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The influence of peer interaction in micro-computer based problem-solving.

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CONTENTS.

CHAPTER III: THE TOWER OF HANOI.

CHAPTER IV. THE BALANCE BEAM AS AN EXPERIMENTAL TASK IN THE STUDY OF PEER INTERACTION.

CHAPTER VI: THE ALTERNATIVE BALANCE TASK.

CHAPTER VII: OVERVIEW AND CONCLUSIONS.

LIST OF FIGURES

Page No.

LIST OF TABLES.

PAGE NO.

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ABSTRACT

FACULTY OF SOCIAL SCIENCES

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THE INFLUENCE OF PEER-INTERACTION IN

MICRO-COMPUTER BASED PROBLEM-SOLVING

by Teresa Foot

This thesis is concerned with the importance of social factors in cognitive development: specifically it addresses the question of the extent to which interaction between children can affect learning or developmental progress. Six studies were conducted in local schools using micro-computer based problem-solving tasks. In the first two studies, a Tower of Hanoi problem was used to explore the importance of peer-interaction in learning. In the four subsequent experiments a balance-beam problem was used to investigate the importance of variation in task and social circumstances in determining individual benefit. Subject ages ranged from eight to fourteen years. It was found that precise differences in the experimental circumstances were capable of influencing the extent to which interaction with a peer enhanced the individual child's post-test performance. The findings suggest that previous studies of peer-interaction have demonstrated a less general effect than previously supposed. The variability in benefit demonstrated may indicate, not that interaction is of no practical importance, but rather that the replication of an effect may be heavily dependent upon repeating the exact circumstances in which it was first elicited. The concept of cognitive tactics is proposed as a means of describing cognitive processes in a way that acknowledges their relation to particular contexts.

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Due to the time constraints of a three-year studentship, this research programme has been necessarily restricted in its scope. It leaves a sense of frustration in having raised more questions than provided answers, although its value as a training exercise - in bringing an appreciation of the problems of experimental research - is in no doubt. At the end I feel that I am ready to begin..

CHAPTER I. SOCIAL INTERACTION AND COGNITIVE DEVELOPMENT.

I.1. INTRODUCTION.

This thesis is concerned with the importance of peer-interaction in cognitive development. The empirical work was conducted mainly in primary schools using micro-computers that are in regular use as part of the school facilities. The thesis brings together two elements of the study of children: firstly it is concerned with theoretical issues regarding child development, and secondly with less theoretically precise but equally important educational issues regarding the circumstances in which children learn. The advent of micro-technology into the schoolroom has provided new impetus for research in respect of both these areas.

'Theory-driven' research can be distinguished from that which is 'need-driven' or 'methodology-driven' (Wheldall 1985). Although the present work is primarily concerned with developmental issues and it is thus 'theory-driven', the use of micro-computers as a tool may mean that the findings address some of the many unanswered practical questions about the use of computers in education. Methodological issues are also prominent in that the question of 'what' is to be investigated is inextricably linked with the question of 'how' this should be done.

The first two chapters of the thesis aim to set the subsequent empirical work in an adequate context, with emphasis on a selective review of relevant work rather than a global re-appraisal of the literature. Firstly I shall introduce the subject area of social cognition, and then devote some space to considering the importance of Piaget's theory in relation to it. I shall then discuss the empirical work that has been most concerned with social interaction in cognitive development, particularly that concerned with peer interaction. The limitations of this research will also be considered. In the second introductory chapter I shall consider the change of emphasis that is apparent in recent psychological enquiry, namely a concern with the process of development including the development of metacognitive functions, rather than a pre-occupation with structure. I shall refer to the current debate regarding the importance of micro-computers in schools as an illustration of this trend. The last section of the introductory chapters will consider the relevance of some information processing concepts to the present computer-based research programme.

I.2. THE SUBJECT AREA OF THE PRESENT RESEARCH.

The area of enquiry concerned with the importance of peer-interaction in learning and development is part of the more general reseach topic known as 'social cognition', so called because it lies at the boundary between social psychology and cognitive developmental psychology. The majority of social cognitive studies (reviewed by Shantz 1983) are situated within the constructivist/structuralist perspective that is characteristic of Piaget and are concerned with the way the emerging structures of the mind determine the development of social understanding. In contrast, a second area focuses on the social antecedents of the individual's intellectual development. Modelling studies (eg Murray 1974) based upon social learning theory, and the constructivist approach of Doise et al (eg Doise and Mugny 1984; Doise, Mugny and Perret-Clermont 1975) both contribute to this interpretation of social cognition. The majority of work concerned with the importance of peer-interaction in cognitive development has been set firmly within this paradigm.

I.3.THE THEORETICAL BACKGROUND: PIAGET'S THEORY.

Piaget has had a dominant position in developmental studies for the past twenty-five years. His structuralist approach is based upon the theoretical strands of biological equilibrium, constructive evolution and mathematical logic. The principle of development as an invariant sequence of stages forms a central tenet of Piaget's work. The young child at the pre-operational stage of development is perceived as being egocentric - as being unable to appreciate other's points of view so that both reasoning ability and social behaviour are limited. However, when the child achieves concrete-operational thinking he becomes able to decentre in respect of himself and the previous egocentrism is replaced by a system of reversible operations. At this stage the child becomes able to move freely from one perspective to another in both the intellectual and social spheres. The concept of egocentrism thus illustrates Piaget's assumption of parallelism between social and individual aspects of development. Finally, in adolescence, Piaget describes the child's growing ability to reason in abstract, and to use a form of thinking that is independent of context. Piaget sees concrete operations as being a means for structuring immediately present reality; during the formal operational stage, however, the adolescent begins to reason with propositions and hypotheses, rather than with given data alone. Such reasoning makes it possible for the subject to isolate variables and deduce potential relationships - to combine propositions mentally and to isolate those which could confirm or falsify his hypothesis. Piaget acknowledges that not all adults achieve this degree of abstract reasoning capability.

The individual structures that make up the concrete operational stage of development are said by Piaget (1950) to come together as structured wholes known as structures-d'ensembles, and there has been much debate regarding their nature. Some theorists assume that Piaget refers only to logico-mathematical knowledge, although Piaget himself maintains that his structures serve for understanding of both the physical and the social world.

The process of adaptive integration that permits developmental progress, particularly the integration of cognitive structures is known as equilibration.

> *"Little by little there has to be a constant equilibrium established between the parts of a subject's knowledge and the totality of his knowledge at any given moment. There is a constant differentiation of the totality of knowledge into the parts and an integration of the parts back into the whole".*
> (Piaget 1977a, page 839).

The notion carries an assumption that disequilibrium followed by re-equilibration at another level is the mechanism of developmental progress and this mechanism is the central object of investigation within the paradigm.

I.4. INDIVIDUAL VERSUS SOCIAL APPROACHES TO INTELLECTUAL DEVELOPMENT.

A central criticism of Piaget's theory has been his apparent pre-occupation with the individual child, viewed in the process of development in isolation from his environment. Piaget's anecdote of the child alone on a beach, discovering number conservation through solitary playing with pebbles (Piaget 1964) is often quoted as a stereotypic example of this view. Piaget has argued that co-operation of any kind is not possible before the concrete-operational stage because of the reciprocal nature of exchange of viewpoint. He believes that earlier social exchanges are egocentric - they are assimilated to the childs own actions. In contrast, for older children social input is co-operative in that it is assimilated to the co-ordination of actions (Piaget 1969, page 118).

Although individualism is undoubtedly dominant in Piaget's later work, in early references he acknowledged the importance of social interaction as an essential component in the child's development. He viewed discussion with equals as the mode within which the developing child could integrate his own views with those about him (Piaget 1926). Only with peers could the apparent contradictions between different perspectives be resolved. He contrasted the benefits of peer-interaction with adult-child interaction which he held to be essentially asymmetrical and thus not conducive to developmental change. In recent years Piaget's argument has been that social and individual elements are complementary:

> *"If logical progress thus proceeds in tandem with that of socialisation is it necessary to say that the child becomes capable of logical operations because his social development qualifies him for co-operation or should one assert on the contrary that it is these individual logical acquisitions that allow him to understand others and thus lead him to co-operate? Since the two sorts of progress are on even terms the question seems without solution except to say that they constitute the two indissoluble aspects of a single and identical reality, at the same time social and individual"* (Piaget 1965, p.158).

Renewal of interest in the importance of a social element in the developmental process can be seen to stem from a series of studies conducted by Smedslund (1961; 1964; 1966). He investigated the circumstances in which children's interactions with objects would facilitate cognitive advancement and he attributed his negative findings to the lack of social interaction involved. This issue was taken up within both the behavioural perspective of social-learning theory and a constructivist-developmental perspective. I shall consider the first of these approaches in the next section.

I.5. MODELLING STUDIES.

The considerable number of modelling studies based upon social learning theory carried out in the United States in the 1970's provide examples of relations that are asymmetric in terms of knowledge but not necessarily in terms of authority or age differences. The modelling hypothesis has its roots in a behaviouristic psychology which is concerned with overt behaviour rather than internal processes. It contrasts sharply with the Piagetian focus on cognitive structures.

In relation to the importance of social factors in learning, the modelling hypothesis is that benefit to a less able child will result from the opportunity to observe the behaviour of a more able child or adult. This implies that interaction between the participants is not a necessary part of the process. A number of researchers (eg Kuhn 1972; Rosenthal and Zimmerman 1972; Waghorn and Sullivan 1970) have conducted studies in which children were required to watch other children perform various cognitive tasks before having their own performance assessed on similar tasks. They have shown that improvement in performance resulted from mere observation of a correct model. Murray (1974) investigated modelling effects on children's understanding of conservation. He found that although initially non-conserving children could be induced to give conserving judgements after having simply watched another child model such judgements, conserving children who watched a non-conserving model failed to regress. Murray describes this as evidence for modelling being effective only in what he describes as a 'developmentally sensible' direction.

The children in Murray's study could not explain or justify their judgements, which raises the question of what criteria are reasonable in assessing the extent of progress. Performance has been shown to be improved following such modelling procedures; it is by no means certain that this improvement reflects cognitive gain in any stable developmental sense, although some evidence of generalisation of acquired conservation has been found (Zimmerman 1974; Murray 1974; and Rosenthal and Zimmerman

1972). A second option, the Piagetian criterion of justification, would only be satisfied if such justifications could be shown to be novel rather than imitations of previously encountered explanations. This has been established, albeit on a limited basis, by Botvin and Murray (1975). Evidence for the durability of performance is also limited, being found only by Kuhn (1972) who showed that gains on a classification task were maintained one week later.

Some workers within the social learning perspective have investigated task settings of a more active kind. Studies have been conducted involving not just observation but actual interaction between 'pre-operational' and 'operational' children (Murray 1972; Silverman and Geiringer 1973; Miller and Brownell 1975). These studies illustrate a change of emphasis within social learning theory: the behaviouristic pre-occupation with overt behaviour has given way to a recognition of internal processes such as cognitive dissonance. For example, Murray, Ames and Botvin (1977) asked children to pretend that their judgements and explanations to a series of conservation problems were the opposite to what they were. They found that non-conservers and transitional subjects made large and significant gains in conservation in comparison with appropriate control groups but that conservers did not regress. They also found that newly acquired conservation was not extinguished by a second dissonance treatment in which subjects gave non-conservation responses. They argue that cognitive dissonance provided an explanation of the process although they acknowledge that this does not account for the uni-directionality of the changes observed.

Botvin and Murray (1975) used a conservation task to make a direct comparison of modelling and interactive conditions. Children either simply observed a conserver's performance or argued with conservers in a social conflict situation. They found no significant differences in conservation performance between the modelling and social conflict treatments. Botvin and Murray conclude that the effects could be adequately explained in terms of modelling, although what was learned was not a simple non-reflexive imitation of the conserver's performance, since the new conservers gave patterns of reasons which did not reflect those of the initial conservers. They suggest that both the modelling and the interactive conditions induce cognitive dissonance which fosters cognitive growth. This explanation is very different in emphasis from the simple modelling hypothesis and represents an attempt to overcome the previous incompatibility with Piagetian notions of assimilation as the mechanism of change. Murray (1979) argues that Piaget's (1962) theoretical position concerning the phenomenon of imitation is not necessarily incompatible with social learning principles. Piaget suggests that a child will be able to imitate behaviour which can be assimilated to existing structures or schemes; imitation will occur to the extent that the behaviour diplayed by a model falls close to the observer's level of operative knowledge.

Kuhn(1972) has attempted to reconcile the two approaches by analysing the effectiveness of different models in relation to the subject's initial cognitive level. She suggests that there is an optimal mis-match between the child's current state and the model to be presented: structural change would be most readily induced by presentation of the model one stage beyond the child's current understanding.

These studies support the idea that the effectiveness of the modelling procedure is in part dependent upon its relation to the child's current stage of development. Thus the modelling hypothesis in its simplest form is inadequate to account for the mechanisms of developmental change: mere imitation does not provide a sufficient explanation of the learning process. The importance of interaction between participants in the learning process will be considered in the next section.

I.6 PEER INTERACTION STUDIES.

Recognition that changes taking place in modelling studies reflect a process more complicated than pure imitation has led to a renewed interest in the idea that interaction, rather than imparted knowledge, may be a crucial element in the developmental process. Doise and colleagues (Doise, Mugny and Perret-Clermont, 1975; Mugny and Doise, 1978) in Geneva have explored this theme. Their work reflects a dissatisfaction with what Doise and Mugny (1984, page 12) describe as 'traditional' ideas on the psychology of intelligence. They suggest that both psychometrics and Piagetian practice isolate the individual from the social context in which his intelligence develops: they prefer to see intelligence as elaborated in inter-individual relations established within specific social situations. Doise and Mugny argue that their thesis does not directly contradict the Piagetian view of cognitive development which accords an important function to social co-ordinations and regulations:

> '*human intelligence develops in the individual as a function of social interactions which in general we far too often neglect*' (Piaget 1971, page 260).

However, they dislike the fact that Piaget has, within his epistemological system, what they see as a 'defence mechanism' justifying omission of the study of any causal links between the cognitive and the social. In contrast to Piaget their work is premised upon an assumption that a causal relation exists.

To explore this issue Doise and colleagues have conducted experiments based on Piagetian concrete-operational tasks. Subjects were of the appropriate transitional age as far as the achievement of operational thinking is concerned, namely five to nine years of age. The tasks used included a spatial transformation problem in which the subject was required to 'decentre' from his own point of view, several types of conservation of length and conservation of liquid quantity tasks, and a co-operative game involving the manipulation of pulleys. The experimental format typically consisted of individual pretest, followed by joint sessions in which two or three children worked together, followed again by individual post test.

Although these tasks all have in common that they are concerned with the transition from pre-operational to concrete-operational thinking they are different in some important respects. A conservation task creates a test situation in which identification and verbal transmission of rules and principles are a potentially crucial factor in determining whether progress is made. In contrast, in a spatial orientation task verbal rules have no part, but rather the manipulation of materials and discrepancies in visual perspectives are the dominant features. At a behavioural level the nature of potential interaction is clearly different according to whether the task involves verbal reasons and explanations on the one hand, or active hypothesis testing with concrete materials on the other. However, it has been assumed by Doise et al.(1975) that a common underlying mechanism, namely socio-cognitive conflict, can account for the benefits accruing in all these situations.

In an early study, using a spatial co-ordination task (Doise et al 1975), the performance of children during the interaction session was shown to be typically at a higher level than that observed when children were given solitary practice. Children who had had experience of peer interaction were superior in performance both in training and at individual post-test when compared to control subjects who had worked on the task alone.

A problem of interpretation of the findings of studies such as this is that when a child is presented with a partner who both disagrees with him and offers a correct solution, two potential explanatory factors are confounded.

Progress may arise either from the provision of the correct answer or from the asymmetry in the pre-test levels of the participants. Subsequent research clarified this issue. Doise, Mugny and Perret-Clermont (1976) found that children progressed on a conservation of length task as a result of being presented with a verbal solution which, while being no more correct, contradicted the child's own. They concluded that the equal effectiveness of both incorrect symmetrical interaction and correct asymmetrical interaction could be accounted for in terms of 'socio-cognitive conflict'. Inter-individual encounters lead to cognitive progress insofar as socio-cognitive conflict occurs during the interaction. A study by Valiant, Glachan and Emler (1982), using a multiple classification task, also supported the proposal that conflict with a parallel or inferior position may be productive of cognitive gain. The children in this study improved even if their partner was less capable than themselves.

Mugny and Doise (1978) used an experimental design that enabled both the opposition of subjects at different cognitive levels and the juxtaposition of subjects at the same level. They compared the performance of different types of child dyads on the reconstruction of a model village from a different orientation. They found that children with the same incorrect approach did not benefit from interaction with each other: this was a symmetrical relation. However, they established that asymmetry and thus conflict could be brought into the situation by changing the subjects position thus creating a visual discrepancy in perspectives.

The relationship between partners in a paired learning situation is further complicated by the potential for social dominance. Mugny and Doise (1978) found evidence of dominance that prevented cognitive gain by excluding the non-conserving partner. The circumstances of occurrence of dominance were clarified by Doise (1978) who found that, using a task involving manipulation of materials rather than verbal explanations, the less able child did not benefit if the able child dominated by virtue of doing the task, whereas in a verbal conservation task the less able child profited from the dominant child's explanation. The potential of dominance thus varies according to the type of task.

If the mechanism for developmental change is correctly identified as socio-cognitive conflict, then there may be situations in which conflict within the individual achieves similar ends. On the basis of their research, Doise et al (1975) view intra-cognitive conflict as less effective than inter-individual conflict as a stimulus to progress. Mugny and Doise (1978) have demonstrated the superiority of inter-individual over intra-individual conflict but Emler and Valiant (1982) failed to replicate this and found that intra-individual conflict could be equally effective as a spur to progress. Emler et al. demonstrated intra-individual conflict by getting the child to move his position and then asking him if he was satisfied. However, this procedure may be a reflection of adult-child rather than intra-individual conflict - the child interpreting the intervention as the experimenter quarrelling with his first decision.

It seems clear that a number of factors influence the extent to which social interaction facilitates individual progress. Doise (1975) points out that the relation between task difficulty and the individual's initial level of ability is important and goes so far as to suggest that only when the child has some partial grasp of the principles involved in the correct solution of a task is interaction with a partner likely to be beneficial to him. Kuhn (1972) and Perret-Clermont (1980) both suggest that benefit is greatest when one subject is at a developmental stage just above the other. However Silverman and Stone (1972) and Silverman and Geiringer (1973) have demonstrated benefits from interactions based on very discrepant levels of understanding. These disagreements do not detract from the undoubted evidence that in some circumstances positive findings have been made that meet the criteria for success set by Piaget. For example, Doise, Mugny and Perret-Clermont (1975) reported a majority of novel explanations at post-test in a conservation task, and found that newly acquired judgements were still present one month later. Similarly, evidence of generalisation in conservation tasks is cited by Perret-Clermont (1980).

I.7. LIMITATIONS AND ELABORATIONS.

Despite their challenge to some aspects of Piagetian theory, the studies of Doise and colleagues in Geneva remain firmly rooted within the constructivist perspective; this has limited both the type of task used and the conclusions to be drawn from their findings. Not all researchers are content with the socio-cognitive conflict hypothesis. Glachan and Light (1982) argue that a more convincing explanation, one that can account for the discrepancies in various studies so far, is that the opportunity to resolve conflict may be the crucial element in determining whether children gain from an interactive task setting. They have widened the debate by using alternative problem-solving tasks that are not bound to concrete operational concepts, namely the Tower of Hanoi puzzle and a version of the 'Mastermind' problem.

Russell (1981) also challenges Doise's view: he argues that children's performance lags behind their competence and suggests that they may give inappropriate responses in individual testing situations due to a lack of an appropriate propositional attitude (Russell 1982). Russell believes that children have a 'subjective' view when young and assume that all questions relate to appearances. He suggests that what is lacking in the child is a socialised concept of objective shareable truth. To account for Doise's findings of cognitive advancement following peer-interaction Russell suggests that children go through a transitional phase in which they can be triggered to move from a subjective to an objective interpretation when faced with a conflict of views. In promoting an appropriately objective attitude towards the task socio-cognitive conflict enables the child to effectively utilise his existing knowledge. Unlike Doise, however, the transition is seen as not between one structure and another, but rather as a process of enculturation to which adults contribute substantially. Russell's acknowledgement of some sort of transitional process (1982) represents a compromise from his earlier rejection of the conflict hypothesis (Russell 1979), but he remains convinced that the situation in Doise's experiments constitutes only a marginal part of the socialisation process. In a similar vein, Light and Perret-Clermont (1986) propose that social interaction may lead to re-interpretation of the task, which, when re-interpreted, is already understood. What the child learns in this case is in effect, not *how* to do it, but *that* they know how to do it. Similarly, Bryant (1982) suggests that children may possess the logical structures in question but do not always know when to use them so the problem may be one of deployment of logical skills, and not their existence. He conducted a series of studies using a measuring task to test the hypothesis that it is agreement and not conflict between strategies which produce intellectual change in young children. Bryant argues that conflict tells the subject that something is wrong, but not what it is, and certainly not what is the right strategy. On the other hand if one strategy consistently produces the same answer as another, the child can be reasonably sure that both are right. The agreements and conflicts induced are all intra-individual however, and therefore not strictly comparable with inter-individual conflict.

Apart from peer-interaction studies, there is growing evidence from elsewhere that failure on a concrete-operational task does not necessarily mean that the appropriate logical structure is 'missing'. A range of studies have highlighted the importance of contextual determinants of performance in concrete-operational tasks (eg Light and Gilmour 1983; McGarrigle and Donaldson 1975; Neilson and Dockrell 1982). In a conservation study, Samuel and Bryant (1984) showed that subjects modified their responses to the experimenter, apparently on the assumption that to be asked the same question twice implied that the first answer was wrong. In a related but contrasting fashion Cox (1980) found, in a co-ordination of perspectives test, that a response that was seen to be adequate previously may be repeated: a child was more likely to give egocentric answers if he had been first asked about his own view than if he has not. As Donaldson (1978) points out, the manner in which a problem is presented, the language used, the choice of task material and the way changes in the task materials are brought about, all interact to affect the child's performance and thus his apparent rationality.

Piaget's clinical method was very dependent on the language used by the tester and on accepting the child's response as being a true reflection of his cognitions, but he failed to acknowledge this restraint. Light and Perret-Clermont (1986) suggest that Piaget is perhaps guilty of making an overready assumption that failure in such a task derived from logical inadequacies. These findings all lend support to the idea that development may be more a matter of achieving a match between pre-existing forms of logical inference and the social conventions of language and dialogue in the adult culture, than of the acquisition of logical structures.

If the studies concerned with the importance of contextual variables demonstrate that the experimental situation is inescapably social, even when social-interactive issues are not the object of study, then it may also be that an inappropriate boundary has been drawn between interaction studies and those in which interaction is not the focus of attention. Some task situations previously assumed to be testing the child in isolation, would perhaps be more accurately described as adult-child interaction. Perret-Clermont and Schubauer-Leoni (1981) draw attention to the parallels between the processes at work in peer-interaction studies and in individual cognitive testing situations. A separate strand of developmental research has concerned itself with adult-child interactions and their importance in cognitive development: the relevance of these studies will be considered in the next section.

I.8. ADULT-CHILD INTERACTION.

Piaget's early reference (1926, 1932), to the importance of co-operation between peers, served as a counterpoint to his views on adult-child interaction. He rejected the possibility of direct social transmission as a mechanism of cognitive development, believing that asymmetric relations were unproductive in fostering intellectual progress. This assumption may reflect the authoritarian approach to adult-child relations that was still prevalent at the time of his writing on the subject. In contrast - rather than assuming the existence of irretrievable asymmetry - recent research has been more concerned to identify the nature of the relationship. Light (1983) suggests that the adult may interact with the child on the basis of a 'constructed' equality, in which case studies of adult-child interaction do not necessarily imply rejection of Piaget's emphasis on reciprocity between equals as an essential component of the interactive process. Wertsch (1978) claims that if you look at the adult-child dyad as a whole, the adult often performs a metacognitive function, providing the other-regulation necessary for the child to carry out a task. Wood's (1986) notion of 'scaffolding' provides an alternative description of this adult support. He cites three ways in which interaction, in the form of a tutorial dialogue between mother or teacher and child, is responsible for the solution of immediate learning tasks and of the mastery of some general intellectual skills: the three principles are exploitation of recognition-production gaps, scaffolding of means, and progressive relaxation of adult control.

The importance of language in the co-construction of meanings has been under scrutiny. Robinson and Robinson (1981) conducted an experimental study in which the influence of the adults verbal input into a task situation was systematically explored. Children were paired with an adult listener who provided one of several kinds of feedback whenever the child's descriptions were ambiguous. They found that subjects' referential skills were significantly enhanced if given the appropriate adult support - if young children do not recognise that messages can be ambiguous the adult fulfills a metacognitive function. Similarly, Wood and Middleton (1975) drew attention to the role of a mother's use of language in directing and structuring the child's learning and in helping him to 'decentre' from his immediate experience. The benefit of contingent interaction has also been demonstrated by Heber (1981) and Wood, Wood and Middleton (1978), studies that all have in common that they highlight the social component in the learning process.

Although the majority of work in this area has centred on parent-child relations, there are some recent examples of studies concerned with the relationship between teacher and child. Walkerdine and Corran (1978) analysed transcripts of the interchanges between teachers and children in the classroom with a view to identifying the process by which understandings are co-constructed. Rommetveit's (1978) concept of the 'architecture of intersubjectivity' presents a framework for understanding the conditions that enable a teacher and a learner to achieve a common intersubjectivity and hence to communicate effectively with each other. This accords with Vygotsky's (1966) view that the most important index of a child's development is not his current ability, but rather what he can do in collaboration with adults.

With these studies the interests of psychologists are brought more into line with those of classroom teachers. Issues of greater significance to education are also brought to the fore by the shift in emphasis from the study of skills to the study of knowledge of skills: metacognition. This topic will be further explored in the next chapter.

CHAPTER II. THE PROCESS OF COGNITIVE DEVELOPMENT: THEORIES AND APPLICATIONS

II.1. METACOGNITION.

The concept of metacognition provides a link between individual and social processes. Flavell(1977) claims that metacognition is really a form of social cognition:

> "*there is a sense in which interpropositional 'second degree' thinking is automatically social cognitive in nature: propositions are stated about thoughts rather than physical objects, and hence thinking about such thoughts represents a kind of social cognition*"(p123)

Flavell (1979) describes the move towards an interest in metacognition, or as he refers to it - 'cognitive monitoring', as a new area of developmental enquiry. He distinguishes four types of metacognitive understanding relating to knowledge, experiences, goals and strategies. Lefebvre-Pinard (1983) suggests that current understanding of metacognition is that it consists of the knowledge people have of their own cognitions and of the control they are able to exercise upon these cognitive activities. It has also been defined in terms of executive processes (Brown 1977) and self-communication (Merchenbaum and Asarnow 1979), while Kitchener (1983) suggests that a further term, meta-metacognition is needed. He distinguishes between knowing about knowing in an epistemic sense ie. in ill-structured problems, and in the sense of the monitoring that occurs in problem solving. All of these ideas carry an assumption of conscious awareness and it is this aspect that appears to be a defining feature of metacognition.

If the term metacognition is relatively new, the skills and understanding referred to were recognised by Vygotsky (1962; 1966). He was one of the first theorists to highlight the importance of self-awareness in the developmental process, seeing a direct relationship between consciousness of cognitive processes and the ability to control them. In this view, the conditions under which the child achieves mastery of his own thoughts become of prime concern. Vygotsky lays great stress on the child's potential, rather than his actual performance as a measure of development and he describes the gap between the two as the zone of proximal development. Studies of assisted problem-solving (Stone and Day 1979; Wertsch 1980) and of co-operative problem-solving (Forman and Cazden 1982; Garton 1983) have utilised this theoretical view as an interpretive framework.

The construction of individual self-awareness is also a powerful theme in the writings of Mead (1934). Mead believed that one can know oneself only to the extent that one knows others. He sees the child's growing ability to internalise conversations as the precursor of reflective thinking; the ability to be reflectively self-aware is thus a function of social-interactive experience. The childs growing awareness of himself enables him to be aware of the attitudes of others to him - to view himself as an object or to 'take the role of the other'. Selman (1970) suggests that this ability to 'take the role of the other' constitutes a fundamental social-cognitive skill.

The distinction between the views of Vygotsky and Mead on the one hand, and Piaget on the other, is by no means an absolute one, but is rather a question of priorities. Vygotsky (1966) was specifically interested in the development of 'higher mental functions' and the social context in which these are acquired, a priority that is not shared by Piaget. Inhelder and Piaget (1958) argue that in order to understand conceptual development, both the logical combinatorial actions and the rules that are embodied in those actions must be taken into account; a very structural emphasis. The importance of these differences is that what constitutes the object of investigation varies according to the theoretical perspective, which in turn determines both the path of developmental research interest and the way in which findings are interpreted.

Although Doise et al. have in general not discussed their theory of socio-cognitive conflict in metacognitive terms, it may be that metacognition is an important part of the developmental process observed in their studies. Robinson (1983) suggests that Doise's work is based on the assumption that contact with peers forces awareness, and that children's awareness of a problem is thus considered to be in part responsible for their advancing to a higher level of understanding. A relevant peer interaction study is that of Carugati, De Paolis and Mugny (1979). They found that children who are relatively competent at the outset of a task still gain from peer interaction with one who is less competent, and they improve at individual post-test. The need to *defend* their correct answers appeared to be the source of progress, arguably by increasing their awareness. It may be that peer-interaction facilitates explicit thought, with awareness of hypotheses etc and therefore more efficient task solution. Much adult-child interaction appears to serve the same purpose to the extent that it raises children's level of awareness. Younger children may be able to use feedback from another about their own actions, thoughts and feelings to improve their problem-solving skills in the same way that older children and adults use their own metacognitive knowledge.

If the work of Doise has failed to explore the metacognitive issue, the same cannot be said of Karmiloff-Smith who has investigated the role of metacognitive understanding and developed a model of the way that children 'grapple' with new problems. She has been prominent among those arguing for a change of emphasis - towards an understanding of how knowledge is reconstructed during actual functioning. Karmiloff-Smith (1984) believes that one of the major shortcomings of developmental theorising has been to neglect mechanisms of change. Where change or transition has been invoked, it has been explained almost exclusively by a negative feedback or conflict-reducing mechanism. She suggests that children's progress cannot be explained by failure or conflict alone and argues that conflict is the *product* of the process rather than the cause of it: in her view children change because they seek control over both their environment and their internal representations. From a series of studies, Karmiloff-Smith concluded that initially children use bottom-up procedures; at an intermediate level an inappropriate theory is held or over-applied, and finally bottom-up and top-down reasoning are combined.

In this view, success becomes a pre-requisite for development, while negative feedback is seen as a source of low level behavioural change but not representational i.e. developmental change. The importance of Karmiloff-Smith's work is that she derives a model of the process by which children achieve understanding with problem-solving. In distinguishing between implicit and explicit knowledge metacognitive issues are brought into the foreground.

In a similar vein, Robinson (1983) distinguishes between knowing *how* to perform a task that may include a strategy for action, and knowing *that* one has a strategy. She draws the boundary between cognition and metacognition at this point: only the latter is metacognition. Shatz (1978) accounts for the distinction in terms of the subject's information processing capacity. She suggests that conscious monitoring occurs only when capacity is not fully taken up with actually carrying out the task in hand. If basic performance is automated due to prior learning, it frees cognitive capacity for a metacognitive function. Since adults have far greater experience than children they are much more likely to have the spare capacity needed for metacognitive activity.

At a general level Lefebvre-Pinard suggests that the importance of metacognitive studies is the extent to which they portray the individual as an active participant in the developmental process, thus creating a positive account of development.

> "*Instead of portraying the individual as a kind of 'victim' of his developmental stages, of his reduced information processing capacity, or of a host of inferential biasses of all kinds, the emphasis is now on the individuals potential for becoming aware of the positive and negative factors that affect his cognitive functioning and for working out strategies that enable him to take advantage of the former or compensate for the latter*". (Lefebvre-Pinard 1983, page 24).

Lefebvre-Pinard also argues that many professional psychologists working in education, for example, find the traditional models of cognitive development, such as that of Piaget, of very little use in explaining the behaviours and performances that are significant in educational contexts. She argues that metacognitive studies may bridge the gap between cognition and behaviour.

The current interest in metacognition does appear to bring psychological and educational concerns into the same focus; the question of how children may be helped to achieve metacognitive growth leads naturally to educational issues. European reseachers interested in the dynamics of peer group interaction have recently begun to move towards the use of tasks in an educational context (eg Perret-Clermont and Schubauer-Leoni 1980). The convergence is mutual in that educational theorists have increasingly acknowledged the importance of metacognitive understanding in the learning process in the classroom. A leading example is the work of Papert (1981) who has based his view of the merit of computer use for schoolchildren on a metacognitive approach to learning. I shall consider his views and the use of micro-computers in schools in the next section.

II.2 MICRO-COMPUTERS IN EDUCATION

The advent of micro-computers in schools has created excitement and controversy. It has been suggested on the one hand that they may, in some fundamental sense, favourably alter the potential for education, or on the other hand that they may lead to a regression in educational practice. Taking the latter view first: the traditional joke about the school bus being the only successful piece of educational technology reflects what was until recently a prevailing attitude in respect of children's education. It existed perhaps as a reaction to the first generation teaching machines which had their roots in behavioristic psychology and programmed learning. These typically involved the pupil in a linear progression through a subject domain with rewards given for correct responses.

Piaget was surprisingly complimentary about early simple teaching machines, but perhaps only because they demonstrated beyond all possible doubt the mechanical nature of the schoolmaster's function as it is conceived by traditional teaching methods. Much earlier, he had made the case that the individual work he saw as characteristic of traditional schools ran contrary to the most obvious requirements of intellectual development (Piaget 1932, page 412).

The anxiety amongst educationalists that micro-computing might be detrimental has been expressed:

> *"There is every sign that the headlong rush into micros is causing a reversal to techniques and philosophies which have been discredited in computer assisted learning many years ago"*
> (O'Shea and Self 1983, page 3).

There is insufficient evidence to ascertain whether this pessimism is justified, however one survey has been conducted to identify the extent to which micro-computers are in use in Hertfordshire primary schools (Jackson, Fletcher and Messer 1986). This survey found that the numbers of available machines were extremely limited, averaging less than two per school. In general micro-computers were used with groups of two or three children at a time, usually mixed in terms of ability, sex, personality and experience. In younger age groups 'drill and practice' software was the most used facility. The majority of teachers said that they encouraged groups of children to talk about the tasks because they thought it would be beneficial, however the type of benefit wasn't stated. A positive effect on motivation towards work presented on the micro-computer was reported by a majority of teachers, and just over a half reported an increase in attention; however, only a minority reported an improvement in children's memory for work presented on the computer. Jackson et al. concluded that, whether due to limited resources or active teacher choice, most children used computers in groups, and in doing so were learning important interaction skills like co-operation, group decisions, and turn-taking. The implications of this survey were that the worst fears of O'Shea and Self had not been realised, although the quality of the programs then in use was clearly limited.

In contrast to those who express pessimism about the use of computers, Papert is a leading exponent of the view that information technology may have a seminal influence on teaching practice. He supports Piaget's belief that learning is an assimilatory process and for this reason he is in favour of 'discovery' learning without a set curriculum, and believes that the computer provides an ideal medium for this type of education. Papert (1980) argues that experience with LOGO or similar programming languages may provide children with reasoning strategies and metacognitive structures which could profoundly influence the pace and pattern of their subsequent cognitive development. Papert believes that the computer can concretise the formal; it can allow the boundary separating concrete and formal knowledge to be shifted, so that knowledge previously accessible only through formal processes can be approached concretely. It is assumed that programming encourages the child to bring his inner thought processes into consciousness.

A lot of emphasis is placed by Papert on 'debugging' ie the search for - and correction of - mistakes, which he believes both requires and develops a high level of reflective self-awareness. The effectiveness of 'debugging' as a facilitator of learning depends on the logic of the structure inherent in the programming language. For this reason, Papert is severly critical of the programming language 'BASIC' which, because of its obscure structure, he sees as unintelligable to all but the most able children. He is also critical - naturally in view of his theoretical orientation - of the use of computers for behavioristic learning programmes, particularly if these lead to a completely individualised kind of education.

The issue of group versus individual learning should be understood in the light of educational practice. Although the introduction of Piaget's theoretical ideas into the classroom in the 1960's led to an increase in small group activity, education remains highly individualistic; within groups children normally function in parallel with each other rather than collaborating on joint tasks. Perret-Clermont and Schubauer-Leoni (1983) found that group activities are typically justified in social terms rather than cognitive ones; teachers tend to emphasise the social benefits of peer interaction rather than the cognitive ones. Co-operative learning is by no means a dominant feature of educational life, nor is it a priority concern for teachers. However, limitations in the availability of computer hardware makes it a matter of concern; for the foreseeable future the number of computers in primary schools is likely to remain substantially below the number required for regular and frequent individual use. Therefore, by virtue of resource limitations, if for no other reason, the question of whether shared use of a computer influences the extent to which individual pupils may benefit is an issue of importance. The limited evidence available to date suggests that the introduction of computers increases rather than decreases interactions in the classroom. Hawkins (1983) observed two classes learning LOGO and found from both teachers' comments and direct observation that children talked to each other more about their work when they were doing programming tasks than when they were doing non-computer tasks. This may, of course, have been a function of the novelty value of the computers, although the difference was fairly stable over the whole year of study. Hawkins comments that given the common picture of the computer 'hacker' as a social isolate, the amount of peer collaborative work going on was something of a surprise. The computer screen is capable of being attended to by more than one child at a time and provides a shared common representation of the problem; in this respect it provides a source of encouragement of group work. Freeman (1986) found that the use of computers noticeably changed the focus of attention away from the teacher to the computer. He suggests that teachers will have to be prepared for more pupil autonomy by creating an atmosphere that encourages discussion and collaboration between teacher and pupil and between the pupils themselves.

Hoyles and Sutherland (1984) have investigated children learning LOGO in the classroom over a sustained period and confirm that effective collaboration occurs in programming although the relative merits of this compared to individual functioning have not been directly compared by them. Two aims of this project were to investigate the problem-solving strategies used by pupils within the LOGO programming environment, and to examine the nature and extent of the collaboration between the pupil pairs. Hoyles and Sutherland see the role of interaction as 'pushing' the participants towards an objective as opposed to a subjective attitude to the problem, which they regard as crucial for the abstraction of mathematical ideas (cf. Russell 1981). Their reseach, which is at this time still in progress, aims to discover how the cognitive and communicative functions of the social interactions between pairs of children learning LOGO contribute both to the construction of their own learning goals and to development in programming strategies. In this program pupils were encouraged to discuss and justify their strategies, which Hoyles (1985) views as a shift in the social relations in the classroom from a teacher-centred to a pupil-centred approach. Hoyles and Sutherland observed that within effective collaborative research the relative dominance between pairs varied during different kinds of programming activity. One pupil may control the planning activity while the partner controls the 'hands on' time. They also found that the longer pairs worked together, the more interchangeable the roles became, as pairs adjusted to both their partner's needs and the needs of the task.

Hoyles and Sutherland were not making any experimental comparisons between the learning to be expected with and without the benefit of peer-interaction. However, Fletcher (1985) specifically addresses the issue of whether groups of nine to eleven year-old children engaged on a micro-computer task perform better or worse than children doing the task alone. He found that group performance was superior, but that when an individual measure was applied of ability to report what they had done, there was no difference between children who had worked alone and those who had worked in groups of three. However, it is possible that the verbal reports obtained did not accurately reflect the level of children's understanding.

In a study of twelve year-old children, using the programming language MicroPROLOG, Light and Colbourn (1986) studied the effect of differences in the structure of groups on the learning process. In contrast to out-of class experimental studies, children were not isolated from their peers even when working alone. Individual progress following peer interaction over a school term was measured and it was found that children who had worked in pairs showed no differential benefit compared to children who had had a machine to themselves throughout. One possible explanation for this finding may lie in the nature of the task. Light and Colbourn point out the similarity of the claims made for high level structured programming languages and for peer-interaction. It is possible that both MicroPROLOG and peer interaction enhance individual understanding by virtue of increasing metacognitive awareness; it may be that interaction would be best able to enhance individual progress in task circumstances themselves not conducive to such understanding. Alternatively the informal interaction between individuals in the ecologically valid classroom setting may have contributed to their learning process.

Although the evidence for peer-facilitiation in Light and Colbourn's study was limited, there is evidence, in areas other than computing, of the benefits of peer-interaction in an educational setting. Vandenplas Holpner (1982) using left right co-ordination tasks and measurement problems with younger children attempts to describe, particularly for teachers, the kinds of social interaction which fosters cognitive development in semi-structured situations close to the real classroom.

Schubauer-Leoni and Perret-Clermont (1980) used a mathematical addition task to compare the perfomance of children working alone and in pairs and found that co-operative training led to better subsequent transfer to a parallel task individual performance if it was accompanied by a requirement to communicate to a peer. The children who had experience of working in pairs were better able to make explicit the operations involved in the task and were better able to transfer these operations to other contexts. Mathematical learning has also been investigated by Gilly and Roux(1982) who looked at the effects of social interaction upon children's ability to abstract and articulate rules. At the secondary school level, Balacheff (1982) has investigated the effects of peer interaction on the production of mathematical proofs.

