two domains.

CHAPTER 7

CONCLUSION

This chapter will provide a brief review of the main results and consider their consequences for the original hypotheses.

1. The Lever Task

The analysis of the data from this task supported the hypothesised effect of age on performance. Age was found not only to produce quantitative differences in performance but also qualitative ones.

The qualitative differences were found in the physical actions that children employed in moving the lever and also in the direction of their gaze during lever manipulation. For example, older children spent more time gazing at the object while moving the lever compared to younger subjects.

In addition to the influence of age upon performance, the lever design employed was also found to be an important variable. Comparisons of children's performance on various lever designs was not considered by Koslowski and Bruner (1972) or Richardson (1934). However, the present study has demonstrated that the lever design does influence performance.

In the present study, the cross lever design produced the highest success rates followed by the standard lever, with the covered lever proving to be the most difficult.

The performance of children on the covered lever supported the argument that lever success was not simply the attainment of a skilled behaviour (Koslowski and Bruner, 1972) and that cognitive factors may be an important element (Piaget, 1954; Bower 1979a).

The analysis of the lever data also produced one unexpected result, namely the influence of sex upon success.

The performance of males on the lever was superior to that of females and it was argued that this could be interpreted within the differential hypothesis of sex roles, whereby differing parental attitudes and expectations for male and female infants is reflected in the subsequent behaviour of those children.

Future research on the lever task needs to focus upon the performance of the 12-18 month old subjects on the covered lever. It was suggested that the cover could be influencing performance by:

(a) distracting subjects
(b) making the task physically more difficult
(c) removing necessary information.

Further research on this task may allow us to distinguish between these alternative explanations. For example, the physical difficulty which may be increased by the cover could be investigated by using the cross lever design with a cover placed over it. The presence of the cross-strut would remove any question of physical difficulty in explaining the results of such an experiment.

2. <u>The Bent Wire Task</u>

The results indicated that age was the major variable influencing performance on this task and therefore supported the original hypothesis. As with the lever task, the differences in performance between age groups was reflected, not only in quantitative terms, but also qualitatively in the behaviour displayed while tackling this task.

Davis (1974) noted that aspects of the wire design influenced performance. For example, wire complexity and the direction that the lure had to be moved, either 'away' or 'toward' the subject. While the analysis supported the hypothesised influence of wire complexity upon performance, it failed to support the argument that 'away' wire tasks would present more problems for subjects. In addition, the results showed that left or right presentation of the task was an influential factor. Davis (1974) had not found this to be the case in his research.

The failure to find support for the hypothesised difficulty of 'away' wire tasks must be noted, given that a central argument of this research is that children experience more difficulty on tasks that require the subject to move the goal object away from themselves in order to achieve a solution.

The more positive aspect of the results is that it has been demonstrated that this task can be employed in assessing the abilities of 12-24 month old children. This in turn opens up two obvious areas of research. Firstly, since error patterns are recorded for this age group, it is possible that between species comparisons could be made with this task. Secondly, given that the wire task is simple in construction and easily administered, it may be possible to develop it as an assessment tool. This, however, would require detailed study to consider the relationship between performance on this task and traditional infant assessment scales.

(3) <u>The Spatial Task</u>

Wishart and Bower (1982) employed the three-cup task to investigate the spatial knowledge of children. The results of the present study supported their earlier results and the current hypothesis by indicating that age was the major influence on performance. The results showed that children in the second year make errors in this task which reflects the continuing development of their spatial knowledge.

In contrast to the earlier work of Wishart and Bower (1982), the present research did not find the same error patterns. This was partly attributed to the fact that the current study employed a design which required the child to be moved in contrast to Wishart and Bower's study where the table was moved.

4. Relationship between the Tasks

In considering the results of the analysis, little support was found for the hypothesised relationship between tasks. This is not only a problem for the present study, but also raises the wider issue of synchrony between tasks, an issue that is of central importance to the structuralist's view.

A number of alternative explanations were discussed to explain this result. For example, McKenzie and Bigelow (1986) suggested that detour ability emerges at different rates on different tasks and the question of comparability between the wire and lever task was considered.

The failure to find any support for the hypothesised relationship between spatial ability and detour performance is of particular interest given Piaget's (1954) argument that these two aspects are closely linked. The current results may be due to the spatial task employed or the type of detour tasks that were used. However, it must be borne in mind that other researchers have failed to find the hypothesised link between spatial knowledge and detour ability (Lockman, 1984).

The hypothesised relationship between these tasks may be questioned by other writers. Fischer (1980) has argued that synchrony will be the exception in development and that decalage is far more common. The search for synchrony between tasks, according to Fischer (1980), requires a more detailed consideration of the demands of any specific task.

The failure to find any relationship between these tasks raises a further more fundamental question for infant assessment, namely that if decalage is the norm, assessment of infants and decisions regarding their level of development cannot be made by relying upon one measure of ability.

