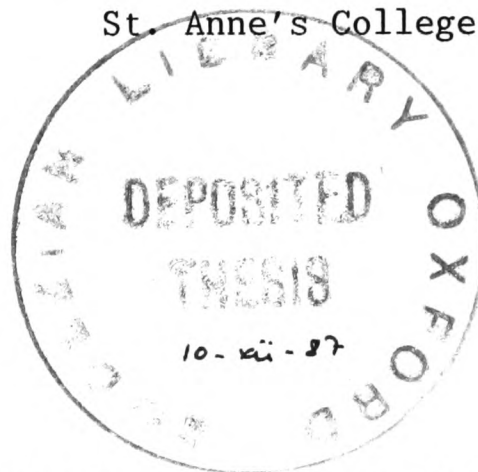


CAUSES AND ASSOCIATIONS - A DEVELOPMENTAL INVESTIGATION

Prajnaparamita Das Gupta

St. Anne's College



A thesis submitted for the degree of Doctor of Philosophy
in the University of Oxford, Trinity Term, 1987

for my father

with many thanks for introducing me to the subject

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Abstract

This thesis explores preschoolers' use of causal-associations (associations between specific instrument and effects) and causal relations incorporating knowledge of transformation from initial to final states.

Gelman, Bullock and Meck (1980) claimed that preschoolers use causal relations. However, in their study it was possible to make correct choices using causal-associations. Therefore, in Experiments 1 and 2 tasks were designed to distinguish between use of the two relations. Preschoolers made inferences about instruments which could produce the transformations depicted within event sequences (based on those used by Gelman et al.). Performance on tasks requiring selection of causal relations was significantly worse than performance on tasks where causal-associations could be used. Two methods of reasoning, Relational (causal) and Associative-Causal Matching, were identified.

Modified versions of the tasks in Experiment 1 were used in Experiments 3, 4 and 5. Four-year-olds were more proficient at using Relational Methods than 3-year-olds although both ages demonstrated the ability to use this method.

In Experiment 6 children had to construct sequences. Three-year-olds preferred associative constructions to causal ones. This preference may have influenced their performance in the previous experiments. Experiments 1, 2, 3 and 5 incorporated sequences with compound end-states (e.g. wet & broken cup). Three-year-olds clearly preferred to focus on just one of these attributes, chosen on the basis of salience. This preference evidently contributed to their lower scores throughout these experiments. However, even when relative salience was controlled (Experiment 7) or when single attributes were used (Experiment 4) 3-year-olds' performance was worse than 4-year-olds' in terms of choices based on causal relations.

These experiments indicate that preschoolers use both Associative-Causal and Relational Methods. There is evidence for a shift from a preference for judgements based on associative relations to a preference for causal relations between 3 and 5 years. The ability to deal with compound features also appears to develop over the preschool years.

Note This thesis contains approximately 98,000 words.

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ABSTRACT

This thesis investigates the interrelation between causal and associative knowledge. The central question is whether an understanding of causality is totally divorced from associative knowledge.

Different philosophical viewpoints about the nature of causes and associations were examined in Chapter 1. This led to a distinction being drawn between causal-associations and causality as a transformational relation. Such a distinction appears not to have been made before. Comprehension of the causal relation must incorporate a notion of transformation from an initial to a final state. Causal-associations can be made on the basis of associations between instruments and effects. Although causal-associations share some characteristics of the causal relation (they are undirectional and involve some knowledge of the causal powers of objects) they need not imply a relation between the beginning and end state of a particular object in terms of transformation. The importance of such a relation for comprehending causality as an objective relation was outlined in Chapter 1. It was concluded that a basic understanding of causality may comprise both associative and relational (causal) knowledge. A distinction was also made between causal-association and association. Ordinary associations are multi-directional and may be based on similarity, contiguity etc. but do not incorporate any notion of production

A review of the literature on the development of notions of physical causality, in Chapter 2, showed that the causal/associative distinction had rarely been addressed directly. Most research either dichotomised or ignored this distinction. Whereas some studies focused on children's acquisition of Humean principles of causality (contiguity, priority and constant conjunction) without clarifying whether they accepted his basic premise that causation was a special instance of association, others focused on the understanding of causality as a generative relation without clarifying whether there was any associative basis for such knowledge. Studies which deal with the direct perception of causality (Michotte, 1963; Leslie and Keeble, 1987) indicate that causal reasoning must involve more than a system of associative causal links. One study which focused on how children reason about causality (Gelman, Bullock and Meck, 1980) concluded that preschoolers' understanding of causal relations was not based on memory for contiguously associated events. However, the authors did not clarify the difference between causation and association. Correct responses could be made by using causal-associations in their study. Experiment 1 was designed to find out whether preschoolers used causal-associations to deal with such sequences.

Experiment 1 (Chapter 3) investigated preschoolers' (3- and 4-year-olds) abilities to deal with causal event sequences which necessitated, for their understanding, the imposition of a causal relation between beginning and end states of objects (Experimental Condition). Three-element event sequences, based on the Gelman et al. sequences, were created to show an object in one state (Wet Cup) transformed to another state (Wet BROKEN Cup). Children were asked to choose the instrument responsible for the transformation (from

the initial to the final) state from an array of three choice-instruments. In the Experimental condition children had to relate beginning and end states to find out which transformation occurred in the sequence. The Control Condition was similar to Gelman et al.'s because correct responses could be made on the basis of causal-associations.

No significant difference was found between 3- and 4-year-olds in the Control condition, but the older children had significantly higher scores in the Experimental condition. Although 3-year-olds' scores were significantly above chance in both Conditions, they did far better in the Control than in the Experimental condition. Three-year-olds made a large proportion of associative-causal errors in the Experimental Condition. An incidental finding was that these children made significantly more correct choices of instruments for Salient transformations than for Non-salient ones in this Condition. (Salience was defined as a dramatic change from the standard form of an object (eg. broken or cut). Non-Salient changes altered objects less dramatically, without affecting the normal function of objects. (Independent raters coded all sequences in terms of salience. There was 90-100% agreement between raters).

Two methods of reasoning in causal sequences were suggested on the basis of these results: the Relational Method (causal) which requires use of transformational information and the Associative-Causal Matching Method which requires an ability to match appropriate instruments to given effect. This can be done on the basis of causal-associations between instrument and effect.

In Experiment 2 (Chapter 4) sequences from Experiment 1 were extended (Cup--1--> Wet Cup--2--> Wet BROKEN Cup) to control for any confusion that might have arisen from presenting an object

in an altered first state. Only the second transformation necessitated use of a Relational method. Both 3- and 4-year-olds made significantly more correct responses for the first transformation than the second.

Comparison of correct-scores on the second transformation (Experiment 2) with correct-scores in Experiment 1 showed that performance was still worse than on the Control (Experiment 1). However, extension of sequences improved performance on the relational task: significantly more correct responses were made on the second transformation than on identical sequences in the Experimental condition (of Experiment 1). Nevertheless, the overall pattern of results in both experiments was identical. Older children did significantly better than younger ones only when use of a Relational Method would produce correct choices. These results provided some support for the two methods proposed.

Although 3-year-olds' responses were above chance expectations they still made very few correct choices in comparison to older children. This finding raised questions about the materials used in Experiments 1 and 2. It was suggested that younger children may find it difficult to deal with the two end states presented, especially if they prefer to focus on end states and do not consistently relate beginning and end states. The finding that salient transformations elicited more correct choices than non-salient ones suggested that children focus on salient states. These possibilities were investigated in Experiments 3, 5(ADD task) and 7.

In Experiment 3 (Chapter 5), sequence information was eliminated. Children (3-4 years) were presented with compound end states in the Experimental condition (Wet Broken Cup) and single end states in two Control Conditions and again had to choose appropriate

instruments of transformation. The Controls were (1) Salient (Broken Cup) and Non-Salient (Wet Cup). All the children made near ceiling correct responses in the Controls. Although there was no significant difference between older children's scores in the Experimental and Control conditions, 3-year-olds had significantly lower scores in the Experimental. The two ages also differed significantly only in this Condition. Children's errors in the Experimental condition mostly took the form of choosing a single instrument to account for the compound states. Younger children made far more Salience errors (choice of instrument for the more Salient of two states) than older ones.

Experiment 5 (Chapter 7) gave children (3-4 years) the opportunity to 'add' or integrate two features within a sequence (ADD task). In case selecting two separate photographs had been difficult for young children, a JOINT choice was offered (two instruments in one photograph). Again older children made far more correct choices than younger ones. The younger children's correct (JOINT) responses could have arisen by chance. These results suggested that only older children consistently integrate both features. However, the salience factor could have influenced choices. Younger children's errors were mostly choices for single salient states.

Experiment 7 (Chapter 9) was designed to investigate children's abilities to deal with two features when salience was controlled. The two "features" in this task (planks) were perceptually identical. The task was also a more active one, in that children were required to make something happen (fill a sandbox) rather than make judgements about past events. To fill the sandbox they had to distinguish and remove the plank/s which obstructed the progress of sand into the box. The results were identical to those

of previous experiments. Older children solved the problem significantly faster than younger ones when two features were involved (TWO PLANK condition). There was no significant difference between ages on the Single plank condition so the task was not intrinsically difficult.

The results of these three experiments (3, 5, 7) imply that an ability to deal with multiple features may be developing over the preschool years. Even when there is no potentially distracting salience information 3-year-olds prefer to deal with single features.

In Experiments 1 and 2, use of a Relational method and feature integration were intertwined. **Experiment 4** (Chapter 6) was designed to investigate whether preschoolers use the Relational method more consistently when no integration is required. To avoid the possibility of associative-causal matching yielding correct responses, the sequences in the Experimental (Relational) condition were designed to show a reversal of change (Wet Cup ---> Cup [dry]). Only use of a Relational method would produce correct responses. The cause of the transformation could not be inferred by matching instruments to final states as no marked end-state was present. The Control Condition contained sequences in which a Matching method would yield correct responses (Cup ---> Wet Cup). The scores of both age groups were above chance expectations in both conditions. However, only the younger children made significantly more correct responses in the Control than in the Relational Condition. The two age groups only differed significantly on the Relational condition. It was surmised that the inferior performance of the 3-year-olds compared to the older children arose from a preference for 'matching' rather than from a complete inability to make 'relational'

judgements.

Experiment 5 (Chapter 7) investigated preschoolers (3-4 year olds) performance on Matching (AC), Relational (DISC), and integration (ADD) tasks, in two conditions: INFERENCE and PREDICTION. Schmidt and Paris (1978) suggested that children were better at predicting consequents than inferring antecedents. Both age groups did best on AC tasks (in which a Matching method could be successfully used). Furthermore, contrary to Schmidt and Paris' findings, performance was best in the Inference condition. The types of errors supported the notion that younger children erred because they used a Matching method. It was concluded that, although both 3- and 4-year-olds can use both Relational and Matching Methods, the younger children err in using the Matching method inappropriately. Older children are much more consistent than younger ones in using the Relational method. It was proposed that younger children may prefer associative relations to causal ones.

Experiment 6 (Chapter 8) was designed to test this proposition. Children (aged 3-to-6 years) were asked to construct sequences given a starter photograph of an object and 4 choice photographs. They had to choose two photographs to complete a 'story' about the starter object. A verbal skills measure (BPVS) was also administered. Causal, Associative and Random structures were possible. The Causal structure included a transformation of the starter object and the instrument of transformation (Eg. Cup - Paint - Painted Cup). There were two conditions (Salient - which included salient transformations such as BROKEN; and Non-Salient - including transformations such as WET). These conditions were designed to test whether salient transformations would elicit more causal structures than non-salient ones.

The proportions of causal stories in both conditions were above chance expectations. Five-year-olds made more Causal stories than either 3- or 4-year-olds. The two younger age groups did not differ significantly in the number of causal stories made. All the children made significantly more causal stories in the Salient condition. It was also found that children with high verbal skills made more causal stories than those with low verbal skills. Three-year-olds made the greatest number of associative stories (AS - above chance expectations). Four-year-olds' AS stories were above chance only in the Nonsalient condition. AS stories made by 5-year-olds were significantly below chance expectations. The youngest group seemed to have a distinct preference for AS stories. The results of this experiment suggest a shift from a preference for associative structures to a preference for causal structures between the ages of 3- and 6-years.

In Chapter 10 a summary and integration of the experimental findings is presented. Limitations of experiments presented in this thesis are outlined and suggestions for further experiments are offered. The thesis ends with a brief discussion of the implications of present findings in relation to previous research on the subject. It is suggested that although the relational ability is separate from causal-association, specific causal-associations may be used within a relational framework. It is concluded that there is support for the notion that preschoolers have access to a number of rules or strategies for dealing with certain problems. What seems to develop is the ability to use these strategies appropriately and consistently.

CHAPTER ONE

1 CAUSATION AND ASSOCIATION - THEORETICAL BACKGROUND

1.1 Introduction

The notion of causation is an ancient one. In the mythology of most civilizations there is the idea of a First Great Cause which, or who, brought the universe, the earth and man himself into being. The search for causes of natural and unnatural events led to beliefs in entities who caused these things to happen. The culmination of this mode of thought was aptly expressed by the poet William Cowper:

"Nature is but the name for an effect

Whose cause is God."

The view that the concept of causation was a necessary pre-requisite of a rational universe was commonly held for centuries. Darwin's evolutionary theory however, dispensed with the need for a theology that traced causal sequences back to a first cause. Many post-Darwinian scientists and philosophers argued that the very notion of cause was unnecessary (Russell, 1946).

Nevertheless, although the term **cause** may rarely appear in current scientific treatises, the idea is implicit in :

"investigations into human affairs by economists, social psychologists, and historians; it is also pervasive in the accounts natural scientists give of their laboratory procedures as well as in the interpretations offered by many theoretical physicists of their mathematical formalism...In short, the idea of cause is not as outmoded in modern science as is sometimes alleged", (Nagel, 1965:12).

Causal thinking is not limited to the sciences however. The idea of cause is used implicitly or explicitly in everyday life. Causal

implications are present in statements such as : "the beaker broke when I dropped it"; or "Jane fell because she tripped on the carpet"; or "I cut my finger with the knife". In social and interpersonal situations inferences are made about the causes and effects of our own, as well as other people's behaviour. Such causal analysis is an integral and important of our daily functioning, for, as Kelly (1973:127) emphasised:

"Man's concern with reasons for events does not leave him lost in thought about these reasons. His causal explanations play an important role in providing his impetus to action and in his decisions among alternative courses of actions. When attributions are appropriate the person undoubtedly fares better in his decisions and actions than he would in the absence of causal analysis".

1.2 Causality and Causation

Causality is essentially a philosophical term which denotes "the abstract quality that links occurrence of some event or state contingent upon the prior occurrence of some other event or state", (Reber,1985:111). The term **causation** is preferred in psychology as it refers to the empirical principle that "for whatever effects are observed, there was a cause that preceded them" (ibid.). Fundamentally, both terms refer to the relation of cause and effect - a relation which seems integral to our understanding of the world. Knowledge of the causes of events not only help us understand and explain events but also enables the prediction, and sometimes the control, of those events.

The way in which children learn and use cause-effect relationships and the manner in which this process varies over age is an important topic both in developmental psychology and in education. As Ausubel and Schiff (1954:109) pointed out, the concept of the causal relation is not only important for understanding the environment, but is also "directly implicated in the learning of

school materials related to the physical, biological and social sciences."

DEFINITIONS OF CAUSALITY

There has been much debate about the nature of the abstract quality (causality) that links one event to another. A variety of definitions exist, but it is widely accepted (Sorokin, 1943:38) that they all fall into two distinct classes:

CLASS I - Causality is seen as a necessary relationship, "either objectively sustained by the variable or subjectively imposed by our minds as an a priori category"

CLASS II - No necessity is seen in the causal relationship. It is viewed as an "empirical, stable association of two or more variables".

Sorokin's two classes broadly define the two major theoretical standpoints regarding causation: the Generative theory (Class I), the Kantian approach; and the Regularity theory (Class II), the Humean approach. The Kantian approach sees the relation of cause and effect as the "productive, generative relationship between the antecedent condition and the subsequent effect" (Jaspars, Fincham and Hewstone, 1983:7). The Humean approach on the other hand denies that any knowledge of the causal connection can be verified and regards this relation as an impression arising from the constant conjunction of certain events in the environment.

1.3 Causality and Association

The concept of association has been closely linked with that of causality. Indeed much of the philosophical debate about the nature of causality has centred on the issue of whether the two notions are interchangeable, or whether causality is something more than association. This issue was greatly influenced by the way philosophers characterised the mind.

The doctrine of Association considerably influenced the development of psychology as a separate discipline, especially in relation to ideas about the nature of the mind. As McGinn (1982:83) points out:

"Philosophers have been prone to take one or other of the cognitive and conative aspects of mind as fundamental, downgrading the importance of the less fundamental side; and this has enabled them either to claim that the mind (by which they typically mean the human mind) is essentially passive and contemplative, its office being to reflect the world; or to claim that it is essentially practical, its office being to treat the world as a repository of human instruments".

The emphases chosen affects conceptions of the relation between the mind and the world. Opinions about the nature of the mind, which was seen as either active or passive, had a great influence on the development of ideas about causality.

In this chapter an attempt is made to trace the influence of these two views of mind on the shaping of concepts of causality. Sorokin's first class of definitions stemmed from conceptions of a more active mind than the second class, which saw mind as basically passive – a typically associationistic view. Psychological research on causation has generally adopted one of these two classes (implicitly or explicitly). McGinn (1982:83-84) however, emphasises that there are two sorts of relationships which the mind has with the world:

"The world is on the one hand, the object of our practical concerns and is accordingly viewed as instrumental in relation to our wants; but it is also the object of our disinterested representation, demanding to be depicted as it is in itself, independently of human ends."

He warns that philosophical systems which "emphasise only one side of the mind at the expense of the other" should be regarded with suspicion.

In view of this warning and the fact that psychological

literature on causation has not dealt specifically with the role of associations in causal thinking, the two most influential approaches to causality, the Humean and the Kantian, are also explored in this chapter. The associationist position on the nature of the causal relation is presented, as well as opposing positions, with a view to building up a picture of causality which integrates these various elements.

1.4 Different Pictures of the Mind

It is important to clarify the distinctions between notions of mind as being either passive or active. The empiricists denied that the mind was active in so far as they did not believe that the mind had any innate ideas or knowledge, and so, the mind could not contribute any independent, innate structures to the analysis of sensory data (i.e. the mind did not have any active input in cognitive processes). Nevertheless, the mind was active in that it processed sense data and organised them using certain principles, such as those proposed by Hume. Kant, however, believed that the mind had innate structures which it uses to organise and analyse sense experience. Thus, while the Humean view of mind is of a mind which processes a lot of sense data and organises them in terms of **observed regularities** in that sense data, the Kantian view of mind sees mind as acting on sense data by imposing its **innate structures** onto these data (i.e. it sorts the sensory input with reference to these structures). In this thesis, reference to the passive mind is reference to the viewpoint which denies any innate, or pre-existing input. The active mind, refers to the viewpoint that the mind has innate structures, which are not solely derived from observation of regularities, and which it uses to analyse sensory inputs.