Perret-Clermont and Schubauer-Leoni (1981) argue that the process by which children benefit is as yet unclear. If it were better understood it would be possible to specify the social and cognitive characteristics of educational settings that would promote both specific learning and more general cognitive development. This emphasis on the process by which children gain brings the discussion back to the question of how such processes should best be characterised.

The final section of this chapter is concerned with some of the alternative ways that the cognitive and metacognitive processes of children have been described within the information processing perspective. This approach is important in the present context to the extent that it introduces a range of constructs that may be relevant to a more broadly based enquiry into peer-interaction.

II.3. INFORMATION PROCESSING THEORY.

The emergence of information processing as a part of cognitive developmental studies reflects the relative decline in the dominance of the structuralist approach of Piaget in developmental psychology, and also reflects a more general move towards a functional approach in psychology as a whole. As is explicit in its title, information processing theory emphasises the functional processing aspects of cognition; although a number of terms suggesting structure are used they are used in characteristically functionalist ways. It must be noted however that the distinction between structural and functional approaches is not clear-cut, so that there may be differences of opinion as to whether a particular approach is more appropriately described as structural or functional. Newell (1972) argues that what is structure and what is function depends, within a time perspective, on what is fixed and what is changing. As what is structure in one context may be seen as process in another context and vice-versa, he suggests that the state of a system at any point should be seen as its structure, and whatever changes that state as process.

Gagne's (1968) view of Piagetian conservation operations as skills is an early example of this trend: the 'skill' concept is used by Gagne as an alternative to structural explanations of competence. More recently, structures such as schemata (eg Bobrow and Norman, 1975), and rules (Siegler, 1978), have been conceived of as dynamically organised representations, rather than static structural entities. Other organisational notions such as scripts (Nelson 1978) and strategies (Bruner, Goodnow and Austin 1956) are even more closely identified as process concepts. Case (1978) proposes that in the developmental process simple strategies become automatic through use and then are modified into more powerful strategies. In Case's (1974) 'information processing' revision of Piagetian theory, the level of the child's strategy depends on the amount of attentional energy available in working memory - what Pascual-Leone (1976) calls 'M-space'. In this view it is assumed that for the young child even a simple strategy requires much attentional energy, because each step must be monitored, whereas older children and adults can develop increasingly sophisticated strategies because simple strategies become automatic. This highlights the apparent paradox that on the one hand development implies increased conscious awareness and on the other hand it implies increased automation of thinking.

Piaget is apparently in accord with information processing principles when he maintains that a functional analysis is necessary to the delineation of structures.

> "*Functional analysis represents the essential framework which must be set up before any structural analysis..there can be no question of investigating structural isomorphisms until we have examined the functional correspondences which alone can endow them with an acceptable meaning.* (Piaget 1971, page 145).

There is, however, substantial difference in the two interpretations as Piaget sees structures as constructed out of the child's own activity, while in information-processing theories structures are merely descriptions - interest in them is restricted to understanding how the system performs. The emphasis on functional aspects of development is apparent in some of the more recent Genevan work (eg Inhelder, Sinclair and Bovet 1974; Inhelder and Piaget 1980;

Karmiloff-Smith 1979).

Support for the notion that development involves the use of more sophisticated strategies is provided by Klahr (1978) who uses an information processing framework to look at the process of problem-solving, using a task in which the end is known but the means of achieving that end are uncertain. This enables a 'means-ends' analysis to be carried out which is, in effect, a method of identifying the strategies used in solving 'move' problems. In means-ends analysis the problem solver establishes sub-goals whenever a desired goal cannot be directly accomplished. Klahr (1978) presented a version of the Tower of Hanoi problem to young children using an apparatus consisting of three inverted cans of graded size which hung on three pegs. The appeal of the task was increased by describing the cans as monkeys and the pegs as trees. Klahr then developed computer simulation models at six levels of sophistication in order to describe different perfomance levels. Incidentally, Klahr makes the point that in everyday life children may effectively be using means-ends analysis at a very young age. He gives the example of the young child who has an overall goal of riding his bicycle and recognises the intermediate requirements of getting Daddy to unlock the basement door to find his socks in the dryer before he can go outside. The child in this case has shown that he can 'stack' sub-goals. (Klahr 1978, pp 181-182).

In contrast to Klahr's theoretical orientation, which leads him to focus on information processing issues without emphasis on social factors, in the present work the importance of the social element is a central, rather than a peripheral issue. This takes the focus of interest back within the domain of social-cognition. However, in selecting the Tower of Hanoi as a suitable task for the first two of the present studies, a strong link is retained with the information processing approach, as well as providing continuity with the most relevant preceding research in the field of social cognition.

The information processing concepts developed by Klahr and others may provide a means of gaining access to the exact nature of the difference in the child's experience in a social learning situation. In what aspect is understanding modified by peer-interaction? It is known that following some social learning situations children can subsequently succeed in a task that they would have otherwise failed, but it is not always clear what they have gained. Have they learned what the question is? Have they learned a principle, or have they learned a specific and particular behaviour limited to the exact circumstances of its elicitation? Does the improvement rest upon an understanding of how to manage the task, or is it more specific? Do children learn specific sub-goals or do they rather learn the principle that adopting sub-goals is an effective strategy? There are a whole series of overlapping questions that await an answer. The empirical work presented in this thesis will address some of these issues.

All of the theoretical strands mentioned in these two introductory chapters have a relevance to the present work. Firstly, modelling studies raise the question of how much children can learn merely as passive observers; secondly, studies within a Piagetian framework demonstrate some of the variables that mediate progress in co-operative learning; and thirdly the importance of adults, including the experimenter, in the interactive process has been shown to be a relevant issue. Some of the limitations and developments in understanding in these areas have been indicated, and reference made to the growing emphasis on the process of development. Metacognitive or information processing concepts may provide useful tools for further investigation of peer-interaction, and the use of micro-computers in schools provides a means of linking these theoretical issues to practical educational concerns. The present research program has its starting point at the convergence of these various strands. The first two studies are reported in the next chapter.

CHAPTER III. THE TOWER OF HANOI TASK.

III.1. EXPERIMENT 1: INTRODUCTION.

The introductory chapters have drawn attention to the wide variety of contexts in which social influences in learning have been studied. The evolution of ideas has already led some researchers to distance themselves from a restrictive preoccupation with the development of cognitive structures. Children have been shown to change in their performance levels following peer interaction in tasks that do not lend themselves to interpretation within a Piagetian framework. This more eclectic approach to child development (eg Glachan 1983) allows the researcher to use a variety of task circumstances that may provide evidence that is no less important, and that may have interesting links with other theoretical orientations, in particular with information-processing concepts. It is this trend that the present studies will follow and, for this reason, the Tower of Hanoi puzzle was selected as a suitable initial task. The choice of a problem-solving exercise has the additional advantage that, because the end is clearly stated and only the means of achieving that end in doubt, one of the major problems of conservation studies is removed, namely the question of what criterion should be used in assessing performance.

The Tower of Hanoi has a considerable history as a tool of psychological research. It originated as a toy in the nineteenth century, and consists of three vertical poles or pegs on a solid base and a number of movable discs of graded sizes. A pyramid of discs on one peg has to be transferred to another designated goal peg to make an identical pyramid and the rules of the game are that only one disc may be moved at a time and that no disc may be placed on one smaller than itself; the third peg is used as as the necessary intermediate resting place. The aim is to complete the task in as few moves as possible. The most simple version of this task, in which a pyramid of two discs has to be transferred, requires only that the subject recognises the need to place the smaller disc on the intermediate peg, before placing the larger disc on the goal peg, and finally transferring the smaller disc likewise. In the case of the three-ring version of the task, the subject must realise that the initial requirement is to transfer the smaller disc to the goal peg, the next disc to the intermediate peg and the smaller disc to the intermediate peg before moving the largest disc to the goal peg. It follows that there is a logical solution pattern that holds good regardless of the number of discs, as within the four-disc problem there are two three-disc problems, and within those three disc problems there are two nested two-disc problems. The minimum number of moves required to solve a problem is given by the formula 2^n-1, where n is the number of discs. The Tower of Hanoi is useful as an experimental task because it is a well structured problem, having a well defined initial state and goal state, together with a well defined solution path.

There is evidence of the way in which the ability to master the Tower of Hanoi problem changes with age. For example, Piaget (1977) found that young children aged five to six years were unable to solve the problem even after much practice, and could only solve the two-disc problem on a trial and error basis. At this age each particular action becomes an end in itself and is not directed by conceptualisation; the child is operating inductively. Piaget found that older children of seven to nine years of age, who had developed the ability to make predictions, were better able to subordinate means to ends and were able to master the three disc problem after some practice. By the ages of eleven to twelve years children were able to solve the three disc problem rapidly and to use their experience to infer the solution to four or five disc problems.

It is of interest to know how children come to realise that they must tackle several small sub-goals of the problem in order to achieve the final goal. The Tower of

Hanoi task is one in which recognition of sub-goals may form an important part of any improvement in performance. Newell and Simon (1972) have identified goal recursion, involving reduction of the problem to a series of sub-goals, as one of three strategies used in solving the Tower of Hanoi. They describe two further types of strategy; one is a perceptual strategy again involving the achievement of sub-goals, while the second is a move pattern strategy in which basic rules are learned in 'rote' fashion and stored in long-term memory for future use. Although this work does not relate specifically to children it provides a model of the processes that children may use increasingly as they become older. There is evidence that younger children do not use plans in their problem solving (Richards 1982). Similarly, Spitz,Webster and Borys (1982) found that only older children used a sub-goal strategy that extended two moves ahead. It may be that co-operative learning in this task will be beneficial to the extent that it enables children to appreciate the relevance of sub-goals.

A further issue of importance is the extent to which any acquired understanding enhances children's performance in problems that are structurally identical although different in superficial format. The ability of adult subjects to recognise the common characteristics of tasks of an analogous nature to the Tower of Hanoi has been investigated by Reed, Ernst and Banerji (1974) who found that subjects were in general not able to recognise the basic similarity. On the other hand Luger and Bauer (1978) found transfer effects even though subjects did not recognise similarities; thus the evidence is mixed. Sweller (1980) argues that no transfer effects can reasonably be expected in problems such as the Tower of Hanoi because such problems are usually solved by means-end analysis. Transfer could be expected only in tasks in which the process of solution involves rule induction.

The efficacy of the task in promoting differential individual benefit for subjects working co-operatively has already been demonstrated. Glachan (1983) has conducted a series of studies that took as a starting point the more recent peer interaction work of the Doise group. Using the Tower of Hanoi in a three-stage design of individual pretest, differential intervention and individual post-test, Glachan found that children in a competitive paired condition produced significantly more efficient problem solutions at post test than did children in an individual condition. In this study the performance of children in a co-operative condition was not significantly different from either the competitive or individual conditions.

In a second study Glachan modified his apparatus by the addition of handles to ensure equal participation in the physical manipulation of the discs. As a result of this modification he found that a co-operative condition elicited superior post-test performance, although this superiority was restricted to those children who had evidenced some degree of understanding at the outset. Children who initially lacked any kind of strategic approach to the problem showed no selective advantage from working in pairs. In a third study Glachan compared three types of paired conditions: a 'structured' paired condition comparable to that in the previous study, an unstructured condition in which there was no requirement for co-operative action and thirdly an instruction condition in which subjects were told the correct sequence of moves. In this experiment only the structured interaction condition produced significant pre- to post-test improvement on trials other than the particular ones used in the intervention sessions; the unstructured interaction condition was substantially less effective.

Glachan concludes that neither being presented with the right answer nor being presented with a conflicting viewpoint is necessary or sufficient to induce learning. As mentioned earlier, he argues that it is the ability to resolve conflict that is important, and he suggests that verbal reasoning and the active manipulation of materials may both be elements in the resolution process.

The importance of the choice of the Tower of Hanoi as an experimental task by Glachan (1983) was that it brought into focus more general questions than those posed within the framework of concrete operational test situations. It had the advantage that the age restriction that necessarily applied to such tasks was lifted. In choosing a micro-computer version of the Tower of Hanoi for use in my first study the scope of enquiry has been broadened still further.

The change of presentation mode enabled an experimental situation to be created that was very similar to normal classroom activity. In the school in which this study was conducted, it is usual for one or two children to be detached from the main class activity and given a short period of individual or paired use of a particular program in a corner of the room. The only modification needed to this situation in the present study was that a small study room adjoining the classroom provided a less noisy environment. The presence of computers in the classroom provides an opportunity to balance the need for ecological validity with the need for objective data, as the schools now have in daily use what is in effect the experimental apparatus.

The first aim of this study was to determine whether individual benefit resulting from peer-interaction would be demonstrated using the computer-based version of the Tower of Hanoi. The experimental hypothesis was that children provided with the opportunity to practice the task with a peer would show significantly enhanced learning when compared to children who had worked alone. A second aim of this study was to investigate the nature of any differential gain by establishing whether the benefit facilitated performance on the more difficult 4-ring version. A third aim was to establish whether the task as presented on a computer was comparable to the wooden version used in previous studies. If performance on the two versions proved to be comparable, it would mean that the adaptation to the computer format had not altered the problem in any fundamental sense.

There were additional objectives in this study: the first was to familiarise the experimenter with the educational computer environment and the second to discover any problems that might be associated with the use of a computer-based task.

III.2. EXPERIMENT 1: METHOD.

Subjects.

Fifty-six children from a Poole Middle school took part in this study. The school was situated in a predominantly middle-class area. The children's ages ranged from 8 years 5 months to 9 years 4 months, with a mean age of 8 years 10 months. There were sixty subjects in the original sample but four were eliminated from the study at pre-test when it was found that they had prior experience of the Tower of Hanoi problem. Subjects were allocated to conditions and to partners in the paired condition on a random basis. All the children had some prior experience of the use of the computer, although this was very limited as the six machines then in use were a recent acquisition and were shared between more than three hundred pupils.

The preparations for the work in school meant that by the time the first study was conducted I was already becoming a familiar figure in the school environment. There was a period of several days during which the purpose of my presence in the school was made clear to the children. The news that I had come into school to work with the children using a computer was greeted with excitement. Any reservations that may have been felt by potential subjects appeared to be totally outweighed by a general enthusiasm for anything connected with computers.

Apparatus.

The equipment used in this and all subsequent studies was a B.B.C. Model B micro-computer with disc drive and colour-screen monitor, all placed on a computer trolley.

The screen display is shown in FIGURE III.1. The pegs are represented by numbered positions on the screen and the discs by coloured bands of varying sizes. The goal peg is labelled with a letter G. Each position has a corresponding numbered key and a move is executed by pressing first the key of the old position and then the key of the new required position. The computer will not execute an 'illegal' move, such as placing a large disc onto a smaller one; instead it issues a warning tone. The program is adjustable so that the number of discs can be varied. The second piece of apparatus, a wooden version of the Tower of Hanoi, is shown in FIGURE III.2. This has a series of wooden tiles of graded size, which can be moved from peg to peg.

Design.

Many of the previous studies concerned with peer-interaction have utilized a three-step procedure that is represented diagramatically, as shown in FIGURE III.3. The illustrated format of individual pre- and post-tests, with differential intervention according to condition, was used in this and all subsequent studies.

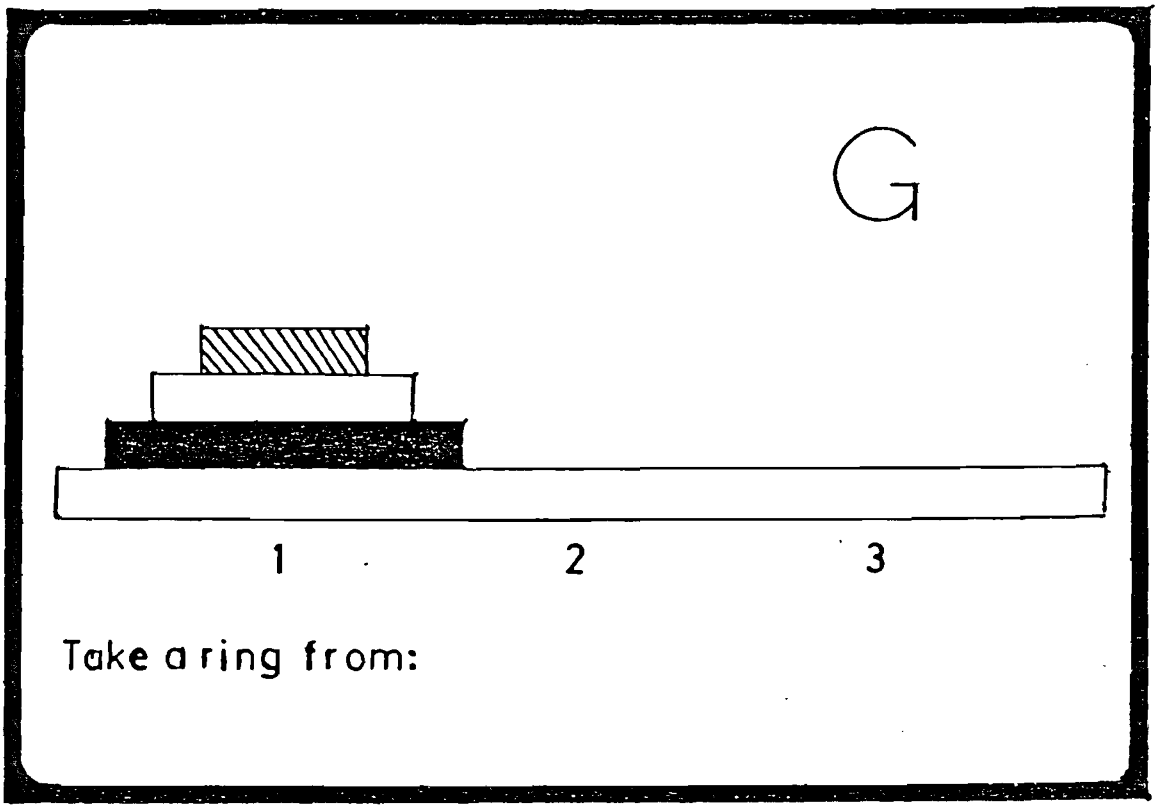

FIGURE III.1. THE SCREEN DISPLAY FOR THE TOWER OF HANOI MICRO-COMPUTER TASK

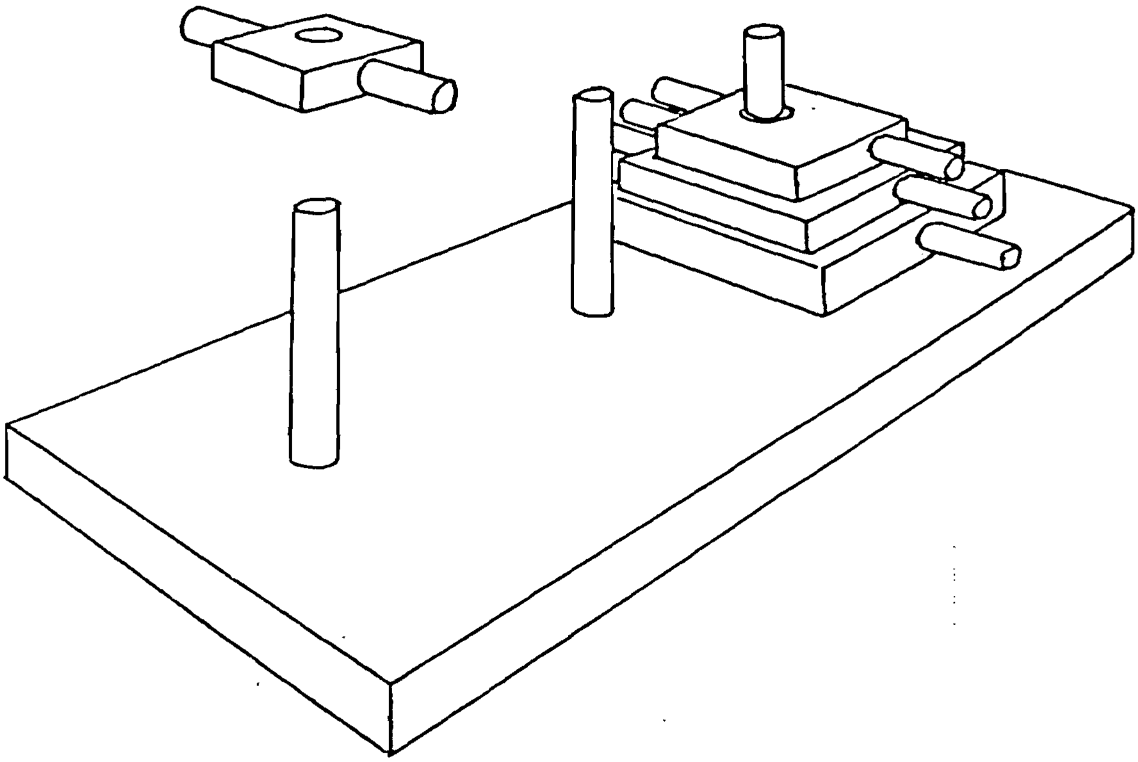

FIGURE III.2. THE WOODEN VERSION OF THE TOWER OF HANOI

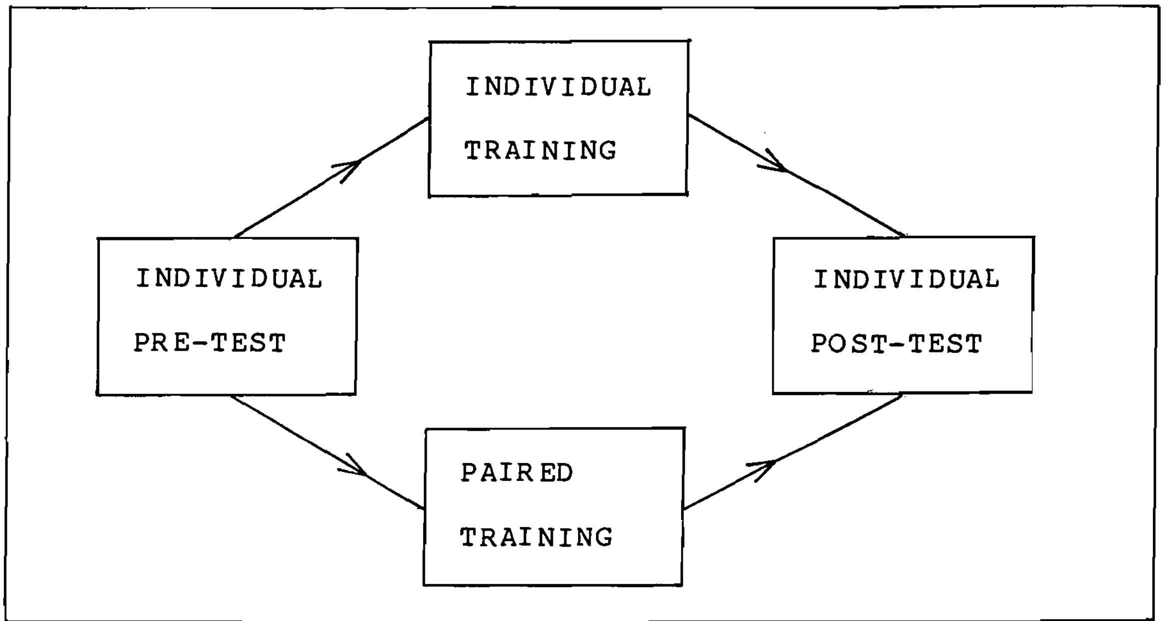

FIGURE III.3. THE EXPERIMENTAL DESIGN.

In the initial experiment there were two conditions. In the first condition subjects worked individually throughout, while in the second the children received individual pre- and post-tests but worked in pairs during the intervention (training) session. In view of the fact that previous studies in this area (eg. Glachan and Light 1982) had failed to reveal any sex differences in performance at this age, no attempt was made to control for this factor in the design, however the random selection process anyway resulted in approximately 50% mixed pairs and 50% single sex pairs.

The types of trial used were kept constant throughout the experiment. In the first trial the left hand peg was used as the start peg and the right-hand peg as the goal peg (1-3). In the second trial the centre peg became the start peg and the right-hand peg, as before, was the goal peg (2-3). One of each type of trial was given at pre-test and three of each, ie. six trials, in training. At post-test there were four trials, 1-3 and 2-3 as before, plus two additional trials not previously encountered. The first of the latter two trials took the right-hand peg as start and the left as goal (3-1), and the second took the centre peg as start and the left hand peg as goal (2-1). These last two trials were in effect a generalisation measure, since although requiring the same solution in principle, in practice they necessitated a different set of moves to completion.

Two additional individual post-tests were provided. The first of these consisted of three trials using the 4-ring version of the Tower of Hanoi (1-3; 2-3; 2-1). This was included to indicate whether any differential benefit found in the main post-test would be reflected in superior performance on the more complicated task. If this were to be the case it would provide some evidence that the nature of the understanding was at a strategic level rather than rote learning. A characteristic of the 4-ring version is that it requires the opposite initial move to that required in the 3-ring Tower of Hanoi.

The wooden version of the task was included as a means of comparing performance with that of the computer presented version, and in doing so to provide a point of reference with previous studies. If this version of the Tower of Hanoi functioned effectively as the 'same' task as the micro-computer version, then any differential learning in the latter case should be reflected in performance on the former. The second post test consisted of three trials using the wooden three-ring version of the task (1-3; 2-3; 2-1).

Pre-tests.

The pre-testing session was conducted in a small study room adjoining the classroom. This room, or its equivalent in other schools, was used throughout the research programme.

The individual child was welcomed into the test room and engaged in conversation during which it was again explained that they were to participate in a computer 'game'. The general nature of the apparatus was demonstrated, although in practice it was found that all of the children had some limited experience of use of the machine. Time was taken to ensure that each subject felt at ease before proceeding. The details of the task were then explained; a problem was presented on the screen and the experimenter demonstrated each of the key functions. A fixed sequence and identical phrasing was used for this element of the introduction to ensure that all subjects were equal in experience at the outset. The demonstration did not provide a complete example of a method of task solution. The aim of finding the solution in as few moves as possible was explained and it was emphasised that the speed with which the task was completed was not important. Reassurance was given that the task was not a school test and had nothing to do with school work. Subjects were given time to familiarise themselves with the test situation and with the operation of the computer, although in practice it was found that all children understood the process immediately with no difficulty.

The two pre-test trials (1-3) (2-3) were then presented. On completion of these trials subjects were thanked for their participation and allowed to return to their classroom.

Training.

The training session was conducted approximately one week after pre-testing. Very little familiarization was needed at this stage as the children remembered the task from their previous encounter, and seemed pleased to have the opportunity to 'play the game' again. The children were reminded at the outset that the main aim was to complete the task in as few moves as possible.

In the Individual condition the children worked alone, as before. In the Pairs condition the experimenter explained to the subjects that they were to co-operate in the task. The children were asked to work out the solutions together and not to press the keys until they had agreed on a course of action. To encourage equality the pairs were instructed to take turns at pressing the keys and care was taken to make sure that they understood that this did not mean taking turns to *think*. If episodes of substantial physical domination of the keyboard occurred, such as one child persistenty leaning over and obscuring the second child's access to the keys, the experimenter intervened to re-establish equality of position, although in practice this was not a frequent problem.

Six trials were presented, three of each type used at pre-test (1-3) (2-3), presented alternately.

Post-tests.

Post-tests were conducted one week after pre-test using the same facilities. At this stage of the experiment all subjects were tested individually. As this was the third test occasion subjects understood the procedure. The first post-test consisted of four 3-disc trials: the first two were a repeat of the pre-test (1-3) (2-3) and two were a reverse form (3-1; 2-1).

The second element of the post-test session was the presentation of three trials using the 4-disc version of the computer-based task. It was explained that the aim in this task was the same as before, namely to transfer the discs to the goal peg in as few moves as possible, and that the rules were unchanged. The trials given were 1-3, 2-3 and 2-1.

The third post-test, consisting of three trials (1-3, 2-3 and 2-1) of the wooden version of the Tower of Hanoi, was then presented. The identity of this task with the micro-computer version was not alluded to, although in giving the necessary instructions the correspondence was readily apparent.

On completion of this test, subjects were asked to give an account of how they solved the Tower of Hanoi problem, including what rules they used. The screen display was on view for reference at this time. The children were then asked what they would say to someone else to help them solve the problem. These verbal protocols were recorded using an audio tape-recorder. At the end of the post-test session subjects were thanked for their participation and allowed to return to their classroom.

III.3. EXPERIMENT 1: RESULTS.

Performance on each trial of the Tower of Hanoi was recorded in terms of the number of moves taken to transfer the discs to the goal peg. The mean score of individual subjects was used to make comparisons between conditions and at different stages of the experiment. Three individual mean scores were generated from the three-ring computer post-test: firstly the mean of all four trials; secondly the mean of trials 1-2 ie. those identical to the trials used at pre-test and in training; and thirdly the means of trials 3-4, ie. those trials not previously encountered.

The data were also categorised according to the pre-test performance of subjects, on the assumption that differences in performance might be evidenced if the initial ability of the subject was taken into account. In order to analyse the results in this respect the data were divided up into those subjects who were better than average performers at pre-test and those who were worse than average. The former are described as 'strategists' and the latter as 'non-strategists', on the assumption that the performance of the better subjects reflected some systematic behaviour in attempting the problem (cf. Glachan 1983). The criterion selected was that subjects scoring less than 14 at pre-test should be categorised as strategists while those with a pre-test score of 14 or more should be categorised as non-strategists. This was based on the mean pre-test score which was 13.5.

The overall findings, including the results sub-divided according to the strategist/non-strategist criterion, are set out in TABLE III.1. FIGURE III.4 illustrates the mean performance at each stage of the experiment. It can be seen that the most obvious differences in performance lie firstly between pre- and post-test performance; subjects improved as a result of opportunity to practice the Tower of Hanoi and the improvement in their understanding was also reflected in performance on the wooden post-test. FIGURES III.5 and III.6 show histograms of the total score distributions for the 3-ring micro-computer and wooden post-tests respectively.

A three-way analysis of variance confirms that there was no significant difference between conditions but there were significant within subject differences in performance at different stages of the experiment ($F = 69.7$, $df = 2,54$, $MS(error)=2.93$, $p < .001$).

	INDIVIDUAL CONDITION n=30	PAIRED CONDITION n=26
PRE-TEST:		
ALL SUBJECTS	13.08	13.23
STRATEGISTS	11.21	11.28
NON-STRATEGISTS	15.25	15.46
TRAINING: ALL SUBJECTS	10.53	9.06
3-RING POST-TEST:		
ALL SUBJECTS (FOUR TRIALS)	9.81	9.93
(TRIALS 1-2)	9.85	9.57
(TRIALS 3-4)	9.77	10.12
STRATEGISTS (ALL TRIALS)	10.23	9.73
NON-STRATEGISTS (ALL TRIALS)	9.31	10.14
WOODEN POST-TEST:		
ALL SUBJECTS	10.13	10.08
STRATEGISTS	9.95	9.87
NON-STRATEGISTS	10.33	10.31
4-RING POST-TEST:		
ALL SUBJECTS	24.97	26.73
STRATEGISTS	24.90	27.00
NON-STRATEGISTS	25.10	26.40

TABLE III.1. EXPERIMENT 1: SUMMARY OF MEAN SCORES.

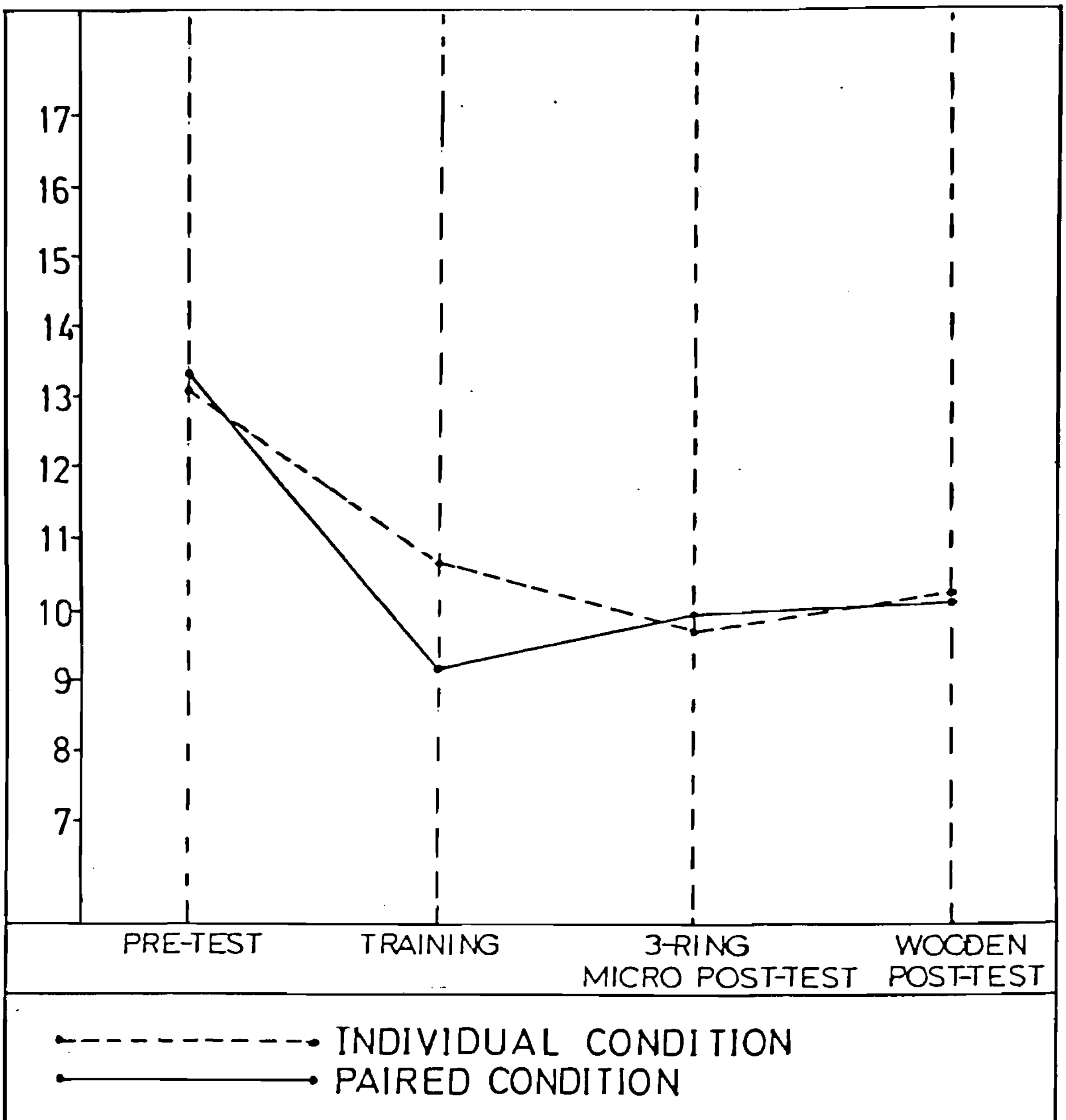

FIGURE III.4. EXPERIMENT 1: MEAN SCORES AT PRE-TEST, TRAINING, 3-RING MICRO POST-TEST AND WOODEN POST-TEST (OPTIMUM SCORE = 7)

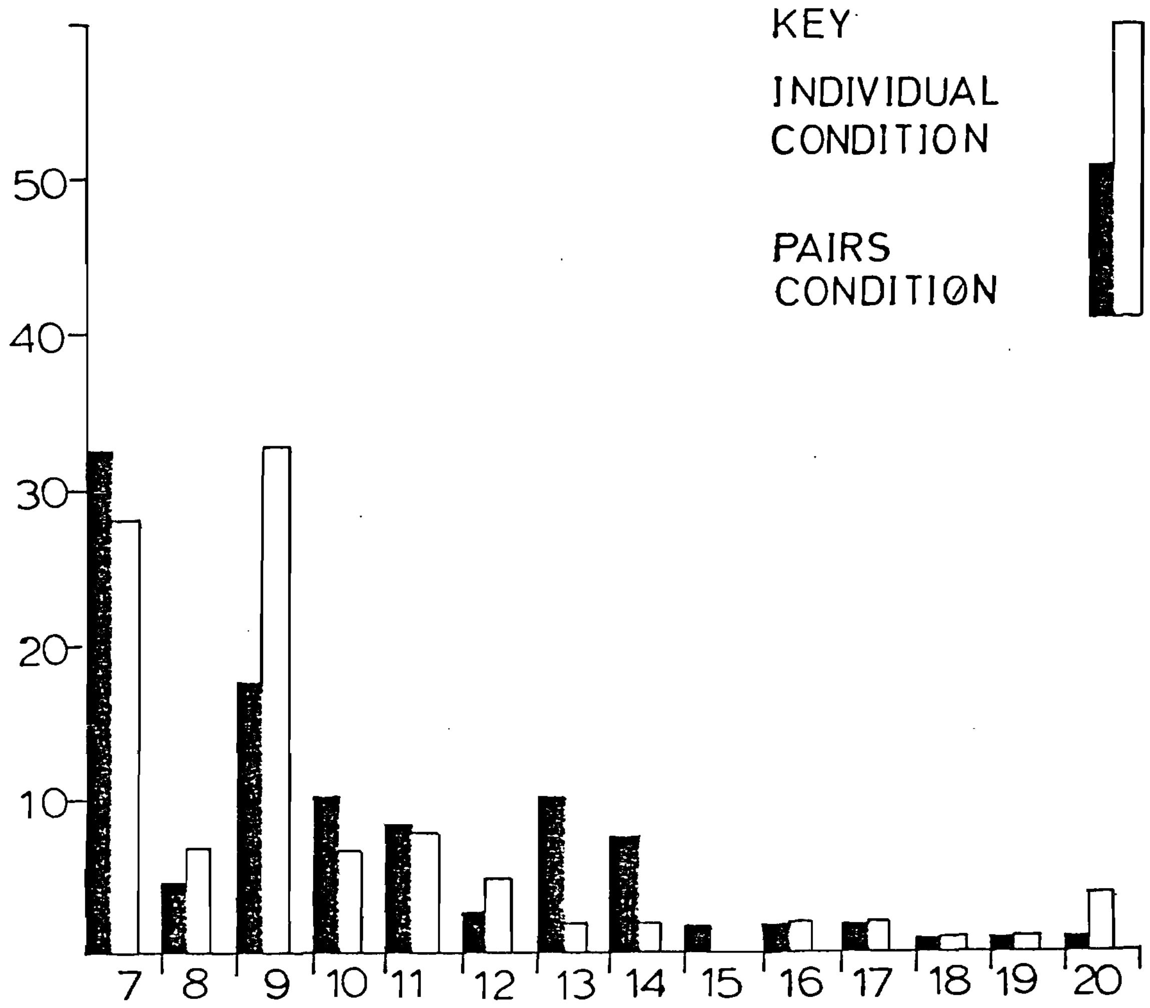

FIGURE III.5. EXPERIMENT 1: HISTOGRAM OF TOTAL SCORE DISTRIBUTION: 3-RING MICRO COMPUTER POST TEST.