APPENDIX 1

STRATEGY PROFILE FROM LEVER TASK

SUBJECT =

TRIAL	STRATEGY
1	II, I, II, V
2	I, II, I, II, III
3	I, II, I, II, I, II
4	II
5	I, II

APPENDIX 2

PRINT-OUT OF GAZE DIRECTION DURING LEVER MANIPULATION

```
S 0
D 18
A 20
D 23
S 25
D 37
A 39
D 43
S 45
D 50
A 52
Y 62
A 326
D 337
S 339
J 365
A 388
D 397
S 399
Y 409
Z 415

HAN 20 5 37 9 7 27
HOB 18 7 14 3 2 18
LEC 365 1 23 6 23 50
OBJ 0 5 71 17 14 16
BRK 62 2 270 65 135 6
SUC 415 1 0 0 0 0

CATEGORY DESCRIPTORS

A HAND HAN
D HANOBJECT HOB
J LEVCENT LEC
S OBJECT OBJ
Y BREAK BRK
Z SUCLEV SUC
```

APPENDIX 3

Appendix 3a - Correlation Tables - Correlation of gaze direction and lever success/failure for each experimental group

STANDARD LEVER GROUP

Gaze / Trial	Hand	Object	Hand Object	Away	At Exp.	At Mother	Lever Centre	Cross	Cover	Break
12-14 months 1	0.0222	*** 0.7349	0.1863		0.2462		-0.0172			-0.4223
" 2	0.2760	0.2628	-0.1313	-0.5638			0.4454			-0.2686
" 3		* 0.6315								-0.2068
" 4	-0.0239	0.3061	0.1610		-0.1538		-0.2408			-0.1430
" 5	-0.3536	-0.2592	-0.0303							0.2672
14-18 months 1	0.3436	-0.0712	0.2113	-0.0725	0.3045		0.2721			-0.2490
" 2	0.0173	0.5613	0.1120	-0.3101	0.5371					-0.4495
" 3	0.0444	0.3633	0.2936							0.0201
" 4	-0.2863	*** 0.7340	0.3420	0.4266			-0.3727			*** -0.8173
" 5	0.0104	0.0570	0.1066	-0.4705						-0.2119
18-24 months 1	0.1937	0.1190	0.0600				-0.1050			-0.1512
" 2	0.1024	-0.0266	-0.2465				0.1372			0.0990
" 3	0.3622	0.0413	0.0437				0.0636			-0.2263
" 4	0.3180	0.1624	0.2867				0.2433			-0.4178
" 5	0.1892	0.2526								-0.0841

Sig. Levels two tailed Pearson's 'r'
* 0.05
** 0.02
*** 0.01
**** 0.001

Appendix 3b - Correlation Tables - Correlation of gaze direction and lever success/failure for each experimental group

CROSS LEVER GROUP

Gaze / Trial	Hand	Object	Hand Object	Away	At Exp.	At Mother	Lever Centre	Cross	Cover	Break
12-14 months 1	-0.3734	0.4270	0.0238		-0.1846					-0.2713
" 2	-0.0136	0.1350	-0.1068		-0.1315		0.5465	-0.0767		-0.0275
" 3		** 0.7535	*** 0.9306				0.5229			
" 4		0.4620						0.5276		-0.2518
" 5		0.4938	*** 0.8020							-0.0045
14-18 months 1		** 0.7715						0.8515		** -0.7221
" 2	-0.1838	** 0.6562	0.4725	-0.3873	-0.2728		0.3202	-0.0758		** -0.6187
" 3	-0.1356	* 0.6586	0.0803		-0.1736		0.4045	0.1945		-0.5232
" 4	-0.0669	0.4035	0.4679				-0.0615			-0.2016
" 5	-0.1356	*** 0.6645	0.1067	-0.2236	-0.3304		0.1460			-0.5423
18-24 months 1	-0.3486	* 0.6593	0.3676				-0.1984			** -0.6940
" 2	0.1172	** 0.7233	0.3450				-0.1678	0.3660		-0.4538
" 3	-0.4129	0.3880								-0.1711
" 4		*** 0.6958								-0.5544
" 5	-0.4129	* 0.6196	0.4632				0.3483			-0.5709

Sig. Levels two tailed Pearson's 'r'
* 0.05
** 0.02
*** 0.01
**** 0.001

Appendix 3c - Correlation Tables - Correlation of gaze direction and lever success/failure for each experimental group

COVERED LEVER GROUP

Gaze Trial	Hand	Object	Hand Object	Away	At Exp.	At Mother	Lever Centre	Cross	Cover	Break
12-14 1										
" 2										
" 3										
" 4										
" 5										
14-18 1										
" 2										
" 3										
" 4										
" 5										
18-24 1	-0.2379	0.3961	0.5937						0.5962	* -0.7439
" 2	-0.1324	0.5449	-0.1443						0.4897	-0.5040
" 3	-0.0080	0.3374			-0.3873				0.3843	-0.3163
" 4	0.3771	0.5595	0.6523							-0.5291
" 5	0.4234	0.6148	0.6299							* -0.6139

Sig. Levels two tailed Pearson's 'r'
* 0.05
** 0.02
*** 0.01
**** 0.001

* NB no successful lever solutions by 12-14 or 14-18 month group.

APPENDIX 4

Reliability of Measures

Ten undergraduates produced lever strategy profiles for seven subjects and these were compared with the experimenter's to assess reliability.

Two aspects were considered:

1. The highest strategy achieved over five trials.

Only three of the undergraduates' records differed from the experimenter's and in all three cases, r = 0.87.

2. The highest strategy achieved on each trial.

This analysis resulted in 70 comparisons between the experimenter's and undergraduates' coding. Of these 70 comparisons, 35 produced variations between the experimenter's and undergraduates' results. Twenty-eight of this latter group produced correlations of r = 0.9 or above. The seven remaining comparisons produced five correlations where r = 0.75 and two where r = 0.85.

The reliability of the coding when using the Apple IIe programme was assessed by means of test - retest comparisons.

Eleven test - retest comparisons of wire behaviour and gaze direction results produced a high degree of reliability. The lowest recorded correlation for the eleven comparisons was r = 0.98.

APPENDIX 5

	Standard Lever Group	Cross Lever Group	Covered Lever Group
correlation between wire-lever success	0.431*	0.466*	0.257
correlation between wire-lever success with age partialled out	0.213	0.189	-0.058

* significant at 0.01 level

Correlation results of lever and wire task performance before and after partialling out age.

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