1.4.1 THE ASSOCIATIONISTS: PICTURES OF A PASSIVE MIND

One of the earliest accounts of association was given by Aristotle. He distinguished three Principles of Association - Similarity, Contiguity, and Contrariety (or contrast) - essential for "recollection":

"Acts of Recollection...are due to the fact that one movement has by nature another that succeeds it in regular order. If this order be necessary, whenever a subject experiences the former of two movements thus connected, it will [invariably] experience the latter; if, however, the order be not necessary but customary, only in the majority will the subject experience the latter of the two movements. But it is a fact that there are some movements, by a single experience of which persons take the impress of custom more deeply than they do by experiencing others many times..."
(Aristotle: extract from De Memoria, 1931:451a - 452b)

This account clearly distinguishes between what I will call a 'pure' association (which is not a necessary but a customary relation), and what I will call a causal-association (which, because of the nature of the causal relationship implies a necessary succession, the effect occurring after the cause). The case for such a distinction being made is elucidated at the end of this chapter.

By the eighteenth century the empiricists had concentrated on Aristotle's principles of association and made it seem that these principles "afforded the essential and only key to an understanding of the development of mind", (Flugel and West, 1933:12).

The word "empiricism" comes from the Greek "empeiria", translated into Latin as "experientia", from which the word "experience" is derived. Empiricists held that "experience rather than reason is the source of knowledge" which led to the belief that knowledge "depends ultimately on the use of the senses, and what is discovered through them" (Hamlyn 1967:499). Such a framework does not leave very much room for the contribution of an active mind to

the development of knowledge. The processes of organisation were mirror images of sensations and the way they had been encountered in the environment. The views of some of the major proponents of empiricism are summarised here because association played a leading role in these accounts of mental organisation.

John Locke

John Locke opposed the doctrine of innate ideas. He saw the mind as a passive 'tabula rasa' on which simple ideas of sense made their imprints. In Locke's terminology idea was "the object of the mind when it thinks" (Brett, 1921:259). Although Locke insisted that all ideas derived from experience, he did not hold that sense knowledge was the only form of knowledge. He expressed a belief in "the active spiritual substance which intuits **relations** between ideas, the relations which form the foundations of our knowledge" (Locke, 1895/1975:324).

Locke differentiated between simple ideas which could not be broken down, and complex ideas which were linked temporally or synchronously. In his chapter on "Association", Locke emphasised the way ideas "cling together...in the nature of our complex minds" and attributes this to **habits** which are "but trains of motion...which once set agoing continue in the steps they have been used to, which, by often treading, are worn into a smooth path, and the motion in it becomes easy and as it were natural (Locke, 1895/1975:396).). This is "the central tenet of associationism" (O'Neil, 1968:26).

In maintaining that we have no knowledge of the real essence of things but only of their nominal essence, Locke introduced the idea of "powers": "as able to make or receive any change"

(1895/1975:234). He stated that "Power includes in it some kind of relation, a relation of action or change" (ibid). Our ideas of substances, according to Locke, are mostly those of powers: "the powers things have to affect us and each other" (in Hamlyn, 1967:502). In this, and in his entertaining the notion of an active 'substance' which intuitively relations, Locke differed from the more rigid empiricists of his day. The notion of power, as well as the notion of mental activity, have had a great influence on the study of causality.

Hume

David Hume, another major British Empiricist, believed that minds do not have ideas, they are ideas. Hume used the word 'idea' differently from Locke. For Hume, both ideas and impressions were types of perceptions, and a perception was whatever could be presented to the mind. An impression was seen as the "image of external objects conveyed to our senses" (Treatise 1738/1968 - Bk.I, 1:11). Ideas were "the faint images of these in thinking and reasoning" (ibid.). Impressions were more forceful and lively than ideas which were their pale reflections. Whereas Locke's account of reflection and sensation implied an internal as well as an external sense, Hume's new terms idea and impression, dispensed with this dualism leaving only perceptions of differing strengths.

Hume tried to account for the orderliness of experience using the principles of association but his view of association differed significantly from Locke's. According to Locke, association was a process of the passive mind, which produced trains of ideas when no active process was under way. Hume saw association as "a substitute for activity", and for him, "the self and its synthetic power [activity] were names for nothing but actual connexions

between ideas" (Brett,1921:273). In declaring mind as nothing more than its contents, Hume was able to "treat the order and connexion of the contents of the mind as the whole sum and substance of what others regarded as the activity of the mind" (ibid.).

Hume's influence on the study of causality is dealt with later. His picture of the mind greatly influenced the Associationists. It has been said that Hume claimed to be "the Newton of psychology" (Brett,1921:272). Indeed, it was within Hume's system that the principles of association first came to be considered as "scientific principles governing the working of the mind" (Peters and Mace, 1967:14).

James Mill

James Mill also rejected the idea of an active, creative mind. For Mill, mental life was composed of phenomena which were either sensory or ideational, simple or complex. The ideational derived from the sensory, and the complex from the simple. In "Analysis of the Phenomena of the Human Mind" (1869), Mill was primarily concerned with ideas and the associations of ideas. Essentially, he saw the mind as a mirror which simply reflected sensations and the general law of "Association of Ideas" expressed the order of occurrence of sensations, for : " Our ideas spring up or exist, in the order in which the sensations existed, of which they are the copies" (Mill, 1869, in Dennis 1948:142). In accordance with Hume, Mill equated the mind with associations. In his account, as O'Neil (1968:32) stated, "There is no mental agent. Nor is there any dynamic beyond association".

The principle of causation, one of the three principles postulated by Hume, by which ideas are associated, was summarily dismissed by Mill (in Dennis, 1948:153):

"Causation...is the same with contiguity in time, or the order of succession. Causation is **only a name** for the order established between an antecedent and a consequent; that is the established or constant antecedence of the one and the consequence of the other."

Thus, Mill reduced causation to a label for an observed order of events. The reason for this order was not explored. He agreed with the Humean analysis of causation: that causation is no more than an association engendered by the constant conjunction of contiguous events. For Mill, there was only ONE principle of Association - Contiguity. All other principles, even those of resemblance or similarity were reducible to it, as "we are accustomed to see like things together" (Mill,1869, in Dennis,1948:153).

1.4.2 THE RELEVANCE OF ASSOCIATION OUTSIDE THE RIGID ASSOCIATIONIST FRAMEWORK

Thomas Brown

James Mill and Condillac represented the extreme, mechanistic viewpoints of the Associationist position. This position however was mostly clarified by a man who was not an associationist. Thomas Brown believed in an active controlling ego and thus did not accept the picture of the totally passive mind drawn by Mill and others. Nevertheless, he adapted and extended the associationist viewpoint.

Substituting the term "suggestion" for association, Brown proposed two distinct principles of mental life:

SIMPLE SUGGESTION - association in the usual sense; and
RELATIVE SUGGESTION - a process which "accounts for the
creative aspects of the mind...[and] allows us to judge
and compare things..." (Flugel and West,1933:21).

The latter principle enables us to notice the relations between

things, later termed 'the eduction of relations' by Spearman. Brown did not elucidate the principle of relative suggestion which is by no means the same as traditional association. The ability to see relations however is crucial for comprehending the world. The principle of relative suggestion implied a creative mind, capable of judging and relating ideas. By stressing the creative abilities of the mind, Brown moved away from the common associationist conception of a passive mind. He did not however dismiss association as a way in which the mind organises its contents but attempted to show in detail why association occurs.

Brown's "Secondary Laws of Association" (in Flugel and West, 1933) outlined how certain principles (those of recency, frequency, duration, liveliness, and co-existence, as well as constitutional differences between individuals, variations in the same individual, and prior habits of life and thought) explained why associations took a particular course in any given case. The first 5 principles have been the subject of numerous experimental studies in memory. The importance of the latter ones, lie in the fact that they take into account individual differences and abnormal conditions, which had not been considered before. Thus, these last principles especially, took into account the input of the individual, implying that associations were affected by internal factors.

J.S. Mill

John Stuart Mill, while accepting the laws of association as laid down by James Mill, deviated from the traditional associationists in his treatment of the origin of 'complex' ideas. He argued that mental compounds were similar to chemical compounds and might, therefore, exhibit properties which could not be deduced from the properties of the single elements as: "...the effect of

concurring causes is not always precisely the sum of those causes when separate, nor even always an effect of the same kind with them..." (Mill, 1843:CIV)

J.S. Mill was thinking in terms of chemical reactions, and the quote above shows that he not only accepted that combinations of various causes could result in something totally different from any of them but also that different causes produce different effects. In suggesting that mental laws were analogous to chemical ones and that complex ideas, though generated by simple elements, were not composed of these elements, J.S. Mill accepted a more dynamic principle of combination than association. He also implicitly accepted the notion that specific causes, at least in chemistry, had specific effects. This is a point which will be of importance when considering the nature of the causal relation in the next section.

Although Mill talked about the generation of ideas, he did this within the framework of a passive mind. The mind itself did not have an input; the ideas, like chemical elements bonded together. However, in later work, Mill expressed doubts as to whether "even mental chemistry can adequately account for the generation of belief" a mental state which "implies something more than mere inseparable associations" (Flugel and West, 1933:64).

1.4.3 TOWARDS A DIFFERENT PICTURE OF THE MIND

There have been a variety of conflicting ideas about the nature and workings of the mind. One major dichotomy was between viewing mind as no more than its contents, which were passively associated ideas; and viewing the mind as being more than its contents. These contents were seen as only part of the whole mind,

relations between them being actively organised by the mind.

The recognition of the importance of activity began with Leibniz and "after being almost submerged by the wave of empiricism reappeared as an assertion of the rights of form against matter, and of the total life of the mind as against particular contents..." (Brett, 1921:327). Even philosophers in the empiricist tradition, such as J.S. Mill, questioned whether the principles of association were sufficient for understanding the nature of mind.

Leibniz, Kant and Hegel all greatly influenced German psychology from whence the major emphasis on mental activity originated. Kant, for example, insisted on an active self which organises experience using the categories of space and time but also accepted that experience was the foundation not only of knowledge, but also of psychological laws.

Kant

Kant made it clear at the outset of his "Critique of Pure Reason" that whilst agreeing with the empiricists that knowledge begins with experience, he did not agree that all knowledge is derived from experience itself. On the contrary, he argued that:

"Our empirical knowledge is made up of what we receive through our impressions and of what our own faculty of knowledge (senuous impressions serving merely as the occasion) supplies from itself. If our faculty of knowledge makes such an addition, it may be that we are not in a position to distinguish it from the raw material, until with long practice of attention we have become skillful in separating it." (Kant, 1787/1929, Critique I:42)

Kant sought to investigate *a priori* knowledge: knowledge that is independent of experience. Such knowledge, he argued, could either be "pure" or "impure". As he explained it:

"Pure knowledge *a priori* is that with which no empirical element is mixed up. For example, the proposition, 'every alteration has its cause' while an *a priori* proposition, is not a pure proposition, because alteration is a concept which can be derived only from experience" (Critique, I:43).

Kant firmly rejected the Empiricist notion that mind was simply ideas arising from experience, organised by the laws of association. He regarded the mind as "a structure regulated by principles which are ultimately its own activities", (Brett,1921:346). Kant argued that sensations are patterned, or ordered in the mind and this patterning arises from the mind NOT from sensations. All sensations are conceived in temporal and spatial terms. Since all our sensations are patterned in this way, it seems necessary for all our experience to be structured. Contrary to Humean claims, Kant argued, sensations in themselves could not supply any reason for their nature, or pattern.

As pointed out before, there are two very different notions of activity. One viewpoint sees an active mind as having a rich contributory structure (or content) of its own which it uses to organise sensory data. Those who, like the Empiricists, reject this structure, have to view the mind as active in another sense. Indeed, they have to view it as more active than the Kantian sense because the Empiricists conceive the mind as continually processing endless streams of sense data into some coherent order. Sensations in themselves do not supply any reason for their order; order is abstracted from their contiguity, similarity, or constant conjunction.

In view of this, Kant proposed 'FORMS' that people impose on experience. The German word is "*anschauung*", literally translated as "looking at" or "viewing". Space and Time in this account, were not concepts, but forms of intuition, ways of looking at experience. These forms, which were considered to have strong a priori elements, did not derive from experience, but were imposed by the mind on experience. For Kant, causality, like space and time, contained a largely a priori element (Lucas,1984).

Kant thus postulated an ACTIVE mind which imposed structure on sensations. The categories of substance, cause and effect, and continuity, were components of this structure and ordered and systematised sensations. There were four major categories: Quantity, Quality, Relation and Substance. Kant saw the categories as *a priori* notions which are the basis of knowledge.

Kant's analysis of causality will be discussed later on. His importance for the conception of mind lies in his rejection of the associationist picture of the passive mind and his postulation of *a priori* categories. As Brett so succinctly noted, before Kant, "the psychologist was not unlike a physiologist who tried to explain digestion without any reference to the organism as a process"; Kant was the first to question this and insist that "we must start from the mind to explain ideas, not from ideas to explain the mind" (Brett, 1921:346). This rejection of associationist doctrines was highlighted by Ward (1886, cited in Flugel and West, 1933) who pinpointed the limitations of Associationism. Though important as a mechanism by which the mind organised experience Associationism could not account for the unity or creativity of the mind. Rejecting the idea that the complexity of mind could be explained by "the combinations and recombinations of various elements...", Ward suggested that it was the result of "a gradual differentiation of a primary unit" (ibid). Such differentiation could only be the result of mental activity.

1.4.4 CONCLUSIONS

This brief survey of the different pictures of the mind (active or passive) shows that the rise and fall of the doctrine of Association had a profound influence on the different concepts of mind, especially with regard to the perception and integration of

experience. The concept of an active mind, also influenced ideas on causality because if the causal relation was not a principle of association, what was it? Why was it so powerful a notion? Hume had explained this in terms of constant conjunction, but this had been within an associationistic framework. With the rejection of that framework many notions had to be reanalysed, of which causality was one.

1.5 Utility of Concepts of Causation

The most general idea of cause is something which produces change and thereby accounts for it. This notion of cause is the focus of the present thesis. Traditionally, a cause was defined as:

"that which produces something, and in terms of which that which is produced, its effect, can be explained. That which is caused may either be a new substance or simply a change in something that already exists". (Taylor, 1967:56)

However, as Taylor (1967) noted, in modern science there has been a tendency to eschew causal concepts wherever possible, leading to a viewpoint held by scientists and philosophers that "the very concept of a cause is worthless..and replaceable by .. concepts such as concomitant variation, invariable sequence, and so on" (Taylor, 1967:57).

Modern science often does not use causal laws explicitly. However, as Lerner points out, although the "probabilistic trend of contemporary science reformulates the concept of causality", it by no means disposes of it. The Associationists tried to show that causality was simply a type of association, a correlation, or covariation of certain events. Correlational analyses stress the concurrence of variables without making any commitments about whether their relationship is causal or not. But, Lerner insists, "the causal question can be safely ignored" ONLY as long as "there

is no reason to doubt that the relationship between the variables is symmetrical" (Lerner, 1965:7).

When variables are interdependent, A is related to B in the same way that B is related to A. When two variables are causally related however, there is an ASSYMETRICAL relationship: A can cause B without B being able to cause A. When the joint occurrence of variables is "low or erratic, additional information is needed to eliminate the observed errors and to obtain a more accurate model of the relationship.."; One of the ways to do this, Lerner goes on to suggest, is to "test for a causal relationship - to show that the variables are connected, but not symmetrically.." (Lerner,1965:8).

Simon (1965), worked out a rigorous system of equations for determining when a causal relationship can be assumed between two variables, or groups of variables. Simon defined causality as "an asymmetrical relationship among certain variables, or subsets of variables, in a self-contained structure" (Simon,1965:159). He argued that the utility of the causal concept, should not be, and is not dependent on its use in science. Simon showed that the causal relation can be separated from others, such as correlation, by virtue of its asymmetrical nature. This is a very important feature of causality, and distinguishes the causal relation from relations which are symmetrical.

More recently, Mulaik (1987) has argued for a faceted definition of causality. Such a definition incorporates a notion of probabilistic causality in which:

"the values of the independent or causal variable do not determine the specific outcomes of the dependent variable but rather the specific (conditional) probability distributions with which the values of the outcome variable occur" (Mulaik, 1987:24).

Mulaik shows how such a definition of causality is applicable to

experimentation and causal modeling. Thus, although there has been a great deal of controversy about the nature of causation it is still seen as valuable as well as necessary. It is a notion that permeates our lives -

"the idea of causation is not only indispensable in the common affairs of life but in applied science as well. Jurisprudence and law would become quite meaningless if men were not entitled to seek the causes of various unwanted events...No one doubts that the battle against malaria began with the search for the cause of it, and measures taken against it have all been aimed at eliminating its cause or moderating its effects." (Taylor, 1967:57)

This brief survey attempted to highlight the fact that the utility of the causal concept is well established. The following sections examine different views of causation.

1.5.1 ARISTOTLE'S VIEW OF CAUSATION

Aristotle presented a very comprehensive analysis of causation, and this has been the base, as with so much else, of later developments in the understanding of this concept.

In Aristotelian terms, the word **cause** had a much wider meaning, than it has today, referring to anything contributing to "the constitution of a thing, whether it be that on which the thing depends or that in which it consists" (Hawkins, 1937:17). Aristotle defined four types of causes: efficient, formal, material and final. Of these, the first is nearest to the common use of the word cause for, as Hawkins points out, "it is with the nature of efficiency or production that the central problem of causality is concerned" (1937:17).

Aristotle emphasised the importance of change observed in the world and argued that the "the reality of change is a basic truth of physics" (in Hawkins, 1937:18) and is inducible from experience. When change occurs "a state of fact in which something

is not is succeeded by a state of fact in which that thing is, or vice versa" (Hawkins,1937:18). Aristotle also insisted that a changed state, an effect, or new thing, cannot just happen. Change is related to an underlying substance, or continuum, and "the previous situation must already bear some intelligible relation to that which will succeed it..." (ibid.:19).

The efficient cause is that which initiates and produces change. It is a conception derived from the notion of an agent, "of that which does or makes something" (ibid:26). Aristotle saw the cause as producing the effect, but Hawkins points out that "Production does not explain itself but asks for analysis" (1937:27). The problem of production, for Hawkins, is the fundamental problem of causality. As far as Hawkins (1937:28) is concerned Aristotle's causal theory "contains all the elements of a common sense view of causality, all the elements therefore to which a complete analysis must do justice".

1.5.2 TWO PILLARS OF CAUSAL THEORY

As we have seen, many of the Associationists regarded causality merely as one of the principles of association which had no empirical justification. David Hume was one of the major proponents of this viewpoint. Hume's analysis of causality not only awoke Immanuel Kant from his "dogmatic slumbers" but also led him to present an alternative analysis. Since most psychological research on the subject has been influenced by one or other of these viewpoints, they are summarised below.

(1) David Hume's Analysis of Causality

The framework for Hume's analysis has been described in the previous section (1.4.1). Hume proposed that ideas were "attrac-

ted" to each other because of:

- (1) their RESEMBLANCE to each other;
- (2) their CONTIGUITY to each other, in space and time;
- (3) their being in a relation of CAUSE AND EFFECT.

These principles are similar to Aristotle's outline of the principles of association. Hume (1740/1965) stated that "all reasoning concerning matters of fact are founded on the relation of cause and effect, and that we can never infer the existence of one object from another unless they be connected together..." (Abstract, 1740/1965:11). He tried to trace this 'connexion', the idea of causation, to its origin. Hume denied any necessary connection between cause and effect as well as the reality of the idea of power. He explained the necessity that people attached to the causal connection by postulating that as causes

- (1) precede their effects;
- (2) are contiguous to their effects, and
- (3) are constantly conjoined to their effects

so, "the mind, through custom, tends to pass from one to the other. The feeling derived from this, which is an impression of reflection, constitutes the feeling of necessity which we find in the causal connection" (Hume, in Kahn, 1967:503). Hume believed that the notion of 'power' arose from the constant conjunctions of certain events and the resulting uniformities that were perceived.