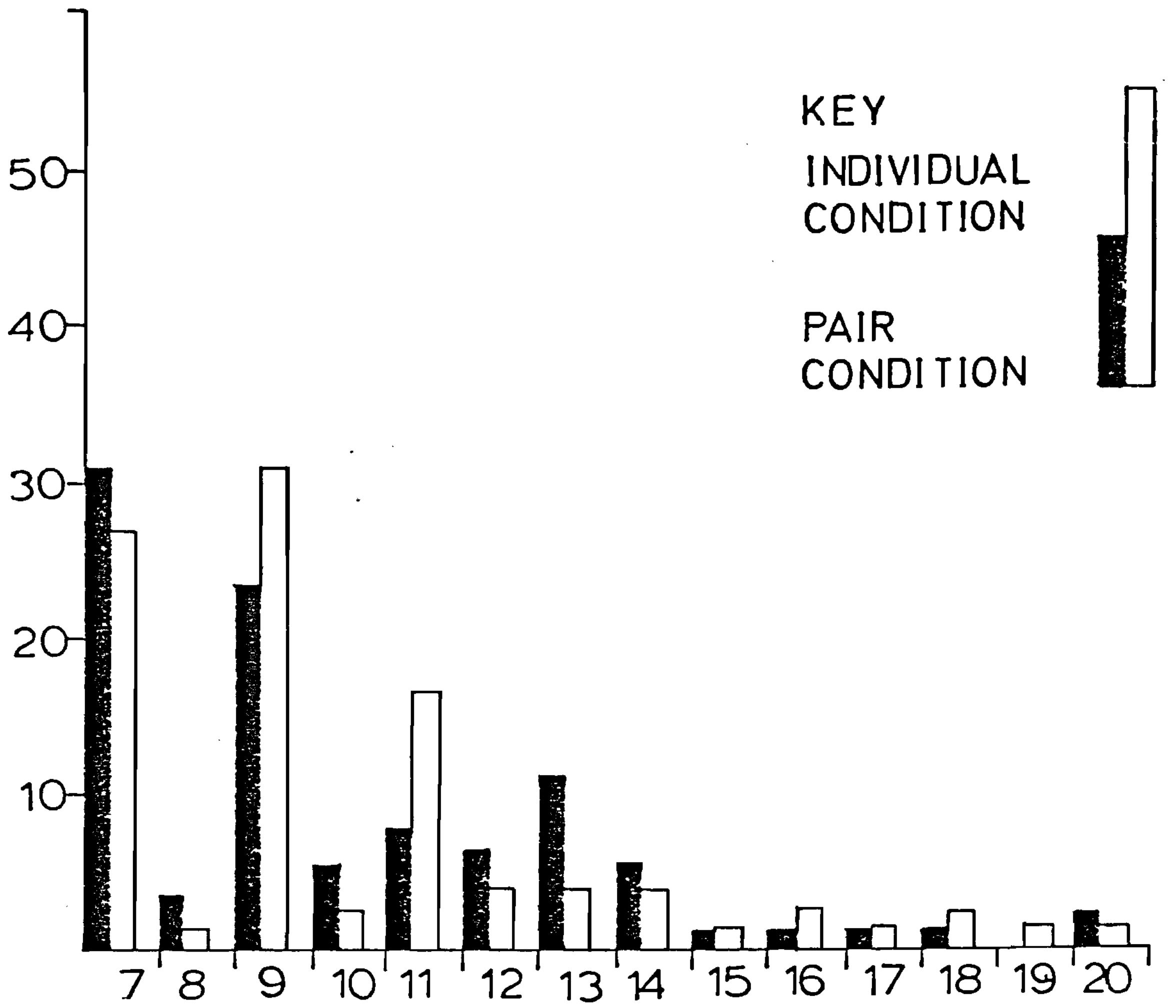

FIGURE III.6.EXPERIMENT 1: HISTOGRAM OF TOTAL SCORE DISTRIBUTION: WOODEN TOWER OF HANOI POST TEST

The similarity of the mean scores in both three-ring post-tests makes a formal sub-analysis unnecessary.The second between-subject variable, strategy type, was necessarily significant, however the potential for interaction between strategy-type and stage of the experiment or condition was of interest. A significant strategy by stage interaction was found ($F = 26.18$, $df = 2,54$, MS (error)= 2.93, $p < .001$). The Anova table is shown in the APPENDIX . The nature of this interaction is apparent from the Table of Means: all subjects improved from pre-test to post-test, but the most noticeable gain lay in the performance of non-strategists, who improved substantially. It is clear that those subjects with an initially poor score had greater scope for improvement, but the difference in the extent of gain cannot be dismissed as a ceiling effect. The lack of strategy by condition interaction means that the expectation that strategists in the paired condition would benefit differentially was not confirmed.

It is possible that an analysis of the results based solely upon mean performance may conceal important differences within the data. There were a number of subjects in each condition who 'solved' the puzzle, meaning that they completed the task using the minimum number of moves. In their accurate knowledge of how to do the task these children formed a separate category from those who did not know and this may be an important distinction: there are several ways or degrees of 'not knowing', but only one way of 'knowing' in an absolute sense. A second consideration is that changes in trial type, ie. in the goal peg used for different trials, altered the task in a way that may have been important in the context of the social conditions of learning. If the nature of the discussion led subjects to adopt a verbally explicit rule such as 'put the first disc on the right-hand peg' then changes in the goal peg might result in improved performance in some trials and worse performance in trials in which this rule was not appropriate. These issues can be examined if the number of subjects who achieved optimum scores is examined on a trial by trial basis. TABLE III.2 presents these data.

POST-TEST	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4
INDIVIDUALS (N=26)	11	6	8	4
PAIRS (N=30)	14	6	8	7

TABLE III.2. EXPERIMENT 1: SINGLE TRIAL DATA: NUMBER OF SUBJECTS WHO ACHIEVE OPTIMUM SCORE AT EACH POST-TEST TRIAL.

Chi-square analysis of performance indicated no significant differences between conditions on any of the four trials. Thus the possibility that differences not apparent on an overall analysis would be revealed on a trial by trial comparison of optimum scores was not confirmed.

The nature of the understanding that led to improved post-test performance can be investigated further by examining the 4-ring post-test results. FIGURE III.7 shows the 4-ring post-test score distribution; this test was separately analysed because of the expected substantial differences in the number of moves to solution compared to the 3-ring version. The optimum score possible is 15 and very few subjects in either condition achieved this goal, nor were there differences between the mean performance of subjects in the two conditions ($t = 1.19$, $df = 54$, n.s.). If subjects in the paired condition had learned a specific rule to help them in the solution of the three-ring Tower of Hanoi, namely to make the first move to the goal peg, and if learning had been limited to this one aspect, then it would have been possible that these children would have exhibited worse performance in the four-ring task than children in the individual condition. This was shown not to be the case. An alternative, that some generalised understanding of the Tower of Hanoi would facilitate subjects' performance in the

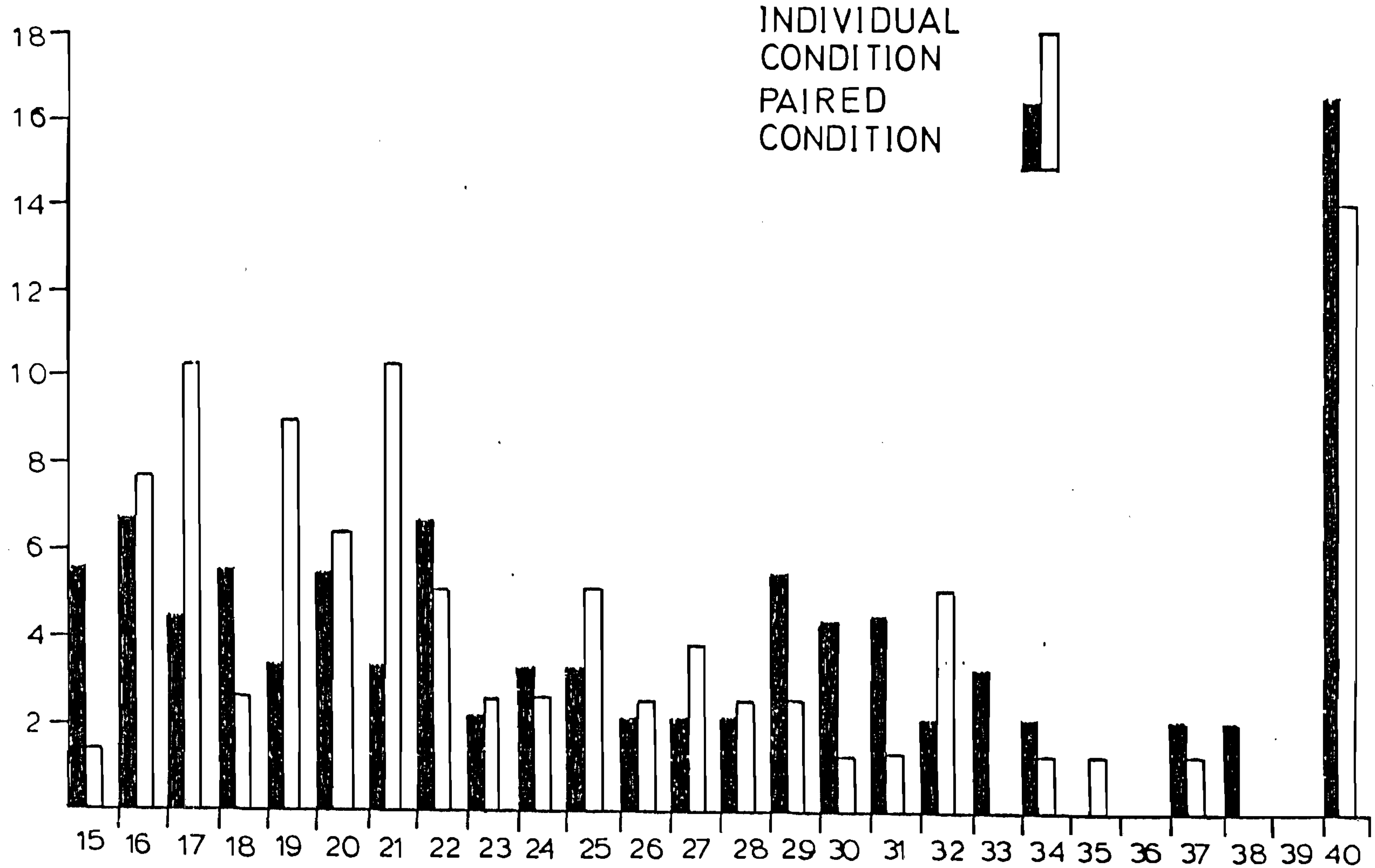

FIGURE III.7. EXPERIMENT 1 HISTOGRAM OF TOTAL SCORE DISTRIBUTION: 4-RING TOWER OF HANOI POST TEST.

four-ring task, was not evidenced in the Paired condition relative to the Individuals. This is not unexpected, given the lack of difference in the main post-test. It is possible that there was a confound of these two potential sources of influence, but this is unlikely in view of the lack of conditions difference in the main post-test.

In the 4-ring post-test subjects were classified as strategists or non-strategists on the basis of the pre-test scores and the two groups were compared in each category. There were no significant differences. This is consistent with the similar lack of significance demonstrated in the previous analyses.

So far, the results have indicated very little of quantitative value in distinguishing between the learning experience of pairs of children compared to individuals. The remaining potential source of a difference is in the childrens' verbal protocols. Analysis of the audio-recordings of the interview between each subject and the experimenter during the post-test session shows, as before, no differences between conditions. The number of subjects in each condition who, when asked to do so, could correctly specify the seven move sequence, was Individuals = 11 (out of 26 subjects) Pairs = 18 (out of 30 subjects). This difference was not significant. The remaining children offered a variety of incorrect solution paths, often 'back-tracking' in their explanations, which made quantitative analysis unrealistic. However, the protocols did provide an interesting insight into some of the reasoning used by children of this age in attempting the Tower of Hanoi. The following examples illustrate the variety of responses to the request to specify rules:

> *"I just try to spread them out and form them back up again"*
>
> *"First I try and get the red one there"*
>
> *"I just move these two away from that one and then move that one"*
>
> *"Once you've got the red one there it's easy".*
>
> *"I stop and think about half way through".*

These examples demonstrated sub-goal awareness. In contrast, some children express themselves in general memory terms:

> *"I just remember it - I just think about it and then I know what to do.*
>
> *"I can memorise it because my Dad works on computers".*
>
> *"I just remember what I did last time".*

Yet another type of response was denial of any method:

> *"I don't know what you mean by a rule. I can't say what I do."*
>
> *"No, I just do it. My rule is that I have to do it."*
>
> *"I just press them (the buttons) and when I see a*

chance to do it I just do it".

A proportion of children responded by repeating the move sequence that they had used:

> *"I put that there and that there and that there"* *(etc.)*.

Some children on being asked to specify the rules translated the request into one for a practical demonstration of the move sequence. Others specified the rules that I had previously given them such as the rule not to put a big disc on a smaller one. Some subjects who could verbally neither express the need to put the first disc to the goal peg, nor express the sub-goal of putting the top two discs on the middle peg, could nevertheless point to the correct move sequence for a seven-move solution path. These protocols illustrated sub-goal usage, but there was no difference between conditions in the number of instances of such sub-goal awareness.

III.4. PRELIMINARY DISCUSSION AND INTRODUCTION TO EXPERIMENT 2.

The first study has established that there can be no automatic assumption of benefit following peer-interaction in a problem-solving task. The main findings of this first study were that whether looked at overall, or at a more specific level, little evidence of peer facilitation of individual learning was demonstrated. In retrospect, reference to Glachan (1983) indicates a possible explanation: he found no differential peer interaction benefit using the wooden version of the Tower of Hanoi in a co-operative condition, relative to an individual condition, until some element of control was imposed by the addition of handles. Glachan suggests that either joint manipulation of materials or the opportunity for verbal resolution of conflict are typically found in those tasks in which peer learning occurs. In the present studies neither of these requirements were fulfilled. Firstly, the computer version of the task gave little opportunity for manipulation of materials, except in a limited sense of operating the keyboard. Secondly, observation of the training session and examination of the protocols of the children in the first study indicated that the Tower of Hanoi was not readily amenable to verbal discussion; in the majority of cases children could not specify how to do the task, either for themselves or for anyone else.

From the two issues identified by Glachan, and as the next step in the current research programme, a choice was made to examine the importance of physical participation in ensuring beneficial co-operation. The findings of the first experiment merit further discussion but this will be postponed until the second study has been reported. This followed directly on the previous study in being concerned with the structure of the interactive situation and with the effect this has on the potential for peer-interaction benefit.

As a means of creating a more structured task environment, advantage was taken of the flexibility of the computer software to introduce dual-key operation of the machine. This enabled a physical restraint on unilateral action to be created by making every move dependent on joint key action by both members of a pair. It was hoped that this might throw an interesting new light on Glachan's findings as dual-key control would not involve the child in motor movements that map the solution path. If the dual-key intervention proved an effective means of creating a productive environment, then such a facilitation would not be attributable to the opportunity afforded, as in Glachan's task, to making the appropriate moves, with the assumption in this that physical performance of an action creates a more powerful mental image than would be generated by a visual or verbal percept. Glachan does not make it clear in which respect the enforced physical operation was supposed to be effective. It may be that the physical co-operation forced some mental involvement by both children and cut out the domination of one child by the other.

The dual-key facility consisted of two sets of response keys at opposite ends of the keyboard which were suitably labelled. The computer responded only to joint simultaneous use of these keys with the result, provided that the children were sufficiently restrained to only operate their own set of keys, that the requirement to co-operate was effectively 'written in' to the apparatus. The second modification was that instead of the Wooden version of the Tower of Hanoi an alternative post-test was introduced, consisting of a copy of the 'Cans' apparatus used by Klahr and Robinson (1981). FIGURE III.8 shows this apparatus. It consists of three inverted cans of graded size that are placed over three pegs and is, in effect, an inverted version of the Tower of Hanoi. In the previous experiment the indications were that the wooden Tower of Hanoi was very similar to the micro-computer version, however without a significant conditions difference it was not possible to establish this conclusively. The Cans task provided a test that was less obviously identical and was included to provide a measure of generalisation. Benefit to the individual following interaction with a peer may stem from a specific and limited enhancement of a particular performance on the part of the child. Alternatively it may reflect the growth of some higher level strategic awareness that has a wider utility. The Cans task was included

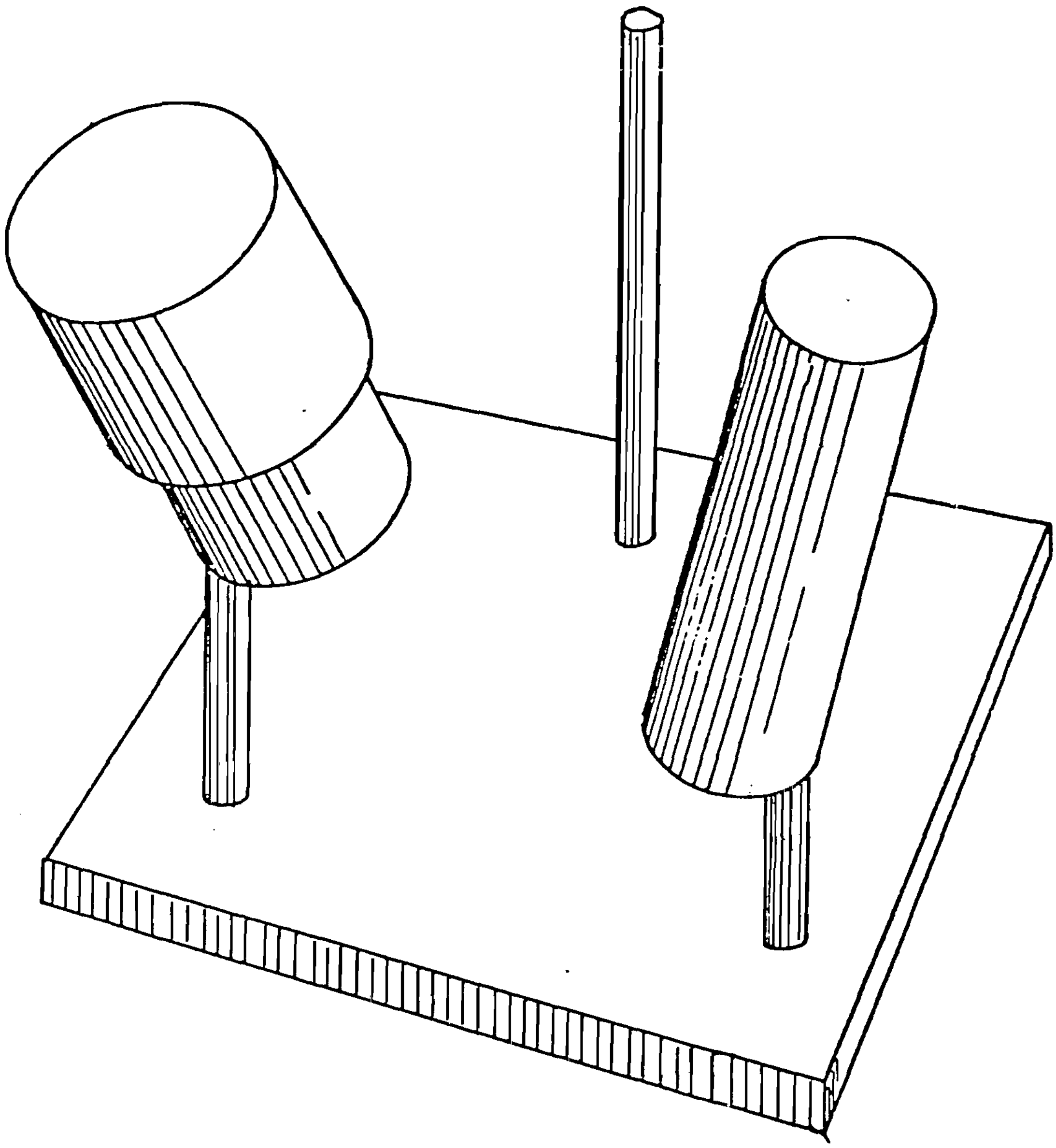

FIGURE III.8.EXPERIMENT 2:
THE CANS APPARATUS.

because the question of what is the quality of learning may be more important than the question of whether a child's understanding is enhanced following peer interaction. Thus one aim of this second study was to determine whether any peer benefit demonstrated would be reflected in enhanced performance in the Cans task. However, the main aim of this study was to determine whether the inclusion of a more structured interaction condition would result in enhanced individual post-test performance by subjects in that condition, when compared with subjects who worked alone. The experimental hypothesis was that this would be the case.

III.5 EXPERIMENT 2: METHOD.

Subjects.

The children participating in this study were pupils at a Poole First school serving a similar catchment area to that of the school used previously. The ages of subjects ranged from 7 years 11 months to 8 years 10 months, with a mean age of 8 years 4 months; the children were thus on average six months younger than in the first experiment. As before, subjects were allocated to conditions and to pairs within conditions on a random basis. A total of sixty children took part in the study. An introductory period in the school enabled the children to adjust to my presence and to the purpose of my visit.

Design.

The experimental design was the same in principle as the previous study. It differed in having an additional condition, and in using an alternative post-test task - the previously described 'Cans' apparatus. There were three conditions: in the first subjects worked alone at all stages of the experiment; in the second, pairs of subjects were asked to co-operate with each other, with single keyboard control; and in the third similarly paired condition, co-operation was enforced by means of the dual-key facility.

In reporting this study the paired conditions will be referred to as Single-key Pairs and Dual-Key Pairs respectively. The Single-Key Pairs condition was identical to that of the co-operative condition in the first study.

Procedure.

The testing of the children was conducted in similar conditions to those of Experiment 1. The procedure used was in most respects identical and only those aspects that were different will be mentioned here.

The main difference in procedure was that required in the Dual-Key Pairs condition. In addition to the instructions on co-operation given to the Single-Key Pairs,

the Dual-key Pairs were shown the joint key facility, and the necessity for joint operation of the keyboard was explained. In practice it was found that the the children had no difficulty in understanding this facility.
The trials presented to all subjects were identical to those used in the previous study.

The second difference was the use of the 'Cans' version of the Tower of Hanoi. The Cans apparatus was introduced after the completion of the computer-based post-test. The rules for moving the cans were explained in a similar manner to that used to explain the wooden version of the task. As before, no mention was made of its similarity to the computer task. Three trials were given at the Cans task. The trial sequences were the same as for the Wooden version in Experiment 1. namely (1-3), (2-3), (3-1).

III.6. EXPERIMENT 2: RESULTS.

The findings of this study were categorised on the same basis as that used in Experiment 1. The results are set out in TABLE III.3; a graphic representation of the mean scores is provided in FIGURE III.9, and FIGURE III.10 shows a histogram of the total post-test score distributions. A three-way analysis of variance of the main findings shows that there was no significant difference between the conditions. As before, there was a substantial within-condition effect for this stage of the experiment ($F = 20.06$, $df = 2,108$, MS(error)= 6.344, $p < .001$). There was no interaction effect. Thus all subjects gained substantially from pre- to post-test but there was no overall evidence of differential learning. FIGURE III.11 shows a histogram of the total score distribution in the Cans post-test.

An alternative analysis based on the first two post-test trials (those used in training) was similarly non significant in respect of conditions differences, and in line with the first analysis demonstrated a significant effect according to the experimental stage ($F = 56.69$, $df = 1$, MS(error)= 5.2, $p < .001$) and a significant strategy by stage interaction ($F = 29.45$, $df = 1$, MS(error)= 5.2, $p < .001$). The table of means scores indicates that the interaction effect closely matched that evident in Experiment 1, namely that non-strategists showed greater improvement in their performance relative to strategists. Without statistical analysis it was clear that a similar pattern of results was found for Trials 3-4.

Although the t-test confirms the analysis of variance in demonstrating no significant difference between conditions, these analyses should not be taken as the final

	INDIVIDUAL CONDITION	SINGLE-KEY CONDITION	DUAL-KEY CONDITION
PRE-TEST:			
ALL SUBJECTS	13.60	13.70	13.20
STRATEGISTS	11.30	11.11	9.94
NON-STRATEGISTS	15.10	16.30	15.86
TRAINING:			
ALL SUBJECTS	11.07	9.48	9.42
POST-TEST:			
ALL SUBJECTS			
(FOUR TRIALS)	10.54	10.56	10.10
(TRIALS 1-2)	10.78	10.20	9.40
(TRIALS 3-4)	10.30	10.92	10.80
STRATEGISTS	10.25	11.08	9.14
NON-STRATEGISTS	10.73	10.05	10.89
CANS POST-TEST:			
ALL SUBJECTS	12.52	11.58	12.30
STRATEGISTS	12.62	10.93	11.07
NON-STRATEGISTS	12.45	12.23	13.30

TABLE III.3. EXPERIMENT 2: SUMMARY OF MEAN SCORES.

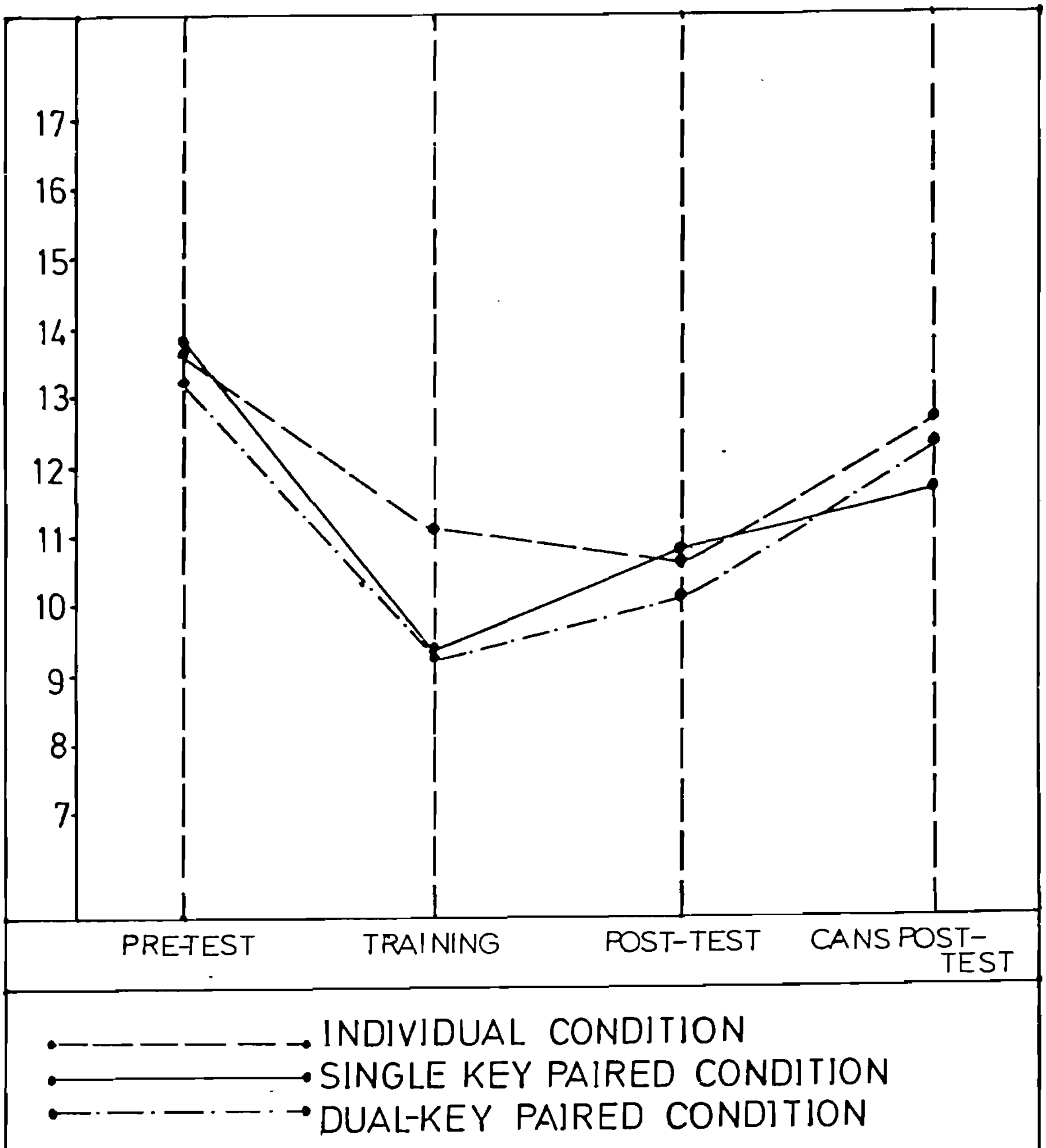

FIGURE III.9. EXPERIMENT 2: GRAPH OF MEAN SCORES: PRE-TEST, TRAINING, POST-TEST AND CANS POST TEST. (OPTIMUM SCORE = 7)

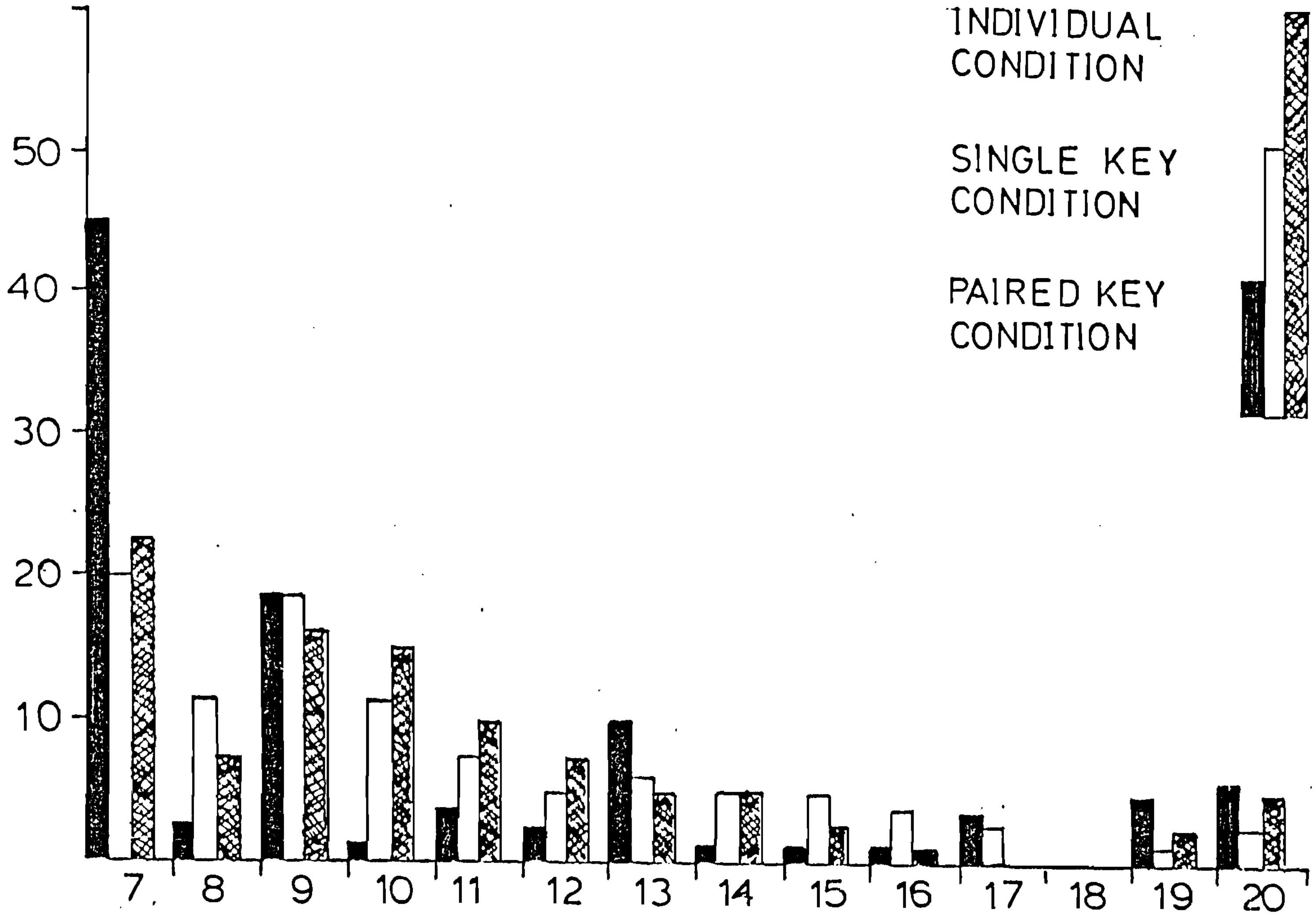

FIGURE III.10. EXPERIMENT 2: HISTOGRAM OF TOTAL SCORE DISTRIBUTION: 3-RING MICRO-COMPUTER POST-TEST.

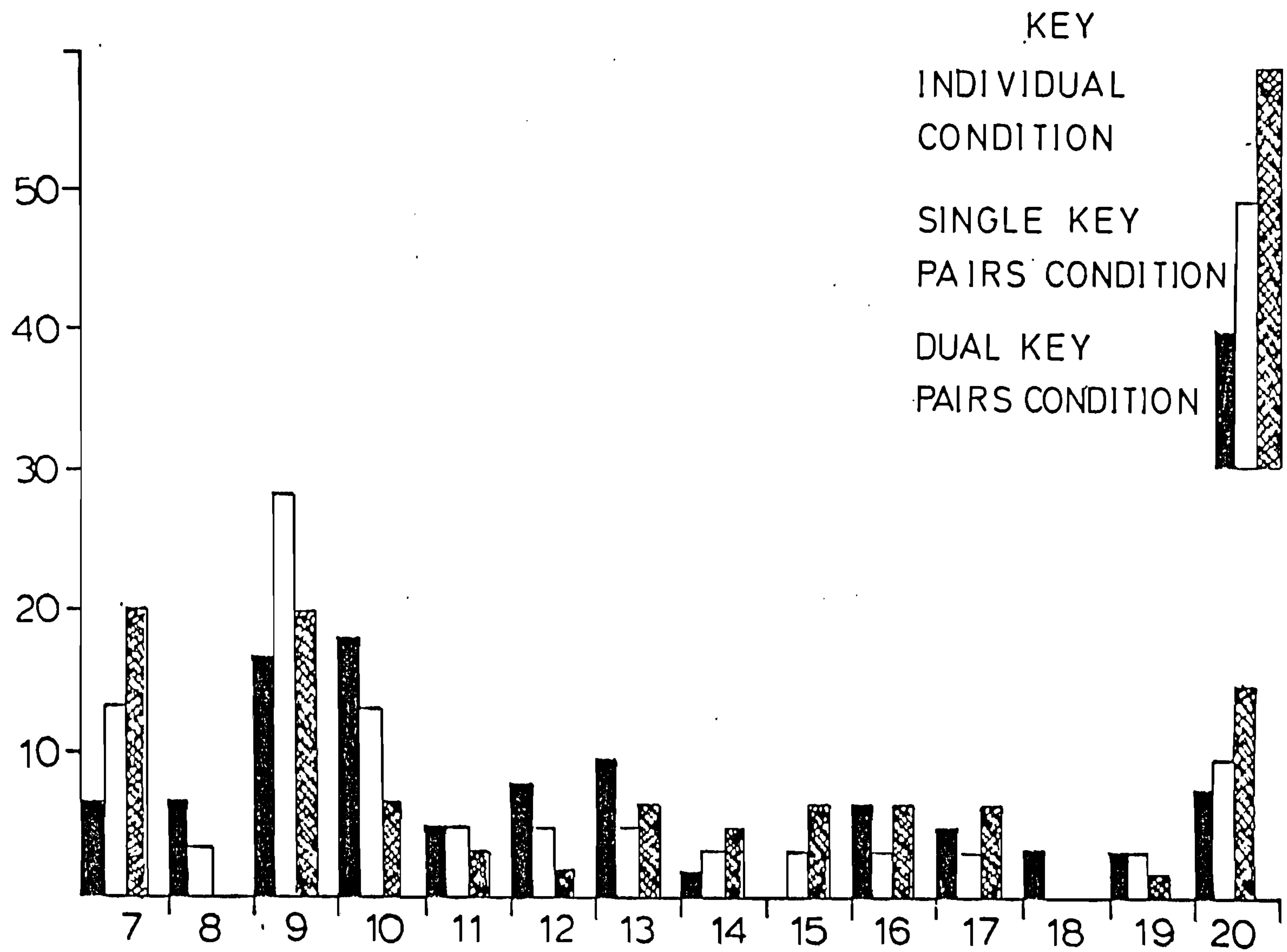

FIGURE III.11. EXPERIMENT 2: HISTOGRAM OF TOTAL SCORE DISTRIBUTION: CANS POST-TEST word. FIGURE III.10 makes it apparent that performance in the Dual-Key condition differs from that of the other two conditions in an important respect, namely in the number of optimum solutions achieved. Although this histogram combines 'within' and 'between' subject data, this rather striking difference deserves further analysis. Examination of the 'optimum score' data on an individual trial level indicates the pattern of responses in relation to type of trial. TABLE III.4 shows these scores.

Analysis on a trial-by-trial basis showed that there were significant differences between groups in the number of optimum solutions at Trial 1 ($\chi^2 = 9.6$, $df = 2$, $p < .01$). In this case, as the Individual and Single-key Paired conditions had identical scores, the difference lay with the Dual-key condition. At Trial 2 there was also a significant difference ($\chi^2 = 4.775$, $df = 2$, $p < 0.05$, one-tailed). Analysis of Residuals (Everitt 1977) showed that the significant difference lay between the Dual-Key condition and the other two conditions (adjusted residual = 2.16, $p < .05$). At Trial 3 there was no significant difference between groups, and at Trial 4 the numbers of correct scores were too small to permit statistical analysis.

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4
INDIVIDUALS	4	5	4	5
SINGLE-KEY PAIRS	4	4	6	2
DUAL-KEY PAIRS	12	10	9	5

TABLE III.4. EXPERIMENT 2: NUMBER OF SUBJECTS WHO ACHIEVED OPTIMUM SCORES AT EACH TRIAL (N=20 IN EACH CONDITION).

Trials 1 and 2 were the only ones that exactly duplicated those presented at pre-test and in training; thus it was only in those trials in which subjects had practice that the Dual-key Paired group achieved significantly better post-test performance - as measured by the number of subjects achieving optimum solutions. The number of optimum solutions in the Cans task was insufficient to allow statistical comparison. The histogram of the Cans test illustrates that, in contrast to the 3-ring micro-computer post-test, the number of subjects achieving the optimum score was least in the Dual-Key condition. This is perhaps the most certain evidence of the strictly local nature of the learning that had taken place.

The prediction that the use of a more structured interaction condition, in the sense of being more controlled, would result in peer interaction benefit was not realised in the overall analysis. However, on the basis of the experimental hypothesis, an *a priori* comparison was made between the Dual-Key condition and the Individual condition ($t = 0.57$, $df = 162$, n.s.). The rationale for the use of this statistic derives from Kirk (1968, page 73), who sets out the circumstances in which planned orthogonal comparisons are justified. Kirk points out that whether or not an over-all test using an F-ratio has been applied to answer the question of whether *anything* happens in an experiment, *a priori* t-tests can be used to address specific hypotheses, provided the comparisons made are orthogonal, meaning that they utilise non-overlapping pieces of information.

III.8. EXPERIMENT 2: DISCUSSION.

The second Tower of Hanoi study has failed, in any general sense, to demonstrate the efficacy of peer-interaction in promoting individual learning. No overall post-test differences between experimental conditions were demonstrated. However, the findings have revealed differences in performance in specific terms, particularly in the extent to which structured interaction, as in the Dual-Key condition, facilitated the achievement of optimum scores at trials encountered in training. The dual-key facility was introduced as a means of structuring the interactive condition, on the assumption that this would provide a comparable form of control to that of the provision of handles by Glachan (1985) in his Tower of Hanoi studies. Glachan did not make clear at what level he supposed the joint manipulation of materials was effective. If it was at the level of ensuring that both members of a dyad maintained a mental engagement in the task, then it might be expected that the dual-key facility would similarly engage the subjects. If the physical process of moving the wooden discs was an important element, perhaps by creating a proprioceptive memory, then the dual-key would not be comparable to the wooden handles on Glachan's Tower of Hanoi. In the present study, it may be that the benefit, albeit limited, demonstrated in the Dual-Key condition, derived from the restraint on precipitate action that the joint operation of the keyboard provided. There is evidence in conservation studies of domination preventing cognitive gain by excluding the non-conserving partner. For example, Mugny and Doise (1978), in a manipulation of materials task, found that the less able child did not benefit if the able child dominated by virtue of doing the task. In the present studies, as domination did not necessarily relate to skill, and as the dominant child did not necessarily produce any verbal guidance for the other child, then, in the Single-Key pairs, an explanation suggesting that lack of progress derives from domination accords with previous findings.

As a social situation the micro-computer presentation was not very conducive to equality of interaction. The seating arangements meant that the children did not naturally focus on each other, in a way that would be possible, for instance, if they were sitting on opposite sides of a table. A keyboard is designed for one operator and two people sitting side by side creates a slightly cramped atmosphere. Almost inevitably one or other subject achieves a dominant physical position in respect of the apparatus. Additionally, the speed and facility with which buttons could be pressed meant that subjects who were inclined to dominate could do so easily. For example one boy said that he agreed with his female partner's choice, and then pressed the key that was not that choice with the comment "We don't want any of your silly mistakes". The Dual-Key Condition was an effective remedy for this type of domination, but it did not rule out more subtle forms that may have been operative.

The fragility of the superiority of the Dual-Key pairs, and the extreme specificity of the benefit demonstrated, may be accounted for if the Tower of Hanoi task is looked at in more detail. The Tower of Hanoi presents a problem that may be solved by means end analysis. It requires the child to recognise the sub-goals that lead to success. Klahr (1978) observes that children learn about problem-solving, without instruction, before they get to school age and that they acquire a range of problem-solving abilities that although they are typically characterised as "common sense" are a systematic means-end chain. The child functions effectively, and achieves desired goals, by noticing relevant features of the environment and organising a wide range of facts, constraints and simple inferences in a systematic manner. However, although the sub-goals in the Tower of Hanoi may be, as Klahr suggests, the same in principle as recognising the means of accessing one's socks from the dryer, they are very different in practice. The subtlety and lack of distinctiveness of the various moves in the Tower of Hanoi problem requires a very abstract appreciation of the nested character of the solution path. Hence Bryant's (1982) suggestion, that social interaction may be beneficial by virtue of leading the child to recognise the relevance of his pre-existing logical skills, may be true but irrelevent in the context of the Tower of Hanoi. Similarly, Light and Perret-Clermont's (1986) suggestion, that social interaction may operate by clarifying the nature of the task, is arguably inappropriate to this type of problem. Karmiloff-Smith's (1984) view, that success is a pre-requisite for change, seems more relevant, as it is the successful completion of the task in seven moves that may lead subjects to recognise the importance of the first move. This recognition may have been a means to overcome what appeared to be a dominant, but inappropriate, concern not to 'clog up' the goal peg. This sub-goal was seen to work against subjects in their disinclination to use the goal peg for the first move. "If I put that there (pointing to the goal peg) I won't be able to put those on top" was a frequent comment. Those without that inhibition were more likely by chance if not for any purposeful reason to place the first disc on the goal peg, and having done so the solution path rapidly becomes obvious. It may be that the Dual-Key pairs were successful to the extent that they lost the inappropriate sub-goal of not "clogging up" the goal peg.

Some subjects clearly recognised the need to place the first disc on the goal peg. This is an intermediate sort of understanding in the sense that it is less than the ultimate strategy of knowing that the first move is dependent upon the number of discs but it is of course an efficient heuristic in the 3-ring task. The lack of well stated goals or intentions was consistent with my informal observation that during training very little 'strategic' discussion took place between pairs of children - the only comment heard was that of a child in the individual condition who said "you put the first one on the place you want to go to". The protocols reported in the results section of Experiment 1 provide some examples of sub-goal thinking that was consciously expressed.

Children appeared to view the instruction to co-operate very much as co-operation in action rather than co-operation in any planning activities. Very little discussion took place between pairs of children. The lack of verbalisation was particularly apparent when subjects jointly decided on an appropriate move, and then lost sight of it because they had not expressed it explicitly. Not infrequently, they were seen to agree on the right sequence and then to make the wrong move: it was not that they were pressing the wrong key, but rather that they lost sight of their decision before implementing it.

The assumption of Doise and Mugny (1984) that peer interaction is beneficial by virtue of forcing awareness leads one to ask, in the case of the Tower of Hanoi, awareness of what? The inability of pairs of subjects to hold in even short term memory their joint decisions, highlights the importance of the verbal elements of a task in determining whether interaction promotes subsequent individual benefit. The problem of memorising a move sequence may contribute to the fragile nature of the peer benefit in the present study; in contrast in a conservation task there is only one rule to be memorised or understood.

A second relevant factor is that in the Tower of Hanoi, unlike some spatial transformation tasks that have been used to demonstrate peer interaction, there are no discrepancies in visual perspective to engender cognitive conflict. However, it seems feasible that there was a visual element in the gain demonstrated by some subjects in the Dual-Key condition. It is clear that the enhanced ability of the Dual-Key pairs is highly specific. It is clearly not the principle of the Tower of Hanoi that has been learned as that would allow solution of the problem regardless of the number of discs. Nor is it the principle of putting the first disc on the goal peg, because this principle, if implemented, would not have resulted in the discrepancy in performance on the first two and last two trials. It suggests that enchanced understanding was in terms of a perceptual appreciation of the correct first move, specific to a particular goal peg and start peg eg. a heuristic rule for putting the first disc on the right hand peg. This highly specific differential learning was necessarily ineffective in relation to the trials not previously encountered, and in relation to the alternative tasks.

It was apparent at the time, and as evidenced by the results, that the wooden version of the Tower of Hanoi was of comparable difficulty to the computer-based version. The Cans task was different, not only in being an inverted form, but also in that the pegs were not set in a line but were arranged in a triangle, which created a different visual perspective. However, there seems no reason to suppose that the Cans task should be intrinsically more difficult or easier than the traditional Tower of Hanoi. The mean scores suggest that subjects found this post-test slightly more difficult than the wooden version.

As expected, subjects found the four-ring task, which has a minimum solution path of fifteen moves, noticeably more difficult to complete. The four-ring version is interesting in that a lower level strategic understanding, namely the heuristic rule to put the first disc onto the goal peg, is positively counterproductive: only the principle of recognising the relationship between number of discs and first move would allow subjects, new to the task, to perform effectively. A sophisticated understanding of the principle of the Tower of Hanoi, which would lead to optimum solutions regardless of the number of discs was, predictably, not acquired. Performance in sub-problems within the four-ring task might well be aided by prior experience using the three-ring version. There was no difference between conditions which perhaps strengthens the idea that the acquired differential benefit evidenced in the single trial data related to the first move.

In analysis of the present findings the performance of subjects at pre-test was used to divide the data into two categories of strategist and non-strategist. The assumption underlying this description was that those whose performance was in the better group already possessed a systematic approach to the problem. The present study followed that of Glachan in describing better performers as 'strategists' although it is by no means certain that such a description is necessarily a true reflection of the distinction between them and the 'non-strategists'. Glachan's categorisation may have given the subject credit for mental activity that was not present. He supposed that the predominance of scores of 7, 9, 11 or 13, as opposed to 8, 10, 12 or 14, reflected a systematic move strategy, but it is possible that rather than having a predisposition to do one thing, subjects may have had a powerful inclination *not* to do something - specifically - not to reverse the immediately preceding move. Strategic behaviour in Glachan's terms may have meant no more than that subjects had this inhibition. The finding that there was no differential superiority in strategist's performance in the

Dual-Key condition runs contrary to Glachan's finding that it was for this group of subjects that social interaction was beneficial.

The role of the experimenter was similar to that in Glachan's study, although there is inevitably some potential for effects derived from individual differences in style. Very little collaboration was required between experimenter and subject, except when the children were asked about their performance. At this point there was scope for intersubjective differences, but as this was the last element of the post-test session there was no potential for it to have a differential affect on performance.

In the Individual condition some children stopped and addressed the experimenter with remarks such as "I'm stuck - I can't do this." On several occasions such a pause was followed by an 'ah-ha' phenomenon, namely that the child had a sudden 'realisation' of what was required, although this 'realisation' was not necessarily correct. This may be an illustration of the impossibility of creating a truly 'individual' experimental situation. Although the experimenter role was a neutral one, it may not have appeared so to the subject, in which case a form of tacit interaction can be said to have occurred.

The potential influence of the adult on the learning situation brings the discussion to educational concerns. The relevance lies in two areas: the first is the extent to which the Tower of Hanoi study illustrates the importance of sub-goals in learning. The ability to recognise sub-goals is clearly an important logical skill and one that Papert claims is fostered by programming in LOGO. A computer task environment was created similar to that frequently encountered in educational computing. The hardware is used to present a task that has no specific relevance to the machine - it is merely an alternative presentation mode. The dual-key control issue is also relevant; in particular, it may be important to the question of how computer facilities are best utilised, particularly in the face of hardware shortages. The computer certainly provided evidence of the motivation factor - but this must be seen in the context of the very recent introduction of micro-computers into schools. It is not certain how long the novelty value will last.

The educational relevance of the present study may be considerable, if it indicates that there are ways of modifying social factors in learning using the computer hardware, or software. The present findings highlight the need for close attention to the circumstances in which micro-computers are used in schools; one cannot assume that the ideal learning environment is one child to one computer, nor on the other hand that paired or group practice is necessarily beneficial unless joint participation is ensured in some way.

The first two studies have shown that benefit from peer-interaction is not a robust or automatically occurring phenomenon. Despite the significant sub-analyses, in neither experiment was an overall conditions difference demonstrated, although the second study has shown that the control over social interaction afforded by joint manipulation of the keyboard was effective to a limited extent and this aspect itself merits further investigation. Faced with a number of theoretical issues worthy of further investigation, for the next study it was decided to focus attention on those questions of most relevance to previous peer-interaction studies. For this reason a task was selected that required judgements from limited options to be made, and that had the characteristic of being amenable to solution by rule induction. The balance beam, which was chosen as a suitable task, has been used frequently in developmental research. It is particularly interesting because it has the potential to reveal specific response biases, as particular forms of response in the balance task are identifiably related to particular underlying cognitive mechanisms. It was hoped that, using this task, some aspects of the process by which children benefit in social settings would therefore be revealed. In the next chapter two studies using the balance beam are reported.

CHAPTER IV. THE BALANCE BEAM AS AN EXPERIMENTAL TASK IN THE STUDY OF PEER INTERACTION.

IV.1. INTRODUCTION

The preceding studies have provided a very tentative illustration of the benefit to children of structured social conditions of learning. A general point must be made about these results before reporting the next studies. Findings which are indeterminate, in the sense that no large statistically significant overall differences between conditions are demonstrated, but which nevertheless reveal in the data evidence of some alteration in performance arising from differential intervention, pose something of a problem. Much of the previous research in the area of social cognition can be criticised for the generality of the conclusions drawn from very specific task circumstances: it may not be appropriate to make claims for the process of cognitive development from one type of study alone. However the need to avoid over-generalisation applies in more than one direction - it is equally important not to dismiss a phenomenon in general terms on the basis of any one type of intervention. The results of the first two studies in the preceding chapter do not support the more assertive claims made in favour of the benefits of peer interaction, but neither do they provide strong evidence against them. Further experiments using yet another task may clarify the issue.

The balance beam problem was selected as a suitable task for the next study. This choice was based on several considerations: firstly, ability to solve balance beam problems develops gradually over a wide age-span so that investigation need not be restricted to one age group; secondly it can be used as a judgement task which makes it - in that respect - comparable to conservation judgement tasks; thirdly it seems likely that in a co-operative learning situation more verbal interaction would be forthcoming using the balance beam task than was produced using the Tower of Hanoi; and lastly reports by previous researchers using the same task (e.g. Inhelder and Piaget 1958; Siegler 1976; Martin 1983) provide a useful point of comparison. This previous work will now be described as a way of setting the scene for the next study.

IV.2. THE BALANCE BEAM IN DEVELOPMENTAL RESEARCH.

Inhelder and Piaget (1958) used the balance beam in one of a series of studies of the growth of logical thinking from childhood to adolescence - from concrete-operational to formal operational reasoning. They identified stages of understanding of balance principles. In the first stage, from about three to five years, children tend to intrude on the working of the apparatus with their own actions which they fail to distinguish from the actions of the objects that they are trying to control. At this level, the child does not even understand the need to put a weight on each side of the fulcrum to make the beam balance. At the next stage, from five to eight years, the child understands that weight is needed to achieve a balance but does not understand the importance of distance from the fulcrum. From about eight years the subject discovers by trial and error that equilibrium between a smaller weight at a greater distance and a greater weight at a smaller distance is possible, but he does not yet draw out general correspondences. Co-ordination goes no further than intuitive regulations, the child's behaviour consists of concrete-operations without systematic co-ordination between them. Inhelder and Piaget note that during this stage, on searching for a common denominator of the two relations that they can compare, subjects erroneously conclude that this common relation is additive. Later, at adolescence, the child progresses to the point of co-ordinating two dimensions, namely weight and distance from the fulcrum, and discovers the law of proportionality and hence the dynamic concept of moment. The structural mechanism which enables him to make these combinations of facts is an example of formal operational reasoning. Inhelder and Piaget's four stages can be summarised as firstly, symmetrical actions; secondly, inversely corresponding actions; thirdly, trial and error moves to transitivity; and fourthly, law of proportionality. This theoretical framework provided a means of interpreting the child's progress from physical manipulation of materials to an abstract understanding of the physical law of moment. The balance beam was just one of several tasks used to provide evidence of the development of such abstract reasoning processes.

An alternative approach, but one that draws on the preceding analysis, is that provided by Siegler (1976), using an information processing theory of cognitive development. Siegler bases his views on an assumption that children's problem-solving strategies are rule-governed, with the rules progressing from less sophisticated to more sophisticated with age. He identifies the components of a task and creates a formal 'decision-tree' model that in principle can account for the problem-solving choices children are seen to exhibit at various ages.

Siegler uses a variant of Inhelder and Piaget's beam to undertake this task analysis. On the basis of his work and that of Inhelder and Piaget, he argues that the different types of knowledge that children might have about the balance beam can be represented in terms of four rule models. A child using Rule-1 considers only the number of weights on each side of the fulcrum: if they are different the child predicts that the side with the greatest number will go down. For a child using Rule-2, a difference in weight still is conclusive, but if weight is equal on the two sides, then the distance dimension is also considered. A child using Rule-3 considers both weight and distance in all cases. If both dimensions are equal, the child predicts that the beam will balance; if only one dimension is equal, then the other one determines the outcome; if both are unequal and one side has the greater value on each of them, then that side will go down. However, in a situation in which one side has the greater weight and the other has the weights farther from the fulcrum, a Rule-3 child does not have a way to resolve the conflict; therefore he 'muddles through' or guesses. Finally, Rule-4 represents mature knowledge of the task. In this case the child computes the moments on each side by multiplying the amounts of weight on each peg by the pegs distance from the fulcrum, and then compares the sum of the products on the two sides.

Siegler created a rule assessment methodology based upon the six types of balance beam problem. In simple Balance problems, there is the same configuration of weights on pegs on each side of the fulcrum; simple Weight problems are those with unequal amounts of weight equidistant from the fulcrum and simple distance problems have equal amounts of weight different distances from the fulcrum. In the more complex conflict problems, firstly Conflict-Weight problems have more weight on one side and more "distance" on the other, and the configuration arranged so that the side with more weights goes down. Secondly, Conflict-Distance problems are similar to Conflict-Weight except that the side with the greater distance goes down. The third type of conflict problem, Conflict-Balance, is similar except that the scale remains balanced (Siegler 1978, p114).

TABLE IV.1 sets out the developmental changes in rule use identified by Siegler. A feature of the changes in rule use that is apparent is that children with a naive concern only with the weight factor, and who ignore the importance of distance, will make correct predictions in conflict-weight problems, but do so for the wrong reasons. Their performance declines to chance level as they begin to appreciate the importance of distance but do not yet have an accurate understanding of its relationship to the weight factor. Although this approach sets out the transition from one stage to the next it does so without reference to the context in which change occurs.

PROBLEM TYPE	RULE 1	RULE 2	RULE 3	RULE 4
Balance	100	100	100	100
Weight	100	100	100	100
Distance	0	100	100	100
Conflict-weight	100	100	33	100
Conflict-distance	0	0	33	100
Conflict-balance	0	0	33	100

TABLE IV.1: PREDICTIONS FOR PERCENTAGE OF CORRECT ANSWERS AND ERROR PATTERNS FOR CHILDREN USING DIFFERENT RULES.

In a study of peer interaction using a balance task, Martin (1983) found that the variable of most significance in learning was task related interaction. Martin criticises both Piaget and Siegler for what she argues is their tendency to effectively locate learning in the apparatus, by virtue of neglecting important variables, specifically the social circumstances in which the task is presented.

The present study takes Martin's work as its starting point, in using a balance task but with micro-computer presentation of the task. It is also similarly concerned with the social circumstances of learning. The use of the computer version creates a symbolic representation of the balance scale and it may be that this alters the potential for understanding, although the findings of the Tower of Hanoi studies provide an indication that the attributes of the task are not necessarily altered to any important extent by the transformation. The micro-computer presentation, which is both symbolic and reactive, provides an interesting intermediate level of presentation, arguably half-way between the abstract and the concrete. This raises questions regarding the importance of the level of abstraction in teaching new concepts, which may be of educational relevance. The computer presentation has the additional advantage of ensuring a high level of subject motivation.

The aims of this study were to assess the potential for peer-interaction benefit in learning in the context of the balance task, with particular reference to the importance of conscious self-awareness as a mediator of progress. Finally, this study provided a means of assessing the usefulness of a micro-computer based version of the balance problem as an experimental task.

IV.3. EXPERIMENT 3: METHOD.

Subjects.

Sixty children, pupils at the Poole Middle school used in the first study, took part in this experiment. Their ages ranged from 8 years 2 months to 9 years 1 month, with a mean age of 8 years 8 months. A minority had already participated in the previous study, and all were familiar with using the computer as part of their school work. They were all pupils in the same year grouping in two parallel and academically streamed classes. In view of the streaming an equal number of pupils were selected from each of the two classes, so that the two streams were equally represented in each condition. Within this constraint, subjects were allocated to conditions on a random basis, and randomly allocated to pairs in the paired condition.

Design.

The design format was identical to that used in the Tower of Hanoi studies. There were three conditions: in the first Subjects worked individually throughout; the second was a co-operatve paired condition and the third also co-operative pairs but with an added requirement that subjects justify their decisions. In the first peer condition the training session was conducted in pairs; in the second, similarly paired, subjects were additionally required, before operating the computer, to explain to the experimenter the reasons for their choice. The request for subjects to justify each decision was an attempt to introduce a controlled manipulation of the extent to which conscious reflective self-awareness influenced the learning process. To specify in words one's intentions and the reasons underlying them is necessarily a conscious action. This pursues the issue of what it is that peer interaction facilitates. A recurrent theme in much of the research reported in the introductory chapters is that peer interaction may operate mainly as a mechanism for raising consciousness levels, by making explicit reasoning that might otherwise remain implicit. If the social interaction in the experimental situation using the balance beam facilitates metacognitive awarenesss, and thus facilitates individual learning, the requirement to justify may not add anything that derived from the co-operative social condition. If on the other hand, the nature or extent of the social interaction is insufficient for this in the computer environment, then the necessity to justify may make a significant difference to individual progress.

In this study pre- and post-tests were conducted using paper and pencil tests. This response mode was chosen for two reasons. Firstly, the reactive facility of the micro-computer was unnecessary as the design involved the pre-test and post-test presentation of a number of problems with no feedback. Secondly, the disruption to normal class activity was reduced because - in using paper and pencil tests - several children could be tested simultaneously at post-test. For consistency the pre-tests were also changed to paper and pencil tests. An example of the pre-test/post-test form is shown in FIGURE IV.1.

The form consisted of 24 illustrations of the balance beam with up to four weights on one peg on each side. The 24 trials were presented on the form in a random but uniform order. The arrangements of the weights were such that each of the six types of problem identified by Siegler (1978) were represented as follows:

a) Two simple balance problems in which an equal number of weights were placed equidistant from the fulcrum.

b) Two simple weight problems in which the distance from the fulcrum was equal and the number of weights on each side different.

c) Two simple distance problems in which the distance from the fulcrum was unequal but the number of weights on each side was equal.

d) Six conflict-balance problems in which, given unequal weights and distances from the fulcrum, the distribution was such that the beam would balance.

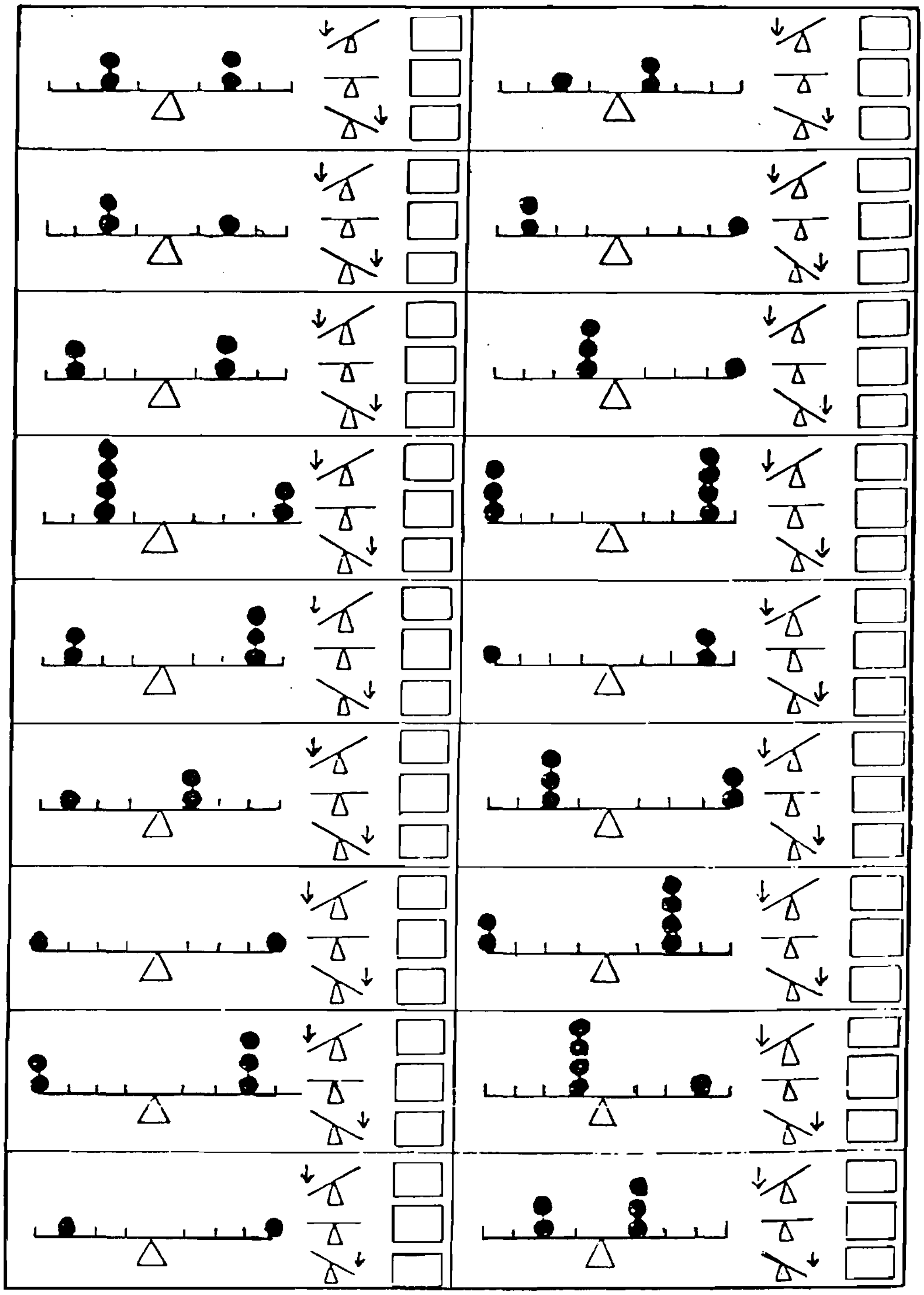

FIGURE IV. 1. EXPERIMENT 3:
EXAMPLE OF PRE-AND POST-TEST FORM FOR BALANCE TASK (PHOTO REDUCED FROM A4 SIZE)

e) Six conflict-distance problems, in which given a conflict between the weight and distance factor, the beam would tip to the side on which the distance from the fulcrum was greatest.

f) Six conflict-weight problems, in which given conflict between weight and distance, the weight factor would dominate.

Subject responses were scored according to the strategy assumed to underlie each decision. Thus in the case of a conflict-balance problem, the response could either be conflict-balance (ie. correct) or one of the two incorrect responses, namely conflict-weight or conflict-distance, according to whether the beam was predicted by the child to tip on the side with the greatest number of weights, or on the side with the weights furthest from the fulcrum. The primary measure was whether the child or dyad gave a correct answer, but the data were recorded in a manner that would allow dominant incorrect response strategies to be revealed. The construction of the test form and training programme was such that a response bias for ticking, say, the first box, would not appear to represent a weight or distance strategy. However, a response bias in selecting the middle box - the balance option - would appear to demonstrate a balance strategy.

Although in planning the response form it would have been possible to vary the order of the boxes, it was decided not to do so because of the alternative risk, observed in preliminary investigations, that children would make recording errors through mis-reading the symbols. In practice, there was little evidence to suggest that response biases of this sort intruded into the experimental situation.

An illustration of a 'real' balance beam similar to that used by Siegler is shown in FIGURE IV.2. This was used as a demonstration model in the introduction phase of the study, and was subsequently used in the training phase of later experiments. It provided the model for the beam illustrated in the computer program which was written specifically for this study. The wooden balance consists of a beam with a central fulcrum and with a series of pegs on each side. The distance from the fulcrum to the first peg, and between the other pegs is uniform. There are a number of identical wooden blocks that can be placed on pegs on each side. The even distances and weights means that a simple multiplication rule can be used to calculate the moment and hence which way the beam will tip. The beam is designed so that a maximum of four blocks can be placed on one peg, and the rule of the game is that blocks should be placed only on one peg on each side of the fulcrum.

The computer version of this apparatus provides a screen illustration of the beam with weights in place on both sides. The text makes it clear that the subject is required to predict whether the beam will tip or remain balanced with the weights in that position. Decisions are recorded by pressing one of three buttons: Tip to A (Press button A); Tip to C (Press button C); Balance (Press button B). The screen display is illustrated in FIGURE IV.3. Following entry of the subject's prediction the computer illustrates the beam tipping, according to the weight configuration, and indicates whether the subject had made a correct decision.

The computer task was presented using the same equipment as that used in the two previous studies.

Pre-tests.

Subjects were pre-tested individually, immediately before the training session. In order to be certain that the nature of the task was understood a wooden balance beam was shown to the children at the outset and used to demonstrate the effect of firstly having no weights on the beam, and secondly of adding a single weight to one side. It was pointed out that the distances between the fulcrum and the nearest peg, and between the other pegs, were identical, and that the weights were all the same. Having

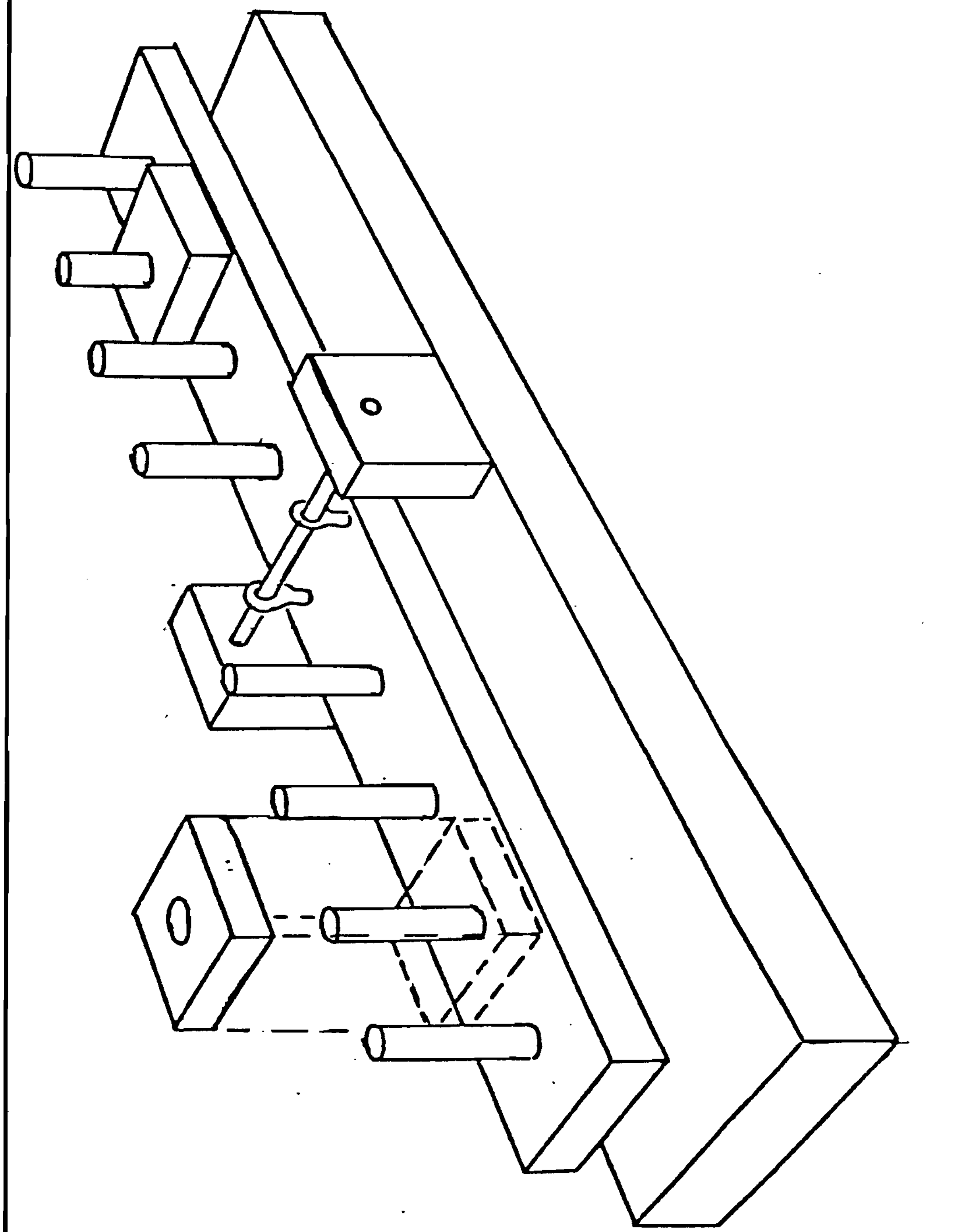

FIGURE IV 2 EXPERIMENT 3 THE WOODEN VERSION OF THE BALANCE BEAM

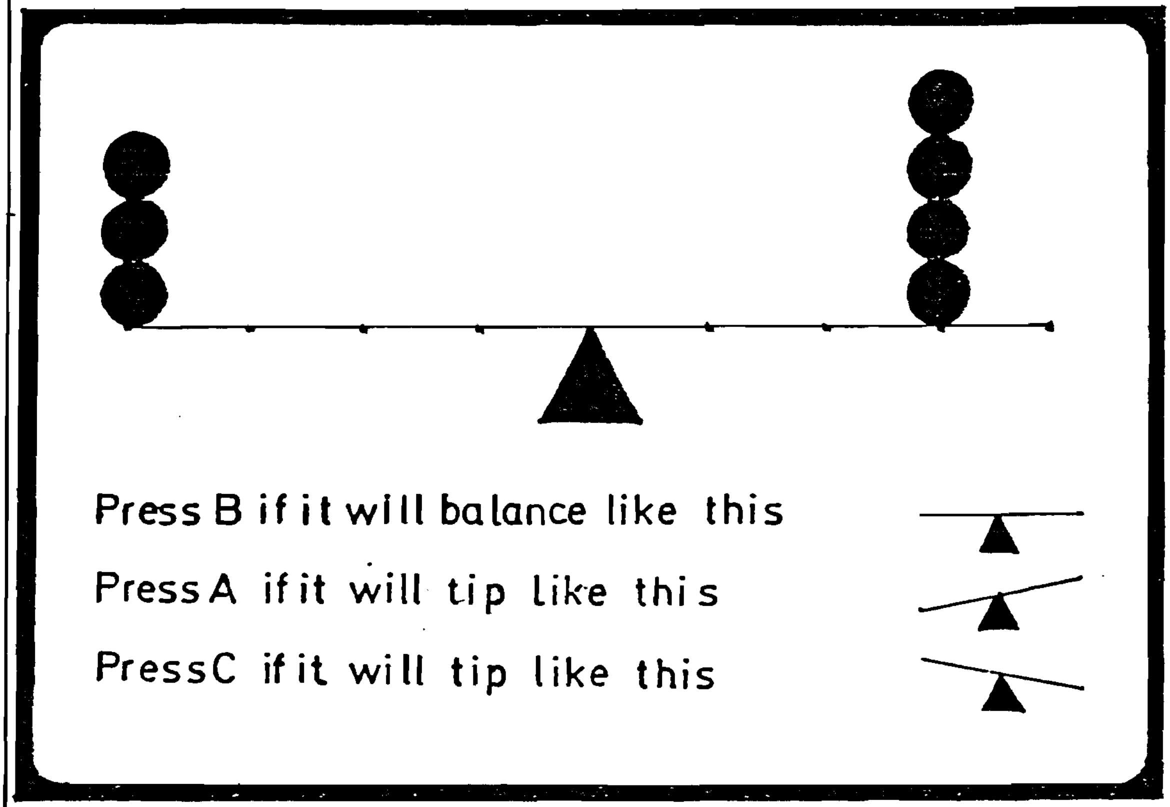

FIGURE IV.3. THE SCREEN DISPLAY FOR THE MICRO-COMPUTER VERSION OF THE BALANCE TASK provided this minimal demonstration, the wooden balance was removed from view. The experimenter then explained to the subjects that they would be asked to look at a series of pictures of a similar balance, either on paper or on the computer, and to decide whether the beam would tip, according to where the weights were placed in each case. Subjects were then shown how to complete the pre-test form by ticking the appropriate answer boxes. It was explained that there was no need to hurry, as the task did not have a time limit.

Training.

This was conducted immediately after pre-testing. The child or pair of children were introduced to the computer apparatus and encouraged to familiarise themselves with it. The program was demonstrated and the operation of the keyboard explained using a simple example of one weight placed on one side of the beam. It was pointed out that the screen diagram represented the wooden balance shown at pre-test. The children appeared to have no difficulty in grasping the instructions and were eager to proceed. The 24 trials used were identical to those used at pre-test, but were presented in an alternative random but uniform order. The experimenter established that the subject understood the procedure on the first trial and thereafter maintained a supportive presence. Any questions regarding the solution to the problem were parried with a neutral response. Subjects were reassured that "nobody gets them all right" if they indicated disappointment at their performance. On completion of the 24 training trials the children were congratulated on their performance, thanked for their participation and allowed to return to the classroom.

In the first paired condition the same procedure was adopted with the addition that at the outset the need to co-operate was made clear. Subjects were told that they should do their best together, to agree what to do, rather than merely take turns in providing answers. It was emphasised that if they could not agree they should discuss the problem until they could reach agreement. Having given this emphasis on the need to co-operate, no further restrictions were placed on the pair. However, if one child was persistently dominant a verbal reminder was given.

In the second paired condition the procedure was identical apart from one additional requirement. This was that each member of the dyad was asked to justify their intended move before pressing the response button at each trial. The experimenter invited each child in turn to explain why they had arrived at their decision. The order in which subjects were questioned was alternated at each trial.

Post-tests.

Individual post-tests were conducted at an interval of six to seven days after training. The post-test consisted of the same problems, presented in revised order using the same paper and pencil format as used at pre-test. Subjects participated in this stage of the experiment in batches of eight, but care was taken to ensure that no interaction took place so that each child completed the form unaided.

IV.4. EXPERIMENT 3: RESULTS.

In describing the findings, the paired condition without justifications will be referred to as Peer-1 and the paired condition in which subjects were required to justify their responses will be known as Peer-2. From Siegler's work it was predicted that, from pre-test to post-test, the number of correct responses in Conflict-Weight trials would be reduced, as subjects improved from a simple weight strategy to one including distance factors. For this reason these trials were subject to a separate analysis: to have combined all scores would have confounded the data. Using the first 18 trials, ie. excluding Conflict-Weight problems, the subject mean scores obtained at each stage of the experiment are shown in TABLE IV.2. The findings are also represented in FIGURE IV.4.

	INDIVIDUAL	PEER-1	PEER-2
PRETEST	6.35	6.5	6.85
POST-TEST	7.95	7.95	8.65

TABLE IV.2. EXPERIMENT 3: 18-TRIAL DATA: SUMMARY OF MEAN SCORES.

A two-way analysis of variance shows no significant differences attributable to the experimental conditions in which the children were trained. In contrast to this it was apparent that there had been a significant improvement in performance overall from pre- to post-test, indicating that subjects had benefitted in general terms from the learning experience ($F = 18.9$, $df = 1,57$, $MS(error) = 4.15$, $p < 0.001$). There was no interaction effect.

The use of number of correct responses as a measure of progress failed to demonstrate significant differences according to the circumstances in which children were trained. An alternative analysis based on level of rule-use was therefore undertaken, on the assumption that

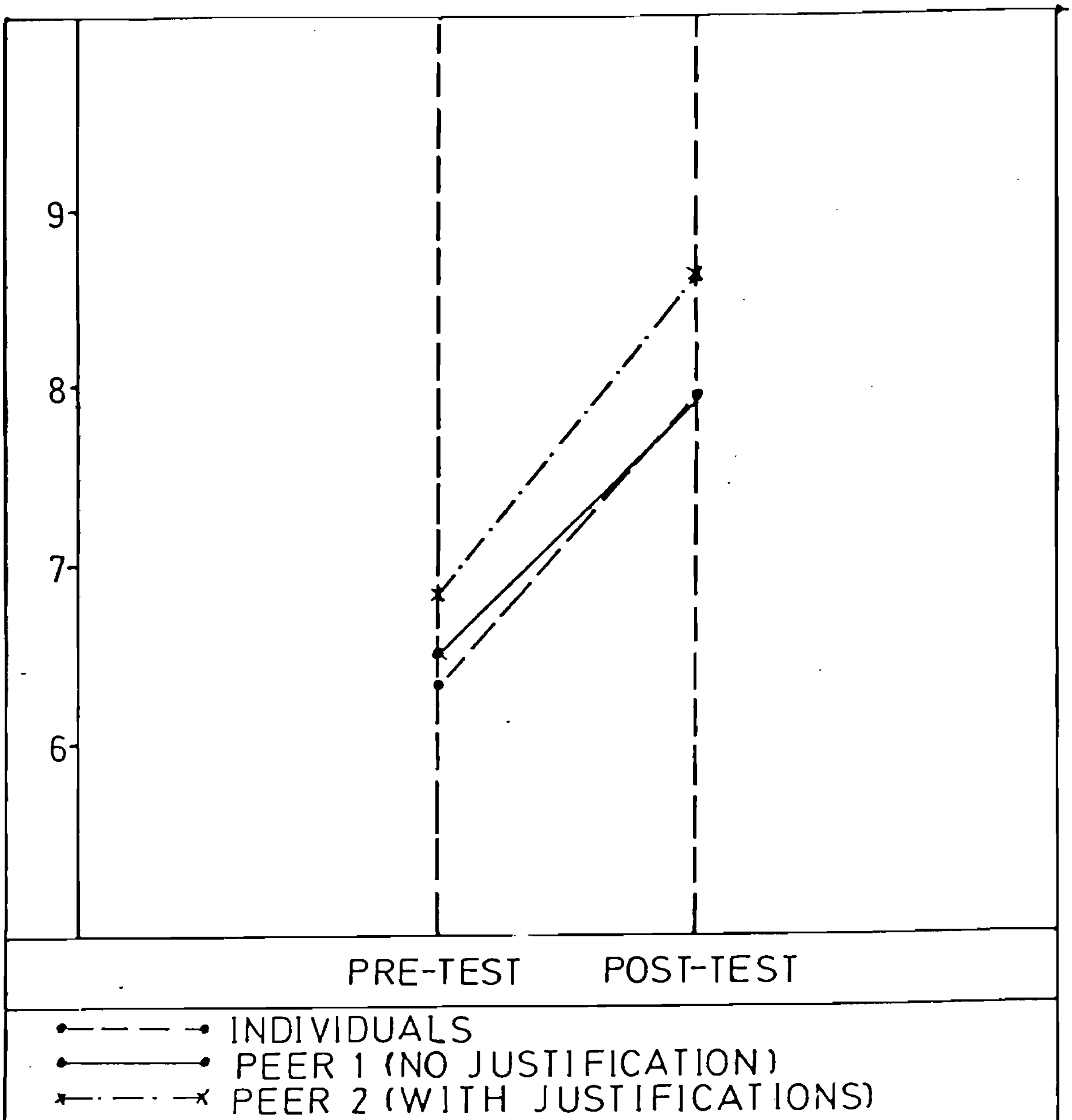

FIGURE IV.4..EXPERIMENT 3: 18 TRIAL DATA
MEAN SCORES AT PRE-TEST AND POST-TEST
(OPTIMUM SCORE = 18)

this might provide a more useful measure of children's understanding. The criteria used by Siegler were accepted here as a fair reflection of consistent rule-use. Rule-1 subjects were expected to respond with Weight consistent answers in five out of six responses, and to fail to answer Distance trials correctly. Using the criterion of failure on both Distance trials, an analysis of the data shows that over all conditions 13 subjects used Rule-1 at pre-test and that this number dropped to 8 subjects at post-test.

Rule-2 subjects were categorised as those who provided Weight responses on at least five out of six of conflict trials,and who also responded correctly to at least one simple Distance trial. At pre-test 17 subjects used Rule-2, and at post-test this number was reduced to 4. The two sets of data were combined and are set out in TABLE IV.3. On this basis it is clear that there was little difference between conditions. At the other end of the Rule use scale, a criterion for Rule 4 use of five out of six correct answers on all sets of trials shows that none of the eight-year-old subjects had this degree of understanding at pre-test, nor did training lead them to it. No subjects reached this level of performance. The number of subjects using Rule-3 are deduced by exclusion from the other Rule-use data, and are set out in TABLE IV.4.* Although once again the differences between the conditions are

* These subjects all met Siegler's criteria (c.f. p 111) for Rule 3 use, responding correctly on Weight and Distance trials, but giving mixed responses on conflict trials.

slight, overall a McNemar test for the significance of changes shows that there was a significant change in Rule use from pre- to post-test in the Peer-2 condition $\chi^2 = 3.9$, d.f=1 $p < .05$), but that in the Individual and Peer-1 conditions this did not reach significance.

	INDIVIDUAL	PEER-1	PEER-2
PRE-TEST	10	11	12
POST-TEST	4	6	4

TABLE IV.3. EXPERIMENT 3: NUMBER OF SUBJECTS CATEGORISED AS USING RULE-1 OR RULE-2.

	INDIVIDUAL	PEER-1	PEER-2
PRE-TEST	10	9	8
POST-TEST	16	14	16

TABLE IV.4. EXPERIMENT 3: NUMBER OF SUBJECTS CATEGORISED AS USING RULE-3.

The pre-test performance on simple Balance and Weight problems was so good that no analysis would be helpful; however,the simple distance problems revealed a less than optimum performance and inspection of the data shows that mean performance improved from pre- to post-test. The means derived from the sum of subjects' individual scores on the two simple Distance trials are given in TABLE IV.5. This illustrates that a proportion of subjects at this age remain very uncertain about the importance of the distance factor in affecting the balance of the beam.

	INDIVIDUAL	PEER-1	PEER-2
PRE-TEST	.95	.95	.90
POST-TEST	1.15	1.25	1.20

TABLE IV.5. EXPERIMENT 3: SUMMARY OF MEAN SCORES: SIMPLE DISTANCE TRIALS (maximum score=2).

Two-way analysis of variance of the simple Distance data shows that there was no difference between conditions; that there was a significant trial effect

($F = 6.47$, $df = 1,57$, $MS(error) = 0.33$, $p < .05$), but that there was no interaction effect. This shows that subjects at this age do improve in their understanding of the importance of distance from the fulcrum as a result of practice with feedback. The Anova Table can be seen in APPENDIX 1. These findings in effect confirm the previous analysis in terms of Rule-use.