Having discovered no sense experience of causality, Hume concluded that when we thought of one thing being the cause of another, this was the result of habit. As Lucas (1984:24) puts it, for Hume, :

"Causal reasoning was nothing more than a conditioned reflex. From having often encountered one thing followed by the other, we got accustomed to expecting the latter whenever we saw the former; and this habit of mind expressed itself in a

belief that the one thing was the cause of the other."

Hume examined the importance of experience on the making of causal inferences. He conducted an experiment with billiard balls to investigate why the motion of the first was seen to be the cause of the motion of the second and concluded that:

"..were a man such as Adam, created in the full vigour of understanding without experience, he would never be able to infer motion in the second ball from the motion and impulse of the first" for "i. is not anything that reason sees in the cause, which makes us infer the effect." (Abstract, 1740/1965:13)

Therefore, we need experience of cause and effect to form associations, so that, for example, whenever we see one ball moving towards another we would conclude "without hesitation that the second would acquire motion" (Abstract, 1740/1965:13).

Such a conclusion, Hume argued, would be made because all reasoning about cause and effect is founded on experience, and reasoning from experience is founded on the presupposition of uniformity - "the supposition that nature will continue uniformly the same" (Abstract:14). This type of reasoning leads us to think that like causes will produce like effects, and that future events must conform to past events. Conclusions such as these stem from "custom". It is not by reason that we believe that the effect will be the same as in the past because :

"The powers by which bodies operate are entirely unknown. We perceive only their sensible qualities: and what reason have we to think, that the same powers will always be conjoined with the same sensible qualities?" (Abstract, 1740/1965:16)

The argument runs like this: since nothing is in our mind unless we have experienced it, the idea of a necessary connection must stem from experience. But we cannot find it in experience nor can we find an idea of power. Hence other things must be responsible for this such as constant conjunction in experience. It is

this that makes us believe that one thing causes the other. When several instances of two objects conjoined are considered, we immediately conceive a connection between them and begin to draw an inference from one to another (Treatise, 1738/1968). Hume argued that the source of our belief in necessity and power stemmed from such a "multiplicity of resembling instances". In his words:

"Necessity then is the effect of this observation and is nothing but an internal impression of the mind, or a determination to carry our thoughts from one object to another.." Experience "never gives us any insight into the internal structures or operating principles of objects, but only accustoms the mind to pass from one to another" (Treatise, 1738/1968:163).

Nevertheless, Hume struggled with the nature of this belief in the causal connection. In both the Treatise (1738) and the Abstract (1740) he devoted himself to analysing the nature of this belief. Although custom, not reason produces the conception that an effect will occur one not only conceives the effect but also believes that it will occur.

Hume saw belief as something more than a conception, for as regards the relation of cause and effect, we not only conceive that an effect will follow a cause, we also believe that it will. Hume concluded that "Whatever name we may give to this feeling which constitutes belief...it has a more forcible effect on the mind than fiction or mere conception" (Abstract:20). However, Hume was unable to analyse either the nature, or the source, of the belief in the causal relation adequately. This is a shortcoming of his thesis which stems from his denial of the empirical reality of the causal relation.

Hector-Neri Castaneda (1980) pointed out that most anti-Humeans, including Kant, adopted Hume's main tenets about the nature of the causal relation, that is, it involved temporal prior-

ity, contiguity, and constant conjunction. Their disagreements focused on "the origin of the concept of cause, the constitution of the mind that has a concept of causality, or in the most radical cases about the metaphysical source of causality" (Castaneda, 1980:81). Castaneda is not so much concerned with the necessity of the causal connection as with investigating what it is. Hume's analysis, he argues, did not account for the "performative" element which is subjective. People react differently, so while some may infer an effect from a particular cause, others may not do so, thus "what is causally related for one person, may not be so related for another." (ibid.:86)

Lucas (1984) makes a similar point. He argues that because Hume's account of human nature is of "passive percipients" not of active agents, Hume failed to take into account the fact that we learn by doing things, by a form of experimentation. As Lucas puts it:

Agents who intervene in the world around them, and attempt, not always successfully, to make nature conform to their own wishes, readily form the concept of natural necessity, and also have no difficulty in distinguishing causal connections from chance concomitances." In acting with the world we can distinguish between general concomitances and causal ones by a form of naive experimentation." Thus, "...Any coincidence or pre-established harmony, would thereby be disrupted, and only those concomitances that were due to genuine causal connections would be left". (Lucas, 1984:36)

Lucas emphasises the reality of the external world, and therefore the reality of the causal connection in the external world, even though it [the causal connection] is not a sensation. This is a very important distinction which changes causality from a passive relation of associations following certain principles, to an active, dynamic relation operating in the external world.

Castaneda stresses that the fundamental fact that we

live in one world "with one causal structure which is the ground of our communication and cooperation requires our claims about causal connection to be objective, or at least, deeply inter-subjective" (Castaneda,1980:84). The only way that this could happen, he argues, is if the Humean custom of connecting causes to effects were deeply ingrained in the mind. This of course presupposes some knowledge of the workings of the mind. Hume recognised this, as his musings about the nature of belief show, but "it was Kant who saw quite clearly what had to be done within the Humean framework" (ibid.:1980:86).

(2) Immanuel Kant and the Causal Relation

The Empiricists held that all concepts were either derived from, or reducible to, sensations. Kant, a Rationalist, rejected this viewpoint, maintaining that the Empiricists had confused experience with sensation. (A brief description of Kant's theoretical framework was presented in section 1.3.1.). Scruton (1982:26) succinctly explains Kant's position:

"Experience can provide the grounds for the application of a concept, because it already contains a concept...Sensation, or intuition, contains no concept, and provides grounds for no judgement. Until transformed by mental activity, all sensation is without intellectual structure, and...provides no ground for no belief."

Hume's analysis established a dichotomy between the sensations projected into mind by the external world, and the structures (such as the necessity of the causal relation) projected by the mind on the world. Indeed, the Humean analysis is very similar to the old Jewish proverb that - "We do not see things as they are. We see things as we are." Kant, however, postulated that we do see things as they are. Experiences can be understood "because they already contain within themselves the concepts which we supposedly derive from them" (Scruton,1986:26). The world is not, for Kant, a

"booming buzzing confusion" of sensations on which minds impose order; rather, the world is structured in a certain way, and minds are equipped to perceive these structures.

In the Kantian account experience is structured and pre-supposes certain concepts: these are the CATEGORIES. Categories are forms of thought which order and systematize sensations, making it possible to have knowledge of experience. Experience is already organised in accordance to space, time substance, and causality..."Hence there is no knowledge of experience that does not point towards a world of nature. Our point of view is intrinsically a point of view of an objective world" (Scruton,1982:28).

Kant attempted an objective deduction of Categories. This was based on the premise of self-consciousness. Self-consciousness implies the reality of the objective, for it is only in relation to the objective that experience can be ascribed to self. The UNITY of apperception consists in the awareness that various experiences all belong to self, thus, this unity of apperception is only possible in an objective world. Kant's arguments on this point are rather obscure, but these concepts are important for the deduction of the categories which are implied by the unity of experience. For example:

"If objects did not persist and past and present events were not causally connected, there would be no unity in the temporal series" ; and
 "If spatial objects did not interact, there would be no unity in space" (Kant, Critique of Pure Reason, 1787/1929).

Categories of substance and cause were central to Kant's discussion of objectivity. Kant tried to show that "causal relations are necessary, both in the sense that objects enter into them (there is no event without a cause) and also in the sense that they are themselves a species of necessary connection" (Scruton,1982:37).

Scruton, has singled two important theses in Kants's Analogies:

(1) Kant's insistence that all explanation of change requires the postulation of an unchanging substance. This is similar to the original Aristototelean conception and has influenced the doctrine of the unity of science. One version of this doctrine posits "a single law of conservation involved in the explanation of every change and hence a single stuff (for example, energy) whose laws of transformation govern the whole of nature" (ibid:38).

(2) Kant's defence of the doctrine that the "relation of cause to effect is the condition of the objective validity of our empirical judgements" (Critique, A 202, B 247). Only if we believe in the reality of the world, and "a realm of enduring things", can we discover how things really are, for things can only exist and change in an enduring world. For Kant, therefore, "Causality leads to the concept of action, this in turn to the concept of force, and thereby to the concept of substance" (Critique A 204)

The Category of Causality:

The Fifth Proof in Kant's Second Analogy is that :

"Precedent time necessarily determines subsequent time since I can only reach subsequent time by passing through the precedent" (cited in Ewing, 1938:158).

This implies that precedent events must determine the nature of subsequent events. Time itself cannot be seen directly, therefore it can only be perceived through the perception of changes. The perception of changes falls under the category of causality, which thus becomes necessary for our perception of time. As Ewing puts it:

"The experience of perception of the objectively sequent includes experience of the time order of our perceptions as necessitated (forced on us whether we will it or not) and therefore includes the conception of causality even though we may be quite in the dark as to what are the reasons of their having this time order." (Ewing, 1938:161)

Kant accepted that we are confined to a relational mode of thought. He held that "we must accept relation and change as basic principles of all our experience and thought.." (ibid). In considering the nature of change Kant recognised that power, or force was needed to generate change. In "Thoughts on the True Valuation of Active Forces" (reported in Ewing, 1924:24), he stated that

"the one inevitable result of the exercise of force was change in the internal state of the object on which it was exerted...motion was only one of the possible results of that internal change".

In accepting that objects held in themselves the power to affect other objects, by virtue of their nature, Kant's conception of causality differed from Hume's, which could see no necessity in the causal relation.

1.5.3 CONCLUSIONS

Hume's analysis of causality was made from an Empiricist standpoint and influenced largely by his view of the mind. He believed that the only source of knowledge was sense experience and having discovered no sense experience of causality, he concluded that the notion of causality was "not derived from any form of reasoning from any sense experience, but was the result of habit" (Lucas,1984:28). The major modification of this viewpoint was made by Immanuel Kant.

Kant accepted Hume's proposition that "our knowledge of causal connections between specific events is a posteriori and not a priori..". His disagreements with Hume arose because he did not accept that the concept of cause is simply the result of our experience of regularities. Kant maintained that though experience of the world was important for the understanding or knowledge of specific causes, people have to have a notion of causation (a priori causal

principles) in order to structure their perception of the world. Kant also did not deny the empirical reality of the causal connection. Thus, although the Kantian and Humean theories of causality (the Regularity theory, and the Generative theory as they have been called) do not stand diametrically opposed to each other, they differ on these two major points.

In some ways Kant's analysis can be thought of as a logical extension of Hume's. Kant agreed with Hume that knowledge of specific causal laws had to be derived from observation and experience. But whereas Hume argued that causal laws were not objectively valid, but are believed because of their regularity and through force of habit (that is, because of the uniformity of nature), Kant highlighted the dynamic nature of the causal relation and insisted that not only were causal laws valid, but also that they were more than "abstractions from repeated experiences with the world".

Kant (1787/1929) did not attempt to "prove causality in the sense of dynamic activity on the part of the cause" (Ewing, 1924:102). He did however, accept that change was generated by force, and recognised change as the most important feature of the causal relation. The dynamic nature of the cause, or causal agents, has been explored by other philosophers, perhaps most extensively by Harré and Madden in their book "Causal Powers" (1975).

1.6. The Notion of Power

Hawkins (1937) identified production, or the notion of the efficacy of the cause, as being one of the fundamental issues in any study of causality. Locke accepted the notion of power as being inherent in the causal relation. Hume, however, tried to eliminate this notion from the study of causation, insisting that it arose

from an observation of regularities and had no empirical basis. Thomas Reid, a contemporary of Hume's, reacted strongly against this proposition. He insisted that although the concept of power could not be explained in terms of other concepts, "the idea of the active power of a cause is everywhere presupposed in any description of deliberate and voluntary human behaviour" (in Taylor, 1967:56). This view was defended by A.E. Taylor (1903) who maintained that

"causes cannot be properly conceived except as things having the power or efficacy to produce certain changes in other things, and that it is this element of efficacy rather than any mere accident of temporal position that distinguishes causes from their effects" (in Taylor, 1967:65)

Taylor concluded that although the notion of efficacy, or causal power, was esoteric, there was no "obvious way of eliminating it from the concept of causation" (ibid:66).

Harre' and Madden (1975), in their analysis of the notion of power, clearly pit themselves against the Humean position and seek to "establish an alternative analysis which makes sense of science and common sense" (Harre' and Madden, 1975:4). They do this by introducing their central notion, the idea of a POWERFUL PARTICULAR. Causation, in their terms, "always involves a material particular that produces or generates something" (page:6).

Harre' and Madden locate causal power in the nature of things. Such power is neither occult nor mysterious, they stress, but based on the chemical, physical and genetic **nature** of things. They state:

"For us, those things and materials will be most fundamental, for which we may maintain, as an empirical hypothesis, that their natures are identical with their powers" (1975:6).

They show, for example, that definitions of the metal copper include its capacity to undergo changes (it is malleable), as well as its

power to act (it is conductive) and conclude that "capacities, just as much as powers, what particular substances are liable to undergo, as well as what they are able to do, are explained by reference to what the thing is in/itself". Therefore, "what particulars can do or undergo is determined by their natures" (pp.:12-13). For example, a knife cannot wet things, but water, by virtue of its intrinsic nature, can.

Having introduced the concepts of the natures and powers of things, which is perceived as complementary, Harré and Madden turn to what they call two of the main paradigms of action. The first paradigm supposes an external cause of action, "the intrinsic factor playing a wholly passive role". The second paradigm supposes an internal cause for action "the sources of which are to be found among states intrinsic to the agent" (p:83). The first paradigm has been considered empirical whereas the second one is seen as mysterious. When power is ascribed to a thing, it is more than a qualitative description (eg. it is red) it is a description of potential (eg. it is brittle - implying it is capable of breaking).

One of the major tenets of this thesis is that "the difference between something that has the power to behave in a certain way and something which does not have that power... is a difference in intrinsic nature" (Harré and Madden, 1975:86). This leads to ascriptions of powers to things:

"'X has power to A' means 'X will/can do A', in the

appropriate conditions, in virtue of its intrinsic nature."

Such an ascription, while not asserting any "specific Hypothesis about the nature of the thing", does imply an understanding of the "nature or constitution of that thing or material" (p:87).

Harré and Madden deal extensively and comprehensively

with the notion of causal powers using examples from physics and everyday life. They found no reason to reject their conception. Their main contribution, it seems to me, is that through their analysis they restore some empirical validity to the importance of power and production in the causal relation.

More recently, Shoemaker (1980) also proposed a theory of properties within an epistemological framework. He argues that it is only within a "causal theory of properties" that we can comprehend how "properties are capable of engaging our knowledge and our language in the way they do" (1980:116). In the tradition of Harre and Madden, Shoemaker argues for the empirical reality of the causal relation and the 'power' of causes to produce effects:

"We know and recognise properties by their effects, or more precisely, by the effects of the events which are the activations of the causal power things have in virtue of having the properties."

(Shoemaker, 1980:117)

1.7 Discussion

The Kantian and Humean accounts of causality complement each other. Hume started with the assumption that mind was passive, a receptacle for impressions and ideas which were abstracted from sensations. Sensations occurred in the mind, but Hume did not make any assumptions about whether these sensations existed in the same form in the real world. Thus, any structure was to be found in the mind. Mind, being passive, however, could not impose structure; what it did was to abstract structures from regularities. Thus the causal structure was derived from certain observed regularities. Investigating the structure of causality, Hume identified three principles which make people see things as being causally connected, or having a causal structure:

1. Temporal Priority of cause to effect;

2. Contiguity in space;
3. Constant Conjunction of cause and effect.

The principles of contiguity and constant conjunction are also important for building up associations, and indeed, in the Humean account, causality is a form of association. But causal sequences are different from associative ones; Hume recognised this, locating it in the strength of 'belief' engendered by constant conjunction and the regularity of experience.

Although accepting the regularity of experience, Hume did not investigate the basis of this regularity in the causal relation. He did not ask why certain causes always produced certain effects because within his theoretical framework the answer would be that "they just do". This may have been because he did not approach causality in terms of production as the notion of production had no place in his theory.

Not being able to find any impression for the idea of power (production) Hume concluded that it did not exist in reality. Shoemaker (1980:109) points out, however, that any event "consists of a change in the properties or relationships of one or more objects". Thus, a close analysis of a causal relationship in terms of objects reveals:

1. A transmission of energy, or an exercising of power;
2. A subsequent change in state or motion.

Hume quite rightly claimed that the former cannot be perceived. There is no sense-impression of it. The changes of state, or motion, can be perceived however, but Hume did not accept the objective fact of change from which an exercising of power could be recognised. For Hume, causal laws were simply constant conjunctions. Causal laws, he claimed, came to be accepted because of a 'belief'

which sprung from a strong association. This association was the result of a constant conjunction of two things.

The three principles of causality - succession, contiguity and constant conjunction - can apply to things which are not causally connected. What Hume did not take into account was the dynamic nature of the causal event. One reason for this was the way he viewed the mind. Hume recognised a 'belief' in the dynamic nature of the causal relation, but he saw this as a result of the way in which sensations occurring in nature were associated in the mind. The constant conjunction of cause and effect produced a 'belief' in the necessity of the causal relation, a necessity, which, for Hume, did not belong to nature.

James Mill further obscured the notion of causal relation by equating it to contiguity in time. He claimed that causation was only a name for an order of established relations. He did not however, investigate the reason for this established order, thus, in his account such an order could arise by coincidence, in the natural world.

Neo-Humean theorists who focused on conditionship, which specifies necessary and/or sufficient conditions, in order to explain the relationship between events cannot account for the asymmetrical, directional relationship between cause and effect. As Shultz (1979) pointed out, the problem of the directionality of causation can only be solved by "some notion of priority and production."

Thomas Brown, however, by introducing Simple and Relative Suggestions into the associationist framework, made way for a distinction between different types of relations. Simple suggestions were akin to customary successions, pure associations; while

Relative suggestions required the mind to distinguish between different relations, such as relations of cause and effect and relations of association. Relative suggestions, required judgement, the hallmark of an active mind. A mind which is only the storehouse of impressions cannot really deal with different types of relations. In order to do so, mind needs to be capable of organising stimuli into different categories on the basis of relations. Thus things which are similar (in function for example, such as chair, stool, settee) are related by association on the basis of this similarity. There is no necessity in this relation, any element can be left out, and they can be associated in any order whatsoever. But when a succession is necessary, because of the nature of the relationship between two things (a cause and an effect) the mind may well store them as related units such that the cause recalls the effect.

Recognition of an active mind led Kant to posit a-priori categories which structured experience. For Kant, sensations in themselves had no intellectual structure but, experience contained within itself a structure which had to be deduced by the mind, with the help of the categories. In addition, Kant believed in the reality of the relations in the natural world in which the concepts of the categories (time, space, substance and causality) are embedded.

Kant also differed from Hume in holding that the effect arose out of the cause, and implying that the cause had the power or properties to produce certain effects, a point of view elegantly developed by Harre and Madden (1975). Kant agreed with Hume that knowledge of specific causes and effects is gained by experience: "Kant makes no claim that we can discover by reason, or know a priori, the connection of any specific cause with a specific effect, and understand its necessity" (Beck, 1978: 126-7). However, in the

Second Analogy, he showed that cause and effect are related to each other necessarily, not merely by association.

To do so Kant focused on the difference between sequences of events that are enduring and sequences of events that show a change and asked **how** people distinguish the two. Matches in a matchbox is one example of an enduring sequence, for we usually see matches with or in matchboxes. When a match is lit, however, a **change** occurs, and according to Kant's argument - "any sequence which is taken to represent an objective change of states of affairs, or an event, must be taken as a necessary sequence..." and "the concept of a necessary sequence is the concept of causation" (Beck,1978:129).

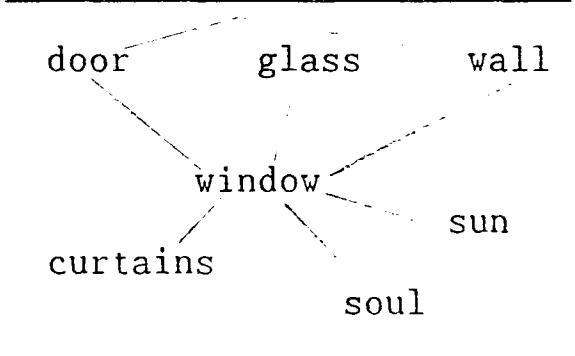
In such sequences, the necessity stems from the properties of the objects that cause, or produce, the effect. Moreover, as Kant has argued, the concept of causality cannot **arise** from experiences in themselves, but "must be presupposed in recognising them" (ibid). It is this a-priori knowledge which is presupposed that helps us distinguish between causal sequences (in which change occurs) and associative (unchanging/enduring) sequences.

With regard to causal knowledge, I see this a-priori 'knowledge' as being based on an apprehension of change, which is the basis of the causal relation. This category then facilitates the acquisition of specific causal relations and is acquired through experiences of different types of relations and sequences. An accumulation of experience of causal as well as other sequences, allows us to use the causal category to distinguish between causal and associative relations. It seems necessary for the mind to have the capacity, very early on, to differentiate between different types of relations purely for adaptive purposes. The ability to differentiate

between relations may be conceived of in terms of 'a-priori' categories.

"Relative Suggestion" allows us to judge and compare things and thus enables us to see the relations between things. When a window is broken, it is our perception of a change (from the usual state) in the window that makes us seek the cause of that change. Thus, when we relate the two states of an object - window and broken window - through the change of state, by comparing them at Time 1 and Time 2, and look for the instrument of that change, this is a causal relation. Windows, however, may be constantly conjoined with curtains or blinds, or doors, walls, etc. In seeing a window, we may relate it to any of these things, as in seeing any of these things we may relate them to window. This is not a dynamic relation, in which change occurs, it is a relation of association. The difference between the two relations is illustrated in Diagram 1.

DIAGRAM 1 CHARACTERISTICS OF CAUSAL AND ASSOCIATIVE RELATIONS

CAUSAL RELATION	ASSOCIATIVE RELATION
window -----?-----> broken window	
C H A R A C T E R	I S T I C S
1. PRIORITY IN TIME (whole--->broken) 2. UNIDIRECTIONAL 3. CHANGE OF STATE 4. UNDERLYING SUBSTANCE (window)	1. NO Time Relation 2. MULTIDIRECTIONAL 3. NO Change of State 4. DIFFERENT SUBSTANCES

To distinguish between the two relations (causal and associative) the intuition, or belief, that every change is caused

is required as well as a conception that relationships involving change are characteristically different from relations that do not involve change. With such a schema experience can be differentiated into causal and other types of experiences. Then it is possible to find specific causes of specific events using Humean principles. For example, in the case of the broken window, past experience might supply us with the association of heavy things and broken glass. If, in the past, a specific sharp and heavy thing, such as a stone, was seen to break glass we might decide that a stone was the causal instrument involved in breaking the window. Is this type of association the same as the type of associations involved in relating curtain to window? It is suggested that this is not the case.

1.7.1 Causality, Association and Causal-Association

Kant agreed with Hume that specific knowledge of specific causes and effect was acquired by observations of regularities. Hume outlined three principles of building up causal-associations, of which the principle of temporal priority, separated causal from other types of associations, to some extent, establishing the unidirectionality of the causal relation. When the idea of power and causal agency are also taken into account, it appears that a distinction can be made between causal-associations and associations. For example, if one always sees stones breaking windows, the constant conjunction of stone and broken window, may set up the association of stone-----broken. Wider experience may show that not all things break windows, thus building up a notion of the power of the stone because of its nature (hard, heavy, sharp) to break windows or glass. (Of course, force and velocity must be taken into account, but this is the simplest example, as less force is needed for a stone to break a window, than say a teddy bear.)

On the other hand constant conjunction of similar things would establish a relation of, say, like things recalling like things, or, perhaps a customary succession of objects or events, with no conception of power, or agency, or change involved. Thus, a causal-association is unidirectional, and dynamic, involving relationship of change. A simple association however, is multidirectional, related either because of similarity (eg. cup, glass, mug) or constant conjunction (cup, saucer, spoon).

The causal relation is different from both associations and causal-associations. It requires the integration of associative-causal knowledge (involving awareness of change) with some assumption of an underlying, continuous substance, or continuum for as Hawkins pointed out change must be related to some underlying substance or continuum (1.4.1). In addition, there must be an understanding that causes precede their effects (they sometimes co-occur but the cause must be activated before the effect can occur).

What happens in a causal event? In a causal event an object in state A at Time 1 is changed to state A' at Time 2. To apprehend this transformation it is necessary to relate the two states of the object in terms of the change from state A to state A'. Only then can one realise what has happened to the object between times 1 and 2.

In conclusion, this brief analysis has distinguished two major types of relations : The Causal and the Associative. Associative relations may be thought of as having different levels, two of which have been distinguished here:

pure associations; and

causal-associations;

Associations may be regarded as subsets of the causal concept; nec-

essary building blocks for specific knowledge about objects/things - their properties and effects. These different components of the causal concept, were distinguished only by integrating the Humean and Kantian accounts of causality, with the analysis of causal powers, and properties of different objects. Thus, the present approach suggests that a basic understanding of causality requires a synthesis of the different types of knowledge proposed by these different accounts. The next Chapter (2) presents a review of research on the development of causal thinking in children with a view to exploring the child's developing understanding of causality.

CHAPTER TWO

2 A REVIEW OF THE PSYCHOLOGICAL LITERATURE ON THE DEVELOPMENT OF CONCEPTS OF PHYSICAL CAUSATION

2.1 Introduction

Philosophical debates about the nature of the causal relation have implicitly or explicitly influenced many psychological investigations. An important distinction between causal and associative relations is that the causal relation involves change and this change or transformation connects two states of the same object into a continuous sequence. Causal associations however are made solely with changed states. No imputation of a sequence or relation need occur. The question I wish to focus on is - How does the young child view the causal relation? - Is it just as a connection between cause and effect governed by contiguity, priority, or production principles (causal-association), or is it as a sequence in which two states of an object are connected by a change of state/transformation (causal relation).

Causal reasoning does not occur in a vacuum. A variety of social situations, physical events, intentions and motives influence this type of reasoning. Not only are terms of causal significance "used by everyone for the purpose of indicating the varied concatenations of physical events which are constantly to be observed in everyday life" (Michotte, 1963:348), but causal terms are used also in social situations where people are "constantly making inferences about the causes and effects of behaviour" (Whiteman, 1967:144). However, it is beyond the scope of this thesis to

investigate the literature on psychological causation which focuses on the role played by motives, intentions, and social factors on causal reasoning (for a review see Shultz and Kestenbaum, 1985).

The question raised in this thesis is whether preschool children's understanding of causality is based simply on observed regularities of cause and effect or whether they have some notion of the causal relation as a relation of transformation. This review of the literature deals with work on physical causation.

A brief description of the early work on physical causality is followed by a review of more recent work on the child's developing causal concept. Firstly, the different Humean principles are identified and a review of studies testing the child's grasp of these principles is presented. The next section reviews work on the child's understanding of generation and production, a more Kantian approach. Following sections deal with studies investigating children's comprehension of causal event sequences and the child's apprehension of the causal relation in terms of generation and transformation within such sequences. This is the main area of interest in this thesis as the concern here is with children's ability to reason about causality. Finally, the distinction between causal and associative relations arrived at in Chapter 1, is introduced as a relevant factor in investigating children's understanding of the causal relation, at least in abstract event sequences.

2.2 Early Studies of Causal Development

The earliest and most extensive series of studies investigating children's understanding of causation was undertaken by Jean Piaget. His main concern was to explain the nature and growth of human knowledge. This concern is important to remember when

studying his work, because his empirical studies as well as his theory of child development are firmly grounded in the philosophical and genetic epistemological stance that he adopted. As Atkinson (1983:6) points out - "Piaget is led by his concern with philosophy to embed his cognitive developmental theory in a philosophical theory about the nature of human knowledge and the human mind".

Activity is of primary importance for Piaget's account of the development of the causal concept in infancy. He presented a step by step account of the development of this concept (1955) based on observations of his three children. Piaget maintained that in the early stages of development (early infancy) there was no distinction between the self and the world. With increasing experience a process of differentiation occurred and infants began to conceive of objects as having independent existence from the self. Ultimately the self was seen as an object that stood in a particular relation to other objects (Piaget, 1955). Development was seen as a process of differentiation and, in terms of the causal concept, Piaget saw it as a differentiation between psychological and physical causality. Psychological causality involves volition and a belief that actions are governed by wishes and desires. Physical causality on the other hand refers to cause-effect relations observable in the physical world.

Piaget proposed that the infant's notion of causality arose through experience of his/her own actions which produced effects. He defined two kinds of pre-causality which are "logically distinguishable but virtually indissociable in early cognitive functioning" (Flavell, 1963:142). The precursor to psychological causality was "dynamism" or "efficacy". When "dynamism" is present causes are vaguely perceived as part of the self, inherent in the

action or wishes of the self but without any differentiation between self and action (Piaget, 1955). The precursor to physical causality was "phenomenalism". Piaget defined it as a belief that any two events that occurred closely in time must be linked causally. In his words "Efficacy is the assimilation of events to personal activity, and phenomenalism is accommodation to the empirical data inseparable from that activity" (1955:316).

This brief summary of Piaget's theory of causal development in infancy is only presented here because it directly influenced his conception of causal development in childhood. Piaget (1930) proposed a stage by stage progression of children's causal concepts from an undifferentiated dynamism-oriented stage, through a stage of mechanical causality (which results from eliminating dynamism) to a stage of logical deductions, which he claimed was the most advanced stage.

Piaget argued that empirical studies of cognitive development could establish that these stages occurred and claimed to demonstrate this in his own work. Before we turn to Piaget's empirical work on the development of children's notions of causality, it is important to mention that the work of the anthropologist Levy-Bruhl influenced Piaget's conceptualisation of children's causal explanations. Levy-Bruhl (1923) asserted that the primitive mentality was qualitatively different from the civilised one, characterising it as "mystical, pre-causal and pre-logical" (cited in Huang 1943). Piaget not only used some of Levy-Bruhl's terminology, but also clearly acknowledged his adaptation of Levy-Bruhl's fundamental assertion (1929), stating that child thought could be placed on the same level as 'primitive mentality' "in relation to adult, normal and civilised thought".

2.2.1 PIAGET'S EMPIRICAL WORK ON PHYSICAL CAUSALITY

Piaget's early works on "Language and Thought" (1926), "Judgement and Reasoning" (1928) and the "Child's Concept of Reality" (1929) all dealt with the child's concept of causality to some extent. But it was only in the latter book and in "The Child's Conception of Physical Causality" (1930) that Piaget states his explicit aim of studying the contents of child thought to see whether the explanations offered by the child are different from those of "savages", the sciences, and philosophy (Piaget 1929).

Piaget proposed three different methods for studying children's causal concepts:

- 1) The verbal method - which consisted of asking questions about physical phenomena, such as wind, clouds, waves, etc.
- 2) The demonstration-questioning method - in which little experiments in physics were demonstrated to the child and she was asked "how" each event had occurred.
- 3) A combination of the first two methods - the child was asked questions about how things work (eg. aeroplanes, trains, bicycles, etc.). Sometimes demonstrations were used, sometimes the child was asked to draw the machine in question and then explain how the different parts worked, and at other times she was simply asked to explain how the machine worked.

Standardised questions were not used on the grounds that children could start "romancing..that peculiar tendency of children to invent when embarrassed by a given question..the only way to avoid such difficulties is to vary questions, to make counter-suggestions, in short to give up all idea of a fixed questionnaire" (Piaget,

1929:3).

Piaget accepted that "romancing" by the child can occur because she makes fun of the question or the experimenter (ibid:16), or creates a myth which she half believes, however he thought he had avoided this problem by using non-standardised questions. Nevertheless, Piaget seems predisposed to believe that young children are 'primitive' thinkers. Thus he claimed that romancing "explains the solutions a child will give when it can find no better" (ibid:17) and argued that what seems like romancing may be examples of primitive thought, artificialism, as he calls it (1929: 246;300-301). He pointed out that similar myths to the ones children produced were to be found in the childhood recollections of the deaf-mute d'Estrella. This seemed worth pointing out because the influence of Levy-Bruhl is very clear here and significantly affected Piaget's interpretation of his results.

"The Child's Conception of Physical Causality" (1930) describes much of the early work done by Piaget - he used all the methods described above, under the general umbrella of "clinical method". The first section of his book reports children's explanations to questions about physical phenomenon such as:

"Where does the wind come from?"

"What is breath? Where does this breath come from?"

"Why does the sun move?", and so on.

For each of the phenomena studied Piaget categorised explanations given by children into various categories ranging from animism to correct, 'logical' explanations.

The second section of the book dealt mainly with children's explanations for phenomena demonstrated to them, such as:

air produced by the pressure of hands;

water level changes by dropping pebbles of different weights into a glass of water; etc.

Children were asked to give the causes of the events portrayed.

In the third section of this book (1930) Piaget reports investigations of children's explanations of how machines work. Here, the third method, described above, was used, and children were asked to explain how the various machines worked. Piaget placed a special emphasis here on children's mention of spatial contact and temporal order as elements of a logical explanation. As in previous sections, different categories and stages of explanation were identified.

Piaget's main concern was with children's explanations of events. He believed that children's causal concepts would be reflected in the types of explanations that they gave. Thus, explanations were categorised according to their **magical** (child's own wishes/motives are seen as efficacious), **phenomenalistic** (two contiguous events are seen to be connected by the relation of causality), **animistic** (physical objects and events are endowed with human attributes), **dynamic** (although animism is eliminated there is a belief that 'forces' in objects can explain their activity and movement), **mechanical** (explanations involve mention of contact and transfer of movement), or **logical** (physics type explanations), elements. Piaget (1930) gives numerous examples of the types of answers given by children of different ages. These are not reported here because of space constraints (but see Piaget, 1930). On the basis of these answers Piaget identified 17 different types of causal explanation, which fell into three major stages of causal development, as summarised below.

STAGE I - all explanations are psychological, phenomenalistic, and

magical. The child extends notions of self to the universe, and confuses psychological causality with physical causality. Piaget characterised this as the most primitive stage of causality, which implies magic and the belief that any desire whatsoever can influence objects (Piaget, 1930).

STAGE II - Explanations are animistic, dynamic and phenomenistic. At this stage there is still anthropomorphism in the child's view of the world. Simple juxtapositions seem to be enough to establish a causal connection, and there seems to be no interest in how the cause generates/brings about the effect. Piaget characterised this stage (2-3 years to 7-8 years) as ego-centric, which corresponds to pre-causality "...meaning all the forms of causality based on a confusion between psychological activity and physical mechanism...Pre-causality confuses motive and cause" (1930:303).

STAGE III - At this stage, Piaget claimed that the child's thought began to break away from the primitive thought of the previous stages. Explanations are more concerned with how the cause brings about the effect, appealing to internal mechanism, spatial and temporal factors, until finally logical deductions are made "by mere law of reason". To arrive at such deductions children use of other kinds of explanations, density, space, time, etc., but these concepts are pure relations and are chosen in terms of the deduction to be made. As Piaget puts it, "during this third great stage of child development a new parallelism grows up between logic and the real categories" (ibid:305).

Piaget called the first two stages "pre-causal" while the third more 'rational' stage is the causal one. The evolution of the causal concept is characterised by "the desubjectification of

causality, the formation of series in time and the progressive reversibility of the systems of cause and effect" (Piaget, 1930:267). His analysis of causal development in childhood (see 3 stages above) was that before the age of 7/8 years children had no objective (desubjective) notion of causality: things happen because either we want them to happen, or they (the things) want them to happen. Neither were they aware that causes precede effects in time: any two events that occur together/ or are juxtaposed are seen as being in a cause-effect relationship. This is a very Humean notion. The phenomenalist category implies association on the basis of contiguity.

However a number of problems are inherent in the method used by Piaget. Firstly, his categorisation scheme is very subjective and influenced to a large extent by his epistemological outlook. As later studies showed (Johnson and Josey, 1931, Oakes, 1947) other researchers using the same methods did not find all the categories that Piaget described, especially not the pre-causal ones. Piaget's criteria for a correct causal explanation may have been too stringent (especially for 3-to 7-year-olds) because he demanded physics type explanations which required specific knowledge about the phenomena to be explained. This type of knowledge is more a product of formal learning and experience than of causal understanding. Secondly, the nature of the phenomena that Piaget wanted children to explain was either unknown (wind, dreams, movement of heavenly bodies) or complex (flotation, bicycle, steam engine). Children, especially preschoolers, would have little or no direct contact with such phenomena. Lack of specific knowledge may well have encouraged 'romancing' or myth-making. For example, a Stage II child says that one pebble sinks in water because it is white, while

another pebble "is light because it is black" (Piaget, 1930:259). No credit is given to the child for mentioning the lightness of the pebble that floats. This answer is categorised "phenomenistic" because the child explains flotation in terms of colour. Neither is any allowance made for the fact that the child may not know the physical laws necessary to explain the situation. As Bullock, Gelman and Baillargeon (1982:219) point out, even adults may not be categorised as being 'truly causal' depending on what they are asked to explain: "without precise knowledge of elementary physics, explanations will be less precise and according to the Piagetian position, less advanced developmentally".

Finally, even if the child has some conception that light things float whereas heavy ones do not, she may not have adequate verbal skills to articulate this. It is very possible that children's poor explanations are a reflection of either "limited verbal skills and/or an inadequate understanding of what constitutes a good or satisfactory explanation" (Bullock et al., 1982:219)

If these criticisms are taken into account then what Piaget's (1930) study of child causality showed was that the level of the child's knowledge about physical phenomena is different from that of adults, but the extent to which this difference is attributable to poor articulatory skills or insufficient experience with the various phenomena, is not made. Furthermore, because Piaget concentrated on the contents of children's explanations their ability or inability to reason about causal events remained an issue for investigation.

Most of the early research on causal development also focused on children's explanations, but attempts were made to control for the methodological problems raised above. The following section

describes some of this early research. Research on animism is not reviewed here because it is not directly related to the focus of this thesis, but Gelman and Spelke (1982) and Golinkoff et al. (1984) provide good reviews.