The Conflict-Weight trials are, as already mentioned, ambiguous in that correct answers may reflect either a sophisticated Rule-4 understanding or an elementary Rules 1 Weight strategy. For this reason it was recognised at the outset that these data would require separate analysis. The results of the Conflict-Weight trials are set out in TABLE IV.6. and in FIGURE IV.5.

	INDIVIDUAL	PEER-1	PEER-2
PRE-TEST	4.55	4.0	3.9
POST-TEST	3.35	3.2	3.6

TABLE IV.6. EXPERIMENT 3: SUMMARY OF MEAN SCORES: CONFLICT-WEIGHT TRIALS (maximum score = 6).

Two-way analysis of variance shows that, as with

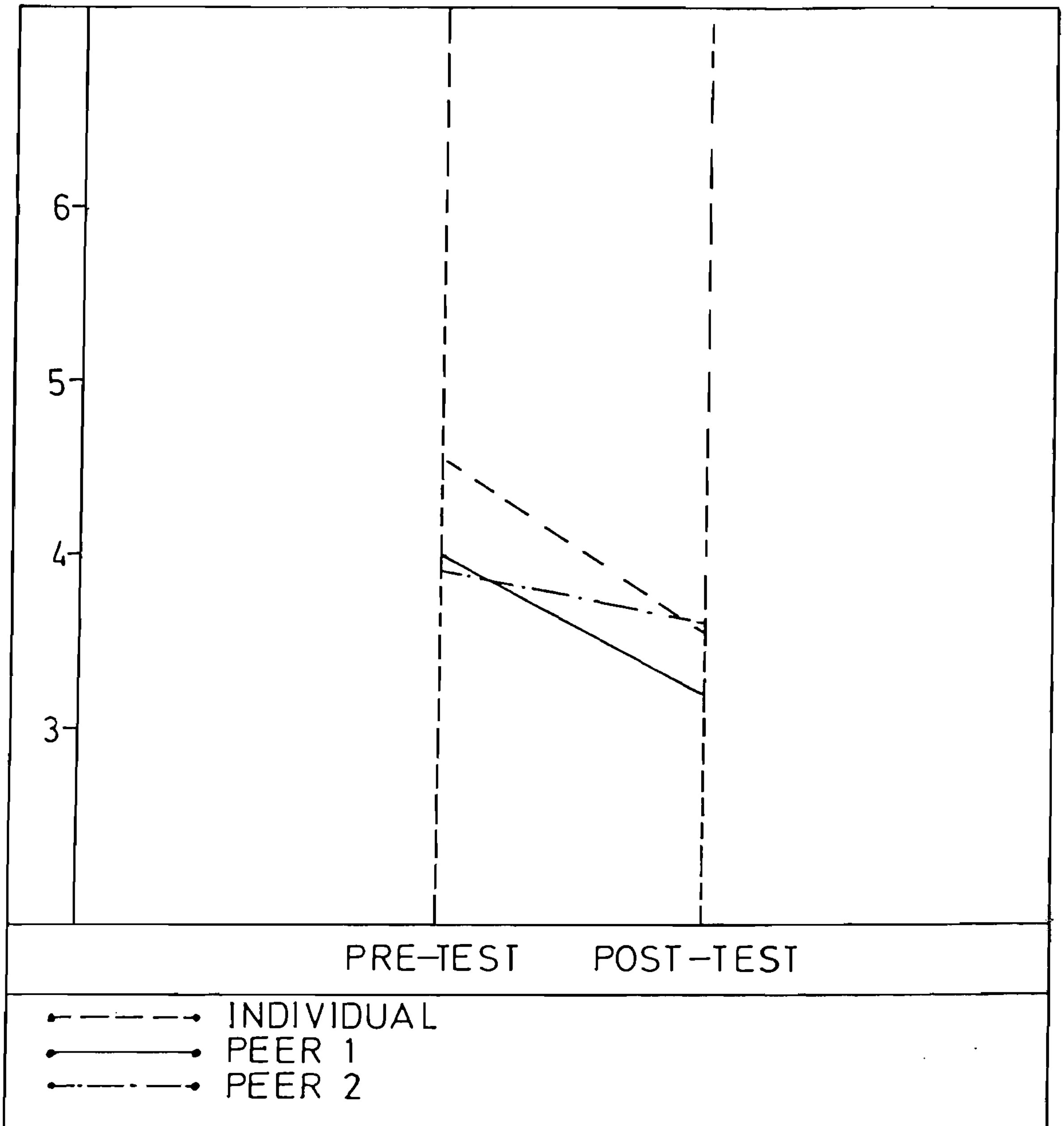

FIGURE IV. 5. EXPERIMENT 3: CONFLICT WEIGHT DATA: MEAN SCORES AT PRE-TEST AND POST-TEST (OPTIMUM SCORE = 6) the 18-trial data, there was no difference between conditions. There was a significant difference in performance from pre- to post-test ($F = 7.96$, $df = 1,57$, $MS(error) = 2.22$, $p < .01$) indicating that there is an apparent deterioration in performance. This is consistent with the previous findings indicating that subjects acquired an increased awareness of the importance of distance factors and were significantly less inclined to respond on the basis of weight only.

IV.5. EXPERIMENT 3: DISCUSSION.

The overall improvement in performance indicates that the feedback provided by the micro-computer presentation facilitated some learning in all conditions. It was apparent that the use of a micro-computer version of the task did not alter the nature of the task in any fundamental sense. The levels of performance reached by subjects overall closely matched the levels predicted by Siegler and Piaget. The micro-computer presentation again proved to be highly motivating, with the majority of subjects eager for their 'turn'. The second aspect of presentation, namely the use of paper and pencil pre- and post-tests also proved satisfactory. Subjects clearly understood the symbols representing the beam and also understood the principle of ticking a response box. This type of test form is of course already in use in schools in achievement tests.

This study has confirmed the findings of previous workers that children of this age are not yet fully aware of the importance of the distance factor. It is clear that with practice, feedback leads them to recognition of the inadequacy of their weight strategy. There is a disruption in previously stable but inaccurate weight responses in conflict balance and conflict distance trials with a more complex and more accurate pattern of responses. In many cases this improvement is from a nil correct to a chance level of accuracy, rather than to some coherent plan or strategy. The change in performance thus represents the abandonment of an inappropriate theory. All children abandon the use of a consistent weight strategy when faced with the negative feedback it produces in training, and three quarters of subjects remain at the new level when responding without feedback at post-test. This means that approximately a quarter of subjects changed from Rules-1 or -2 to Rule-3. It would be interesting to know what distinguishes them from their companions.

The results in the Conflict-Weight trials are very consistent with the view of the results as indicating the disruption to previous beliefs or inappropriate theories.

Some of the positive findings in the 18-trial data could be dismissed as the child learning something new, without the implication that some other understanding had thereby been dislodged or challenged. The Conflict-Weight data offer good evidence that it is not merely success that is the "motor for change"; instead these data clearly indicate that the subject has learned that something is *not* right, and in recognising the inappropriateness of this theory the child is led to use other strategies, either an alternative systematic belief or a strategy of random guesswork, although it is questionable whether it is appropriate to describe a random pattern as a meaningful strategy. There was no evidence in the pattern of discourse witnessed by the experimenter of the use of any coherent alternative strategy. Inhelder and Piaget (1958) argued that general correspondences are not drawn out by children of this age from their experiences with the balance task, and they suggest that co-ordination is restricted to intuitive regulations. The present findings are in accord with this assessment.

In order to understand why neither of the social conditions resulted in significant differences in post-test performance compared to the individual conditions it is necessary to consider in what ways peer-interaction *may* be beneficial. In terms of modelling, watching someone else produce the right answer can only be useful if the observer remembers what it is that the demonstrator did. The balance task provides scant opportunity for such learning, which would have to be based on a memory of the positions and number of weights on the beam for any given problem. The very large range of potential problems, all perceptually very similar, makes rote memory an unrealistic exercise. In practice it was clear from observation of the children during training that they had great difficulty in recollecting even the immediately preceding trial. Therefore this was a task in which learning based on the model provided by a peer would not provide a sufficient mechanism to promote subsequent individual progress.

The major alternative is Doise and Mugny's (1984) proposal that optimum progress derives from a conflict of centrations within a social context. One possible interpretation of the present findings is that the social dimension, in a task situation which itself is capable of generating the necessary conflict of centrations, may be irrelevant. It may be that cognitive conflict that derives from social interaction can only be assumed to be beneficial in those circumstances in which similar conflict cannot be achieved in isolation, although Doise et al imply that a qualitative distinction exists between inter- and intra-individual conflict.

The proposal of Glachan, that some mechanism for resolution of conflict is an essential component of benefit derived from social learning, accords with the present findings to the extent that the task failed to provide a *resolution* to the conflict. There is no doubt that overall subjects learned of the inappropriateness of their theories, but the next step in understanding, which would be to grasp some hypothesis of what should be done, was singularly lacking. No hypotheses as to the relationship between distance and weight factors were advanced during training. The training experience illustrated to all subjects, regardless of condition, the inadequacy of a weight strategy, but the paired conditions failed to go beyond this.

One reason for the choice of the balance task was that it was a judgement task and thus similar to conservation tasks which also require judgements. However, it was dissimilar in an important respect: the conservation judgement involves one rule leading to an identical response i.e.'the same', whereas in the balance task the one rule necessary is used to generate a variety of appropriate responses according to the balance problem being presented. The justification procedure in the Peer-2 condition created what was in effect an adult-child interaction between the child and the experimenter, with the aim of maximising any conscious understanding. The previous interpretation for the lack of peer benefit applies equally to this condition: metacognition or cognitive awareness must be awareness of something. Martin (1985) found that verbal discussion was only useful to the extent that it concerned the task; in other words the conversation must have substance in relation to the problem. This is supported by Fletcher's (1985) finding that children both alone and in groups showed superior performance in a task when required to verbalise concurrently the reasons for their decisions.

The role of justifications in the experimental process in the present study was threefold. Firstly, as already mentioned, it was assumed that it would increase the individual subjects' self-conscious awareness of their own decision making. Secondly, it was used as a mechanism for ensuring a reasonable level of verbal behaviour in the paired condition. If subjects were reticent about expressing their ideas it was assumed that they would at least benefit from listening to their partner's justifications. The same reasoning applies to this second point as before, namely that subjects were unable to offer any consistent rationale for their intended moves, so that the justification was no more helpful to the partner than to themselves. The third, unintended but potentially consequential role of the justification procedure was that it in practice provided an effective control over the relationship between the children. It provided a deterrent against precipitate action by one or both children. It acted in the same way as a dual-key facility in Experiment 2, since the experimenter restrained the subjects until explanations had been given by both participants. For this reason, the lack of differential gain in this study cannot be dismissed as resulting from domination. Interestingly, there were some occasions on which the children revised their proposed moves in the light of their own justifications.

The most significant factor in this study may be the age of the subjects in relation to the task. The eight year olds were chosen to create a point of comparison with the preceding study. This choice may have inadvertently determined the experimental outcome. Subjects were at an age at which they could be led from the relatively primitive weight strategy to a more sophisticated appreciation of the complexity of the problem, but were not of an age where they could begin to grasp the rules or strategies appropriate to that problem. The decision to include only two distance trials in this study was based on an erroneous assumption that subjects would have all reached Rule-2 level of performance at the outset. This made categorisation between Rule-1 and Rule-2 unsatisfactory. This limitation was not important in practice because of the high proportion of subjects who reached Rule-3 performance in all conditions. It is possible to envisage an experimental situation in which, given a more adequate measure of the distinction between Rule-1 and Rule-2, and given a slightly younger age group, it would be possible to investigate the potential for differential benefit in the ability to solve simple distance problems. This would of course require a precise situation in which learning from feedback did not 'drown' the potential for benefit from peer interaction. In view of the number of existing studies of peer interaction utilising younger children, and in order to broaden the scope of enquiry, it was decided to turn instead to an older subject age group for the next study. The choice of age was necessarily constrained by practical considerations: the oldest available children in sufficient numbers were eleven to twelve years of age. In deciding to repeat the balance task with this age group it was assumed that their ability to benefit from the experimental task would be qualitatively different from that of the younger subjects used previously. Children of this age are supposedly on the threshold of the stage of formal-operational reasoning. In the following school year they were due to transfer to secondary school and those in the more academic streams could expect to be taught the law of the lever at an early stage in the Physics curriculum. A pilot study using fourteen-year old children demonstrated that for those who had received the relevant Physics instruction the task was easy. Children of Primary school age were therefore considered more suitable to investigate the potential benefit of peer interaction in a balance task. It was also assumed that at this age children would be better able to express their ideas than eight to nine-year-olds, and that this might be a factor of importance in determining the extent to which a social condition of learning enhanced individual progress.

The previous study demonstrated the feasibility of using a micro-computer based balance problem as an experimental task. Subjects appeared to have no difficulty in appreciating the correspondence between the wooden balance shown to them at the outset and the diagram of the balance on the screen or on the pre- and post-test form. Balance scales are familiar objects in most primary school classrooms, as well as being found in playgrounds in the form of see-saws. However, it remains possible that the symbolic presentation influenced the children's perception of it, or that the computer environment influenced the potential for social interaction. In order to establish whether the micro-computer version altered the nature of the task in some as yet unrecognised respect, it was decided to give half the subjects in each condition training using the wooden beam to demonstrate the task, while the other half were given the computer-based task as before.

There are several practical differences created by the use of micro-computers. One is that subjects of necessity have to sit side by side, with limited potential for eye-to-eye contact. The size of the keyboard makes it difficult to achieve equality of position. This is not a problem in any absolute physical sense, because there is room for either child to reach out to press the keyboard as necessary, and the raised screen provides a good view of the task. However, there may be less tangible disadvantages to a subject not in a central position that would lead to reduced participation.

A second modification in this study was the introduction of an additional Individuals-plus-Justifications condition which was used to allow separation of the importance of the justification procedure and the influence of paired training (cf. Fletcher 1985). It was predicted that in the two conditions in which justifications were not required that there would be a significant difference between subjects who worked in pairs and those who worked alone in their individual performance at post-test. Similarly, in the two conditions in which subjects were required to justify their intended moves, a differential benefit to subjects who had worked in pairs was predicted. It was hypothesised that, overall, whether trained individually or in pairs, subjects required to justify would gain more than those not required to do so. The prime aim of this study remained to determine whether the lack of peer interaction benefit in the previous study was due to the subjects' ages. Could older children benefit in a way not possible for those of younger age?

IV.6. EXPERIMENT 4: METHOD.

Subjects.

Subjects were 80 children, not previously used as subjects, who were pupils in two Poole Middle schools. One school served a very middle-class area and the second a lower middle class to working class district. In order to balance the study an equal number of subjects were selected from each school in each section of the study. Subjects ages ranged from 11 years 6 months to 12 years 5 months, with a mean age of 11 years 11 months. An identical procedure for allocation of subjects to conditions was carried out as before.

Design and Procedure.

The format of individual pre-test, differential intervention and individual post-test was unchanged from the previous experiment. In this study there were four conditions: Individual; Individual plus justifications; Pairs; and Pairs plus justifications. Half of the subjects in each condition were allocated to the micro-computer version of the task for training and half to the wooden version of the balance beam. The pre- and post-tests were the same paper and pencil tests as used before.

The school conditions were identical as all the local schools are built to a standard design so that the facilities available for conducting the study did not vary. The previously used procedure of using the wooden balance to demonstrate what the symbols on the pre-test form represented, was followed. The change in procedure in this study was that half the subjects in each condition were subsequently presented with training trials by the experimenter using the wooden balance, while the remainder were required to use the computer task in training. When the wooden beam was used, subjects required to justify their decisions were invited to do so before the beam was released and allowed to tip; this was at the corresponding point in the proceedings as that in the computer presentation. The beam was held steady in the horizontal position by wooden blocks, which were then removed by the experimenter in order to demonstrate the outcome of the trial. The change in apparatus meant that the experimenter was more directly involved in the proceedings, sitting at right angles to the children in order to manipulate the beam, with a correspondingly more obvious presence. In order to keep the task circumstances comparable, using the beam or the computer, the pairs of children were required to sit alongside each other, so that they viewed the beam from the same perspective.

IV.7. EXPERIMENT 4: RESULTS.

The findings from the 18-trial data are shown in TABLE IV.7, firstly set out according to type of task ie. micro-computer or wooden beam, and secondly presented as the combined overall scores for each condition and FIGURE IV.6. shows the overall mean scores.

The Table of Means makes it apparent that there was very little difference in the performance levels of subjects regardless of whether they had experienced the micro-computer version of the task or the wooden beam. This was confirmed by a three-way analysis of variance which showed no significant differences for this factor. However, as in previous studies, a significant pre to post effect was demonstrated ($F = 24.17$, $df = 1,72$, $MS(error) = 7.04$, $p < .001$) meaning that, overall, subjects improved in their performance on the Balance task as a result of practice. As before, there was no difference between conditions as revealed by the analysis of variance and there were no interaction effects. The Anova table can be seen in APPENDIX 1.

		INDIV-1	INDIV-2	PEER-1	PEER-2
PRE-TEST					
	MICRO	9.4	9.2	10.0	10.6
	WOOD	9.7	9.0	8.5	9.2
	TOTAL	9.55	9.1	9.25	9.9
POST-TEST					
	MICRO	10.8	10.6	12.5	12.9
	WOOD	10.7	11.5	10.3	12.8
	TOTAL	10.75	11.05	11.4	12.85

TABLE IV.7. EXPERIMENT 4: 18-TRIAL DATA: SUMMARY OF MEAN SCORES AT PRE-TEST AND POST-TEST.

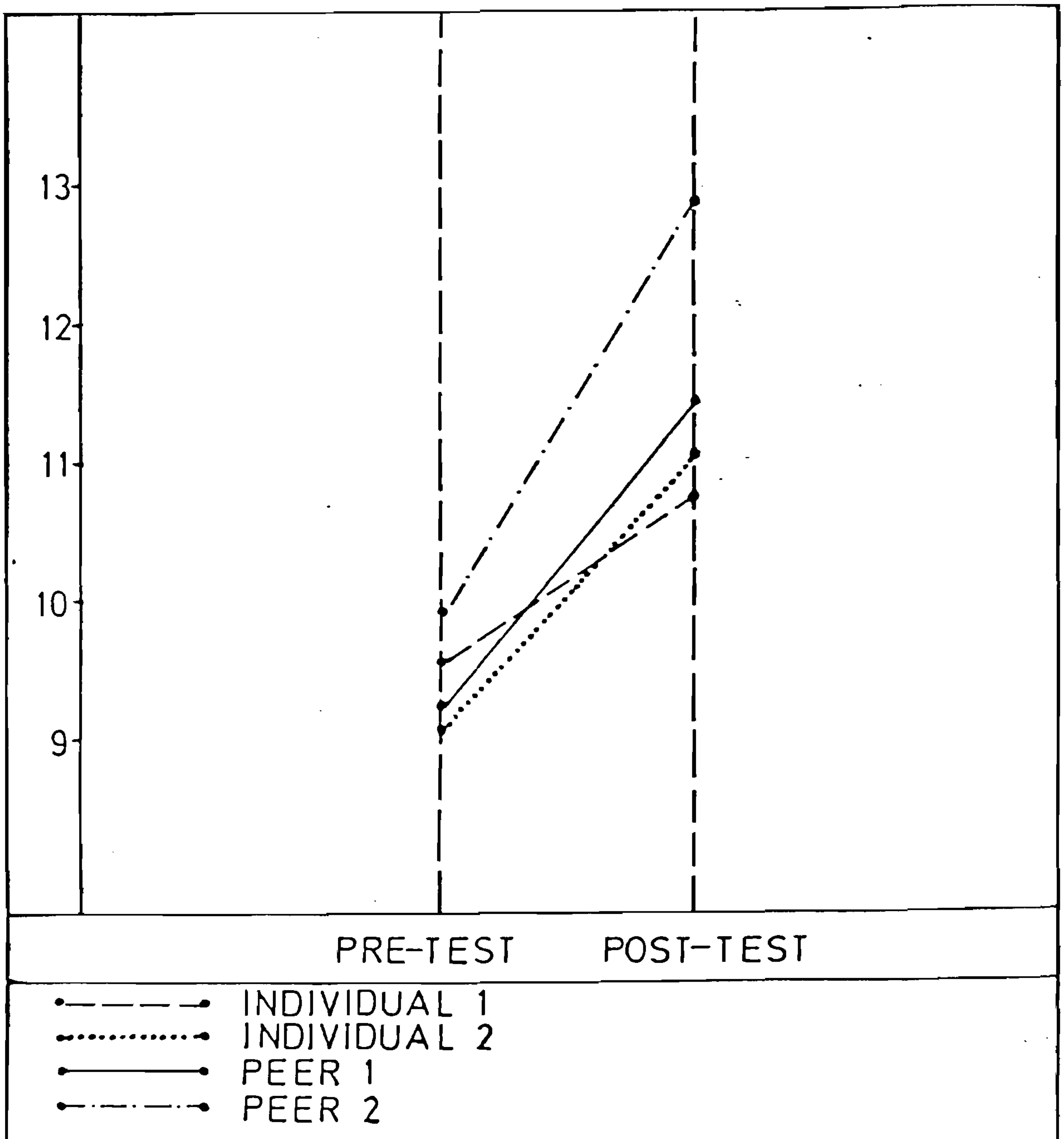

FIGURE IV. 6. EXPERIMENT 4: 18 TRIAL DATA: MEAN SCORES AT PRE-TEST AND POST-TEST

Notwithstanding the lack of group difference revealed by the analysis of variance, the results suggest that performance was by no means equal in all conditions. There were a number of experimental hypotheses which permit a priori statistical comparisons to be carried out. The rationale for the use of this statistic was set out in Experiment 2. Firstly, comparison of the two justification conditions i.e. Individual-2 and Peer-2, shows a significant difference in post-test performance ($t = 1.978$, MS(error)= 8.28, $p < .05$, one-tailed); secondly, comparison of the conditions in which justifications were not required, shows no significant differences ($t = 0.744$, n.s.). These comparisons indicate that the mere fact of being in a co-operative training situation is not sufficient to elicit significant individual differential progress, but that the combination of social conditions of learning and the added constraint of being required to justify is sufficient to demonstrate a differential benefit, albeit at a marginal level of significance. One further orthogonal comparison may be made, based on the experimental prediction that subjects trained in the conditions in which they were required to justify their decisions would show superior performance at post-test compared to subjects in the two conditions in which this was not required. Comparison of the pooled Individual-1 and Peer-1 conditions, with the pooled Individual-2 and Peer-2 conditions, shows no significant difference between the two groups of subjects (t = 1.36, n.s.). This means that the requirement to justify, on its own, was not a sufficient cause of benefit.

Ordinal Dominance graphs (Darlington 1973) are used to illustrate the a priori comparisons of post-test data In these graphs the results of each condition are set out in rank order, with one condition plotted against another. Departure from the diagonal reflects advantages of one or other condition, which may of course vary across the scoring range, and illustrates differences in the shape of variance.

FIGURE IV.7 shows an Ordinal Dominance graph of the combined Individual-1/Peer-1 scores plotted against the combined Individual-2/Peer-2 scores. FIGURE IV.8 shows the Individual-1/Peer-1 and FIGURE IV.9 Individual-2/Peer-2 comparisons. The relative dominance of the Peer-2 condition is apparent from these graphs.

The remaining data from this study, namely the performance of subjects in Conflict-Weight trials, was again separately analysed, for the reasons previously explained. These findings are set out in TABLE IV.8 and are also shown in FIGURE IV.10. It is apparent that the same performance trends exist in relation to Conflict-Weight problems in this age group as at the younger age previously studied. A two-way analysis of variance of the conflict-weight data

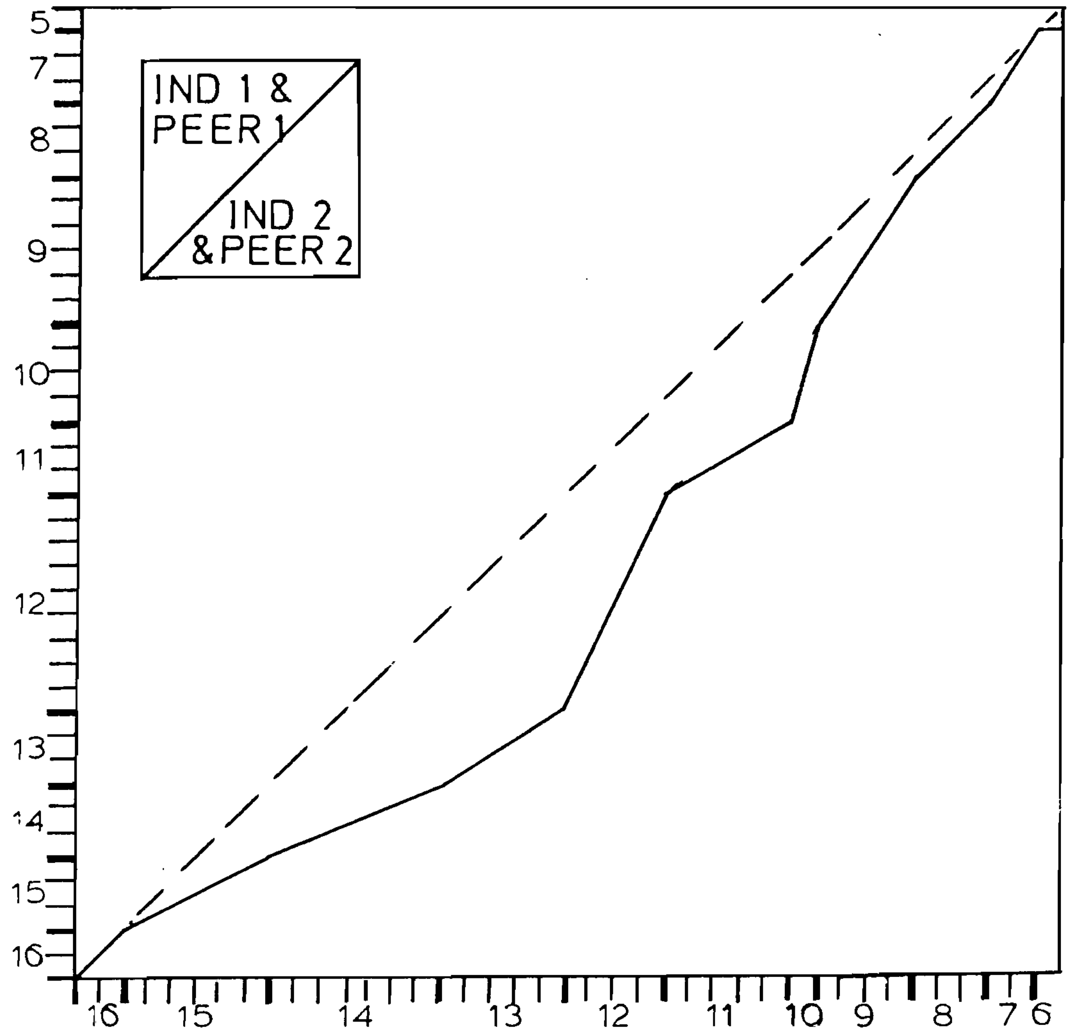

FIGURE IV.7.EXPERIMENT 4:
ORDINAL DOMINANCE GRAPH: INDIVIDUAL 1 AND PEER 1 (COMBINED SCORES OF THE TWO NON-JUSTIFICATION CONDITIONS) V. INDIVIDUAL2 AND PEER 2 (COMBINED SCORES OF THE TWO JUSTIFICATION CONDITIONS)

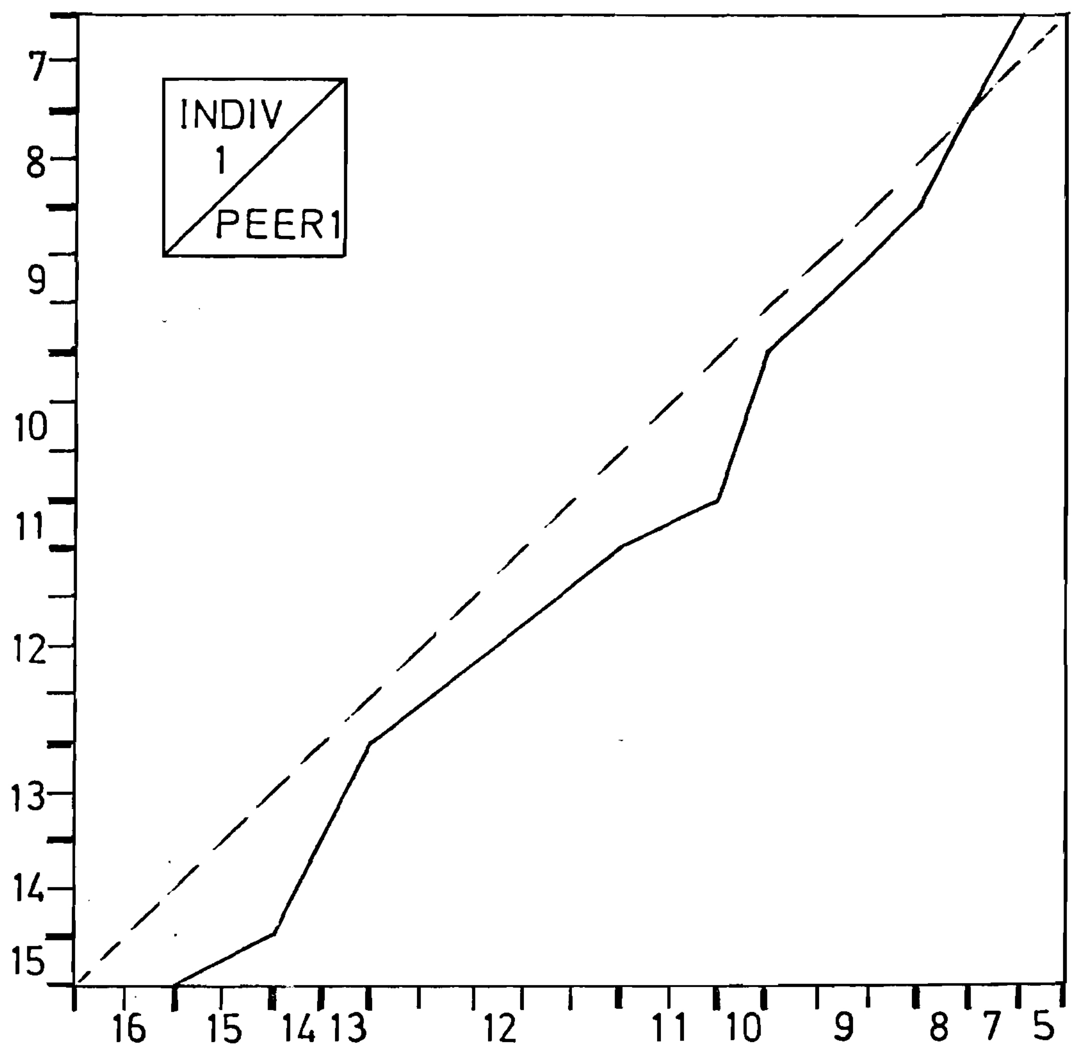

FIGURE IV.8. EXPERIMENT 4:

ORDINAL DOMINANCE GRAPH.
INDIVIDUAL 1 V PEER 1 CONDITIONS

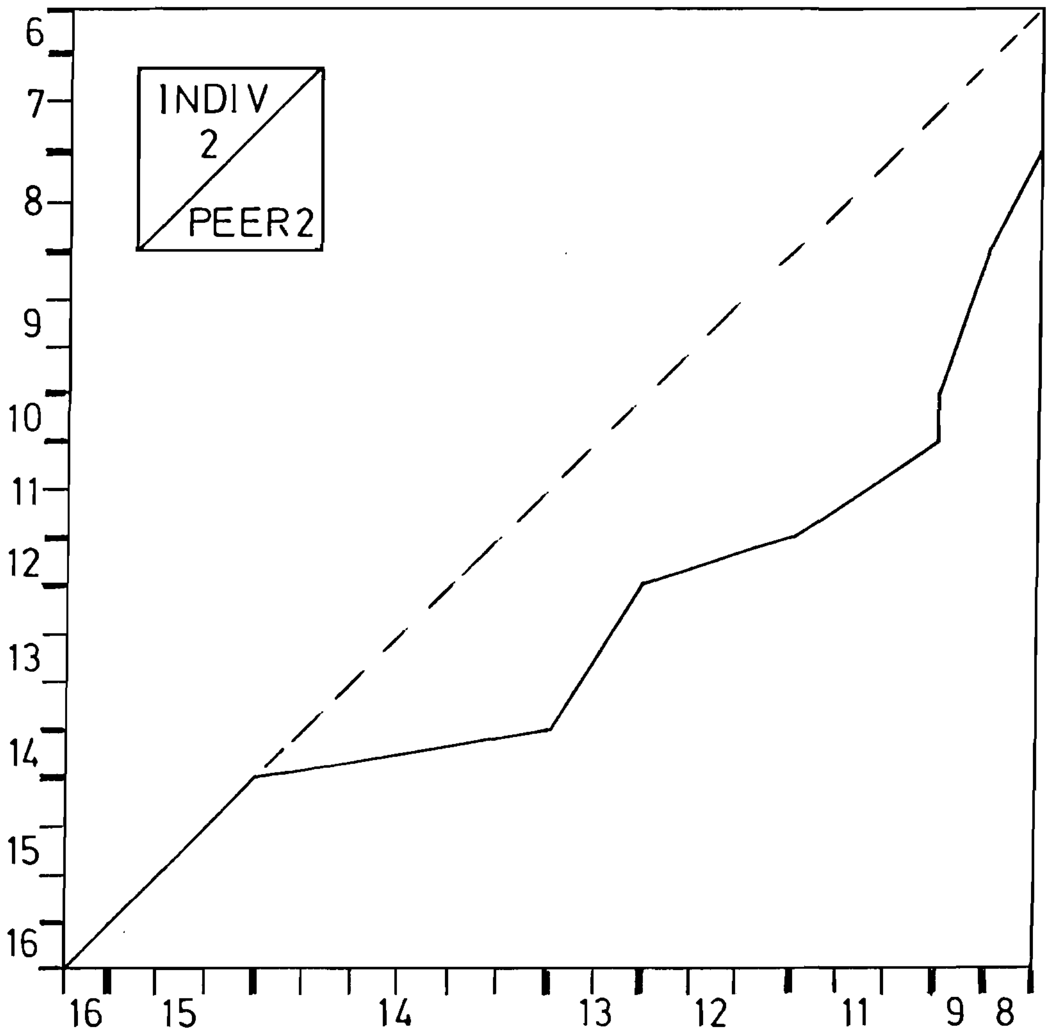

FIGURE IV.9. EXPERIMENT 4:
ORDINAL DOMINANCE GRAPH:
INDIVIDUAL 2 V PEER 2

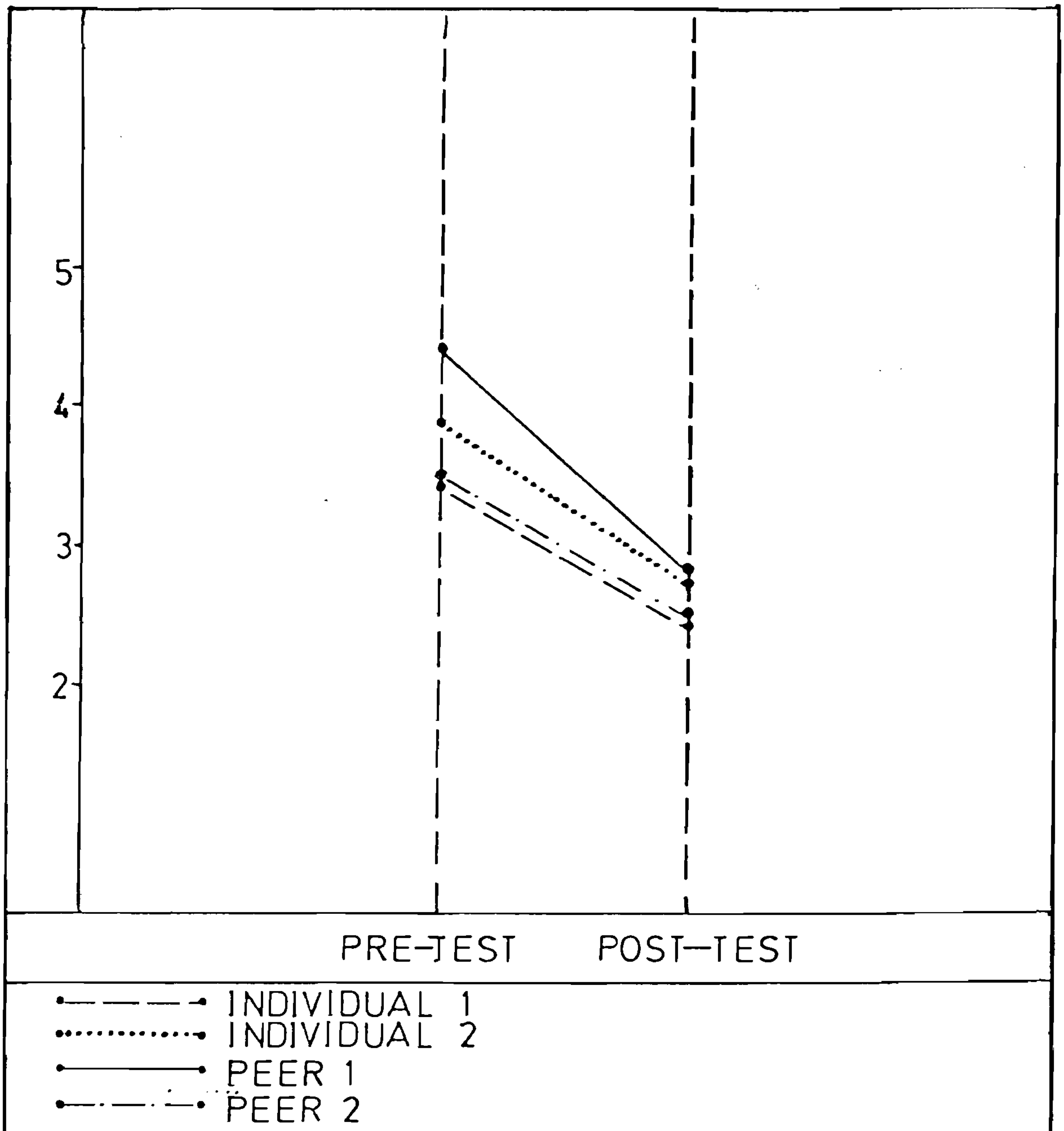

FIGURE IV.10. EXPERIMENT 4: CONFLICT WEIGHT DATA: MEAN SCORES AT PRE-TEST AND POST-TEST (OPTIMUM SCORE = 6) shows that there is a significant change for the worse in performance from pre- to post-test ($F = 19.041$, $df = 1.76$, $MS(error) = 2.78$, $p < .001$). there was no significant difference between conditions and no interaction. These data indicate that the disruption in previous strategy is not replaced by a more competent alternative.

When the data were examined in terms of the Rule use, and based upon the previous criteria, contrary to expectations no subjects were found to have reached Rule 4 performance levels. This accords with the results of the Conflict-weight data. It can also be seen that few of these older children were still at the Rule 1 or 2 level, even at pre-test. TABLE IV.9 shows the number of subjects at Rule 1 or 2.

	INDIV-1	INDIV-2	PEER-1	PEER-2
PRE-TEST	3.45	3.9	4.35	3.5
POST-TEST	2.4	2.75	2.85	2.6

TABLE IV.8. EXPERIMENT 4: CONFLICT-WEIGHT DATA MEAN SCORES (Maximum score=6)

	INDIV-1	INDIV-2	PEER-1	PEER-2
PRE-TEST	1	2	2	4
POST-TEST	0	1	0	0

TABLE IV.9. EXPERIMENT 4: NUMBER OF SUBJECTS AT RULE-1 TO RULE-2 LEVEL OF PERFORMANCE.

This highlights that in contrast with the previous study, the majority of subjects were firmly at the Rule-3 stage. The few at the lower level at pre-test were virtually eliminated at post-test. Classification of the data in terms of Rule use was therefore not a useful measure with this subject age group.

IV.8. EXPERIMENT 4: DISCUSSION.

The findings in this study were in some respects not as anticipated. The similar levels of performance reached by subjects using both the micro-computer and wooden versions of the balance was expected, given the facility with which the children adapted to the requirements of the task at the outset. However, the assumption that there would be a significant difference between those subjects required to justify their decisions, and those not required to do so, was not fulfilled, although it does appear that the justification procedure was not without influence, as it was only in the conditions in which subjects were required to justify their actions that training in pairs influenced individual outcome. Thus neither working with a partner, nor the mere fact of having to justify one's actions were beneficial, but a combination of the two demonstrated, albeit tentatively, a difference in post-test performance between conditions.

The exact nature of the process at work is far from certain, so that consideration of some alternative explanations must necessarily be speculative. The possibility that the justification requirement was influential by virtue of bringing into the individual's consciousness awareness of concepts that were not previously at that level, will not suffice as an explanation, because if this were the case justifications would have been expected to elicit higher level post-test performance levels overall. The quality of reasoning encountered in the Individual-2 condition in training appeared to be at the level of cognition, rather than metacognition, although the distinction is fraught with problems of definition. However, it seems safe to suggest that in this case if justifications alone did not lead to gain it may be because they did not lead to metacognition, rather than that enhanced metacognitive awareness would not lead to progress. The metacognitive theory may not be supported by these findings, but neither was it disconfirmed. What is clear is that, for the individual, being required to make verbal statements about his/her proposed actions is not necessarily useful. A possible explanation for the effectiveness of the combination of working in a pair and being required to justify is that the justification procedure was beneficial by virtue of inhibiting precipitate action, much as the dual-key facility in Experiment 2 provided a more controlled task environment. In this case progress may be facilitated because, deprived of the opportunity for unilateral action, decisions are 'thought through' before being acted upon. The duration of each trial was longer in the Peer-2 condition, which in view of the lack of off-task discussion, supports this notion, although in all conditions subjects were seen anyway to co-operate in a reasonable manner, without the domination apparent in younger age-groups. In a similar vein, it may be that the effect was not so much to prevent precipitate action, as when one child is impatient, but rather to overcome an overready acquiescence in some partnerships. Yet again, it is possible that any advantage in the social condition of learning may be due to some relatively diffuse social facilitation of learning rather than specifically affecting cognition. The effect may derive from the creation of an atmosphere conducive to learning.

In contrast to explanations that emphasise the social processes at work in the learning situation, changes in children's performance following peer interaction may be attributed to changes in their cognitive state, in particular in their use of particular strategies or rules. In this case the benefit in the Peer-2 condition would be assumed to derive in part from the information content of the justification. The idea that the benefit derives from the acquisition of a rule for successful performance would accord with the present findings. In view of the large number of trials, it certainly appears more plausible to suggest that a rule has been learned than to suggest that solutions are remembered in any rote manner. The possibility that children learn a rule runs contrary to the idea of socio-cognitive conflict as a sufficient explanation for change (eg Doise 1984) because this merely implies disruption to previous cognitive states, without providing an account of how the new level of performance is to be achieved. It does accord with Glachan's (1983) argument that some resolution of conflict is required. In this case the resolution is manifested as an acquired strategy or rule.

Wilkening and Anderson (1982) provide a potential explanation of what is occurring in suggesting that children frequently utilise a general purpose adding-type rule in their problem-solving. A multiplication rule involves multiplying the number of weights by the number of spaces from the fulcrum and comparing the product of the two to determine which side of the beam will tip, whereas using an adding rule the child would compare the sum of the distance and weight elements in order to reach a decision. In the latter case the subject applying such a rule would be successful in his performance to the extent that the trials presented were amenable to solution by such a method. Of the 24 trials presented in training three quarters were of a type that use of an adding rule would lead to the right answer. It could be argued that any differences in post-test performance reflected the extent to which children learned this type of strategy from each other. Some instances of subject's offering justifications based on an adding strategy were heard by the experimenter during training. The extent to which this featured is uncertain.

It is clear that no subjects were using a consistent multiplication strategy, as this would have been indicated by a high level of success. It may be that subjects did achieve a small measure of such understanding, but only recognised the merits of its use in a limited range of balance problems. It may be that Siegler's criterion for Rule-4 use was too stringent, and that, if a less exacting measure were applied, evidence of Rule-4 responding would have been demonstrated, although inspection of the raw data did not support this possibility. Thus despite having twenty-four opportunities to learn from the feedback provided by the computer program or balance-beam, no subjects consistently recognised the potential for solving the problem using the multiplication rule. It had not been expected, indeed it would have been quite unrealistic to believe, that eleven to twelve-year-old children would be able to construct a theoretical principal such as the law of moment, but it had been assumed that in some of the more simple balance problems some subjects would recognise, for instance, the two-to-one ratio of some configurations. It was observed that some subjects came close to this recognition at times, and in using terms such as 'times' and 'twice as far', approached the issue without apparently fully understanding it.

These first two balance studies have provided an insight into some of the issues relating to collaboration in micro-computer tasks. It appears that in the most social Peer-2 condition some marginal individual benefit accrues, but it is not clear what it is that has been acquired. The next experiment will attempt to clarify whether the suggestion of Wilkening and Anderson, that children learn an adding strategy, is applicable, and if so whether this may account for any differential gain. It may be the case that in some tasks peer interaction 'benefits' the child in a way that is counter-productive. In the present study, if an adding strategy had been learned, this may have been fortuitously beneficial due to the high proportion of trials amenable to solution using the adding strategy in the post-test. To say this is not to devalue the benefit, but rather to underline the extent to which it derives from a highly specific combination of task and subject circumstances.

CHAPTER V. A FURTHER INVESTIGATION OF THE BALANCE BEAM: WHAT IS IT THAT HAS BEEN LEARNED?

V.1 INTRODUCTION.

The previous discussion has to some extent set the scene for the following study which seeks to clarify the nature of the learning that has taken place. The theory of Wilkening and Anderson (1982) has been mentioned as a possible explanation of the type of reasoning that children may use as they attempt the balance beam problem. This theory has a wider application than merely to the balance-beam; it is suggested that most thought and judgement is governed by simple algebraic models and that the child may deal with relatively complex problems by systematic integration of relations.

Information-integration theory is used by Wilkening and Anderson as a means of measuring apparently subjective values applied by children in their problem-solving. They identify a wide range of test circumstances in which children as young as four years of age can be shown to use some general purpose 'adding' rule to integrate different stimulus inputs in order to solve a problem. For example, Anderson and Cuneo (1978) found that five-year-old children followed a Height + Width rule in attempting to solve judgement-of-area problems. They argue that the young child understands that some quantitative judgement is wanted, seizes on salient clues that seem to be relevant, and then attempts to integrate them.

In relation to the balance task, Anderson (1981) argues that binary decision trees, as described by Siegler (1978), cannot specify what he describes as the transition phase in the balance beam problem of 'muddling through'. He complains that Siegler ignores the fact that children frequently employ an algebraic integration rule, such as an addition rule and that Siegler's criterion may result in the level of understanding being either underestimated or overestimated. Similarly, Wilkening (1980, 1981) argues that Siegler's interpretation of children's thought processes in terms of a binary decision tree may be an artefact of his methodology.

The value of Wilkening and Anderson's approach may be that it draws attention to alternative forces that may be at work, and in doing so provides a reminder of the caution that is required before any dogmatic assertions are made regarding the nature of the cognition underlying a particular behavior. As it is, awareness of the possibility that children of this age may be using an adding strategy or similar mental device provides a means for a functional analysis of the process of peer interaction; an analysis that is not solely reliant upon interpretation of verbal protocols, although in the following study these will in fact be recorded. However, as an introduction to this area, a preliminary study was conducted to establish whether differential responses could be expected from subjects at post-test, according to whether or not the trials presented were compatible with the use of an adding strategy.

At this stage of the research programme a practical problem in accessing a sufficiently large group of children was encountered. For this reason, the study to be reported was reduced from its planned four conditions to three. This modification reduced the number of questions that could be addressed, but did not affect the most important area of enquiry.

The aim of this experiment was to determine whether subjects would evidence use of an adding rule at post-test following training in the balance task as before, or whether use of such strategies would be revealed in an analysis of verbal behavior during training. It was predicted that, if use of such a strategy was demonstrated, it would be most evident in a paired condition with the requirement of justifications, and that the extent of its occurrence would match any differential benefit demonstrated by subjects at post-test. On the basis of the last study, an experimental hypothesis was therefore that subjects in the Peer-2 Condition (ie Pairs plus justifications) would show significantly enhanced performance at post-test compared to subjects in the Individual Condition. This was based on the previous finding that only a combination of co-operation and the requirement to justify together created sufficient potential for such benefit.

V.2. EXPERIMENT 5: METHOD.

Subjects.

The subjects were 60 children from the eldest age-range at the same Poole middle school as used in Experiment 3. None of the children had taken part in previous experiments. The physical circumstances were unchanged. Subjects were randomly selected from two parallel but streamed classes with equal numbers of subjects from each class in each condition. Otherwise, allocation to conditions and to pairs within conditions was decided on a random basis. The age of subjects was 11 years 4 months to 12 years 3 months with a mean age of 11 years 9 months.

Design and Procedure.

There were three experimental conditions that corresponded to the Individual-1, Peer-1 and Peer-2 conditions in the previous study. There were two alterations to the previous experimental procedure. Firstly, an additional paper and pencil post-test was given one week after the first post-test. The problems given in this test were of the same type as before, but in this case exactly half were of a sort in which use of the adding strategy would result in the wrong answer, and half were of the type in which use of the adding strategy would lead to the right answer. For simplicity, these will be referred to as Non-Adding trials and Adding trials respectively. A child who used the adding rule consistently would be correct in half the trials at post-test. It was assumed that trials comparable with the adding strategy were not distinguished by any other characteristic, and that it would be reasonable to assume that relative performance on 'adding' and 'non-adding' trials would provide a measure of the extent to which subjects at this age were using some adding-type strategy in their decisions.

The second modification was that the training sessions were video-recorded with a view to providing evidence regarding the quality of the interactions between the children working in pairs. The pre-test, training and post-test sessions were conducted as before, with the addition of the second post-test. The presence of the camera provided an additional sense of occasion to the testing process, but was accepted by the subjects and largely ignored after some initial curiosity.

V.3. EXPERIMENT 5: RESULTS.

The data were categorised on the same basis as that used in the previous study. The mean scores of subjects based on the 18-trial data are set out in TABLE V.1. These mean scores are also displayed graphically in FIGURE V.1. which shows that performance was highest at post-test in the Peer-2 condition (with justifications). However, a two-way analysis of variance shows that the difference between conditions was not significant. There was, as in the previous study, a significant within subjects effect, indicating that subjects' performance improved overall from pre- to post-test ($F = 26.52$, $df = 1,57$, $MS(error) = 2.84$, $p < .001$). The Analysis of Variance Table can be seen in APPENDIX 1.

In this study, as before, the Conflict-Weight data in the main test were not included in the overall analysis, which was restricted to the 18-trial data. The mean scores in these trials are set out in TABLE V.2 and show the same pattern of results as in previous studies.

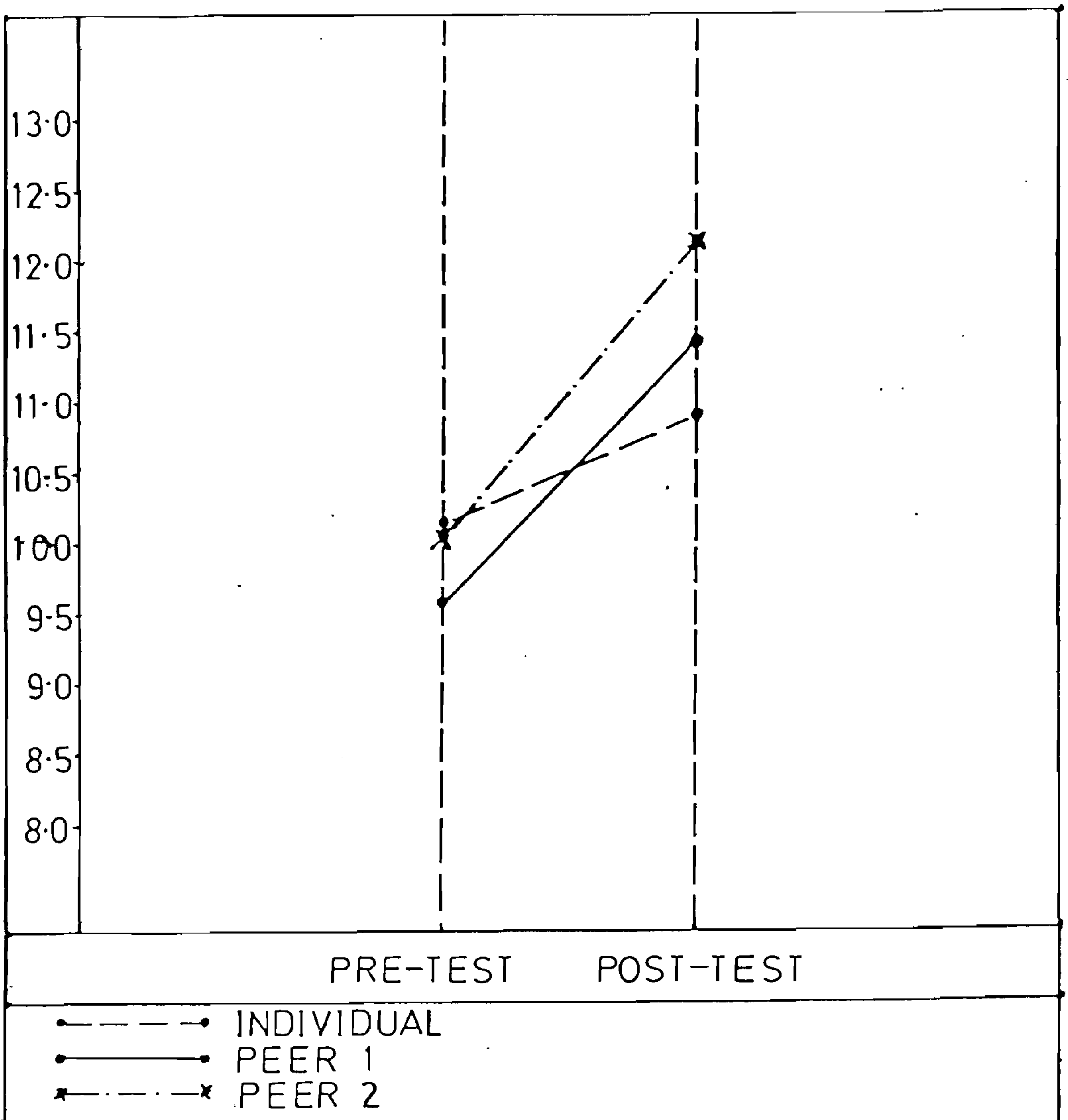

FIGURE V.1. EXPERIMENT 5: 18 TRIAL DATA: MEAN SCORES AT PRE-TEST AND POST-TEST (OPTIMUM SCORE = 18)

	INDIVIDUAL	PEER-1	PEER-2
PRE-TEST	10.15	9.55	10.05
POST-TEST	10.9	11.45	12.15

TABLE V.1. EXPERIMENT 5: 18-TRIAL DATA: SUMMARY OF MEAN SCORES.

	INDIVIDUAL	PEER-1	PEER-2
PRE-TEST	3.60	3.50	3.45
POST-TEST	2.60	2.50	2.60

TABLE V.2. EXPERIMENT 5: CONFLICT-WEIGHT DATA: SUMMARY OF MEAN SCORES.

Two-way analysis of variance shows that as in the previous experiment there is a significant decrease in the performance of subjects in the Conflict-Weight trials from pre- to post-test ($F = 10.61$, $df = 1.57$, $MS(error) = 2.29$, $p < .01$). As before, there is no significant difference in performance between conditions and no interaction. The analysis of variance table is presented in APPENDIX 1.

In accord with the experimental hypothesis, an a priori statistical comparison was made of post-test performance in the Individual and Peer-2 Conditions. This showed that although performance in the Peer-2 group was at a higher level, this only reached a probability level of p = 0.1, one-tailed (t = 1.458, n.s.). Thus unlike the previous study a significant difference between these two conditions was not demonstrated. FIGURE V.2 shows an Ordinal Dominance graph of this comparison, which illustrates that the same pattern of dominance exists as that in Experiment 4, although the trend is less pronounced. FIGURE V.3 shows the corresponding graph of the Individual/Peer-1 data.

The performance of subjects at post-post test is shown in TABLE V.3 which shows the Mean Scores for Adding and Non-Adding trials in each condition.

	INDIV	PEER-1	PEER-2
NON-ADDING TRIALS	5.90	6.30	5.05
ADDING TRIALS	10.25	9.65	10.45
TOTAL	8.08	7.98	7.75

TABLE V.3. EXPERIMENT 5: POST-POST-TEST: ADDING AND NON-ADDING TRIALS: MEAN SCORES.

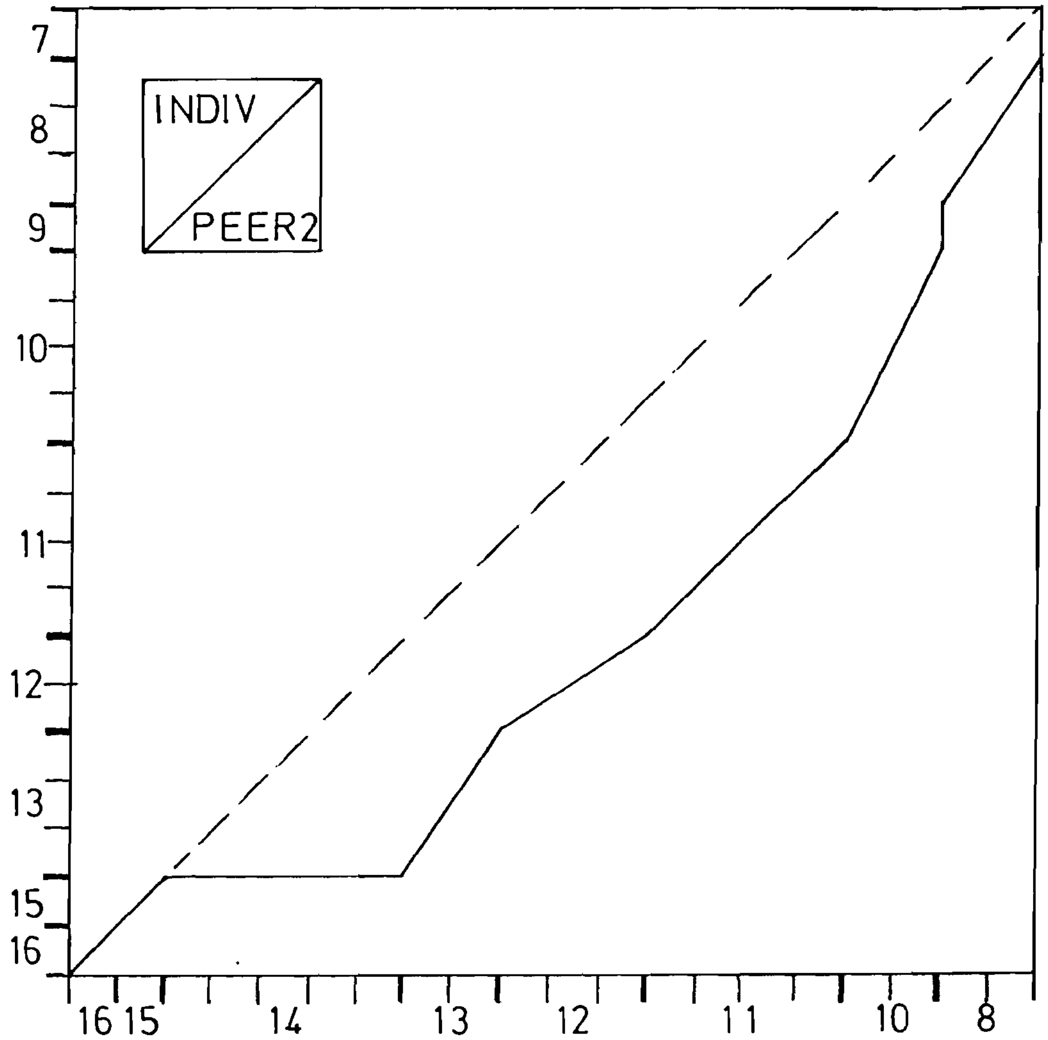

FIGURE V.2. EXPERIMENT 5:

ORDINAL DOMINANCE GRAPH.
POST-TEST SCORE DISTRIBUTION
INDIVIDUAL V PEER 2 CONDITIONS

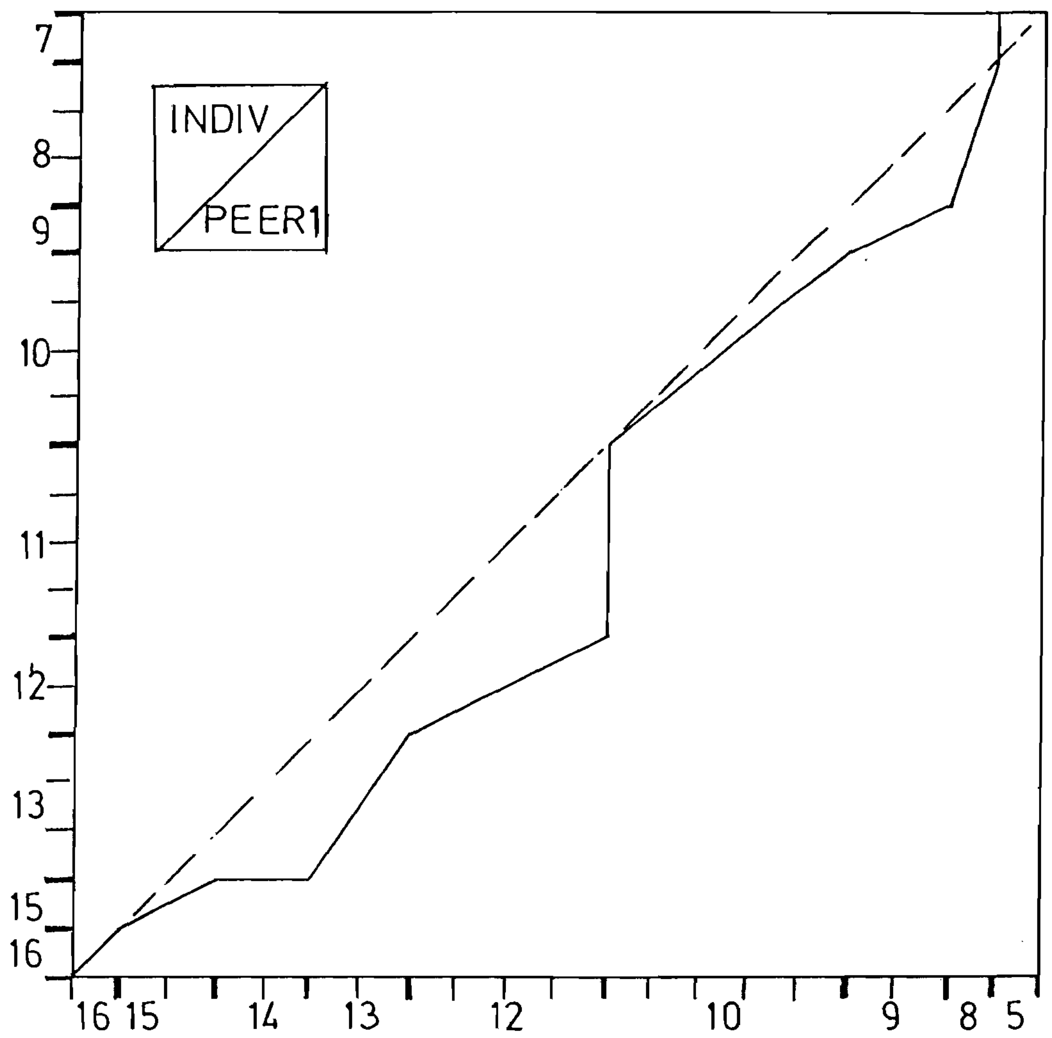

FIGURE V. 3. EXPERIMENT 5:

ORDINAL DOMINANCE GRAPH.
POST-TEST SCORE DISTRIBUTION
INDIVIDUAL V PEER 1 CONDITIONS

A two-way analysis of variance of the post-post-test data showed that there were no significant differences in performance according to condition, but marked differences in all subjects ability to solve the two categories of trial, namely Adding and Non-Adding. An a priori comparison of the Means for the Individual and Peer-2 conditions at post-post-test showed no significant difference in performance levels. Thus the prediction of differential benefit for Peer-2 subjects was not realised.

At this stage it was evident that the mean scores of the Conflict-Weight and Conflict-Distance data were similar. In Non-Adding trials the mean scores were respectively: Conflict-Weight= 0.32; Conflict-Distance= 0.35. These scores are close to chance (0.33) which is the expected response pattern in Rule 3 performance levels. In contrast, for Adding trials mean performance Conflict-Weight= 0.62; Conflict-Distance= 0.61.

It is evident that there are systematic differences in performance in Adding and Non-Adding type trials. Examination of the protocols may provide evidence of the extent to which this performance difference reflects the use of an adding strategy, although of course it may be that subjects are using such a heuristic without the ability to express it verbally. There were three potential levels of analysis of the verbal behavior: firstly, the quantity of discourse could be measured; secondly, at an intermediate level, the type of discourse could be assessed in terms of, for example, the number of arguments; and finally, at a finer level, the quality or nature of the children's utterances could be examined. Of these alternatives, the first was discounted, as it was self-evident from the relatively long length of the training session that children in the Peer-2 group engaged in more verbal behavior. Within each condition it would be interesting to see whether the length of argument would correlate with post-test gain, but the number of reasons correlated with length, so that that measure is incorporated into the other. It was also found that off-task conversation was at a minimum and was insufficient to warrant quantitative analysis. A sample categorisation of the number of arguments (defined as the number of exchanges) was attempted, but this proved to be unsatisfactory because the children engaged in many fragmented, overlapping and repetitive conversations, so that selecting an appropriate division between each became arbitrary. Assertions were difficult to categorise because they frequently occurred as monosyllabic utterances eg. " B" (indicating the appropriate button to be pressed). There were many examples of pairs of children indulging in a string of counter-assertions at this level before abandoning their argument and moving on. An additional problem was that because of the physically static nature of the task it was not possible to relate verbal utterances to identifiable non-verbal behavior. The attempt at categorisation resulted in a very low inter-experimenter reliability and was abandoned. However, as the main interest of this study was a concern with the quality of the children's understanding, the protocols were still a useful source of information.

It was clear from the transcripts that the reasoning used by the children was both varied and interesting. Four categories of reasons were selected. The first category included references to the number of weights, or to the distance from the fulcrum, or to both factors when no specific relation between the two factors was stated or implied. An example of the weight explanation was as follows: *"I'll go that way because there's two on that side and three on there"*. An example of the Distance explanation was: *"Thats on the end and that's one from the end so that'll go down easier"*. An example of both weight and distance factors: *"..go that way because there's only one more and that's at the end...'cos look...the further in..it's difficult to explain..if it was there and you had one on the end it would go down, wouldn't it?"* The three elements of weight, distance or combined reference, were grouped into one category because it was frequently not possible to tell whether the child was referring to weight or distance eg. *"there's more there"* could refer to more weights or more spaces.

The second category consisted of references to previous trials. Reference to prior experience with previous trials included comments such as: *"Last time it was the same so I think it will tip that way"*.

The third category included all references to hypothetical states. Some hypotheses were non-specific 'if' statements: *"if that was there and that was there it would tip that way"*. This form of reasoning was often protracted with a series of alternative positions being considered in turn. There were also reasons that were examples of the use of an adding strategy and, less frequently, examples of a multiplication strategy. An example of the use of an adding strategy was as follows: *"Because two from the end..if there were two there..move it one in.. and then if you add another one..I think it will be C."* A variation on this involved the child in mentally laying out the weights - distributing them one on each peg - which is in effect a form of counting the weights in relation to the number of pegs from the fulcrum. An example of this method is as follows: *"Yeah..balance, because the three laid one on each would make it go right to the end,* *and those one on each would make it to the end".* Or again: *"I think it's going to balance..so does Daniel..because if they were laid one on each they would go to the same position".* There were some instances of children making specific reference to the *product* of the two dimensions of weight and distance, rather than the *sum*, and these were counted as examples of the use of the multiplications strategy, although no children displayed more than occasional or incomplete use of such ideas, for example: *"that's double that"*; or again: *"..think it will go down that way because that's three times the distance of that and that's two times the weight, so I think it'll go down to the right".*

The final category included all reasons that did not fall into any of the above groups. This residual category included reasons such as reference to heaviness or lightness, without reference to the number of weights, for example: *"that will tip because it's heavier".*

The protocols were transcribed from the video-recordings and all reasons allocated to one of the above categories. These allocations were for the most part unambiguous. Reasons that included both reference to hypothetical states and prior experience were placed in the former category. TABLE V.4 shows the number of reasons in each condition.

One aspect of the justification procedure was that on occasions one member of a pair would not verbally express a reason but merely state that he/she agreed with his/her partner. Such agreements were not included as reasons in the present analysis.

	PEER-1	PEER-2
HYPOTHETICAL INCLUDING ADD AND MULTIPLY	39	151
TOTAL DISTANCE, WEIGHT, OR DISTANCE AND WEIGHT.	122	167
REFERENCE TO PRIOR CASES	36	37
OTHERS	12	33
TOTAL REASONS	209	388

TABLE V.4. EXPERIMENT 5: NUMBER OF REASONS EXPRESSED BY SUBJECTS DURING TRAINING.

From TABLE V.4 it is evident that the total number of reasons proffered was greater in the Peer-2 condition in which subjects were required to justify their proposed moves, which is to be expected in view of the fact that reasons were actively solicited in that condition. It is also clear that the largest difference between conditions was in the number of hypothetical reasonings. A statistical analysis shows that this difference was significant ($t = 3.115$, $p < 0.01$). In contrast, the difference between conditions in the number of reasons in the Distance/Weight category was not statistically significant. Thus the requirement to justify led subjects to a greater use of inferential statements in their verbal reasoning. No separate count was made of the use of adding or multiplication strategies; these data were grouped with hypotheses for statistical analysis because the latter group were in effect an overlapping category, with implicit adding strategies evident in many justifications.

An assessment was made of the extent to which the total number of reasons expressed, or the particular type of reasons, correlated with the individual child's change in performance. Change from pre-test to post-test was used as a measure in order to allow for individual differences in ability at the outset. The correlation between total number of reasons expressed and change in performance was not significant ($r = 0.3$). Thus the extent to which subjects expressed their ideas did not relate to performance. An alternative possibility was that learning should have a co-relationship with the number of reasons heard, ie. a comparison of the number of reasons uttered by a subject with his/her partner's change in performance levels. The correlation in this case was minimal ($r = 0.1$).

A number of other comparisons, both to post-test and post-post-test, were made, none of which showed significant correlations between the type of reason used and performance. It seemed clear that these data were either too imprecise, or alternatively, inappropriate as measures of the significant element in interaction. However, notwithstanding the failure of the protocol analysis to highlight any distinctive feature of the discourse that related to performance, the type of reasoning used provides insight into some of the thought patterns of the children as they attempted to solve the balance problem.

The following is an example of the role of justifications in prompting the children to examine the problem in more detail; it illustrates how there was a quick and superficial initial agreement which was disrupted by the experimenter's intervention:

(Screen display appears)

Subject A: *"That way"*.

Subject B: *"Yes definitely - C"*.

(Pause)

Experimenter: (to subject B) *"Tell me why"*.

B: *"Because there's definitely more weight on that end...oh yeah...it's nearer the middle though isn't* *it?"*

A: *"Yeah..we don't want to make that mistake again..but um...I think it will be..."*

B: *"I know it definitely won't go that way."*

A: *"No..it won't go that way."*

B: *"It'll go straight to the left.."*

A: *"I don't think..."*

B: *"If it was there we'd have a problem".*

A: *"I think it'll be C..I mean A".*

(Pause)

Experimenter: (to subject A*) "Why do you think it will be A?"*

A: *"Because if three were put down there it probably would still make more weight because..."*

B: *"I don't know now..mind you..I'm just imagining a seesaw and imaging three people in the middle and one at the end..it most probably will be A won't it?"*

A: *"Yeah..try it".*

B: *"I doubt if we're right".*

The following is an example of one of the more sophisticated exchanges encountered in this study, in which some ratio notions are evident.

A: *"Shall we try our theory again? I don't think our theory will blow up all the time".*

B: *"On the one we did earlier we used our theory and it didn't work.."*

A: *"This I do not understand".*

B: "Two is double that..four is twice as much as that.."

A: *"Well.. that is double that isn't it..and I reckon each time..if you're in that sort of position I reckon you've got to double it..so yeah..B"*.(Wrong).

(On the next trial):

B: *"Maybe there wasn't enough? If we go on to another theory..take one off the top..that's two..take another one off..we've got three..and that one one..so I think it'll be C".*

A: *"I don't think it'll make much difference".*

B: *"Decisions..decisions..I think I'll stick with (button) C..I'll be embarrassed if it isn't. We're going to have to come to some agreement".*

A: *"I just think that that wouldn't be equivalent to that..if it was about two or one in it might balance..but I don't think that would be as heavy".*

B: *"It should work..if my theory is right.. if that was there it would balance but because it's there it will tip that way".*

A: *"If there was three on the end it would balance, but as you go in you don't get so much weight so if* *you add an extra one it will balance".*

Some subjects went to some lengths to try and explain themselves:

"Well look, there's two there and if you move this along three times you get rid of them, wouldn't you? I mean, if you moved it along two times, you'd get rid of two of the weights, one each time, you'd be left with one weight.

Now you've got me all muddled..I don't know what I'm doing..but that's what we did the last time and it went all wrong..how many do you have to move up to put another weight on..you're getting me all muddled here..because you've got four knobs going up and four weights, I would have thought it would be one weight each..when you go up..well..not one there, two there, three there, four there, but...I mean, if there was one weight there and four weights there I'd expect it to balance..yeah it would balance...because you've got four knobs here to take away four, well, you'd be left with one, wouldn't you..and one and four would balance..but I don't know about three and two (laughs)..oh..you've got me really muddled".

The following is an example of one child challenging her partners use of the hypothetical case:

A. *"I think it's going to tip to C because if you put one on there and one on there and two on there it would be more.."*

B: *"But it's not though is it?"*

A: *"I know but you could say it would tip to C".*

B: *"But it's not though is it though?"*

A: *"Yeah..I think it might..but there again..um.."*

B: *"It might be level.."*

A: *"No..it won't be level".*

B: *"Let's try for C..yes".*

A. *"Yes..C".*

Experimenter: *"Why C?"*

A. *"Because there's more weight on that end and it's only two places from the right.."*

B: *"Yes..so it'll probably be C".*

All the examples quoted help to show the quality of reasoning used by subjects in their attempt to solve the balance problem. It was clear that subjects recognised the need to find some way of integrating the two dimensions of weight and distance, but that concise verbal articulation of an integration rule was rare, although the notion of adding was frequently an implicit aspect of the explanations given.

V.5. EXPERIMENT 5: DISCUSSION.

The results of this study have provided a clear demonstration of differences in children's ability to solve the balance problem according to the type of trial presented, thus supporting Wilkening and Anderson's (1982) view that the extent to which children appear competent in the balance task is directly related to the type of problem set. Adding trials (ie. those trials for which use of an adding strategy would lead to an accurate prediction) were twice as likely to be correctly answered compared to non-adding trials. The prediction that use of the adding strategy would be most evident in the Peer-2 condition was not confirmed, nor was there a significant overall conditions difference.

The lack of significant benefit to children who had experienced the most social condition of training may have been due to the presence of the video-camera in the training session. This may have had an inhibitory effect on some subjects in reducing their willingness to express their reasons for each decision, or it may have been a deterrent to learning in a less specific sense, perhaps by increasing levels of affect. The impression gained in observing the training sessions was that some subjects were initially embarrassed, but that the camera was then largely ignored, so it is far from certain that this influenced the outcome. An alternative is that the subject population varied in some undefined way. Experiment 4 was conducted in schools in which there was a greater diversity of social class than in the schools used in the present study, but it is not apparent in what way this might affect the experimental outcome.

The protocol analysis illustrated that there was some substance to the interactions in training, and showed that subjects did make repeated attempts to generate a systematic understanding of the relation between distance and weights in the balance problem. When faced with a problem that they could not solve, it was apparent that some children mentally adjusted the arrangement to give a case in which a decision could be made, and then used that result to tackle the actual case.

The protocols were also characterised by a large number of assertions made by subjects to their partners. These assertions may have had a psychological force rather than a logical force, acting as a spur to the recipient to re-evaluate their own view. However, if assertions were useful by virtue of their information content, then it would not be surprising if they were relatively ineffective, as it would be difficult for subjects to remember the trials to which the assertions related. The balance beam task, in which children were required to make judgements about a large number of similar problems, was perhaps the least favourable circumstance for rote learning; to remember a long sequence of balance problems without using a rule or strategy would be difficult in the extreme.

It seems probable that any benefit in the interaction setting did relate to the *content* of the exchanges. This view is supported by the fact that in previous studies, clearly asymmetrical interactions, such as between a conserver and a non-conserver, have provided the most convincing evidence of the importance of verbal exchanges (eg. Doise, Mugny and Perret-Clermont 1975). Although Doise attributed the benefit to the effect of the socio-cognitive conflict thus generated, the information content of the exchanges may have been an important element in determining progress.

In the Balance task, the relation between the pairs of children was not symmetrical in the sense that pre-test levels were matched, but it is evident that neither were there large discrepancies in understanding, as almost all subjects were at a Rule-3 level of performance. If subjects were 'muddling through' at the outset, then to be taught to 'muddle through' in an alternative fashion by one's partner was not likely to be reflected in any particular performance at post-test; specifically it was not likely to create a noticeable conditions difference. It depends on whether the idea of 'muddling' conceals what is in effect a systematic application of a rule.

In the present study there may have been a two way process in operation. On the one hand, a feature of the children's use of the additive strategy was that they persisted in its use even after a previous feedback had indicated that it was unsuccessful. On the other hand, subjects were sometimes reminded by their partner of previous failure. If the co-operative condition with justification led to greater appreciation of the adding strategy, and also to an increased recognition of its inadequacy, then the lack of overall effect might hide what could be important changes in the children's understanding. The overall impression gained was of a group of children given a problem for which they had no solution, and who, with a growing awareness of their lack of means of resolution, struggled to generate plausible hypotheses.

Wilkening and Anderson (1982) suggest that Siegler's Rule-3 classification conceals some important differences in understanding as children adopt varying integration strategies. The very large differences in post-post test performance in Adding and Non-Adding trials supports the impression that some important understanding centres on this strategy, and it remains possible that this is a factor in determining the extent to which a social learning context benefits the individual child. The final study will attempt to provide a task setting in which some of the intermediate strategies used by children in the balance task are more likely to be evidenced. In a conservation task, Perret-Clermont (1980) has demonstrated that children younger than this age group are capable of communicating ideas of physical laws in a coherent fashion so, given a more suitable version of the balance task, the strategies used by children might be better revealed. The balance task as it has been used so far is - in effect - a judgement task; subjects must make a judgement between three possible options. A balance task with a far greater range of alternative answers might create a very different interactive situation which would alter the potential for differential learning. The essence of socio-cognitive conflict theory is that the benefit of peer-interaction is not dependent upon the *content* of exchanges, but rather derives from the dynamic effect of the interactive process. It is hoped to clarify this issue in the study reported in the next chapter.

CHAPTER VI. AN ALTERNATIVE BALANCE PROBLEM.

VI.1. INTRODUCTION.

The findings of the last study have provided a reminder of the fragility of the potential benefit of peer-interaction in the Balance task, although a marked difference in the ability of subjects to correctly solve adding and non-adding trials was demonstrated. Ability was not however enhanced by the social conditions of learning in any significant sense. It is not clear from these results whether the balance task creates a situation in which social conditions of learning are inevitably of marginal value, or whether, given an alternative version of this task, a more definite peer-interaction benefit would be demonstrated.

Wilkening and Anderson (1982) argue that in using a 'choice task, ie. one in which the subject must choose one of two or three options, some of the subtleties in children's reasoning are hidden. They comment on the very general use of tasks by Piaget in which subjects are required to compare two objects or events and choose between them, and they suggest that both these tasks and Siegler's use of the balance beam effectively disallow the possibility that subjects are integrating two rules. Wilkening and Anderson claim that studies that use numerical rather than choice responses provide a more subtle and therefore more useful measure, and they discuss one way that numerical responses may be obtained from the balance beam task using an adjustment procedure. In this procedure, the investigator sets the weight and distance on one arm, and the subject adjusts the distance of a given weight on the other arm. Blocks under each arm prevent the beam from tipping during adjustment. It is argued that the adjustment task may have advantages for assessing children's knowledge structures, because the choice format in a judgement task may induce comparison procedures that simplify the decision process but that mask or distort the underlying knowledge. In Wilkening and Anderson's view, the choice paradigm makes a greater information-processing demand that may lead subjects to adopt more simple rules to handle the task. In the light of these assertions, it was decided to adapt the previously used computer program for the balance task to provide a version similar to that advocated by Wilkening and Anderson, ie. using an adjustment procedure. This will be described as the 'Alternative Balance' task.

A feature of the alternative version of the balance task is that responses can be coded according to, firstly, whether they are right or wrong and, secondly, whether they are responses that are compatible with an assumption that the subject is using some form of adding strategy. This allows the question of whether interaction leads to a change in understanding that is *unhelpful* to be explored more fully than the post-post test of Experiment 5. At another level, the change in task format may provide a quite different task environment from the social point of view. It remains a choice task in the strict sense, but the range of options is sufficiently large to perhaps generate more interactive debate over proposed actions.

Although Wilkening and Anderson's integration rule theory presents a potentially more sophisticated understanding of the concepts used by children in the balance task and other problems requiring the integration of data, their approach is still firmly within the information-processing theoretical framework and it offers no explanation as to how integration rules come to be acquired. In creating an experimental comparison of Paired and Individual conditions of learning using the alternative balance task, the extent to which the learning that takes place is a socially mediated process can be assessed.