2.2.2 EARLY STUDIES IN THE PIAGETIAN TRADITION

Johnson and Josey (1931) replicated Piaget's procedure on 6-, 8- and 12-year-old children. They found that the youngest group were **not** ego-centric and took great care to explain themselves. Their thinking was not characterised by animism or artificialism. Johnson and Josey suggested that the difference between their results and Piaget's was because of the difference in IQ between subjects. Subsequently, Oakes (1947) matched the IQ records of the children in his study with those in Piaget's investigation. Using the same methodology he found that of the 77 kindergarten children 81.9% gave Stage III-type explanations (what Piaget(1930) called "realistic" explanations) including mechanical and spatial factors rather than magical or animistic ones. Indeed, Oakes claimed that Piaget's categories were not applicable to the explanations that he obtained. In this case, the different results could not be attributable to differences in IQ.

Huang (1930, reported in Huang 1943) tested 47 children (4:10 and 10:3-years) and 10 college girls using Piaget's demonstration and questioning method. Fifteen demonstrations of strange phenomena were presented in which basic natural laws were broken. For example, a toothpick wrapped in a handkerchief was broken by the subject and emerged intact; the water in a tube with a piece of paper covering the rim stayed in the tube when it was turned upside down. Huang reported that the child's first reaction was "joyful

surprise" followed by spontaneous questions such as - "How did you do that?" (Huang, 1943:79). He argued that such reactions were important in showing that children fully appreciated the strangeness of the situation, implying some sort of expectations about the properties and natures of things. In over 370 protocols Huang found only 10 cases which could be interpreted as containing magical or animistic causal explanations.

The responses obtained from children for these strange phenomena led Huang (1943) to conclude that children gave **naturalistic** explanations rather than pre-causal ones as defined by Piaget. Naturalistic explanations depend on distinctly physical forces or processes, rather than magical ones. For example, one naturalistic explanation for the inverted tube of water was - "The paper sticks to the tube because it is wet and therefore sticky". A characteristic of these explanations is their "application of some simple, familiar, tangible principles to the phenomena, in place of the subtler more difficult concepts scientifically required" (p.81). Such explanations, Huang argued, were 'naive' but not mystic. Huang found similar explanations among the College girls which differed from the children's only in the use of technical terms like "inertia" and "friction", often wrongly used.

These studies questioned Piaget's premise that children under 7-years were 'pre-causal'. It appeared that his method of categorising children's responses may have been very different from those of the later researchers. Another difference may have arisen from the child's familiarity with objects, as Huang (1943) pointed out, children may give responses that appear illogical simply because of lack of specific knowledge. Indeed, they try very hard to apply the knowledge they do have to 'surprising' phenomena.

Nass (1956) hypothesised that familiarity with the phenomena they were being questioned about, as well as the way the questions were worded, would affect children's causal explanations. Familiar phenomena were those which children were likely to experience directly (clock, whistle, etc.) whereas remote phenomena (unfamiliar) were those which children could not experience directly (wind, rainbows, thunder, etc.). Nass surmised that children might have some direct knowledge of the causal agents of familiar phenomena but although they had experienced wind and thunder, they could not have any direct knowledge about their causal process. Furthermore, Nass predicted that using "Why" questions, which "suggest the possible operation of animistic or dynamic forces" (1956:192) would elicit more pre-causal responses than using "How" questions as Piaget (1926) claimed that children's "why" questions were affective. Nass's questions were of the forms:

FAMILIAR => "Why/How does..." - the radiator get hot?
REMOTE => "Why do/How is it that.." - the clouds move?

Children aged 8 to 10 years were tested on a number of such questions. Responses were categorised as Non-Naturalistic (pre-causal, animistic); Phenomenistic (contiguous irrelevant events are cited as cause); or Naturalistic (mechanical or logical). Naturalistic responses were not always scientifically correct, but contained underlying ideas which were naturalistic, for example - "The sun is red, the sky is blue and the clouds are white, so they all come together and you see all the colours together and that's a rainbow" (Nass, 1956:194). As predicted, remote phenomena, as well as "Why" questions elicited more pre-causal responses than familiar phenomena, and "How" questions.

Although Piaget claimed that naturalistic and logical

thought emerged at age 8 and was prevalent by age 10-11 Nass's findings show that even this 'advanced' group will give "precausal" explanations for remote phenomena and "why?" questions, suggesting that such factors may well influence younger children's responses as well. It is worth noting that Nass's "Naturalistic" category was far less stringent than Piaget's because his results indicate that even using less stringent coding, supposedly Stage III children fare badly with remote phenomena.

Berzonsky (1971) specifically investigated the effect of familiarity on children's causal explanations. Using the Piagetian interview method he tested 84 first grade children (6:3-7:5) on three measures: a verbal task, a water-level apparatus, and a teeter-totter. The verbal task used Nass's (1956) familiarity criterion, and children were questioned about familiar and remote phenomena, as well as about malfunctions of objects. All the questions used a "What makes...?" format. For example:

"What makes - a clock tick?", or "-the wind blow?" or
 -"airplanes crash?"

The teeter-totter and water-level tasks were demonstrations, and the children were asked to make predictions. The teeter-totter was basically a mini see-saw. Three wooden blocks were used as weights, and it was possible to hide lead weights in these blocks. The weights were arranged on the teeter-totter (2 on one side, one on the other) and the child was asked to predict what would happen when the supports keeping the structure horizontal were removed. After five such trials, a lead weight was hidden in the single block, and the child had to explain the incongruous result. In the water-level task children had to predict which of a number of wooden blocks would raise the water-level in a beaker; as in the teeter-totter, an incongruous

result was produced by hollowing out some of the bigger blocks. Explanations were coded - "I don't know"; Naturalistic (cause related to effect in physical manner); or Nonnaturalistic.

Berzonsky found that on the verbal tests, the largest number ^{of} Nonnaturalistic responses occurred for remote phenomena. Fewer Nonnaturalistic were given for malfunctions of objects, and the least for familiar phenomena. He suggested that function and malfunction were two different kinds of events. Normal functions are more difficult to explain because they require greater complexity of response than malfunctions which can be attributed to single factors. An explanation of a normal function is not usually a single-factor explanation, and Berzonsky (1971:712) found that "single factor explanations of normal functions...tend to be nonnaturalistic". The results of the other two tasks also provide support for the notion that familiarity with phenomena affects causal explanations. It was found that children who gave naturalistic explanations for the standard demonstrations reverted to nonnaturalistic ones for the incongruous situations. However, neither Mass nor Berzonsky followed Piaget's more stringent classification of causal responses and it is not clear just how flexible their Naturalistic category was.

Laurendeau and Pinard (1962) defended Piaget's conclusions by arguing that his critics had defined pre-causality too narrowly. This is true insofar as all explanations referring to physical rather than psychological factors are classified 'naturalistic' by these critics. On the other hand it can also be argued that Piaget "over-interpreted" children's explanations and that his technique is too "impressionistic" (Donaldson, 1986).

A more differentiated categorisation scheme (based on

Piaget's) was used by Das Gupta (1982) who tested 60 children (20 unschooled [US] 6-year-olds, 20 unschooled [US] 12-year-olds and 20 school going [S] 12-year olds) on familiar phenomena - blowing a whistle; using a catapult; pencil in water; and floating of wood. Each of these items was demonstrated to the children in random orders; then they were asked to tell the researcher "What happened?" and "What made it happen?". Responses were categorised as Pre-causal (animistic, phenomenistic etc.), Peri-Causal (naturalistic), Causal (Stage III) (the action or medium that caused the event is mentioned). Causal-Stage IV explanations required explanations of why, for example, blowing produced a noise in the whistle. Causal-Stage V explanations were completely physics type explanations, identifying principles of air pressure, refraction and density. It was found that children did not respond within one particular category for every phenomena, thus, the combinations of responses were taken into account and 4 categories of responses identified-

1. Precausal - mostly precausal answers, at least 50%.
2. Peri-Causal - at least 50% Causal answers of either the Stage III, IV, or V variety.
3. Causal (a) - at least 50% Causal-IV/V answers, and 50% Causal III, or one Causal III and one Naturalistic answer.
4. Causal (b) - only Causal IV/V answers.

Using this method only 30% of the 6-year-olds were classified as Peri-Causal, while 60% were classified as Causal (a). Only 10% were Pre-Causal. All the 12 year-olds (S and US) were classified as either Causal (a) or Causal (b). Even using a more differentiated categorisation scheme than Nass and Berzonsky's it was found that unschooled children, below the age of 7-years, can give largely causal responses.

The type of phenomena significantly affected the responses. The largest number of non-causal responses were given for the pencil-in-water demonstration. Although both items were familiar to the children, the phenomena of the pencil 'bending' in water had not been observed before, especially by the younger age group. The majority of pre-causal answers were given for this item. Almost all the explanations given for the catapult item were Causal (III, IV, V) intimating that items which had been manipulated by the children could be explained in causal terms. This held true for the whistle item as well. Over half the 6-US group (55%) were able to give the Causal-III explanation that the sound was made "by blowing". It was established by further questioning that the act of blowing air into the whistle was somehow responsible for the noise. Another interesting finding, remarkably similar to Huang's (1943) was that the 12-S group often used scientific terms in their explanations without really understanding the process. Thus, explaining the pencil 'bending' in water, one child said: "It's because of refraction it's bent". When asked what he meant by refraction he answered: "Refraction is because the water is heavier than the pencil, it pushes the pencil and bends it". This is a naturalistic, rather than scientific-causal explanation. The 12-US group however, offered explanations based on their observations, such as - "It looks bent because it's in water. The part in water looks bigger than the part that is in air." Further questioning revealed that they did not believe that the pencil had really bent, they knew that it only appeared bent because it was partly in water.

This review shows that Piaget's categorisation scheme has not received unanimous confirmation and also that his interpretations may be questionable. When a less stringent categorisation

system and familiar materials were used young children could give reasonable explanations for physical phenomena. These studies offer support for the notion that the child's developing understanding of causality is not a totally phenomenalist one. Little evidence was found for the magical or psychological components in children's causal explanations identified by Piaget. The child's mode of thought and reasoning may well be causal, but his verbal explanations may be affected by his grasp of the language, by what he perceives the experimenter requesting, by the nature of the task, and by familiarity with the phenomena to be explained.

Since a child's knowledge may not be reflected in her verbalisations (Brainerd, 1977, Donaldson, 1978, Bullock et al., 1982) other response measures such as judgements, predictions or behaviour (eg. surprise, see Keil, 1979), can be used. To see whether the child can reason causally about phenomena rather than explain them, such methods can be used. To reason causally about phenomena children must have some knowledge about the principles governing causal events. Use of these principles would indicate the nature of the child's conception of causality. The difference between this approach and the early Piagetian one is that while the latter dealt mainly with the **content** of children's explanations, the former is concerned with the **structure** of causal thinking. **Structure** here refers to "any real or perceived relationship between events that gives rise to the perception of a causal nexus or that influences the nature of the causal inference" (Kun, 1978:221).

In the following section, research which has focused on how children deal with causal events is reported. Some methods rely on verbal explanation to a greater extent than others, but this research is united by its interest in the principles the child uses

to deal with events. Many studies dealt with children's understanding of the Humean principles; later work investigated young children's understanding of production. This next section presents studies on Humean principles, followed by work on production, and understanding of transformations.

2.3 Children's Knowledge of Humean Principles of Causality

Hume (1738) identified three principles of causality -

- (1) Succession (temporal priority of cause)
- (2) Contiguity (temporal and spatial)
- (3) Constant Conjunction (regular co-occurrence of cause and effect)

The last two principles are also principles of association and are not distinctively causal. Temporal priority and the principle of generativity, or production (the cause produces the effect), are essential features of the causal relation (see Chapter 1) distinguishing it from the associative. Finally, just as the principles of causality help us to identify the causal relation, it may be a conception of change and transformation that helps us differentiate the causal relation from the associative. Perception of causal relations is dealt with in the final section.

2.3.1 TEMPORAL PRIORITY

Of the three principles, this is the one which establishes the directionality of the causal relation. Both Hume and Kant believed that causes preceded, or occurred simultaneously with effects. Many of the early studies on the child's understanding of temporal priority as a causal principle were syntactic in that they involved language skills.

Piaget (1928) used a sentence completion task in which

children were asked to complete sentences such as - "The man fell off his bicycle because _____". Piaget claimed that before the age of 7/8 years children did not distinguish between cause and effect because they incorrectly completed sentences such as the one above, with the consequence (eg. ..because __he broke his arm), rather than an antecedent cause.

Kuhn and Phelps (1976) argued that such answers occurred because (1) children were unable to generate causes spontaneously; and (2) citing a single event may lead children to think about its consequences rather than its causes. They used two types of sentences - **A because B** and **B because A** - accompanied by a drawing. The sentences were of the forms: "The chair gets wet because the water spills" and "The water spills because the chair gets wet". Children were asked to choose the sentence card that best fitted the drawing. Three groups of children aged (means) 5:9, 6:9, and 7:10 were tested on 16 of these sentences. Correct answers increased significantly with age and the youngest children responded far more randomly than the older ones. In order to rule out the possibility that the sentence choice method used affected their results, Kuhn and Phelps (1976) conducted a similar experiment with 15 kindergarten children (mean age 5:9) substituting the word "first" for "because"; eg. "The girl catches the ball, but first the boy throws it. The boy throws the ball, but first the girl catches it" (ibid:250). The majority of responses were correct (84%), compared to 56% correct in the youngest group of the "because" experiment. The majority (80%) of children's responses were not in the random range in this second study.

Kuhn and Phelps argued that the sentence choice task was not inappropriate in itself as young children dealt well with tempo-

ral relations (Experiment 2), but not with causal ones. Therefore they concluded that the youngest group in Experiment 1 did not comprehend causal direction: "any statement which links both elements is adequate" (1976:251) thus concurring with Piaget's claims. However, the type of sentences used may have confused the younger children who may not have had as much syntactic knowledge as the older ones. The instructions given to the children did not make it clear whether the children were to describe the drawing (water spilling, wet chair) or give a cause for the wetness of the chair.

Bebout, Segalowitz and White (1980) suggested that children would be more able to deal with familiar causal sentences (congruent with reality in that the cause is mentioned before the effect) than with unfamiliar (incongruent) ones. They asked 60 children (age range 5:10 - 9:9) to manipulate a number of objects after listening to 3 types of stimulus sentences of the forms:

- (1) X so Y [the pencil moved so the car moved]
- (2) Because X,Y [because the ruler moved, the glass moved]
- (3) Y because X [the ruler moved because the car moved]

Children were instructed to "Make that happen". The results showed that children responded more accurately to the first two sentences (congruent), than to the third (incongruent). It was only at age 9 that this difference disappeared. Thus, Bebout et al. suggested that children under 9 did not pick up the syntactic cues provided by "because" in a task such as theirs, where no semantic or contextual cues were presented. In such cases, they argued, children may use an order-of-mention strategy, in which the first mentioned event is the cause.

Bebout et al.'s findings suggested that in the Kuhn and Phelps study children may have been confused by 'incongruent' sen-

tences. However, one major difference between the two studies was that in the latter children could demonstrate comprehension by action rather than by choosing a correct sentence. If children do find incongruent sentences difficult to understand this difficulty may be compounded by unfamiliar use of the causal connective "because".

Kun (1978) eliminated this factor by presenting children with 10 3-term causal sentences of the form - A caused B caused C - such that A was the antecedent of B, which in turn was the antecedent of C. For example "Scott pulled the dog's tail (A); The dog bit Scott (B); Scott cried (C)" (Kun, 1978:219). The three cards depicting each event were laid out in temporal order. A sentence describing each picture was read out as the card was presented. Twenty children from four age levels (means: 4.42; 6.18; 7.2; 8.10 years) were asked to answer one of three questions ("Why did B happen? / "What happened next? / Nonsense question) by pointing to one of the pictures. Each child experienced all question types over 10 sequences. By using this procedure Kun not only provided a context, but also diminished linguistic and memory demands on the children.

Nearly all the children at each age level gave the correct antecedent event for the "Why?" question, and the correct consequent for the "What happened next?" question demonstrating a clear understanding of causal priority. The proportions of antecedent and consequent choices did not differ significantly from that expected by chance for the Nonsense question, indicating that both were equally associated with the middle event.

In order to ensure that the large number of correct responses to the "why" questions was not due to a 'recency effect',

i.e. young children picked whatever event was mentioned prior to the event to be explained, Kun retested 8 children from each age level who had answered all the "why" questions correctly. The consequent event was eliminated, and an irrelevant 'event' (A' = This is Scott's house) was inserted between events A and B (ie. A, A', B). Following the same procedures children were asked "why" B happened. An additional ten children (naive) were included in this phase. Even in this condition all the children gave a majority of correct answers. There were no age differences in performance between the first group of children and the proportion of correct responses in the new group was 68/80. These results strongly back Kun's claim that in the initial study "answering why questions with the antecedent was not an artifact of the order in which events were mentioned.." (1978:221). She replicated these results with a much younger group of children (mean age 3.18). Her results certainly indicate that children as young as 3-years understand that causes precede their effects. Indeed, Kun (1978) argued that her results suggest "that the temporal order structure may well be present prior to the stage of representational (verbal) thought."

Kun, however, used human actors in some of her sequences, and in view of Piaget's claim that psychological causality emerges before physical causality, it is possible that this factor contributed to the high level of success. Brown and French (1976) also found that preschoolers could correctly reconstruct and complete causal sequences involving a young girl. Although having a human actor, and sequences to which they could relate may have helped young children's performance, the fact remains that these studies do show that young preschoolers do comprehend the notion of temporal priority in causal relations.

Shultz and Mendelson (1975) adopted a demonstration method using purely physical phenomena. They also avoided semantic and syntactic problems by using less verbal procedures. Children (mean ages 6:7, 9:11, 3:8) were shown a mechanical event sequence of the form A - X - B:

(A) marble dropped in one side of a box; (X) bell rings;

(B) marble dropped into other side of box.

The children were asked (1) "What made X happen?" and (2) to produce X themselves, using either A or B. The older children (6-7 and 9-11) significantly preferred the antecedent event as the cause whereas youngest group showed no general temporal preference. Closer analysis showed that the youngest children erred by choosing event B as cause. Shultz and Mendelson accept the possibility that young children may be thinking phenomenistically, as Piaget suggested. Nevertheless, they also point out that these children may have been influenced by a "recency effect" and chosen the most recent event as cause, simply because its recency made it more salient. Kun (1978) suggested that the above findings may suggest deficiencies in memory, but it must be noted that her task was structurally different from Shultz and Mendelson's (1975) in that event C was a **consequence of B**, not a random, similar event (marble) which might have been a potential cause.

Bullock and Gelman (1979) suggested that previous studies had confounded children's specific knowledge and the structure of their causal beliefs. They noted that when children are familiarised to any apparatus they are more liable to express causal relations (Berzonsky, 1971; Mogar, 1960). Thus, in their experiment they used a structure similar to Shultz and Mendelson's (1975), except that a jack-in-the-box was substituted for the bell. Another

difference was that children were given a number of trials which gave them an opportunity to become familiar with the apparatus.

The apparatus was such that two runways led to the jack's box (one on either side). A ball was rolled down one of these runways and almost immediately the jack popped out. The children were presented with the event sequence - X, Y, X' - where X and X' were identical (a ball rolling down a runway) and Y was the effect (jack pops out). Children in three age groups (mean ages - 3:7; 4:6; 5:3) experienced both phases of the experiment. In phase I, the standard sequence (X, Y, X') was demonstrated to the child four times. Children were asked to point to the ball that "made Jack come up", and give an explanation for the last two trials. In phase II children were asked to make the Jack come up using both X and X' balls (separate trials) so they could see that both X and X' could cause Y. A causal judgement for the standard sequence was then requested. As children now knew that both X and X' could cause Y, in the standard sequence they would choose X only on the basis of temporal priority, not because of any potential causal efficacy. Bullock and Gelman argued that their manipulation emphasised that "the main difference between events X and X' in the X-Y-X' sequence is one of temporal order" (1979:92).