The aims of this study were to investigate whether an alternative version of the balance beam task, using, as before, Paired and Individual conditions of training, with and without the requirement to justify, would lead to productive and differential individual gain, in contrast to the previous method of assessment. Three specific predictions were made, the first being that in the two justification conditions, subjects working in pairs would show significantly enhanced post-test performance compared to those working alone. On the assumption that the new experimental task would be more conducive to peer-enhanced learning, it was secondly hypothesised that, in the two conditions in which subjects were not required to justify their intentions, subjects in the Pairs condition would benefit more than those in the Individual condition. On the same basis it was thirdly predicted that overall performance at post-test of subjects in the two justification conditions would be superior to that of subjects in the two non-justification conditions.

EXPERIMENT 6: METHOD.

Subjects.

The subjects were 80 children who were pupils at two Poole Middle schools. One school was in a predominantly working class area and the other in a mixed catchment area. The children's ages varied between 11 years 7 months and 12 years 5 months, with a mean age of 11 years 11 months. As in the previous study allocation to conditions was random, other than ensuring that equal numbers of children from each school were represented in each of the conditions and that children from streamed classes were also distributed equally.

Design.

This study followed the same pattern as previous ones in having four conditions: Individuals, Individuals with justifications, Pairs, and Pairs with justifications.

The task used was a variation of the balance beam task used by Wilkening and Anderson (1982). A computer program was created which presented an arrangement of weights on one side of a balance and required the subjects to position up to four weights on a peg on the other side to make the beam balance. All the weights had to be placed on only one peg, and there was an additional constraint that the peg that matched the one in use on the other side could not be used. In other words the child could not respond with the mirror image ie. with the identical weight/distance configuration. FIGURE VI.1 shows the screen presentation for this task. When the subject 'keyed-in' the number of weights and their position these were drawn on the screen, and then the beam was seen to tip, or balance, as appropriate. At the same time a message appeared on the screen telling the child whether or not he was correct

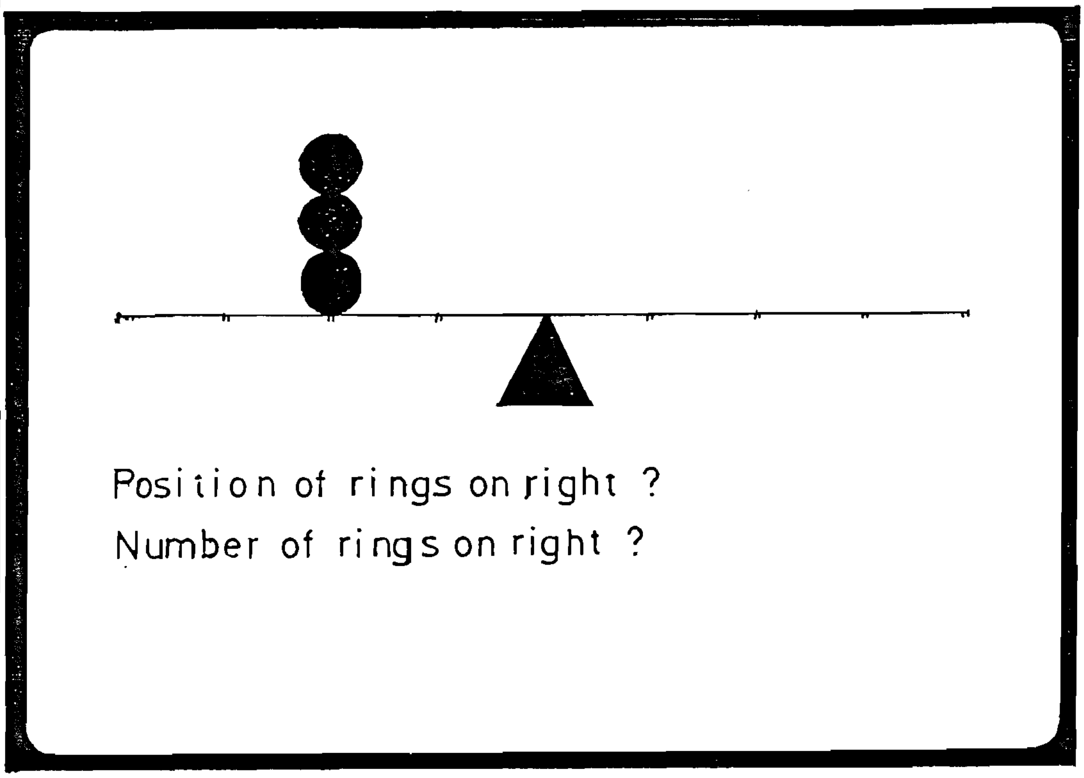

FIGURE VI . 1.EXPERIMENT 6: SCREEN PRESENTATION FOR THE ALTERNATIVE BALANCE TASK.

(although this was self evident from the position of the beam).

The pre- and-post tests were paper-and-pencil tests as before and were in two sections. In one section a series of problems were presented in the same format as that to be presented on the screen, namely with weights positioned on one side of the beam and the child required to pencil-in weights on the other side to make the beam balance. The same instructions about number and position of weights applied. An example of this pre-test form is shown in FIGURE VI.2. The second section, presented at the same time, was a series of judgement tasks, identical to those used in the previous studies.

Procedure.

In both schools the experiment was conducted in a quiet room in similar circumstances to that of the other studies. The child was familiarised with the computer program before the training session began. Once again it was found that subjects had no difficulty in understanding what was required of them, and no difficulty in understanding the operation of the machine. The program was designed so that it was not possible to make an illegal move; on trying to enter weights on a forbidden peg the subject would be invited to re-submit. As before the

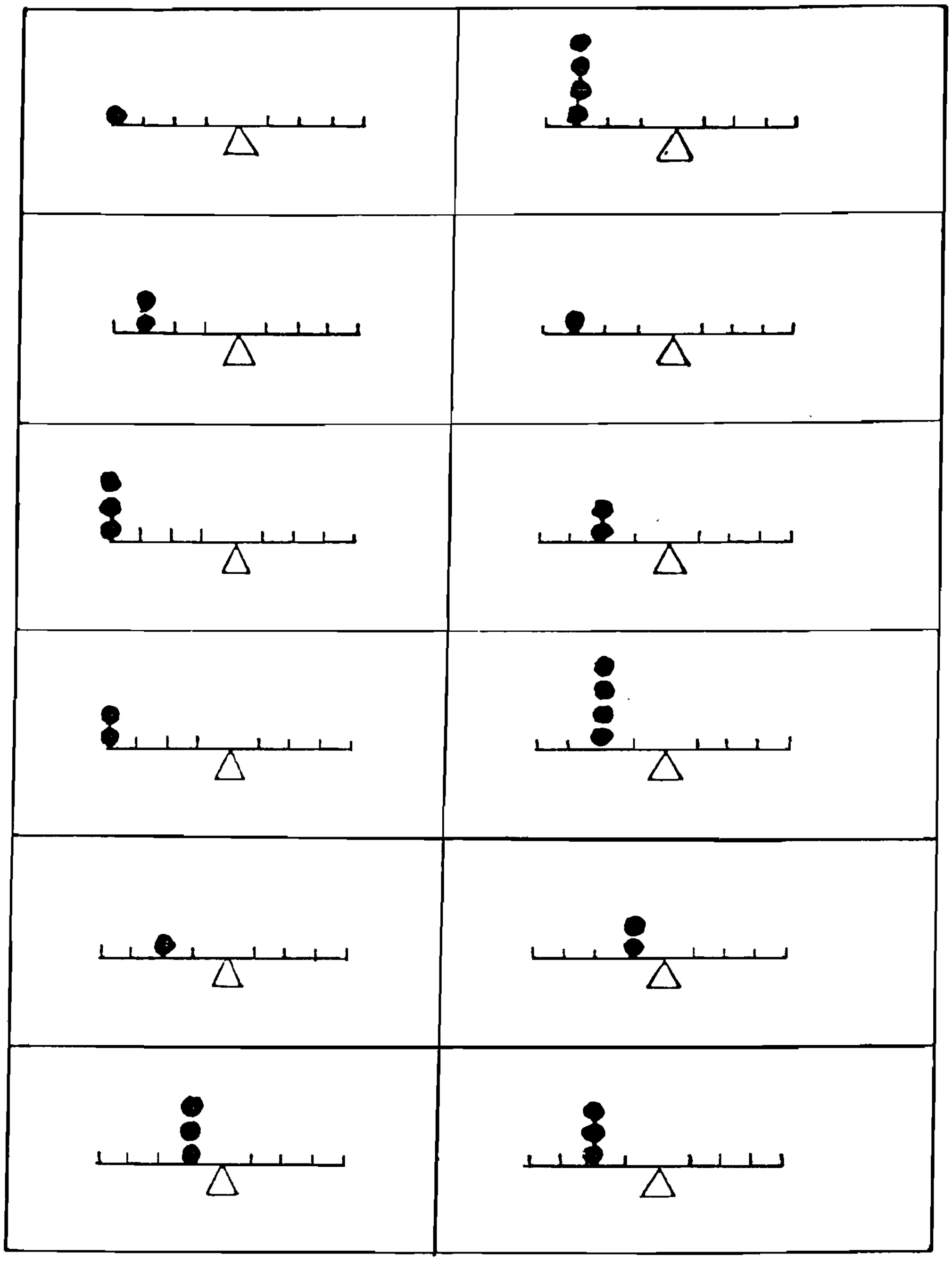

FIGURE VI 2 EXPERIMENT 6
EXAMPLE OF PRE/POST-TEST FORM FOR ALTERNATIVE BALANCE TASK (PHOTO REDUCED FROM A4 SIZE)

post-test session took place one week later.

6.3. EXPERIMENT 6: RESULTS.

Each of the trials presented had twelve potential responses, some of which would be compatible with the child having used an additive strategy to arrive at a decision. The results were recorded in a way that permitted analysis of both the number of correct answers, and the number of responses, right or wrong, which were compatible with the use of an adding strategy. Firstly, the 'Alternative Balance' data were summarised in terms of the number of correct responses at each stage of the experiment. TABLE VI.1. shows these mean scores, which are also set out graphically in FIGURE VI.3.

	INDIV-1	INDIV-2	PEER-1	PEER-2
PRE-TEST	3.1	3.2	3.6	2.95
POST-TEST	4.45	4.6	4.4	5.9

TABLE VI.1. EXPERIMENT 6: ALTERNATIVE BALANCE DATA: SUMMARY OF MEAN SCORES: (Optimum score=12)

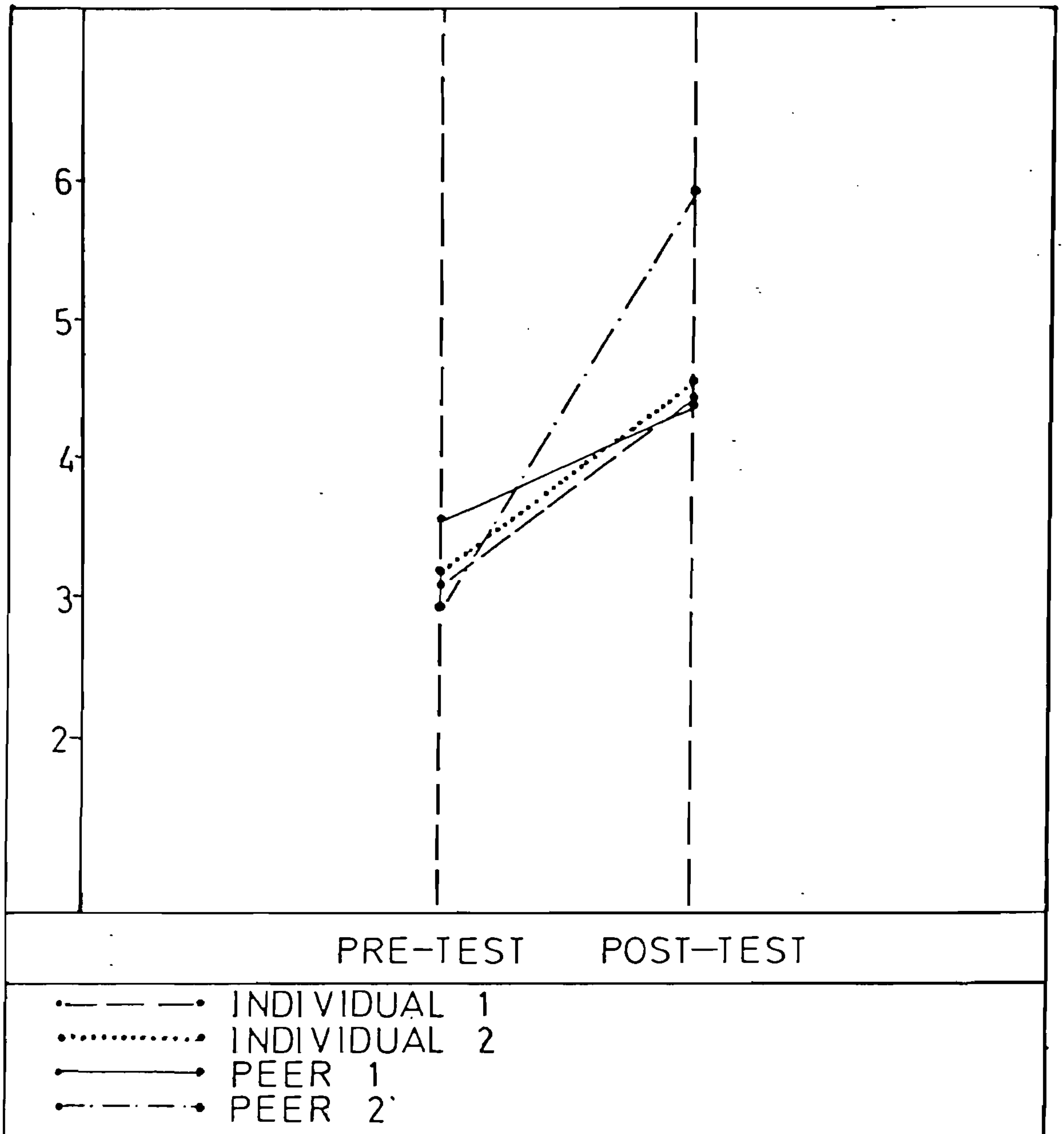

FIGURE VI.3. EXPERIMENT 6:
ALTERNATIVE BALANCE DATA: MEAN SCORES AT PRE-TEST AND POST-TEST

A two-way analysis of variance of the 'Alternative-balance' data shows that there was no significant difference between the four conditions. There was, in this balance task, as in the previous judgement task, a significant within-subjects difference from pre- to post-test. ($F = 18.767$, $df=1,76$, $MS(error)= 5.628$, $p < 0.01$). Thus overall, subjects improved in their ability to solve balance problems as a result of practice at the task. There was no significant interaction effect.

The second set of data to be analysed were the pre- and post-test judgement tests, which were identical to the pre- and post-tests used in the previous studies. As before, the 18-trial data from these tests were used for the principal analysis. The mean scores of subjects in each condition at pre-test and post-test are set out in TABLE VI.2. and are also shown in FIGURE VI.4.

	INDIV-1	INDIV-2	PEER-1	PEER-2
PRE-TEST	9.85	9.6	10.9	9.85
POST-TEST	10.45	10.8	11.8	12.25

TABLE VI.2. EXPERIMENT 6: 18-TRIAL DATA: SUMMARY OF MEAN SCORES.

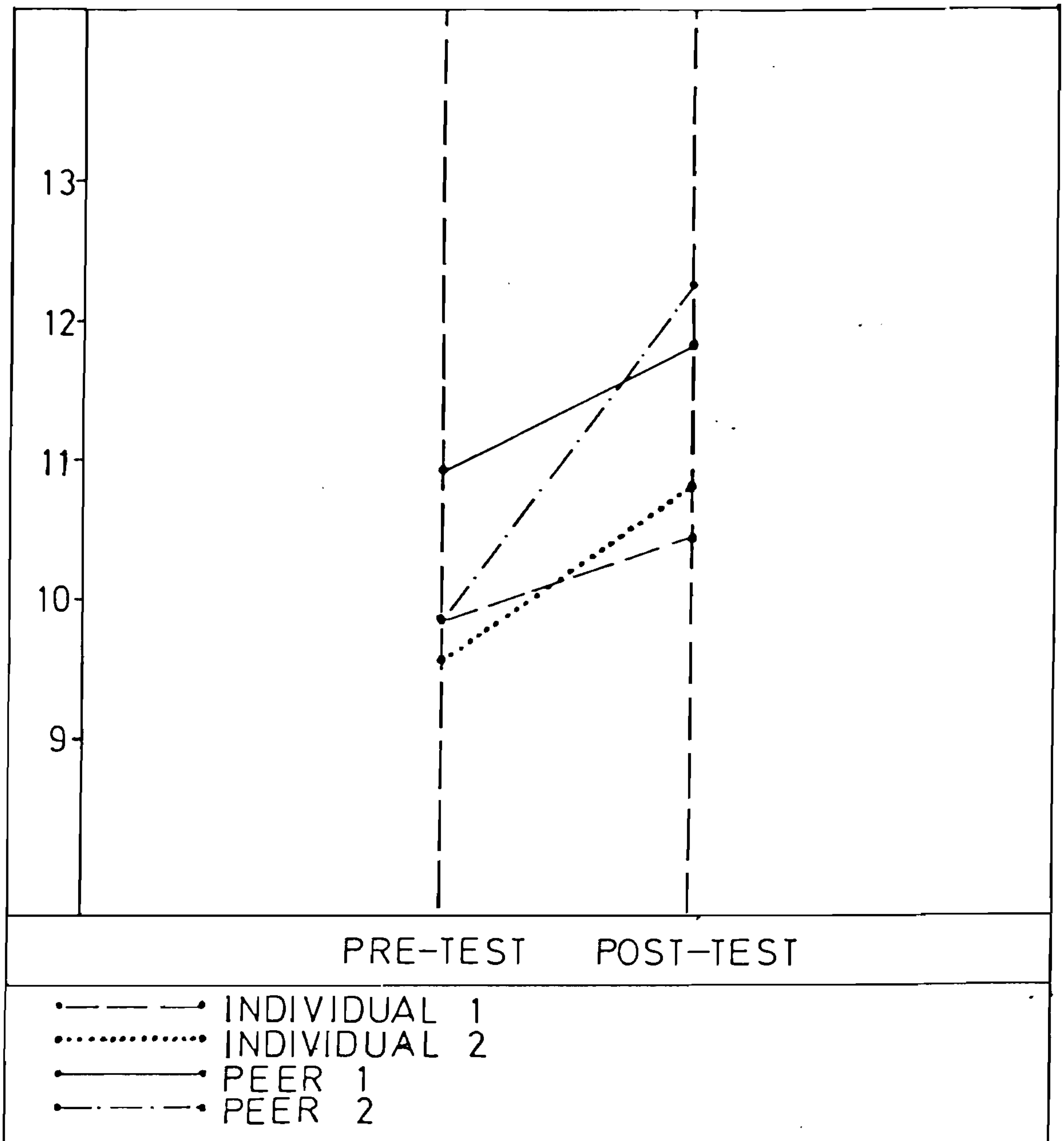

FIGURE VI. 4 .EXPERIMENT 6: 18 TRIAL DATA: MEAN SCORES AT PRE-TEST AND POST-TEST (OPTIMUM SCORE = 18)

A two-way analysis of variance of the 18-trial data shows that there were no performance differences attributable to conditions. There was a significant within subjects effect from pre to post-test ($F = 10.225$, $df = 1,76$, $MS(error) = 6.359$, $p < .01$). There was no interaction effect. These data therefore provide evidence of similar performance trends to those demonstrated by the Alternative Balance results.

In a similar manner to that of the previous studies, a priori t-tests were used to test specific experimental hypotheses using the Alternative Balance data. In this study no significant differences were demonstrated, although the comparison of Individual-2 and Peer-2 conditions, which had proved to be the significant comparison in Experiment 4, showed the same trend. (Individual-1 v. Peer-1 $t=0.057$; Individual-2 v. Peer-2 $t=1.475$: Combined non-justification conditions v. Combined justification conditions $t=1.3$; all non-significant). The same comparisons using the judgement data were also non-significant. Thus the change in task has not apparently created a situation more amenable to peer-interaction benefit. FIGURES IV.5, IV.6, and IV.7 illustrate the relevant post-test score comparisons. It can be seen that the pattern of these results is similar to that in the preceding studies.

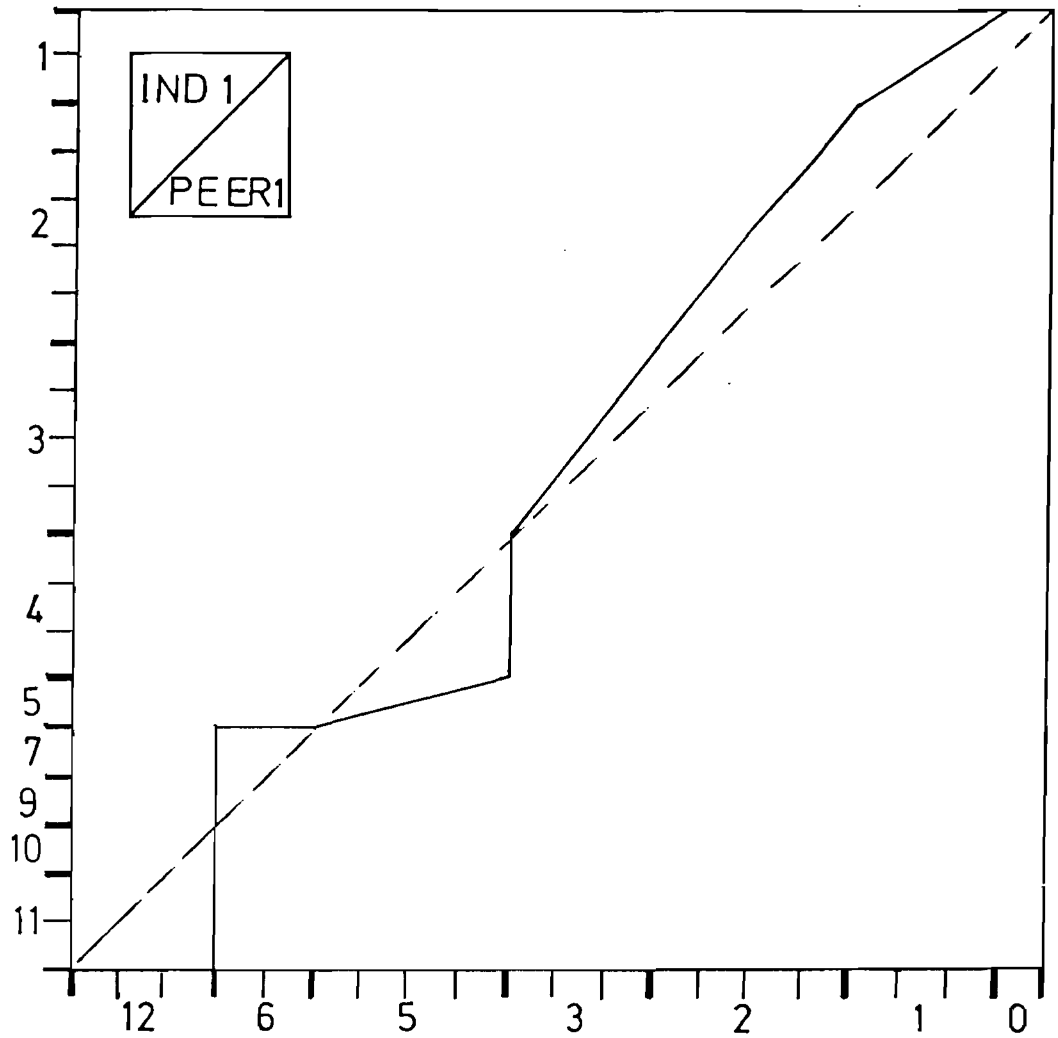

FIGURE VI.5 EXPERIMENT 6:
ALTERNATIVE BALANCE DATA: ORDINAL DOMINANCE GRAPH POST-TEST SCORE DISTRIBUTIONS.

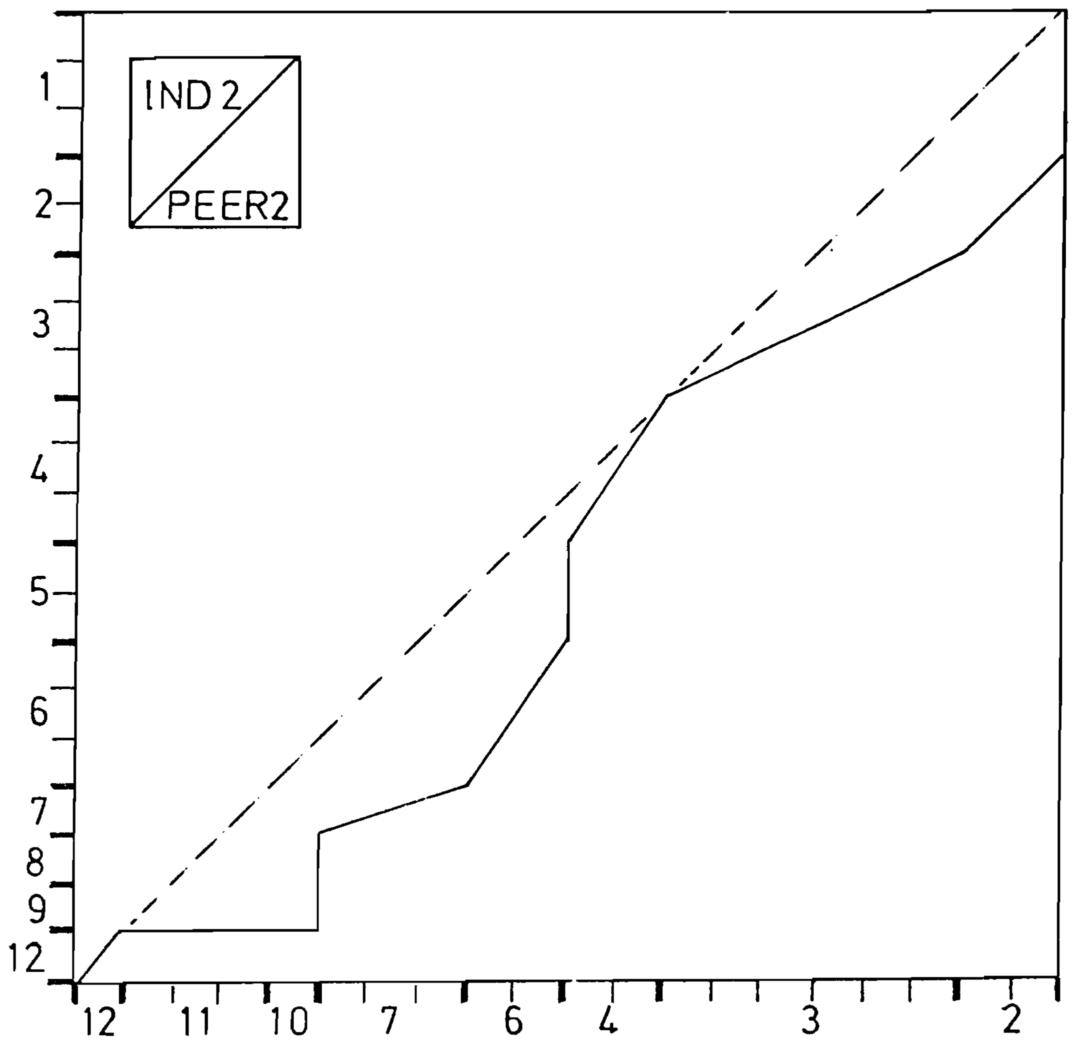

FIGURE VI.6. EXPERIMENT 6:
ALTERNATIVE BALANCE DATA: ORDINAL
DOMINANCE GRAPH: POST-TEST SCORE
DISTRIBUTIONS.

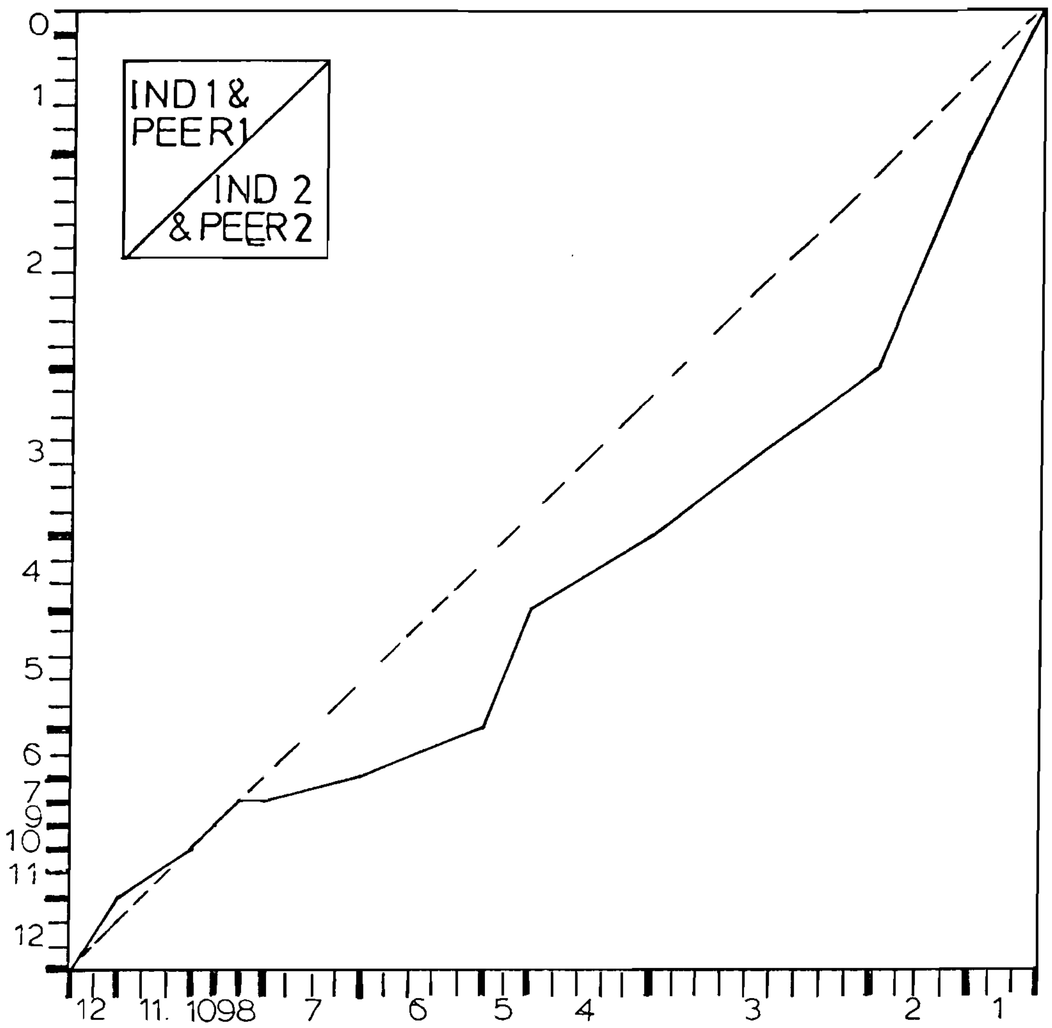

FIGURE VI.7. EXPERIMENT 6: ALTERNATIVE BALANCE DATA: ORDINAL DOMINANCE GRAPH: POST-TEST SCORE DISTRIBUTIONS

Having examined the results in terms of the extent to which children could correctly place weights in order to make the beam balance, a second method of interpretation was to examine the extent to which responses were compatible with the use of an adding strategy. It is important to note that the existence of performance data compatible with the use of an adding strategy does not mean that this was in fact the underlying determinant of the responses. However, to ease reporting of this element of the results, a temporary assumption will be made that it is the case. TABLE VI.3 shows a summary of the use of adding strategies based on the Alternative balance data.

	INDIV-1	INDIV-2	PEER-1	PEER-2
PRE-TEST				
CORRECT	2.75	3.00	3.30	2.60
INCORRECT	3.35	3.85	3.60	3.30
TOTAL	6.1	6.85	6.90	5.90
POST-TEST				
CORRECT	4.10	3.95	3.95	5.25
INCORRECT	2.65	2.80	2.85	2.20
TOTAL	6.75	6.75	6.80	7.45

TABLE VI.3. EXPERIMENT 6: USE OF ADDING STRATEGIES: (Number of trials = 12).

A three-way analysis of variance of correct and incorrect use of the adding strategy shows that there was no conditions difference, no significant difference between pre- and post-test, and no significant difference in appropriateness of use of an adding strategy. There was however, a significant interaction between the appropriateness of use of the adding strategy and the stage of the experiment ie. pre- or post-test. FIGURE VI.8 illustrates the nature of the interaction between test and appropriateness of use of the adding strategy and FIGURE VI.9 shows the relatively small improvement in the overall number of responses compatible with an adding strategy.

Of the twelve trials conducted, six were capable of solution using a simple adding strategy. In this case when moving the position of the weights one peg closer to the fulcrum one weight is subtracted to make the beam balance, and conversely in moving out one peg one weight is added. A further five trials were capable of solution using a two-stage strategy, in which the same principle is used to move the weights two or more pegs along the beam, ie. subjects had to repeat the 'one along -add (or remove) one weight' principle to arrive at the correct answer. Only one trial was such that use of an adding strategy would result in the wrong answer. Inspection of the data makes it clear that there were no differences between conditions

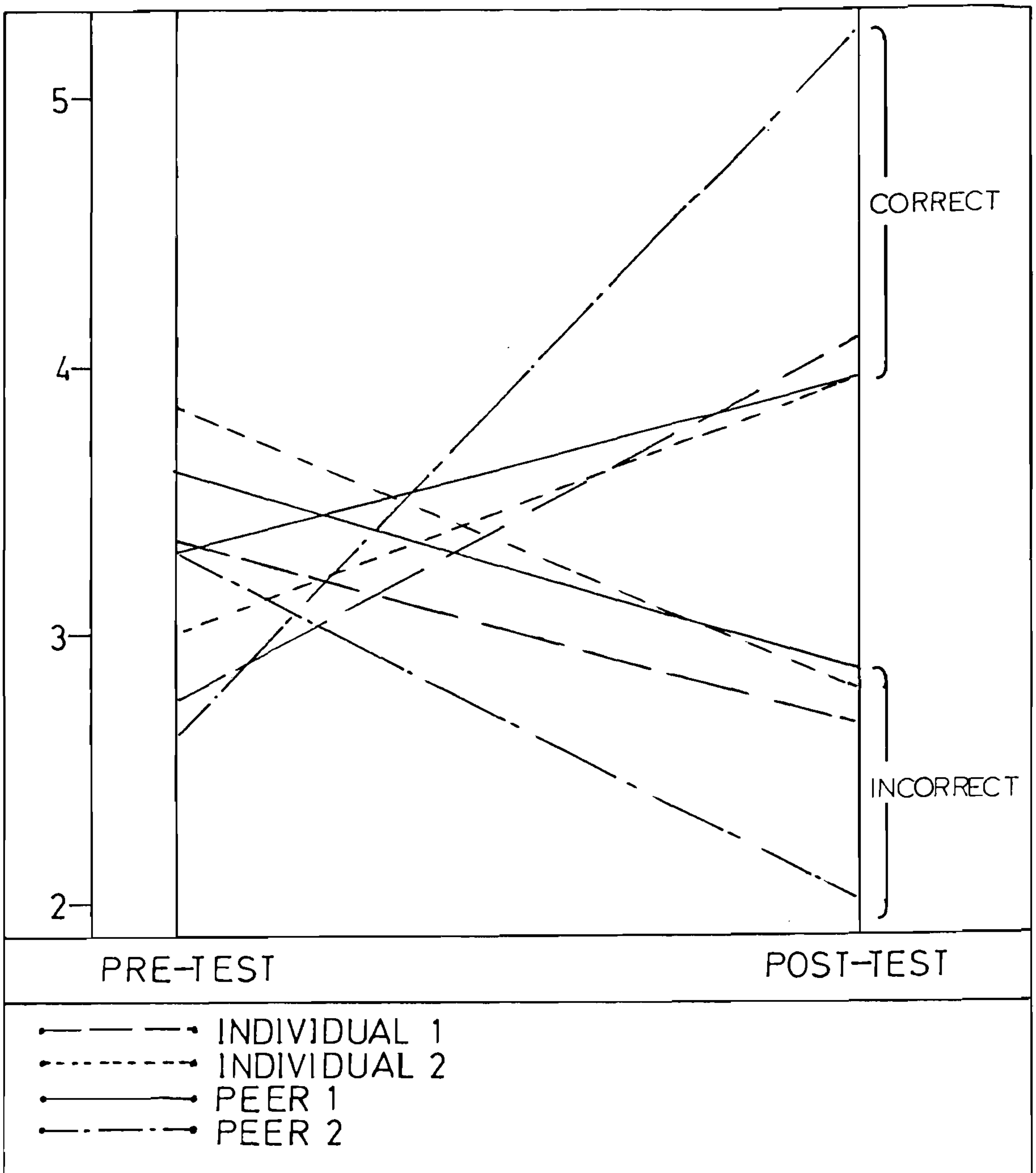

FIGURE VI.8.EXPERIMENT 6: NUMBER OF INCORRECT & CORRECT RESPONSES COMPATIBLE WITH USE OF ADDING STRATEGY

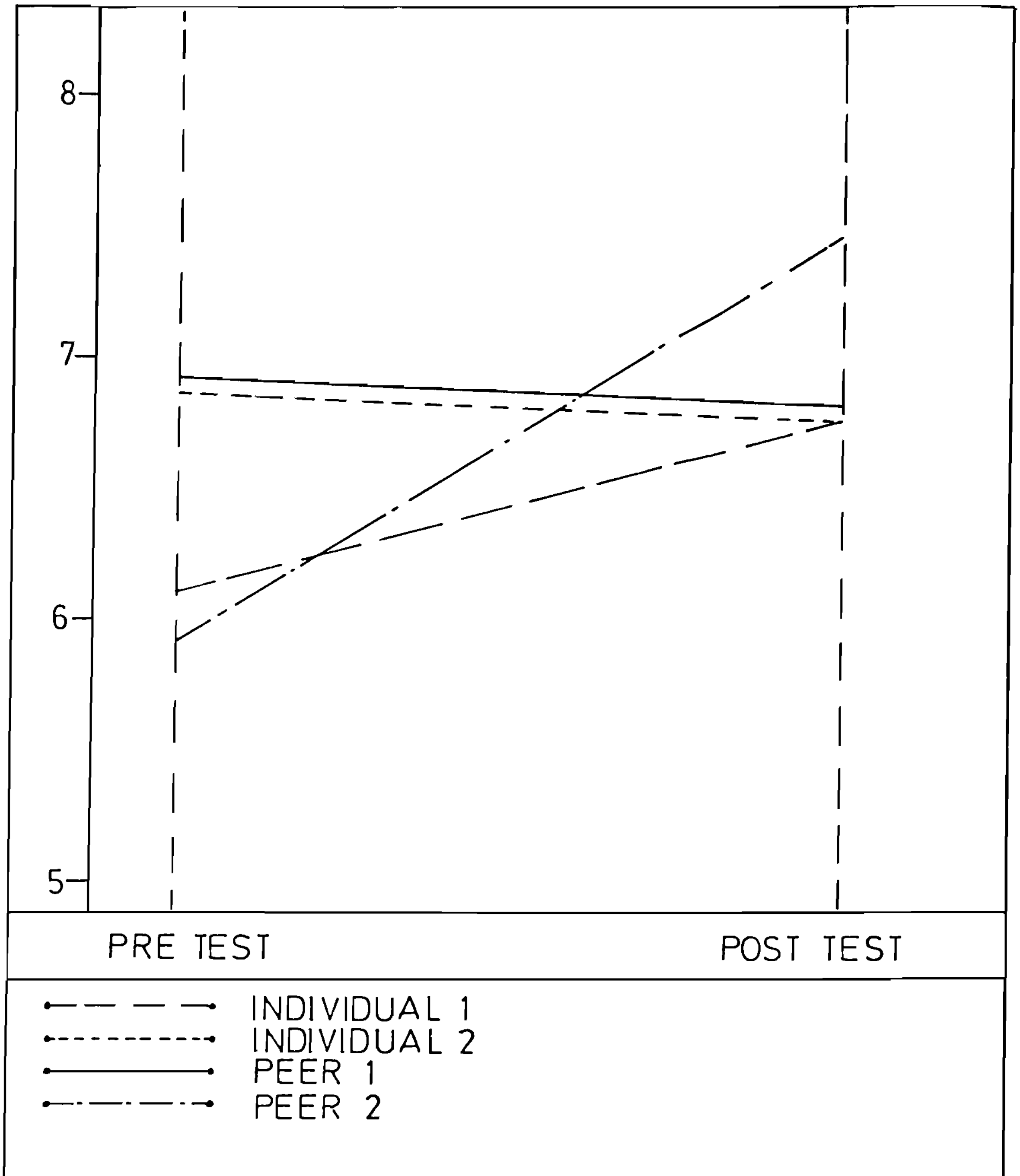

FIGURE VI.9. EXPERIMENT 6: TOTAL NUMBER OF RESPONSES COMPATIBLE WITH USE OF ADDING STRATEGY in performance in respect of this latter trial, nor in the extent to which subjects used the two-stage adding strategy.

The data also show that overall,the trials in which performance was best at both pre and post-test were those in which the solution was compatible with a simple adding strategy, and in which the position of the weights was such that only one response compatible with an adding strategy was possible. The five least successful trials were those in which the correct answer was not compatible with an adding strategy, or compatible only with a two-stage adding strategy.