In phase I, 67%, 83% and 93% of the 3-, 4- and 5-year-olds chose only the first event (X) as cause. These results indicated that all the children had some notion of temporal priority of causes, although the authors pointed out that younger children seemed less certain of their choices.

In phase II the majority of children put their balls in the X runway first. Their judgements of cause, after witnessing both X->Y and X'->Y, still showed a reliable tendency for all age groups

to choose X as the cause for the standard sequence. The majority of children (87.5%, 100% and 93.0%) chose **only** event X when asked to name a cause. Comparing verbal explanations with judgements Bullock and Gelman found that explanations lagged behind non-verbal responses, 63% of 5-year-olds, and 43% of 4-year-olds mentioned temporal order, but younger children either gave no explanation or mentioned some portion of the sequence (eg. "ball went" Bullock et al., 1982:225). They suggested that discrepancies between children's use and articulation of temporal order may have led others to categorise the young child as precausal and they surmised that "children's abilities to use a particular principle may long precede their articulation of that use" (ibid, 1982:225).

In using the same children in phase I as well as phase II, Bullock and Gelman ignored the possibility that a learning effect might occur. Children were more familiar with the sequence by the end of phase II, but they also had the chance to build up conjunctions of the type: roll ball---> produce jack. In a sense whether the ball went down the X runway or the X' runway was irrelevant. The relevant association would be between ball and jack and might have been coded in order of occurrence -ie. jack always appears after the ball. Although Bullock and Gelman (1979) claimed that when causal direction tasks were simplified, and verbal requirements minimized, children as young as 3-years use temporal priority clues to make causal judgements, the distinction between temporal priority per se (first ball, then jack) and causal priority (the cause precedes the effect) is not clear. Nevertheless, Bullock and Gelman's study shows that 3-year-olds (even in phase 1) use temporal priority cues to infer causes.

Shultz, Altmann and Asselin (1987) tried to distinguish

between temporal order and causal priority by asking children (mean ages 4:2, 7:6, 11:8) which of two coincident events caused the other. Two wooden blocks (one red, one blue) were positioned on a track above a plywood box open on one side. A metal rod extended from the bottom of each block into the box so the experimenter could move the blocks along the track out of the child's sight. Children were shown that the blocks could be connected by a string. In some conditions the blocks were partially screened so that the child could not see whether any connection was present. There were three main conditions:

TEMPORAL PRIORITY - one block started moving before the other. No other information was provided

HUMAN INTERVENTION - the experimenter's hand was on one of the blocks and both blocks started moving simultaneously (screened)

GENERATIVE TRANSMISSION - the blocks were connected by a string; either the red or blue block was in the leading position (in terms of direction of movement) but no temporal priority information was given as both blocks began moving simultaneously.

Children were asked which block had made the other one move.

The youngest group chose the 'correct' block far more in the generative transmission condition than in either of the other conditions. Older children showed systematic use of all three rules (see Shultz et al., 1987:71 for details). Shultz et al. also examined children's verbal justifications which were classified on the basis of reference to temporal priority (one block moving before the other), human intervention (experimenter moving block) and generative transmission (one block pulling other/ nature of connection). Whereas justifications on the basis of priority and intervention only occurred in the relevant conditions, generative-justifications

"were most frequent on every problem" even in the screened ones. When transmission information was unavailable (eg. temporal priority - screened problem) children imputed a connection between the two blocks (the block which started first pulled the other).

These results suggest that transmission information (some perceived connection between cause and effect) is more important in judging causal priority (at least in the youngest group) than information about either human intervention or temporal priority.

Shultz and Kestenbaum (1985:230) note that sensitivity to temporal priority "seems to be fragile in the young 3-year-old, and can be disrupted as task demands become more complex". Indeed Sophian and Huber (1984) found that in more complex situations, with several alternative cues, 3-year-olds were not consistent in their use of temporal priority cues, whereas 5-year-olds were. Shultz et al.'s (1987) results suggest that generative transmission is a much more 'robust' feature of young preschoolers causal judgements. Although use of the temporal priority principle can be disrupted by task demands, when task demands are simplified and familiar events used, preschoolers showed that they can use information about temporal priority to judge which of two events is the causal one.

2.3.2 CONTIGUITY

1. Temporal Contiguity

Siegler and Liebert (1974) tested Piaget's claim that children imposed causal connections between events solely on the basis of incidental temporal contiguity. To ensure that children's acquired knowledge would not influence responses these researchers designed a novel situation in which relevant information could only

be secured by firsthand observation. Two metallic boxes, a computer with flashing lights and a card programmer were attached to a light bulb. It was demonstrated that both the computer and the programmer could make the light go on. Children were asked to insert a card into the programmer and asked what made the light go on (6 trials per child).

Both contiguity and regularity (constant covariation of cause and effect) were manipulated in 4 conditions. The bulb lit up:

- I - immediately a card was inserted in the programmer
- II - half the time immediately the card was inserted,
the other half not at all
- III - five seconds after each insertion
- IV - half the time after a 5 second delay, the other
half not at all

Children (aged 5-6 or 8-9 years) were assigned to one of the 4 conditions. Both age levels selected the programmer more often when the effect was immediate (I and II) despite inconsistent covariation information (II). Children's qualitative impressions ("It was always the programmer") were also recorded. The younger group tended to make the same causal choice across trials: 38/48 5-6-year-olds (versus 14/48 older children) stated that one object (computer or programmer) always made the light go on.

These findings implied that younger children relied more on temporal contiguity information than on information about regularities (covariation) in making causal connections. These results support Piaget's claims that the young child is phenomenistic. Alternatively, the younger child may just be slower to pick up the regularity information as Siegler and Liebert suggest. Even older children did not recognize the regularity of the sequence until the

last few trials. The tendency for young children to repeat a first inference may also have blinded them to further covariation information. The computer produced continuous noises and flashes so if children imputed causal connections between events purely on the basis of contiguity there was ample opportunity to ascribe causal power to the computer but children did not do so to any significant extent. Yet another possibility, not dealt with by the authors, is that there may have been an information overload for the children in that two features had to be attended to - the insertion of the card as well as the covariation information.

Mendelson and Shultz (1976) also studied both temporal contiguity and covariation. Two wooden boxes, one with a hole on the top (A) and side (B) through which marble could be dropped, the other with a bell inside were shown to children aged 4:5 and 6:7. The dropping of the marble was a possible cause of the bell ringing. There were two conditions: (1) in which two boxes were connected by an opaque rubber tube; (2) in which the marble box was stacked on top of the bell box. In the first condition, the rationale for a 5 second delay between cause and effect was that the two boxes were spatially separated (tube connection); in the second condition there was no rationale for the delay, as one box was above the other. Children were given a series of observations in which dropping the marble in A consistently covaried with the effect, while dropping a marble in B did not.

The results showed that children chose a temporally contiguous cause (B) (which did not covary consistently with the effect) over the consistently covarying, but temporally separated cause (A). These children used the covariation principle when there was a plausible rationale for delay (tube connection), but used the

temporal contiguity principle when no such rationale was present. These results showed that neither principle was fundamental to the children. They could and did use both, depending on the circumstances. This is contrary to Siegler and Liebert's findings. Although children prefer temporal contiguity information to covariation information they use the covariation principle when temporal contiguity was implausible.

These studies indicate that children do rely on temporal contiguity information as Piaget suggested. In addition, there is evidence that they can use co-variation information as well.

2. Spatial Contiguity

Piaget (1930) claimed that children only realised the importance of spatial contiguity after the age of 8-9-years because they did not give mechanistic explanations before that age. Piaget however, did not believe that the causal connection was immediately perceivable: it was something learnt from experience. Michotte (1963) argued that causal connections, at least of a mechanical nature, were directly perceivable. Michotte (1963) studied several events of this type by simulating them on displays on rotating cardboard discs and established two types of mechanical interaction:

- (1) The Launching Effect - one object strikes another and imparts its motion to the stationary object while becoming stationary itself
- (2) The Entraining Effect - one object strikes another and continues to move for a short time afterwards, gradually coming to a rest.

Adult observers were asked to describe their impressions of various such stimuli representing a wide range of this type of

interaction. When various physical parameters (spatial and temporal contiguity) were within a certain range, observers reported an immediate impression of the one object causing or producing movement in the other. This impression was robust in spite of the rather unlife-like stimuli used (eg. small black boxes moving within a viewing slit). The impression of causal activity was lost if there was a sufficiently long time interval (longer than 150 milliseconds) between impact and movement of the stationary object. Similarly, if the two objects did not seem to touch each other (the gap being more than 1 cm), no causal impression was reported. These findings showed that adults could directly perceive a causal relation. Furthermore, this impression was dependent on both temporal and spatial contiguity.

Michotte's emphasis on contiguity is very different from Hume's. Whereas the latter maintained that any two objects that regularly co-occurred in time/space would in time build up an impression of causality (Hume, *Enquiry* VII:ii; see also Chapter 1), Michotte insisted that the "the perception of causality is quite literally the perception of an act of production...an act of production immediately perceived" (Michotte, 1963:223). Spatial and temporal contiguity help this perception.

Bullock and Gelman (1979) reasoned that if children rely on temporal order over spatial contiguity, violation of spatial contiguity but not of temporal order cues might present children with conflicts about which cues to use. They hypothesised that children who assume "unidirectional causation" would choose a prior though spatially non-contiguous cause, whereas children who do not make this assumption will pick a spatially contiguous, but subsequent (to effect) event as cause. The Jack-in-the-Box apparatus was used, but

the box with runway X was separated from the rest of the apparatus (2 inch gap). The child then saw the standard (X - Y -X') sequence, and was asked which ball produced the effect. Their predictions were mixed (50%, 38% and 50% of the 3-, 4- and 5-year-olds predicted the effect would not occur after the separation), but after the demonstrations the majority of the children picked the temporally prior event as cause regardless of the physical separation. Thus although children demonstrated a knowledge of spatial contiguity principles in their predictions, when this was violated, they used an alternative principle to explain the event that occurred despite the violation of spatial principles.

Bullock and Baillargeon (1981) used the same apparatus positioning the runways such that neither touched the Jack's box but one was nearer to it than the other. Subjects of all ages (3-, 4-, 5-year-olds, and adults) chose the event nearest in space to the Jack as the cause. In this experiment the spatial contiguity principle was chosen over the temporal contiguity one. These results are reminiscent of Mendelson and Shultz's (1976) findings, that although children may display knowledge of a number of principles, the principle used often depends on the task given. It appears from these studies that children are aware that both temporal priority and contiguity in time and space are components of causal events.

2.3.3 CONSTANT CONJUNCTION / COVARIATION

This principle implies that causes and their effects co-vary systematically. Kelley (1973) claimed that this principle is fundamental to understanding causality and is the basis of more advanced causal schemas. When co-variation has been pitted against temporal contiguity, however, (Siegler and Liebert, 1974; Mendelson

and Shultz, 1976) neither has emerged as a fundamental principle.

Siegler and Liebert (1974) studied the covariation rule using the card programmer (cause A) and computer (cause B) described earlier (2.3.2). Older children (8- 9-years) attended to both contiguity and the regularity of covariance. They selected cause (A) more when it was a consistent (100%) covariate than when it covaried inconsistently (50%) with the effect. It was concluded that covariation information was only used in later childhood.

Siegler (1975) replicated the results of the 1974 experiment. The time delay between cause and effect seemed to distract the younger children. He concluded that young children's perceptual distractibility prevented them from searching for and attending to the temporally invariant covariation information.

Siegler (1976) identified 4 different necessity and sufficiency relations between cause and effect :

- (1) 'A' was necessary (the effect **only** after A, but not every A.
- (2) 'A' was sufficient (effect occurred after A, but also after other events.
- (3) 'A' was necessary and sufficient (effect only after A)
- (4) 'A' neither necessary nor sufficient (effect not related to occurrence of 'A'.

(N.B. 'A' = insertion of card into card programmer)

The same materials as in Siegler and Liebert's (1974) experiment were used. Siegler (1976) hypothesised that differences between the 5- and 8-year-old children in this study might lie in differential abilities to obtain relevant information which would influence causal judgements. Children's recall of events, as well as their causal inferences were analysed. Siegler (1976) found that both age groups attributed the effect to 'A' in condition 3 (above)

but not in condition 4. Only 5-year-olds attributed the effect to 'A' in the other two conditions. Causation seems to be a conjunctive concept for the older, but not the younger, children who attributed causality on the basis of contiguity when covariation information was irregular (50%).

Children's standards for drawing causal inferences were also investigated to see whether differences in performance reflected a difference in the ability to acquire relevant information on which to base inferences. Although the majority of children in both age groups had equivalent (correct) information about the task, the 5-year-olds were more likely to choose 'A' as cause, than the older children were, in the necessity only and sufficiency only conditions. Siegler concluded that "the locus of developmental change appeared to be in children's standards for inferring causation"; younger children rely more on temporal contiguity than older children and adults who "introduce additional constraints on what they will call a causal connection" (Siegler, 1976:1062-1063). One such constraint is plausibility, Siegler surmised (as did Piaget) that young children accept implausible causes, while older children and adults do not.

Plausibility:

Bullock and Gelman (reported in Gelman, 1978) investigated children's preferences for "reasonable" versus "unreasonable" ones. Four- and five-year-old children were shown a plexiglass fronted box with two handles on the left side: one started a ball rolling down an incline, the other switched on lights to give the appearance of a single light beam moving down an incline. After play demonstrations, children observed the light and the ball roll down their respective inclines and disappear into another box, from which

a jack popped out after a 3 second delay. The light and ball events occurred together. Children were then asked to "make jack jump". The children chose the ball event, although in the play demonstrations they had shown no preference for either event. Gelman argues that children chose the ball because it makes an impact and thus is a more plausible cause than the light.

In summary, although Siegler's (1976) results suggest that temporal contiguity is a more fundamental principle than covariation (constant conjunction), Shultz and Mendelson's (1975) results show (see Temporal Contiguity) that 3-4 year-olds use the co-variation principle. However the Shultz and Mendelson (1975) task was much simpler than Siegler's. Shultz and Kestenbaum (1985:224) argue that while young children may use covariation under "optimal circumstances...use of covariation can break down in children under 8 years as the information becomes more complex". This seems a reasonable assumption in view of the evidence available. Use of complex covariation information often involves logical deduction. This is very different from reasoning about cause and effect relations using knowledge about contiguity, priority, plausibility, and the causal powers of things.

2.3.4 DO YOUNG CHILDREN USE HUMEAN PRINCIPLES?

The research reported in this section indicates that the answer to this question is "Yes". In different task situations children between 3- and 8-years of age have demonstrated use of temporal priority, contiguity and covariation. Recent experiments (Shultz et al, 1987) indicate that children are aware of causal priority as distinct from temporal priority and this distinction is based on knowledge of generative transmission.

Some studies indicated that preschoolers grasp of some

of these principles is slightly shaky. This may be explained to some extent by task demands. Sometimes, slight changes in procedure (Bullock and Gelman 1979), or a different way of presenting the task (Kun, 1978) enhanced younger children's performance. In experiments where preschoolers showed preference for associative principles, it may have been because these principles had been pitted against principles which required more complex cognitive processes. Mendelson and Shultz's (1976) study indicated that preschoolers were not totally incapable of such processes but that they may have preferred to use the simpler, and therefore more accessible, principle. One such principle, arguably the most fundamental (Michotte, 1963; Shultz, 1982; Shultz et al., 1985; 1987), is production.

2.4 Causal Perception (Generation/Production)

Michotte (1963) asked whether the causal relation was directly perceptible. Experiments with adults suggested that it was and Michotte stated that certain physical events gave "an immediate causal impression...one can 'see' an object **act** on another..**produce** in it certain changes and **modify** it in one way or another" (1963:15).

Leslie (1982) filmed Michotte type events and habituated infants between 4 and 8 months either (a) to a film where an object moved immediately after being struck by another, or (b) to a film where there was a short delay between the two events. Dishabituation was measured by showing a film where either one object struck another with no result, or a stationary object moved without having being struck. He found that infants who had been habituated to film(a) dishabituated more than other infants and concluded that infants saw direct launching as two separate but continuous movem-

ents; they perceived a causal relation between them. Subsequent experiments in the same vein by Leslie (1984a, 1984b) and Leslie and Keeble (1987) have provided strong support for this conclusion.

Research on infant causal perception in the Michotte tradition has been mentioned only to show that there is evidence for direct causal perception in infancy. Infants' awareness of their own actions may also contribute to their understanding of causality (Piaget, 1930, 1955, Michotte, 1963), but Leslie's results indicate that this is not necessarily the only causal impression available to infants.

There are many types of causal events. We have countless opportunities to observe inanimate forces causing change (wind blowing leaves off trees). Experiences of internal agency (wanting a sweet and crying for it) as well as animate force being exerted to bring about a desired effect (push the door to open it) also abound. Finally, animate force may be used to manipulate tools/instruments to change the environment. Michotte-type experiments investigate one very basic type of causal understanding - the interaction of mechanism. But whereas Piaget argued that comprehension of physical causality arose from notions of psychological causality, studies on causal perception of interacting mechanisms indicate that a concept of physical causality may exist early in life. Leslie and Keeble (1987) suggest causal understanding may have its beginnings "in a low level visual mechanism" which may be the "first processing device to introduce a cause-effect format for internally representing events" (1987:286).

The most basic characteristic of a simple causal event is change. Perception of change in a substance leads us to seek cause/s for it. The desire to change something prompts us to find

the instruments or means to do so. It seems a reasonable assumption that perception of changes would be a very basic process, present in infancy, as Lesley and Keeble suggest. Apart from raising very interesting questions about the origins of causality, the infancy studies also raise questions about causal competence in the preschool years. If infants can perceive simple causal connections are young children unable to do so? What is the young preschool child's knowledge of causation? Is it derived solely from experience and based on the Humean principles or do preschoolers have some notion of production, of the causal powers of things?

Harre and Madden (1975) and Shoemaker (1980) stress that knowledge about the causal powers of things is essential for causal reasoning. Understanding of mechanism is entwined to some degree with knowledge of the causal powers of objects. Recent research on children's understanding of causality investigated understanding of specific mechanisms and perception of some generative transmission/causal power.

2.4.1. CHILDREN'S UNDERSTANDING OF CAUSAL MECHANISM

Mechanism is defined as the assumption that "causes bring about their effects by transfer of causal impetus" either directly, or through intermediary events (Bullock et al., 1982:211). This principle, according to Bullock et al. is an "essential part of an adult's causal theory or causal attitude and as such contribute to the structuring and interpretation of events" (p. 211).

Keil (1979) tested very young children's (1:6 - 2:6 years) assumptions about mechanism. Children were shown events where crucial support blocks were removed from under a 'bridging' block. Tasks of varying complexity were designed to test the influence of

task complexity:

- (a) The FOUR BLOCK structure (only one block was removed) required concepts of both balance and support to anticipate collapse.
- (b) The THREE BLOCK structure (two blocks were removed) required only a concept of support to anticipate collapse.

There were two conditions (control and test). In each condition children experienced three trials each for (a) the balance-and-support structure and (b) the support-only structure. In the control condition two trick outcomes (non-collapse of structure after removal of support/s) were followed by a collapse outcome. In the test condition, two collapse outcomes were followed by a trick outcome in order to control for expectancy effects. The response measure was children's expressions of surprise on the third outcome.