VI.4. EXPERIMENT 6: DISCUSSION.

The task used in this study has, in providing an alternative form of measurement, thrown a new light on how children solve the balance beam problem. It has shown that the previous assumption that any improvement was, in part at least, attributable to the acquisition of the adding strategy was not warranted: overall there was no difference in the total number of responses that could be interpreted as reflecting the use of an adding strategy. It is clear that the importance of the use of an integration rule may have been over-estimated on two counts. Firstly, although the protocols in Experiment 5 provide some evidence that subjects do use an adding rule in some cases it is obvious, given that in the majority of trials an adding rule provides the right answer, that all correct responses will reflect the apparent use of such a strategy. It would be equally reasonable to deduce that correct answers reflected the use of formal understanding but this is clearly not the case. The software program did not make it possible to create a number of non-adding trials. This could perhaps form the basis of another experiment. The results in the present study, of the one trial in which only a non-adding strategy response would be successful, do not suggest that a difference between conditions would thereby be demonstrated.

The second point is that the results show that even if the responses do reflect use of the adding strategy then its use does not increase to any substantial extent as a consequence of training. What does improve, however, is the appropriateness of use. Thus the performance of children at pre-test indicated that they may have already had an awareness of the need to integrate the weight and distance factors in solving the balance problem, and, in this view, what has improved is the accuracy with which such a strategy was used. This suggests that what is learned is not related to the adding strategy at all. It may be a 'red-herring' in the attempt to understand how it is that children progress, at least within this age group.

Although no overall conditions differences were demonstrated, the same trends were apparent as in previous studies, particularly in respect of the paired training condition in which justifications were required. It had been assumed that the change from the choice version of the balance task, to the adjustment procedure might create a situation in which the exchange of ideas between pairs, or the requirement to justify, or a combination of both, would have greater impact. The nature of discussion was necessarily altered as the children considered the merits of alternative positions for the weights, although the similarity of the length of each training session to that of the previous studies indicated that there was not a substantial increase in the amount of discussion.

In the light of the lack of evidence of increased use of the adding strategy, there remains a puzzle as to what else may account for the pre-to-post differences observed. The children undoubtedly learn something, but that something is stubbornly intangible. In spite of assertions made in relation to earlier studies, that it was not likely that children could *remember* correct responses, in the absence of any alternative it appears that an explanation based on children's ability to remember previous responses may be the most plausible view. It may be that

that memory was perceptually based, so that children retained a visual recognition of particular trials and the appropriate response. Furth (1977) argues that the recall of a particular figurative situation may be the essential component determining subsequent performance. He suggests that perception and memory always fall under operative control, but the figurative aspect of perception and memory may, for a short while, lead to a performance that is 'correct' although understanding is lacking. Similarly, Liben (1977) questions the legitimacy of regarding the effects of the memorising techniques of fixation and retrieval as operative, in the sense of reflecting the acquisition of cognitive structures. In this view, the notion of memory as an explanation in *competition* with Piagetian explanations in terms of the acquisition of cognitive structures, is reasonable. Alternatively, recollection might be solely based on a verbal record, not in the form of a general rule, but as an understanding specific to a particular trial. This could be seen as children's ability to generate what are in effect trial-specific rules, and to the extent that performance was enhanced by the requirement to justify, this may have led to such a memory.

If rote memory were to be posited as an explanation, in competition with explanations based upon the acquisition of strategies or operative structures, there would be a danger that an unnecessary dichotomy would be created. It may be preferable to view the issue in terms of the acquisition of strategies or rules, in which case the important issue is whether what is remembered does or does not include any rule-based understanding, and at what level any such rules or strategies are based. This raises an argument regarding the point at which it is appropriate to describe knowledge as rule-based or strategic; it could be said that rote memory of the solution to a particular trial constituted a rule for that trial.

Another factor of importance in determining the extent to which children's memory is influenced in the balance task may be their emotional state; it may be that levels of affect generated in the training session influenced subsequent performance. Enhanced post-test performance may reflect the extent to which children were encouraged by their success and improved their concentration. However, if this were the case, it would be reasonable to expect greater differences between conditions, on the assumption that the presence of a peer would provide a likely influence on the child's affective state. Karmiloff-Smith's (1984) view similarly emphasises the importance of success, except that she does not see this as primarily an affective process.

The present study must be left with a number of questions unanswered. It has been unsatisfactory in several respects, but nevertheless a reasonable point in the experimental process has been reached at which to pause in order to discuss the questions raised. The final chapter will relate some of the issues to the theories mentioned in the introductory chapters.

CHAPTER VII. OVERVIEW AND CONCLUSIONS.

VII.1. INTRODUCTION.

The studies presented in this thesis have been concerned with the demonstration of peer-facilitation of learning. Unlike much of the previous work in this area, experimental tasks have been used that are not explicitly tied to a Piagetian theoretical framework. This follows the example of Glachan (1983) and allows the debate to be freed from the restrictive assumptions that are inherent in Piagetian tests such as conservation. Of the six experiments conducted, only one provided significant evidence overall to support the view that peer-interaction in learning could enhance subsequent individual gain. However, in the remaining five studies a consistent trend was demonstrated and some specific differences were identified.

The present studies were innovative in using micro-computer-based tasks that created a novel environment for the study of peer-interaction. The micro-computer proved to be a flexible and effective tool that led to high levels of motivation among subjects. It was evident that a range of social-interactive situations could be created in respect of the operation of a computer, as in respect of any other task setting, and there was nothing to suggest that the potential for social-interaction was altered in any fundamental sense because of the computer presentation per se.

VII.2. THE FIRST TASK: THE TOWER OF HANOI.

The use of the Tower of Hanoi provided a direct link with recent studies of peer-interaction (Glachan 1983), although in using a micro-computer-based version of the task some differences were created. In particular, the opportunity for manipulation of materials was removed, except in the limited sense of operation of the keyboard. Glachan's finding, that in a paired condition enforced joint manipulation of the Tower of Hanoi discs led to enhanced individual post-test performance, left unclear the exact source of benefit. To the extent that a differential gain was demonstrated in the dual-key condition of the micro-computer version of the Tower of Hanoi, these findings suggest that in Glachan's study it may not have been solely the physical process of moving the discs that led to progress. However, it is possible that the the more robust peer-interaction benefit demonstrated in Glachan's Tower of Hanoi studies was due in part to this aspect.

The micro-computer environment used in the present studies was novel, in comparison to previous peer-interaction studies, in providing what was merely a *representation* of the task, but one that was nevertheless reactive to the children's performance. It was thus intermediate in character between a physical task and a paper-and-pencil test. Although the absence of any physical manipulation of the discs meant that this aspect could not account for learning, the dual-key facility may have had an equivalent role in ensuring that one child was not excluded from participation in the joint training process. The results of Experiment 2 lend support to previous findings (eg. Doise and Mugny 1979) that one influence on outcome may be the extent to which one child is prevented from dominating the training session.

It has been suggested that the personal characteristics of the interactants, rather than the level of understanding, may determine which child is dominant in a social interaction (Glachan 1983). In so far as children were all at a comparable level of understanding, the present studies support the idea that it was social rather than intellectual dominance that was disruptive. However, within the one broad level of knowledge there were undoubtedly individual differences in both personality and intellectual ability that contributed to asymmetries in some pairings. It seems probable that a combination of social and intellectual factors were involved.

Because of the nature of the Tower of Hanoi problem, the children's potential for improvement in performing the task was in part determined by the extent to which they recognised the need for, and achieved, appropriate sub-goals. It was evident that the need to achieve sub-goals, such as the necessity to get the largest disc to the goal peg, was sometimes recognised, but it was clear from the protocols that there was little or no metacognitive awareness of this process. This was in line with Klahr's (1978) observation that young children are capable of quite sophisticated 'chains' of problem solution, but that they do not recognise the process that they are using.

It may be that co-operation with a peer in attempting the Tower of Hanoi task was to some extent beneficial in leading the children to appreciate the need for sub-goals, and that the high level of optimum scores in the Dual-key condition of Experiment 2 reflected the children's recognition of a specific sub-goal. In particular, recognition of the requirement to put the first disc onto the goal peg would contribute substantially to the potential for achieving an optimum performance on any one trial. What is lacking is evidence that this was so.

The Cans post-test suggested that in the Tower of

Hanoi task any differential learning was extremely specific, and this specificity raises important issues regarding the way children's cognitive states should be discussed in the light of these findings. It is not at all clear that descriptions in terms of cognitive structures or even cognitive strategies are appropriate. The very particular changes that have been identified may be given excessive significance if a Piagetian terminology is adhered to. This issue will be referred to again later in the discussion.

VII.3. THE SECOND TASK: THE BALANCE BEAM.

In the balance beam task awareness of sub-goals is less relevant and in this respect it provided a contrast with the Tower of Hanoi puzzle. The balance problem is similar to conservation tasks in that it requires a choice to be made between a limited number of alternative answers. However, it differs from conservation problems in providing repeated measures, with feedback given to the subject following each trial. It is attractive as a potential experimental task in having a wide age-span over which change in performance levels have been reported. In the present research programme this was seen as a means of avoiding the age restrictions created by conservation tests which are only applicable to a narrow age-band. It was also of direct educational relevance, as the principle of moment is an important part of the science curriculum.

In retrospect it became apparent that within the long time-scale of change in knowledge of balance problems, there are in effect developmental plateaux, during which understanding remains static. Children do progress over a number of years from an immature regard only for the number of weights, to a mature formal appreciation of the law of moment. However, in practice periods of *transition* may be as limited as those relating to conservation. The last three studies reported in this thesis were conducted within what turned out to be the plateau of Rule-3 (Siegler 1978). It had been expected that there would be scope for socially-enhanced learning within this level but in the event overall measurement failed to demonstrate an effect that could be reliably replicated. In selecting the balance beam as a suitable task it is now clear that the importance of the *incremental* nature of the developmental progress was not sufficiently appreciated.

The results of Experiment 4, in which training in the Pairs-plus-justification condition did lead to differential gain, demonstrated the relative insensitivity of a rule-based assessment. Subjects were at Rule-3 both at pre- and post-test, and using a Rule-based measure the change in performance in the paired plus justification condition would have gone undetected. Although a significant effect was shown in only one study, progress from pre- to post-test in all the balance experiments made it reasonable to pursue the question of the importance of peer-interaction in this context. As long as something was being learned, then that something might be better grasped in the company of a peer, with or without the added stimulus of the justification procedure.

The theoretical alternative of integration theory (Wilkening and Anderson 1982) offered a more sophisticated means of assessing children's understanding of the balance problem. Using this method, it was hoped to identify some of the subtleties in children's thinking that might affect performance within the Rule-3 stage. In particular, integration theory held the promise of revealing whether children used an adding strategy in their attempts to solve the balance problem, and whether this was learned specifically in the paired and/or justification conditions.

The impression gained in observing the earlier Balance experiments was that children may have learned from each other the utility of an adding strategy in determining which way the beam would tip. However, the last study using the alternative balance problem, in which this assumption could be tested, demonstrated on the basis of integration theory that this assumption was largely unwarranted. There was no doubt that children gave responses compatible with their having used such a strategy, and that there was some evidence from the protocols that this was in fact what they were doing, but there was no evidence of this use increasing significantly from pre- to post-test. The results of Experiment 6 suggested that the ill-defined 'something' gained was a means of *using* the adding strategy more effectively, although what it was that led to this was not clear. It is only possible to state with certainty that subjects were successful in a greater number of trials.

In the discussion following Experiment 4 it was suggested that a rule-based explanation was more plausible than one based on rote memory, but in the light of the findings of the last study, the latter explanation cannot be totally discounted. It may be that the improvement witnessed in the Pairs-plus-justification condition of Experiment 4 was based at least in part on a visual memory of particular arrangements coupled with a memory of the outcome. An investigation of children's ability to 'recognise' some configurations more readily than others would be needed to clarify this issue. Alternatively, it is possible that subjects *did* use a strategy but one that is as yet unidentified. Wilkening and Anderson (1982) discuss 'weighted' adding strategies in which subjects give different subjective 'weightings' to the distance or weight element of the task. If such a strategy were in use its presence would not have been detected in the present studies. The evidence from the protocols provided no clear examples of the use of a 'weighted' adding strategy.

VII.4. THE IMPORTANCE OF VERBAL ASPECTS OF THE PRESENT STUDIES.

During the investigations it became clear that no formal solutions to either the Tower of Hanoi or the balance task were available to any of the children. This was in line with Piaget (Inhelder and Piaget 1958; Piaget 1977) who has traced the development of understanding in both the Tower of Hanoi and Balance problems. Any benefit from the verbal element of the task could not be attributed to the transmission of sophisticated verbal understanding of the rules of the games.

Previous research has illustrated that in some circumstances verbal discourse may play an important part in the facilitation of learning. In conservation studies a child who has a fully operational understanding of conservation may provide verbal explanations that are of benefit to the non-conserving partner. For example, Doise, Mugny and Perret-Clermont (1976) found that the cases in which conservers consistently gave reasons for their judgements were most profitable for the non-conserver. However, in this case, the children being tested were all approaching the age at which an appreciation of the law of conservation is likely to be acquired. In contrast, in the present studies, no children were at an age at which a formal understanding of the problems would be expected.

One possibility is that the requirement to justify benefits the child by bringing his own thoughts into a more explicit form - into conscious awareness. From the protocols it was apparent that examples of awareness of the process, ie. metacognition, were rare, and then being limited to only a few references to 'having a theory'. This is consistent with Shatz's (1978) view that children only indulge in metacognitive activity when they are not fully pre-occupied with the task ie. when it is sufficiently easy for some cognitive capacity to be free.

A second alternative is that justifications were useful by virtue of ensuring attention and equal participation, much in the same way that the dual-key control in Experiment 2 may have mediated social behaviour. In other words, the justification procedure may have been influential to the extent that it provided a source of control over dominance by one child. As before, this leaves unanswered the question of why these relatively diffuse social considerations should affect learning.

VII.5. THE SIGNIFICANCE OF THE PRESENT FINDINGS TO PREVIOUS THEORIES OF PEER-INTERACTION.

The most frequently cited theoretical views concerned specifically with peer-interaction are, firstly, the concept of modelling, based upon social-learning theory, and secondly, socio-cognitive conflict theory, which has developed broadly within a Piagetian framework.

The modelling hypothesis cannot be either proved or disproved by the studies reported here. To the limited extent that peer-benefit was demonstrated, it is possible to argue that it derived from the modelling by one child of his partner's behaviour. However, in view of the low level of physical activity in a computer-based task, and as neither the Tower of Hanoi nor the Balance problem was of the sort in which verbal reasoning flourished, such an explanation seems implausible. It seems unlikely that modelling was a substantial element in the process. An explanation based on socio-cognitive conflict may be more relevant. Perret-Clermont (1980) suggests that socio-cognitive conflict is anyway an inevitable part of the process by which children gain, even in learning described as modelling. The converse must also be true, that modelling may be a part of the process by which children gain in interactive situations. This has been acknowledged by Doise and Mugny (1984).

The lack of significant peer-benefit in the majority of the present studies is not inconsistent with the socio-cognitive account of development. In respect of the Tower of Hanoi, there is little evidence that children had coherent centrations to be disrupted. One might argue that they 'knew' that they did not know how to complete the task and that attempts to do so merely confirmed this fact. Although failure to complete the Tower of Hanoi in seven moves, consequent upon putting the first disc on the wrong peg, could lead to recognition of the inadequacy of this move, it could only do so if its significance was appreciated. Recognition of the importance of this sub-goal appeared to be lacking in many cases.

In respect of the balance problem, it seems that it was not so much that children lacked a centration that could be disrupted by social interaction, but rather that any disruption was not followed by a means of resolving the conflict. If children 'muddled through', meaning that they recognised the importance of both weight and distance factors, but had no system for combining these two dimensions, there would clearly be the opportunity for conflict between pairs of children, but with no coherent alternative to replace the previous understanding. It was suggested earlier that the results may have concealed conflicting trends. In particular, peer-interaction may have led both to an increase in use of an adding strategy, and to an increased awareness of its ineffectiveness.

The conflict-weight data provide a graphic illustration of the result of cognitive conflict, in which a previous understanding is disrupted, but without an adequate replacement. This lends support to Glachan's (1983) claim that disruption itself is not a sufficient spur to progress. An important difference between the balance problem and conservation tests may be that, in the latter case, recognition of the inadequacy of one of only two possible answers leads inevitably to the correct solution. Thus the resolution of conflict in some tasks may be a function of the limited range of options available to the child.

If one account of the present findings is that the nature of the tasks limited the potential for resolution of conflict, a second view is that the high level of intra-individual conflict generated by the feedback effectively 'drowned' the potential for socially-mediated benefit. It seems reasonable that disruption from social interaction should be less relevant in a situation in which the task itself provides a similar disturbance to inappropriate thought patterns.

It is not clear whether the quality of disruption is necessarily altered according to whether it derives from a physical or social source. Doise and Mugny (1984) suggest that there is an important difference between the two types of experience:

> *"..we believe this disruption to be above all social in nature. In fact when another asserts an opposing centration to that of the child, the child is faced with a conflict of not only a cognitive but also of a social nature. This socio-cognitive conflict, which allows two opposing centrations to exist simultaneously, cannot be as easily denied as a conflict resulting from successive and alternating individual centrations.* (Doise and Mugny 1984, page 28).

There is an interesting question here as to whether a computer, programmed to react in a quasi-human fashion, can create the same quality of cognitive conflict as that between two individuals. The two programs used in the present studies were not interactive in this sophisticated sense, so the quality of interactions between the child and machine, and between the two children in a paired situation, was clearly different. The result of Experiment 4, in which some evidence of peer-induced benefit was demonstrated, support Doise and Mugny's view, although the discussion is necessarily tentative because of the weak level of the effect demonstrated. It is increasingly apparent that the demonstration of peer-interaction benefit is highly sensitive to the task circumstances.

VII.6. EDUCATIONAL ISSUES.

The question of the importance of the social conditions in relation to learning and cognitive development is clearly of educational interest. To the extent that the present studies have identified 'something going on', that 'something' may be useful to education. Two specific issues in the present studies are worth highlighting. The first is the question of the importance of the relation between adult and child in the learning process and the second is the influence of micro-computers on education.

Firstly, the justification requirement in the balance studies increased the experimenter participation substantially. It was earlier suggested that the justification procedure may have influenced outcomes by virtue of controlling dominance; however it may be that it had more to do with the relation between the adult experimenter and the child. Perret-Clermont and Schubauer-Leoni (1981) suggest that differential levels of performance by children may reflect differential 'distance' between the child and the teacher. The same process may be operative in the experimenter/child relationship. It is possible that in the present studies, the experimenter's request for justifications was taken by some children as a challenge to the wisdom of their selection. This could have either negative or positive consequences according to the child's perception of the significance of this situation. Katz (1972) demonstrated that performance is sensitive to the social relationship between the pupil and experimenter. This is perhaps another way of saying that affect is an important variable in any learning situation.

Dialogue between adult and child has also been shown to be effective in promoting individual progress when compared to didactic instruction (Heber 1981). This suggests that the interaction enhances the child's ability to learn, but does not make clear whether the benefit derives from intellectual or affective considerations. Although Heber's study was similar to the present experiments in that subjects were required to justify their judgements, the relationship was more interactive in the former study, which may have been an important element in determining the potential for gain.

The justification conditions in the present studies created a situation in some ways similar to teacher-child relations when computers are in use: the child being given the opportunity to work alone with periodic intervention by the teacher seeking to establish how much the child understands what he is doing. Clearly, in the experimental situation the intervention was more frequent and regularised, but fairly similar techniques are in common use in the school in which most of the present studies were conducted. Notions of scaffolding may not be appropriate in the experimental context, although a similar construct, Vygotsky's zone of proximal development could be seen as relevant, if the request to the subject to justify his action is construed as a means of leading the child to a more explicit awareness of his own thought processes and thus to a higher level understanding.

The second educational issue concerns the introduction of micro-computers into schools. This new technology creates a very practical problem for teachers in deciding how the available hardware should be utilised. The role of the teacher may require modification in the light of technological advancement. Light and Colbourn (1986) point out that in some respects the computer presents a potential threat to the advancement of socially mediated learning, because the technology makes it feasible to create a totally individualised form of intervention. However, against this, limitations in the availability of hardware means that group work has become the norm for purely practical reasons. Given that this is the likely situation for the foreseeable future, one of the interesting issues that arises from the present studies is the question of the extent to which the quality of the group experience may be influenced, and the effectiveness of the instruction determined, by the design of the software. The differences in performance exhibited by subjects using the dual-key facility in the second Tower of Hanoi study are sufficient to encourage further investigation and clarification. It may be that the tentative difference demonstrated might be translated into a robust advantage in other educational tasks. The point is certainly worthy of further study.

If pupils are to be given an equal opportunity to benefit intellectually in a group learning situation, some means of ensuring equal access may need to be incorporated in the design of software. Skilled teachers may argue that they are capable of carrying out the control function themselves, or that the social processes engaged in by children in negotiating their roles in a peer-group situation are an important part of the educational process. Jackson, Fletcher and Messer (1986) found that teachers commented on the special advantage of computers in fostering interaction skills such as co-operation, group decisions and turn-taking. However, teachers may be making a virtue of necessity in this respect.

One of the advantages of the use of computers is their flexibility which means that adaptations such as the introduction of dual-key control can be used selectively when required. The adaptability of hardware and the technological innovations that are in progress may anyway mean that issues such as dual-key operation are superceded. In particular, the development of networking facilities, in which the functioning of several computers is linked, offers the possibility of a range of beneficial social-interactive learning situations. In this case it will be important that such facilities are used for sound and fully developed educational reasons, rather than merely because they are technically feasible.

It is clear that the number of alternative potential interactive relationships between the computer, the child, his peers, and the teacher are enormous. It seems unlikely in the extreme that any one mode will prove to be the ideal, to the exclusion of all others. It may be that for some types of learning the one-to-one relation between a child and an interactive computer provides the optimum learning environment.

At a simple level the present findings may be most useful in demonstrating that children are not *disadvantaged* by working with their peers. The study by Light and Colbourn (1986) demonstrated that there was no significant difference in what was learned according to whether children worked in pairs or groups of four on a programming task. All such studies contribute to the total picture of the importance of task circumstances in influencing learning outcomes.

A report on the current status of psychological research in primary education (B.P.S. 1986) argues that systematic exploration of variation in performance with alteration in task and social context would inform teachers in ways which might promote pupil learning and enjoyment. It was argued that further research to explore how to bridge the gaps between the naive knowledge of the learner and the knowledge to be acquired is much needed. The present findings provide a reminder that an uncritical acceptance of the merit of peer-interaction in learning is premature.

VII.7. HOW SHOULD THE DEVELOPMENTAL PROCESS BE DESCRIBED?

So far the discussion has centred on the two tasks, on the factors of influence in peer-interaction, and on the significance of the findings in relation to both previous theory and practical application. If the debate is now returned to a theoretical level, there remains an argument regarding the way that theorists describe the cognitive processes that they investigate. Comparison of different views is sometimes made difficult because of the lack of common agreement as to the most appropriate language, which is of course in part determined by the theoretical basis of the debate. The use of terms such as 'cognitive structure' fits naturally in studies of Piagetian milestones such as conservation. However, when the investigation moves to tasks having no specific relation to Piaget's theory, then the terminology to be used becomes more problematic. This has already been touched upon earlier in this discussion. Much peer-interaction research rests uneasily on the Piagetian assumptions that underlie the language used to describe the processes involved. Specifically, when measures of generalisation are lacking, or when tasks such as the Tower of Hanoi are used, then debate in terms of structures are arguably inappropriate. Notions of metacognition are similarly problematic.

One trend has been an increase in the use of the concept of strategies as a means of avoiding the static overtones of cognitive structures. For example, Kuhn (1978) has argued that the development of strategies is *the* process of development. However, the present use of the concept is varied and imprecise. The process-orientated flavour is appealing but it is far from clear at what level of abstraction the notion of strategies is pitched.

To clarify the discussion I suggest the use of an intermediate construct - that of cognitive tactics. The distinction between a strategy and a tactic in my usage corresponds with the dictionary definition (Oxford English Dictionary 1976). A strategy is defined as the art of a commander in chief: the art of projecting and directing the larger military movements and operations of a campaign. It is usually distinguished from tactics, which are the art of handling forces in battle or in the immediate presence of the enemy. In developmental terms, tactics may be seen as cognitive processes that underlie performance, but that are specific to a particular task situation. The idea of cognitive tactics therefore resides between the extremes of cognitive structures and overt behaviour; the social/environmental element is therefore written into the concept, rather than being an external variable. For example, in the balance task, rather than suggesting that the children have changed their strategy, it may be more appropriate to view them as having refined their tactics. In this way the gain in understanding is not given unjustified status. What has been discovered relates to the balance task alone, unless and until its relevance to other task circumstances is put to the test.

The notion of tactics would be useful to differentiate the levels of understanding described by Donaldson (1978). She has investigated the contextual determinants of cognitive task performance and envisages the child as gradually becoming able to deal with issues without specific contextual support. So the developing child first struggles free from himself, then struggles free from the social and verbal context. The adult can be seen as increasingly free from contextual limitations, although he may also on occasions be increasingly constrained by expectations born of prior experience. The concept of tactics would be most applicable to the intermediate stages of this process.

An alternative and more radical approach to that of Donaldson is the view of Walkerdine (1982) who regards concepts of a pre-social individual and a preformed social world as theoretically inadequate. In this view contextualisation is seen as inevitable. The dilemma of whether the subject achieves freedom from contextual constraints is solved by arguing that there is no pre-existing subject to liberate, and they suggest that asserting the importance of context conceals the truth rather than explaining it. For example, Walkerdine states her case as follows:

> *"I want to challenge the assumption that context can be seen as an effect that can be welded onto a Piagetian edifice..the context is not a separate system - not external to signification: context regulates signifying relations themselves". (Walkerdine 1982, page 130).*

The notion of tactics, although clearly not so radical in intent, goes some way to recognising the inadequacy of much of the current debate that maintains a separation between cognitive states and the context in which they occur. It recognises that thinking may be not DE-contextualised, but rather RE-contextualised. For example, the apparently abstract thinking achieved in the classroom may be restricted to that specific environment.

An advantage of the concept of tactics is that it allows the notion of strategy to be restricted to cognition evidenced in a wider context. Using this model, many experiments which purport to find evidence of strategies in children's thinking would be better described as producing evidence of tactics: a post-test that merely repeats the context of the training session is arguably not measuring a strategic ability. For example Glachan describes children who complete the Tower of Hanoi in eleven moves as having an eleven-move strategy. If Glachan's strategists were redescribed as using an eleven-move tactic, this would make clear that on the basis of his findings he was discussing performance in a particular context. My complaint is that in describing such understanding as a strategy Glachan may attribute sophistication to the child's thinking that is unwarranted.

In using the concept of tactics to describe the cognitive state assumed to underlie performance one is making a more limited and therefore more *accurate* claim. The need for caution is recognised elsewhere: Simon (1975) argues that what he describes as strategic behaviour cannot necessarily be assumed to indicate the possession of strategies by the child. Similarly, Kuhn (1974) points out that in conservation tests, children may repeat their conservation judgements in a later post-test because they are in the same situation. Such a level of understanding would be better described as tactical rather than strategic.

The debate on metacognition is clearly concerned with the same issues and is hampered by arguments as to what constitutes metacognition as opposed to cognition. A too simple division fails to reflect the complexity of human thought, and fails to consider the possibility that the same concept may have either a cognitive or a metacognitive role according to circumstances. Other theorists make similar observations, for example Stone and Day (1978) talk about 'levels of availability'. They develop a description of the underlying cognitive state of subjects at each level of strategy availability.

It may appear that the use of a distinction between tactics and strategies ignores the complexity of cognitive states as indicated by, for example, Stone and Day. However, this does not have to be so, if it is recognised that strategic knowledge at one level may be tactical knowledge at another level. In other words, low level strategies may enable the child to develop an effective tactic for a relatively complex task. In this sense there may be an infinite number of embedded layers of understanding. In functional terms, strategies are restricted to automated patterns of understanding that can be consciously manipulated. In other words, 'higher level' refers to the level of abstraction rather than the subject matter of the concept.

In relation to the present findings, the concept of tactics merely provides a way of acknowledging the changes in cognitive states that can be assumed to underlie performance differences, without a tendency to overstate such changes or to 'dress them up' into fundamental statements about cognitive development.

VII.8. CONCLUSIONS.

The spur to this research programme has been the strong claims made by some workers in the area of social cognitive studies regarding the crucial role of peer-interaction in cognitive development. It has been suggested (eg. Doise and Mugny, 1984) that there is a causal and necessary relation between social conditions of learning and children's logical development.

> *"It is in the very co-ordination of his actions with those of others that the individual acquires mastery of co-ordinations which are later individualised and internalised.. co-ordinations between individuals are the source of individual co-ordinations, and the former precede and produce the latter"*. (Doise and Mugny, 1984, page 23).

Does the evidence of the present studies support the social-determinist line? The short answer is that it does not. However, a counter-assertion made in similarly strong terms would be equally inappropriate. Nothing in the findings reported here makes it reasonable to deny, absolutely, the importance of social processes in learning, nor would common sense support such an assertion. In the light of the results reported here, it seems clear that the limitations of *particular* studies in relation to the wider universe must be respected. The present findings demonstrate the extent to which a specific task situation creates a specific environment for the child and leads to a specific outcome.

Global claims made on the basis of limited evidence depend heavily upon the representiveness of both the population sample and the experimental task, and this raises the question of whether there is such a thing as a truly representative sample or representative task in developmental psychology. At one extreme it can be argued that every situation has a unique character that makes it dissimilar to all others; at the other extreme it has been suggested that a common principle or identifiable mechanism underlies all learning situations and determines the pace of cognitive development. The conclusion to be drawn from the present studies is that within this spectrum previous workers may have leaned too far towards the latter extreme and, that in the light of evidence available, a more tentative view of the importance of peer-interaction is required. Perret-Clermont and Schubauer-Leoni (1981) have already made the same point, that in developmental psychology global and universal models are erected inappropriately, and they similarly plead for a more cautious approach.

An overready acceptance of the generality of findings consists, in effect, of taking insufficient account of the specificity of the context of learning. This seems to be encouraged by the language used to discuss children's progress. In particular, the concepts of 'cognitive structures' and 'cognitive strategies' - the abstract entities that operate within the child - encourage a detatchment from context. To counter this tendency, a means of discussing the child's internal processes that draws attention to their contextually limited nature has been proposed. It has been suggested that the level of debate should be made explicit by the introduction of the concept of cognitive tactics. The necessity for such clarification is demonstrated by the deterministic stance of Doise et al. Previous work, that has tended to be pursued in the context of large-scale theoretical polemics such as Piagetian social process or social learning theory, may have led to the case being overstated.

There is a sense in which interest in the importance of peer-interaction has moved arenas and in doing so may have lost its way. It started as a theoretical debate at an abstract level regarding the way child development should be conceptualised. In seeking an answer to this question, the importance of social processes in cognitive development became centre stage. The limitations of investigations of 'social' factors in tightly constrained circumstances became increasingly recognised, as did the limitations inherited from a Piagetian conception of what it is that should be measured. The conservation task studies gave way to spatial tasks, mathematical tasks and problem-solving, and this change of gear has arguably led to the boundary of such debate. Beyond this point, the issues it addresses become - by anybody's standards - simplistic. It is inviting criticism to discuss the importance of peer-interaction as a unitary phenomenon, because, as social psychologists are well aware, this social element embraces a multitude of possible influences eg. the role of sex differences, attitudes, previous relationships etc.

Ultimately, the importance of these ideas lies in their application. If Piaget's notion of invariant stages and structures leads educationalists to concentrate on the individual, without regard to the importance of social factors in learning, important aspects of the child's world may be ignored. If, on the other hand, no account is taken of the limitations of children' performance due to basic developmental deficits, then entirely unrealistic educational targets may be set. Between these extremes there is a potentialy fruitful pragmatic approach to child development which recognises the child as an individual, but as an individual who is always in some specific context. In this light the concept of tactics may be viewed as comparable to the idea of pragmatics in language studies. In that field there is a growing recognition of the need for peaceful co-existence between different levels and type of explanation. There seems no reason in principle why alternative perceptions cannot similarly co-exist in developmental studies.

In discussing issues at a general level many specific questions have necessarily been ignored, some of which could form the basis of future work. One such issue, worthy of further study, is the extent to which alteration in the level or type of feedback affected performance. A measure of the relative importance of intra- and inter-individual conflict could be created using a balance task in which no feedback was given.

At a more general level, and in relation to education, the most important determinants of children's progress may be relatively diffuse social considerations. It may be that schooling is most valuable in generating long-term interaction patterns, the benefits of which may not be captured in a short-term intervention study, and there may be a need to return to longer term studies. Light and Colbourn (1986) have conducted one such study. This form of investigation may identify factors that in practice dominate in the natural environment, rather than identifying spurs to progress that are only relevant to short-term studies. All the present studies departed from normal classroom practice in using random allocation to conditions, and within the paired conditions random allocation to pairs. The choice of pairs took no account of children's relationships with each other and a powerful potential factor of influence was therefore removed from the experimental situation. This could be the subject of further investigation, and a start has been made (Light, Foot, Colbourn and McClelland, n.d.). It has been argued (Papert 1980) that the micro-computer offers more than just a different medium of learning, that it offers new and qualitatively different possibilities as a learning environment. Claims such as this will continue to be a spur to research.

There have been two main strands to this thesis. One has been a concern with theoretical issues regarding the process of cognitive development and how it should be characterised. The second strand has been the practical questions that surround the introduction of micro-computers into the classroom. The same conclusion is pertinent to both strands, namely that views need to be formulated tentatively and with respect for the limitations of the evidence.

SOURCE	DF	SS	MS	F	P
GROUP (INDIVIDUALS x PAIRS)	1	.303	.303	.052	-
STRATEGY (STRATS x NON-STRATS)	1	83.919	83.919	14 277	.001
STRATEGY BY GROUP INTERACTION	1	2.705	2.705	.460	-
ERROR	52	305.665	5.878		
TEST (PRE x POST)	2	408.118	204.059	69.709	.001
STRATEGY BY TEST INTERACTION	2	153.282	76.641	26.181	.001
GROUP BY TEST	2	.391	.195	.067	-
3-WAY INTERACTION	2	3.492	1.746	.596	-
ERROR	104	304.441	2.927		

EXPERIMENT 1: ANALYSIS OF VARIANCE TABLE FOR OVERALL FINDINGS.

SOURCE	DF	SS	MS	F	P
GROUP (INDIVIDUALS x PAIRS)	2	4.358	2.179	.427	-
STRATEGY (STRATS x NON-STRATS)	1	207.338	207.338	40.672	.001
STRATEGY BY GROUP INTERACTION	2	29.897	14.948	2.932	-
ERROR	54	275.284	5.098		
TEST (PRE x POST)	2	254.591	127.295	20.065	.001
STRATEGY BY TEST INTERACTION	2	178.717	89.359	14.085	.001
GROUP BY TEST INTERACTION	4	14.719	3.680	.580	-
3-WAY INTERACTION	4	14.779	3.695	.582	-
ERROR	108	685.181	6.344		

EXPERIMENT 2: ANALYSIS OF VARIANCE TABLE FOR OVERALL FINDINGS.

SOURCE	DF	SS	MS	F	P
GROUP (INDIVIDUALS x PAIRS)	2	19.104	9.552	1.721	-
STRATEGY (STRATS x NON-STRATS)	1	214.866	214.866	38.716	.001
STRATEGY BY GROUP INTERACTION	2	13.425	6.713	1.210	-
ERROR	54	299.686	5.550		
TEST (PRE x POST)	1	294.650	294.650	56.691	.001
STRATEGY BY TEST INTERACTION	1	153.039	153.039	29.445	.001
GROUP BY TEST INTERACTION	2	7.859	3.930	.756	-
3-WAY INTERACTION	2	1.221	0.611	.118	-
ERROR	54	280.662	5.198		

EXPERIMENT 2: ANALYSIS OF VARIANCE TABLE: PRE-TEST AND POST-TEST (1ST TWO TRIALS ONLY).

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	2	8.550	4.275	0.322	-
ERROR	57	756.075	13.265		
TEST (PRE x POST)	1	78.408	78.408	18.900	.001
TEST BY GROUP INTERACTION	2	0.617	0.308	0.074	-
ERROR	57	263.475	4.148		

EXPERIMENT 3: ANALYSIS OF VARIANCE TABLE: 18 TRIAL DATA.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	2	2.467	1.233	0.170	-
ERROR	57	413.000	7.246		
TEST (PRE x POST)	1	17.633	17.633	7.958	.01
TEST BY GROUP INTERACTION	2	4.067	2.033	0.918	-
ERROR	57	126.300	2.216		

EXPERIMENT 3: ANALYSIS OF VARIANCE TABLE: CONFLICT-WEIGHT DATA.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	2	0.067	0.033	0.028	-
ERROR	57	68.400	1.200		
TEST (PRE x POST)	1	2.133	2.133	6.468	.05
TEST BY GROUP INTERACTION	2	0.067	0.033	0.101	-
ERROR	57	18.800	0.330		

EXPERIMENT 3: ANALYSIS OF VARIANCE TABLE: SIMPLE DISTANCE TRIALS.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	3	10.850	3.617	1.232	-
ERROR	76	223.050	2.935		
TEST (PRE x POST)	1	52.900	52.900	19.041	.001
TEST BY GROUP	3	1.950	0.650	0.234	-
ERROR	76	211.150	2.778		

EXPERIMENT 4: ANALYSIS OF VARIANCE TABLE: CONFLICT-WEIGHT DATA.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	3	43.919	14.640	1.538	-
TASK (MICRO x WOOD)	1	11.556	11.556	1.214	-
GROUP BY TASK INTERACTION	3	29.619	9.873	1.037	-
ERROR	72	685.350	9.519		
TEST (PRE x POST)	1	170.156	170.156	24.167	.001
TEST BY GROUP INTERACTION	3	15.519	5.173	0.735	-
TEST BY TASK INTERACTION	1	1.056	1.056	.150	-
3-WAY INTERACTION	3	7.819	2.606	.370	-
ERROR	72	506.950	7.041		

EXPERIMENT 4: ANALYSIS OF VARIANCE TABLE: OVERALL FINDINGS: 18 TRIAL DATA

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	2	9.217	4.608	0.389	-
ERROR	57	676.075	11.861		
TEST (PRE x POST)	1	75.208	75.208	26.515	.001
TEST BY GROUP INTERACTION	2	10.617	5.308	1.872	-
ERROR	57	161.675	2.836		

EXPERIMENT 5: ANALYSIS OF VARIANCE TABLE: 18 TRIAL DATA.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	2	0.617	0.308	0.092	-
ERROR	57	190.350	3.339		
TEST (PRE x POST)	1	24.300	24.300	10.610	.01
TEST BY GROUP INTERACTION	2	0.150	0.075	0.033	-
ERROR	57	130.550	2.290		

EXPERIMENT 5: ANALYSIS OF VARIANCE TABLE: CONFLICT-WEIGHT DATA.

SOURCE	DF	SS	MS	F	PROB
GROUP (CONDITION)	2	2.217	1.108	0.200	-
ERROR	57	316.250	5.548		
TYPE OF TRIAL (ADD x NON-ADD)	1	572.033	572.033	45.542	.001
CONDITION BY TRIAL INTERACTION	2	21.017	10.508	0.837	-
ERROR	57	715.950	12.561		

EXPERIMENT 5: ANALYSIS OF VARIANCE TABLE: POST-POST-TEST DATA: ADD/NON-ADD TYPES OF TRIAL.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	3	9.550	3.183	0.322	-
ERROR	76	751.350	9.886		
TEST (PRE x POST)	1	105.625	105.625	18.767	.001
TEST BY GROUP INTERACTION	3	25.625	8.542	1.517	-
ERROR	76	427.750	5.628		

EXPERIMENT 6: ANALYSIS OF VARIANCE TABLE: ALTERNATIVE BALANCE DATA.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	3	43.875	14.625	0.901	-
ERROR	76	1233.500	16.230		
TEST (PRE x POST)	1	65.025	65.025	10.225	.01
TEST BY GROUP INTERACTION	3	18.675	6.225	0.979	-
ERROR	76	483.300	6.359		

EXPERIMENT 6: ANALYSIS OF VARIANCE TABLE: 18-TRIAL DATA.

SOURCE	DF	SS	MS	F	P
GROUP (CONDITION)	3	2.163	0.721	0.081	-
ERROR	76	674.025	8.869		
TEST (PRE x POST)	1	5.000	5.000	1.048	-
TEST BY GROUP INTERACTION	3	9.225	3.075	0.644	-
ERROR	76	362.775	4.773		
APPROPRIATENESS OF USE	1	23.113	23.113	3.397	-
APPROP. BY GROUP INTERACTION	3	11.763	3.921	0.576	-
ERROR	76	517.125	6.804		
TEST BY APPROP. INTERACTION	1	105.800	105.800	22.220	.001
3-WAY INTERACTION	3	15.325	5.108	1.075	-
ERROR	76	361.875	4.762		

EXPERIMENT 6: ANALYSIS OF VARIANCE TABLE: USE OF ADDING STRATEGY.

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