The support-plus-balance task did not elicit surprise on the trick trial, for either age group, but Keil reported that informal work with adults and 4-year-olds had elicited surprise. In the support-only task however, children of both ages were surprised at the trick outcome (surprise coded by 10 judges). Children younger than 3-years demonstrated knowledge of one physical law (support). When presented with a violation of this law, they expressed surprise, but were unsurprised at the violation of more complex laws.

In a follow-up experiment, Keil tested 16 additional children of the same ages on the same apparatus. He showed the children the following sequence of events: screen, the complete structure, screen, and finally, the trick outcome structure. Two measures of surprise were taken; for the complete structure, and for the trick structure. Keil wanted to see if children would expect

causal relations between the first and last structures to hold even when the causal event was screened from view.

Only older children (2:6) showed surprise, for the support (b) task alone. This finding indicates that two-and-a-half year olds relate the first and last structures in terms of a transformation (the collapse of the structure), but only when a simple structure (b) is used. Younger children did not demonstrate this ability to impose a relation between two events. By the age of 2, children seem to have certain causal expectations (based on simple physical laws) and express surprise when these are violated. Possibly the support-only task was familiar to children because they may have had the opportunity to play with building blocks. However, the balance and support task would have been less familiar because children of these ages do not generally build very complicated structures. Familiarity, as well as the ability to cope with two features, balance as well as support, may have affected performance in this task.

Bullock (1981) asserted that if children lack assumptions about mechanism their causal judgements should not be influenced by cues of physical or spatial contact. If children assume that causal sequences include "a mechanism of action, they should look for causes which..make actual contact with the effects they are trying to explain" (1981:2). The jack-in-the-box (1979) apparatus was modified so that one runway touched the jack's box, while the other was 6" away; a ball was rolled down either runway. This was demonstrated to preschoolers (3-4:6 and 4:6-6 years). Bullock predicted that children indifferent to mechanism would choose randomly between the two runways. Choice of the connected runway would indicate some notion of mechanism.

Of the older children, 72% consistently chose the connected cause, only 44% of the younger children did so. Only the older children explained their choices in terms of contact. Interestingly, none of the children chose the unconnected cause more than the connected one. Bullock (1981) does not give any indication of the temporal ordering of the two ball events (connected and unconnected). The younger children chose a plausible cause but it is not clear whether they were indifferent to mechanism (in terms of contact) or whether, seeing that the event did occur without contact, they postulated some form of mechanism which they were unable to articulate. Experiments by Shultz (1982 - see below) indicate the viability of such a possibility.

Bullock (1981) conducted a second experiment in which children were given more information about mechanism to see whether children conclude that things are connected even when the connection is not visible. Two cars were placed on either side of a closed box, and a piece of string **apparently** attached one car to the other, through the box. In reality the box was empty. The movement of the cars was yoked (when one moved the other moved) by means of a hidden mechanism. Children's explanations for the phenomena and predictions as to what happened if the string broke were elicited. Subsequently, the "game broke" (Bullock, 1981); pulling one car no longer moved the other. Children were asked what had broken, and how it should be fixed.

Children had to claim that the string was necessary to tow the car to show a knowledge of "Visible Connection"; they had to "Predict" that breaking or eliminating the string would stop the game working; "Infer" that the string went through the box; and "Explain" that the string was involved when asked how the game worked.

If the child responded correctly at least once she was credited with concern for causal mechanism (at all category). Only if the child responded correctly at least twice was she categorised as being consistent in her concern with mechanism.

Children of both age groups fell largely into the 'at all' category, there was no significant difference between ages. In the consistency category however older children were more consistent overall. The older group not only inferred the existence of mechanisms they also articulated them. The 3 year-olds were more variable but they did consistently explain the event in terms of the visible mechanism, and were able to predict that if the string was broken one car could not pull the other. They could not, however, explain the event consistently and did not always articulate the inference that the string went through the box.

The picture that emerges is that the 3-year-olds' performance was inconsistent, and tied to the type of questions asked, whereas older children's performance was more robust. It is possible that the younger groups judgements were made solely on the basis of their observations during the pre-test demonstrations while the older group had a wider knowledge of this type of mechanism. Bullock (1981:8) concluded:

"developmental changes do not come from learning that mechanisms are a part of causal events - children already know that. Rather, children become better able to apply their knowledge more consistently, and to use an inference to explain events."

A number of studies have also investigated mediate causal transmissions, stemming from Piaget's (1974) studies on causal reasoning and logical operations. Operations are logical networks of action schemes which possess many properties of mathematical lattices. Piaget tried to link developments in operational

thought, particularly logical transitivity to development of understanding of mediate causal transmission. Mediate transmission problems deal with problems of action at a distance. Apart from the fact that any parallelism between causal and logical thinking is debatable (Bindra, Clark and Shultz, 1980; Shultz, 1979) mediate transmissions address a more sophisticated understanding of causality than that investigated here. Therefore, such studies were not included in this review (see Shultz and Kestenbaum, 1985, and Bullock, Gelman and Baillargeon, 1982, for reviews; also Bryant and Sommerville, 1983).

2.4.2 GENERATIVE KNOWLEDGE - IMMEDIATE TRANSMISSIONS

Harré (1960) argued that scientific investigations aim to uncover the "hidden mechanisms" in things that produce effects. Causal explanations are valuable in so far as they refer to these mechanisms. Both Harre and Atkinson (1983) emphasise that when hidden mechanisms are not easily accessible people content themselves with models and analogies, but always with the intention of finding out how the thing really works.

Shultz (1982: Experiments 1 and 2) showed that children aged 2- to 13-years demonstrate a belief in invisible, immediate 'mechanisms', or causal transmissions, such as wind, sound and light. All these children correctly attributed (1) the extinction of a candle to an electrical blower that was "on" rather than to one that was "off"; (2) the ringing of a hollow wooden box to a vibrating tuning fork rather than a motionless one; (3) the appearance of a spot of light to a lamp that was "on" rather than to one that was "off". The only difference between the two potential causes in these experiments was that one was transmitting causally relevant energy

and the other was not.

These experiments demonstrated that children knew that things had to be activated ("on") to produce effects. In Experiment 3, using the same apparatus Shultz showed that children as young as 3-years know that specific objects produce specific effects (a lamp rather than a blower was chosen as cause for a spot of light; an electric blower was chosen above a tuning fork as cause of a candle being extinguished; and a tuning fork was judged a more likely cause than a lamp, for a resonating wooden box). He also showed that children of the same ages, in a non-technological culture (Mali), could reason causally about these occurrences which are unfamiliar to them (1982, Experiment 4). This finding not only contradicts Levy-Bruhl's (1923) claim that people from traditional cultures do not understand causal mechanism, but also suggests "that the use of transmission rules is a fundamental property of mind and not the result of mere familiarity with technological gadgets used in the investigations" (Shultz and Kestenbaum 1985:209). Nevertheless, it could be argued in these experiments (3 and 4) that children simply chose the source that was "on" (which happened to be the correct choice) on the basis that it was 'doing something' without reasoning about plausibility of transmission.

This argument does not hold because Shultz (1982: Experiment 1) also presented children with conflicting cues (eg. contiguity-vs-transmission). Two electrical blowers were positioned on each side of a candle. The candle was protected from one blower by a 3-sided plexiglass screen, with the open end facing away from that blower. This blower was activated first, after lighting the candle. The second blower was switched on 5-seconds later and the screen turned so that the opening faced the first blower. The first

blower could now snuff out the candle, but its ONSET was not temporally contiguous with this event. Children in the age levels 2-4, 5-6, 8-10 and 11-13 years all demonstrated use of the generative transmission rule and disregarded "any conflicting temporal and spatial information" (1982:16). This rule was found to be fundamental in all groups, except the youngest one.

Since Shultz's (1982) experiments all involved fairly common phenomena (candles being blown out; light appearing when a lamp was switched on; even vibrations may have been experienced) the causal principles used might reflect particular experiences. To counteract such claims Shultz (Experiment 5) used a totally unfamiliar phenomenon, Crookes radiometer, which measures radiant energy. A horizontal wheel is mounted on a pivot, with two pairs of lightweight metal vanes on either spoke. It is mounted in a glass bulb from which air has been partially exhausted. When radiant energy from an adjacent flashlight falls on the vanes the wheel revolves. Adults unfamiliar with the apparatus were unable to explain the rotary motion, even if they thought the light had something to do with it.

Children aged 4- and 8- years as well as adults were asked to explain what was making the "propellor" spin. If the light was not mentioned the experimenter offered 5 methods of verification: Covariation - did the propellor spin only when the light was on?; Temporal Contiguity - Did the light and propellor "start working at the same time?"; Spatial Contiguity - were the light and propellor connected?; Similarity - was something spinning inside the light? and Generative Transmission - was there "some invisible thing" that went from the light to the propellor? (Shultz, 1982:42). Appropriate actions to test each suggestion were offered.

Almost all subjects chose the light as the cause. The proportions of subjects who chose the generative transmission explanation were significantly above chance expectations (.56 at 4-years; .72, 8-years and adults). This 'rule' was chosen above covariation, contiguity and similarity. Subjects who obtained transmission information not only stopped their inquiry about possible cause, but also, in the two older groups, reported greater certainty about their causal attributions after receiving this information. Shultz concluded that across the age range studied, the generative transmission rule was favoured over all others, providing support for the proposition that "the ordinary human observer regards causation in terms of generative transmission even when the mechanism of transmission is not understood" (page 45).

Using similar procedures within a covariation paradigm Shultz (1986) replicated previous results and showed that children (aged 3-7 years) used obvious generative transmission information over covariation information to decide which of two possible causes produced an effect.

While Shultz's experiments neatly demonstrated very young children's knowledge of some causal process, they did not unequivocally demonstrate an ability to reason about causality. It should be noted that the explanation "there is some invisible thing that goes from the light to the propellor" (1982:42) could, in Piagetian terms, be a magical explanation. What is this invisible thing? If children have a vague, undifferentiated notion of causal efficacy this explanation could well appeal. Bullock et al.'s (1982) principle of determinism specified the belief that there are no causeless events. Certainly, the results of Shultz's last (1982) experiment indicate that 4-year-olds have this belief, though they

are far less certain of their attributions using the transmission rule than are older children and adults. Keil (1979) showed that 2-year-olds possessed knowledge of mechanical transmissions (2.4.1) using non-verbal techniques. So, how primitive is the assumption of determinism and how does it relate to understanding causal mechanism?

Wesson (1983) tested 3-, 4- and 5-year-olds using a bead dispensing machine: a bead in the bottom of the apparatus was secured by a plexiglass plate attached to a rotating flywheel. To get a bead out a ball had to be dropped onto a spoke of the flywheel to make it turn. There were two shutes on either side of the flywheel; one (down position) did not drop the ball on the flywheel, the other did (slanted position). Children watched a demonstration and were asked how the game worked; to make it work; and to predict whether it would work when both shutes were down.

As in other studies, older children gave more comprehensive explanations than younger children who simply described the apparatus. However, most children could tell which ball produced the effect (when one was dropped down each shute). All of them could produce the effect given two balls, the younger children used both balls far more than the 5-year-olds. Thus, although children realised that some sort of transmission was required, they did not really understand the causal mechanism although it was clearly visible. Indeed, when asked to predict if the bead would be released when both shutes were down, only one 3-year-old answered correctly ("no") compared to half the 4-year-olds and over half the 5-year-olds. Although 3-year-olds certainly demonstrated a belief in determinism they "showed little evidence of identifying the specific mechanism nor of assuming that a connection between events was necessary for

the apparatus to work" (in Bullock, 1985:19).

Bullock and Kampman (1983) tested assumptions of mechanism by testing whether children looked for causes of unexpected events. They argued that children may be motivated to look for reasons if events contrary to expectations occur, so they set up an expectation, then violated it. In the training phase of this study the experimental group received relevant training about the mechanism while the control group received irrelevant training. Three groups of children, aged 3-, 4- and 5-years watched a ball roll down a trajectory towards a cup containing one piece of candy. Then a cup full of candies and a magnet was put 20 cm. to the left of the trajectory (the cup atop the magnet). The ball was again rolled towards the cup with one candy, but as it passed the full cup, it veered sharply towards that. Children were asked to explain why the ball veered towards the full cup and what would happen if the position of the full cup was changed.

Subsequently, the experimental group received instruction about magnets and were allowed to play with them. They were also given information about the contents of containers (lots of candy) to provide them with the basis for irrelevant, animistic explanations such as the ball wanting lots of candy. The control group played a neutral game during this period. Bullock and Kampman predicted children who understood that some mechanism was necessary for the strange event would use the information garnered in the training phase to explain it.

Comparison of responses before and after training showed that children of different ages treated mechanism information differently. The older children (4-5) improved with training; changes in scores were greatest for 5-year-olds. The youngest group was

little affected by training, no significant difference being found between control and experimental groups. The authors concluded that though understanding improved with experience "the effects of training [experience] depend in part on the age of the child" (Bullock, 198 :22). However, children were required to learn a lot during training - both about magnets and about wanting 'more' candy. The youngest children may have just ignored all the new information because they were not able to take it all in and stuck to what they knew.

2.4.3 DO PRESCHOOLERS UNDERSTAND MECHANISM AND PRODUCTION?

Whereas results of the generative transmission experiments are pretty clear - children as young as 3-years demonstrate understanding of production/generative transmission - the results of studies on understanding of specific causal mechanism are mixed. Keil (1979) and Shultz (1982) showed that very young children do have some sense of mechanism and transmission. Studies by Baillargeon et al. (1981) and Bullock et al. (1982) indicated that preschoolers also shared a similar assumption of mechanism to older children and adults. The later studies by Wesson (1983) and Bullock and Kampman (1983) indicate that 3- and 4-year-old children may give mechanism a different status than adults and older children. Wesson's study in particular suggests that although children may 'know' that some transmission of energy is required, they may not be able to figure out the specific mechanism. Older children and adults assume a causal mechanism, even when one is not in evidence. Younger children on the other hand may use a potential mechanism if it is available, but do not appear particularly concerned by its absence (Bullock, 1985).

However, it should be noted that the last two experi-

ments cited were far more complex than Shultz's (1982) experiments, or the earlier work reported by Bullock et al. (1982). Furthermore, none of the children produced animistic explanations in the Bullock and Kampman experiment, though it might be said that they were encouraged to do so. Especially in this last experiment, it is possible that 3-year-olds were presented with an information overload in the training phase. Also, Bullock (1984) did not give details of the types of explanations made by this children, so it was difficult to gauge to what extent they were uninterested in mechanism.

2.5 Causal Reasoning in Event Sequences

Most of the research reported thus far focused either on children's verbal explanations or their judgements about concrete demonstrations. Another line of research has investigated children's abilities to infer causes or predict consequences in pictorial event sequences. Such research has typically investigated the **structure** of causal thought by testing children's abilities to relate beginning and end events/states in a sequence by a causal relationship (Brown and French, 1976; Schmidt and Paris, 1978; Kun, 1978). Most of these studies however, involved social event sequences.

Brown and French (1978:930) point out that in reconstructing a series of events in the past "we routinely appeal to causal operations, i.e., we establish a plausible chain between causes and effects. Thus, the most easily reconstituted series should be those that actually correspond to causal relationships or logical sequences." Brown (1975) and Brown and Murphy (1975) showed that preschoolers not only remember the order of events in narrative sequences, they are also better at producing logical and causal sequences as compared to arbitrary ones. Nevertheless, work by

Bronckart and Sinclair (1973) and Brown (1976) have shown a disposition in young children to focus on terminal events in sequences. Bronckart and Sinclair found that, although children over 5 years follow the real order of events in a sequence from beginning to end, younger children (3-5 years) begin with the final event.

Brown and French (1976) tested the assumption that young children find it easier to predict consequences than infer initial events by presenting children (mean ages 5:7, 7:3 and 9:3) with 20 action sequences such as:

INITIAL	MIDDLE	TERMINAL
Girl writing a letter	Girl licking envelope with letter inside	Girl standing by mailbox...

After pretraining (with similar sequences) children were asked to complete pictorial sequences, with either initial or final events missing, from 10 choice pictures containing both correct and distractor pictures. The youngest group made fewer errors when asked to complete sequences rather than find initial items. There was an improvement with age in the ability to complete picture sequences and older children provided both initial and final items (causes and consequences) with equal ease.

It should be noted however, that Brown and French's sequences were more logical than directly causal. For instance, in the preceding example, the initial event is not really a cause of the following event. It precedes the middle event but does not cause it in the way that the impact of a rolling ball causes the Jack to pop up. This criticism holds for almost all the sequences. Furthermore, children had to sort through 10 choice-pictures and this may have been too much for the younger children.

Schmidt and Paris (1978) constructed sequences to "maximise the probability of a particular consequence following an

antecedent condition" (p. 1219). Children's ability to infer antecedents as well as predict consequences was also investigated. Children (mean ages 5:1, 5:11, 8:1) were tested using a three-alternative forced-choice (3 AFC) task. They were shown three elements of a 4-component sequence such as:

A woodcutter (1) raising his axe (2) striking a tree(3)
watching the tree fall (4) standing next to a fallen tree

In an 'acquisition' phase, children were shown 6 sequences in all. The three antecedent elements were presented for half the sequences and the three concluding elements for the other half. In the experimental condition the child had to pick from three alternatives, the one picture which either completed or began the sequence, respectively. Schmidt and Paris found that while the two older groups could infer antecedents and predict effects equally easily, the youngest group identified consequences far better than they could identify the antecedents of sequences. The ability to identify both antecedents and consequences improved with age. Thus, using more 'causal' sequences Schmidt and Paris largely replicated Brown and French's results.

These studies however, used narrative sequences involving actors. Narrative sequences have been defined as "chains of events that are connected by temporal, causal, or probabilistic relationships", and inference within such sequences has been defined as "the ability to produce or select events that are consistent with previously presented pictures or sentences" (Schmidt, Paris and Stober, 1979:395). Narrative inferences involve generation of events which are highly probable given the events in the sequence. Using extended sequences Schmidt et al. (1979) showed that while 5-year-olds can choose consequences fairly correctly for four-item sequen-

ces their performance drops when the sequence is extended to six items.

More recently studies by Oppenheimer and Van der Lee (1983) and Oppenheimer and Groot (1985), using techniques similar to Schmidt and Paris', confirmed the findings of previous studies that kindergarten children (mean age 5:7) find it far more difficult to reconstruct sequences by inferring causes/antecedents, than to construct sequences forward in time, by identifying correct consequences. Nevertheless, Kun (1978) showed that children as young as 4 could give correct antecedents and consequences when asked. However, her study differed from the ones reported above in that children did not have to construct sequences. Another factor that may have contributed to these results is that social events are very complex and require a degree of social knowledge which young children may not possess. Additionally, for example in the wood cutter sequence, the final event is far more striking than the first (wood-cutter lifting axe). The child would also have to predict what he was going to do with the axe in order to pick the appropriate initial picture. Indeed, as in Brown and French's study, the initial event was not the cause of the fallen tree at the end. It was just the logical first event. Children may have been able to pick the initial event if it was the causal one.

All these studies however used social event sequences. It can be argued that there is a greater variability in social events than in simple physical ones. Thus, antecedent choices are not necessarily clear-cut and could be influenced by children's affective reactions. For instance in Schmidt et al.'s (1979) study one sequence showed component events of a boy diving into a pool. The correct antecedents were pictures of the boy climbing up to the

diving board, while distractor items showed him walking around the pool, doing press-ups, etc.. Arguably, all these are possible antecedents, especially if children are afraid of diving.

2.5.1 REASONING ABOUT OBJECT TRANSFORMATIONS IN SEQUENCES

Gelman, Bullock and Meck (1980) avoided the complications of using social event sequences by depicting object transformations in their sequences. In their view: "knowledge about transformations and their relation to object states underlies the ability to make causal inferences that go beyond a particular data base", (1980:691). Gibson and Spelke (1983) and Shultz and Kestenbaum (1985) also identified transformation as an essential feature of the causal relation:

"One way to think about a cause-effect sequence is in terms of a transformation of the effect object. The effect object is transformed from an initial to final state by the action of the causal object. The causal object can be considered the instrument of this transformation." (Shultz and Kestenbaum, 1985:210)

Gelman et al. (1980:691) argue that physical events can be thought of in terms of their component parts and given any two of the components in a three-component event, the third can be inferred: "If we see an object in two different states at time *a* and time *b*, we assume that some action involving use of a certain type of instrument was responsible" (for effecting the transformation from state *a* to state *b*). Moreover, the choice of the instrument is constrained by the type of transformation that has occurred. This view not only implies an understanding of the powers of things (for only such an understanding would constrain the choice of instrument) but also implies that children impose a causal relation between states *A* and *B* on the basis of transformation information.

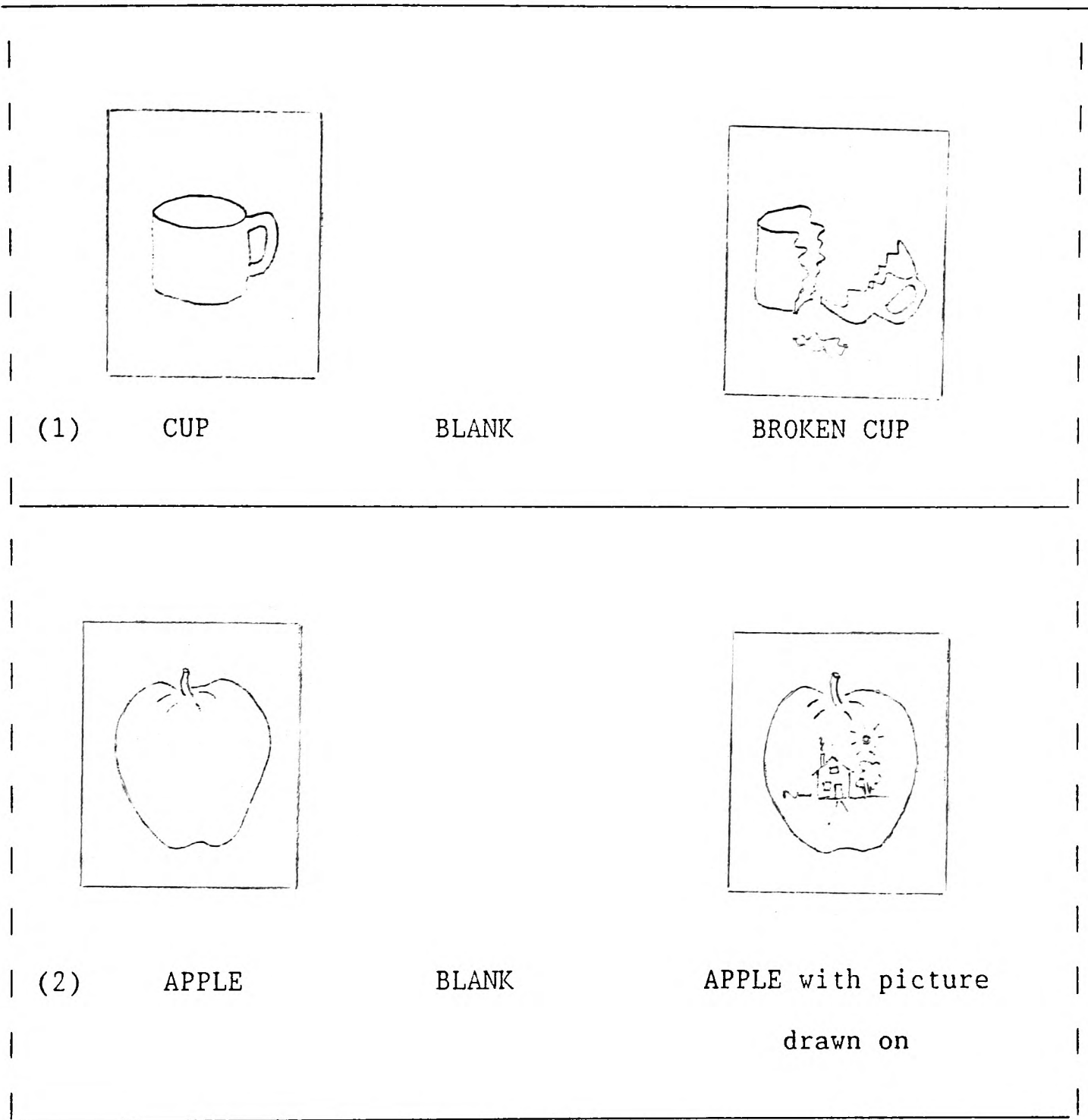
These sequences and procedures were adapted from

Premack's (1976) work on inferences in apes. Premack required apes to choose causal instruments in three item sequences such as: apple ___?___ cut apple. The ape had to choose one of three instruments (water, knife, writing implement) to fill the blank. The apes did well on this task and Premack concluded that they could reason about simple transformations.

Sequences in the Gelman et al. experiments depicted common (1), as well as uncommon (2), events as shown in Figure 1. They argued that by including the latter they could investigate children's reasoning about events in general, not just their remembrance of everyday events. Half the sequences showed objects being transformed from canonical (standard) to altered (noncanonical) forms (Condition A), while the other half depicted transformations from noncanonical (broken cup) to canonical (fixed cup) (Condition B). Line drawings of objects on cards were used as stimuli.

In the first experiment children of mean ages 3:7 and 4:5 were tested on either canonical (Condition A) or noncanonical (Condition B) sequences. Sequences were presented with either first (antecedent), middle (instrument) or end (consequent) positions left blank. Each child filled in all these positions (4 sequences antecedent blank, 4 instrument blank, 4 consequent blank).

FIGURE 1 Examples of sequences used by Gelman et al.



Except for two 3-year-olds (out of 24), all the children performed above chance level in both conditions. Older children made fewer errors overall. When they erred it was in retrieving the initial state for both common and uncommon sequences. The 3-year-olds however did far better when sequences depicted alterations to objects (canonical condition) than when they showed restorations. There was a slight tendency for 3-year-olds to do best on filling the instrument slot. Gelman et al. also asked for 'stories' about the sequence after each trial. As in previous studies older children

gave more complete stories than younger ones.

In a second experiment Gelman et al. investigated preschoolers' abilities to reverse causal sequences. Children were presented with sequences where the middle element was missing. The 3 choices included the ~~the~~ correct instrument for reading the sequence from left to right (hammer in example below) as well as from right to left (glue, same example). This was done to check whether children could deal with the two operations "as a pair that reverse the effects of each other". Other than these modifications the materials were exactly the same as for the first experiment. Sequences were of the form:

Cup ____? ____ Broken Cup

Children (mean ages 3:4 and 4:6) selected from the previous sample (12 in each age group) were trained to read sequences from left to right. For the experiment proper, they had to first choose an instrument for a left-right reading, then for a right-left one. Three-year-olds were correct on 49% of the trials and 4-year-olds on 75%. The younger group erred by choosing the instrument for a right-left reading. Gelman et al. argued that this group preferred to read sequences from right to left, and if they were allowed to do the task "in their own way" they too could cope with reciprocal transformations. Younger children also showed a significant tendency to "interpret any transformation as altering the canonical form of the object" (Gelman et al., 1980).

It should be noted that reversibility in Gelman et al.'s sequences dealt with the transformations themselves (broken --> fixed / whole-->broken) not the causal sequence. In both cases the causal sequence remains unidirectional and irreversible: the effect cannot produce the cause. Gelman et al.'s concept of reversibility

is different from Piaget's (1930/1974). Piaget's conception of causal reversibility was modelled on logical reversibility which is not always applicable to causal problems. Shultz and Kestenbaum (1985:215) emphasise that "there is a sense in which a mature understanding of causality entails the recognition of **irreversibility**" as this underlies the notion of the unidirectionality of causal sequences.

Although Gelman et al. concluded that both 3- and 4-year-olds connected the elements into a sequence by a causal relation and did not just associate appropriate instruments to effects, the major problem with their experiments is that it was possible to make correct responses on the basis of associations. In these experiments children could have focused on the end state (cut apple for instance) and matched that state with an appropriate choice instrument (knife) because they have built up causal-associations between apple and knife. No distinction was made between the causal relation and causal-associations (as in this thesis). This is an important distinction, because if children were making causal-associations then they need not have taken the first state of the object into account, as Gelman et al. assume. In the Gelman et al. study a conceptual leap seems to have been made - that having knowledge about the powers of things entails or includes relating objects in terms of transformations. This is not necessarily true. As mentioned earlier (2.5), Bronckart and Sinclair (1973) noted that children less than 5 years tend to focus on the last event in a sequence.

Sequences such as drawing on an apple or stitching up a banana are unusual but the processes of drawing and sewing are common ones. Associations between the instrument and the effect (for

example between pen and drawing or needle and sewing) could already have been established by past experience. As no distinction was made by the authors between causal inferences and inferences based on "a memory for contiguously associated events", their conclusion that preschoolers make causal inferences cannot be accepted without question.

In their second study, Gelman et al. tested children who had experienced the first experiment but they do not account for carry-over effects. Their results could have been affected by pre-established associations from the first experiment. Furthermore asking children to read a sequence from left-to-right as well as from right-to-left may have 'confused' the child to some extent, especially as children had experienced two trainings in left-right readings.

Gelman et al.'s sequences were similar to narrative sequences in that two states of an object were connected by a causal relationship (transformation) and inferences involved the ability to select a state or an instrument implied by the previously presented pictures, like Schmidt et al.'s (1979) narrative inferences. A similar method was adopted in this thesis as its central concern is to investigate the child's understanding of causal relation as defined at the end of Chapter 1.

The question raised by the Gelman et al. study is this: When children are asked to find a cause for a particular change, do they connect events from the beginning to the end of the sequence and then reason about the change depicted at the end in terms of **change from the beginning state**, or do they focus on the end-state and try to find a causal instrument associated with that state? One way to find out whether children are making causal inferences or

using causal associations with end states is to design sequences with two end-states (eg. wet and cut). One of these, say "cut", is the initial/first state of the object. To find the cause of the transformation that occurs in the sequence presented, children will have to connect initial and final states. If they focus on the final (end) state they will make incorrect inferences. This method was adopted in the first experiment (Chapter 3).

2.6 Conclusions

The emerging picture of children's understanding of causality is a promising one but certain issues remain neglected. Children's knowledge of Humean causal principles have been assessed, as well as their understanding of production and mechanism. Some underlying philosophical problems, in particular the possibility of associative elements in causal reasoning, have largely been ignored. Some researchers investigated use of covariation information but, as pointed out earlier, this is not the same thing as the type of associations discussed in Chapter 1.

Bullock (1985) identified mechanism as a central principle for identifying events as causal. However, the results of studies on children's use of the mechanism principle have been variable, especially for the 3-4-year-old group and "do not provide compelling evidence that the use of mechanism information arises from an underlying principle which specifies that a causal link is a necessary, definitional aspect of causation" (1985:17). The underlying principle referred to seems very close to Kant's 'a priori' category of causality which also posited a direct link between cause and effect. Recent studies by Leslie and Keeble (1987) suggest that

a direct perception of causality may be present in early infancy. Shultz and his colleagues (1982, 1985, 1987) has shown that children not only know about the generative powers of things, they also use the generative transmission principle above others when generative information is readily available. What is not clear is whether this knowledge is purely associative, associative-causal or causal (as defined in Chapter 1).

None of the studies on children's understanding of causality have investigated children's reliance on associations. Children's knowledge of events may be associative in that certain causes and effects constantly occur together; for example knives are seen to cut, lamps are lit by flicking on switches, water wets, and so on. Hume argued that causality was no more than a series of regularities, but as we have seen generation/production is also an important aspect of the causal relation. In fact it is one of the major distinguishing factors between causal and associative relations.

Gelman et al. (1980) focused on the child's understanding of the causal relation itself. In the simplest terms, in a causal relation, an object in state **a** at time 1 is transformed to state **b** at time 2. The two states are connected by the transformation of the object. This is a fairly basic understanding of physical causality. The aim of the current investigation is to find out whether children of 3- and 4-years of age display this type of understanding of causality.

CHAPTER THREE

AN ATTEMPT TO DISTINGUISH BETWEEN CAUSAL AND ASSOCIATIVE
INFERENCES

3 Experiment 1 An Investigation of Types of Inferences
 made in Sequences Depicting Transformations.

3.1 Introduction

This first experiment attempts to investigate the question raised at the end of Chapter 2. The major focus is on children's understanding of the causal relation in terms of **transformation**, or change, implying the activity of a causal mechanism. Gelman, Bullock and Meck's (1980) study dealt specifically with this issue.

In their experiment, however, Gelman et al. made no distinction between causal and associative inferences. It was unclear whether children were relating object states in sequences in terms of the transformations that had occurred, or whether they were simply choosing the instrument associated with, or similar to, the changed end state of the object (2.5.2). There was no control for associative matching in the Gelman et al. experiments. Therefore the present experiment incorporated such a control. There were two conditions. In the Experimental condition, correct responses could only be made if children related beginning and end states of objects. In the Control condition, associative matching would produce correct responses. If children do use causal-associations, as defined in this thesis, to make inferences about causal instruments this may indicate that at least some of their knowledge about causality may be based on specific 'associative' knowledge.

Two methods can be used to choose instruments for the

final state of an object in sequences such as those used by Gelman et al. Children may either

make an inference about a causal instrument after figuring out the change that distinguishes the last state of an object from the first state of that object in a given sequence, or choose an instrument on the basis of past associations between that instrument and an object state without taking transformation information into account.

Experiment 1 was designed to investigate whether children do take transformation information into account when asked to infer a causal instrument, or whether they simply match instruments to effects, based on past associations. As the review of literature (Chapter 2) suggested a major shift in the ability to make correct causal inferences between the ages of 3- and 5 years, it was decided to focus on the abilities of 3- and 4-year-old children in this experiment.

3.1.2 CLARIFICATION OF TERMS

A distinction was made between causal inferences and associative-causal judgements. The definition of a causal inference is based on definitions by Goddard, 1977, Shultz and Kestenbaum, 1985, and Gelman et al., 1980. The definition of associative-causal judgements is derived from the consideration of different types of relations in Chapter 1.

1. CAUSAL INFERENCES are made on the basis of an understanding of transformational relationships: the relation between object states mediated by a transformation. In order to make such an inference children must be able to compare two successive states of an object, relate them in terms of a transform-

ation from one state to another and select the causal instrument implied by the transformation.

2. ASSOCIATIVE-CAUSAL JUDGEMENTS OR CAUSAL-ASSOCIATIONS are based on associations between particular instruments and their particular effects. The term associative-causal is used because this type of judgement implies an understanding of the causal power of an object. Causal power is defined thus - " 'X has the power to A' means that 'X will or can do A' in the appropriate condition, in virtue of its intrinsic nature", (Harre and Madden, 1975:86).

This experiment was designed to investigate whether children really do take the whole transformational sequence into account when making causal inferences or whether they focus on changed states and make associative judgements for change regardless of the sequence portrayed. Although preschool children may be able to use causal-associations to choose correct causal instruments in three-item sequences, this does not necessarily mean that they are relating object states in terms of transformations as Gelman et al. (1980) claimed.

Furthermore, focus on change may be the most basic element necessary for an understanding of causal relations in terms of mechanism. In event sequences change may cue children to look for causes thus leading them to posit causes, or mechanisms, which are not necessarily the right ones. It is suggested here that only when children progress from focus on change per se to attending to the event sequence as a whole can they really attend to the relevant features of the causal relation including the mechanism.

3.1.3 RATIONALE FOR THE DESIGN OF EXPERIMENT 1

A number of 3-element sequences was designed, based on the Gelman et al. sequences, but differing in that the end state of an object showed two effects. One effect was present at the beginning of the sequence (e.g. wet banana). The other was caused by an instrument which changed or transformed the object from the first state shown in the sequence (e.g. wet) into the final state shown in the sequence (e.g. wet and cut banana). Children had to choose the instrument of transformation. Three choices of instrument were presented.

Previously children had not been given the chance to make associative judgements. In this experiment two conditions were designed to see what happened when children were given the chance to make associative judgements. The two conditions differed in the type of choices of causal instrument offered.

In Condition I (Experimental), one **correct** choice (which effected the transformation shown in the sequence); one **associative** choice (associated with the first and continuing state of the object); and one inappropriate, **random** choice was offered for the missing middle element (for the example given above - Wet banana--->Wet cut banana, these were: water, knife, cards).

In Condition II (Control), one **correct** choice, and two **random** choices were given (e.g. knife, matches, flowers). This condition was similar to the Gelman et al. sequences in that one appropriate and two totally inappropriate choices were offered.

Gelman et al. (1980) stated that to make a causal inference we assume that an action involving an instrument took place. The choice of the instrument is constrained by the transformation observed. If this is the case, a child who thinks causally will

always choose the instrument that transformed the object from its beginning state, regardless of the added state which remains constant (wetness, in the example given above). However, if children are not reasoning in a causal way they may, in the Experimental condition, either:

(1) choose the instrument associated with the beginning and continuing state of the object (which, in the example given, is WET); or

(2) choose the instrument associated with either one of the end states of the object, without attending to the transformation depicted in the sequence.

These methods result in associative or associative-causal judgements. In order to identify such judgements, sequences in this experiment were constructed in pairs, such as:

- | | | | |
|-----|------------|---------|-----------------------|
| (a) | WET BANANA | (BLANK) | WET CUT BANANA |
| (b) | CUT BANANA | (BLANK) | CUT WET BANANA |

(Examples are given in section 3.2, details of sequences are given in Appendix 1)

In the pair of sequences shown above, two transformations take place, **cutting** in sequence (a), and **wetting** in sequence (b). In each case the object is initially in one state (wet/cut) and is then further transformed. The child has to perceive that in each sequence a different transformation is taking place, and then infer the causal instrument for each. For instance, in the example given, a child relating the initial and final states of the objects, will discount the continuing state of the object (wet in (a), cut in (b)) and work out that the change/transformation that occurs in (a) is cutting whereas in (b) it is wetting. A child not reasoning in this way may just as easily choose the instrument associated with the

continuing, first state of the object (e.g. water for (a)); or, the instrument associated with either one of the end-states of the object, disregarding the transformation. Such methods will not yield consistently correct responses across sequence pairs.

It should be noted that in the Control condition where only one plausible and two utterly random choices were given, it is possible to make correct responses for both sequences in a pair either by matching an effect with a plausible instrument on the basis of similarity (e.g. water to water-on-banana) or by using past associations that certain instruments produce certain effects. However, in the Experimental condition, this method will result in only one correct answer within each pair. Of the three choices offered, one is random, but each of the two remaining choices is the cause of one of the two compound effects depicted at the end (e.g. in the example given above, water for 'wet' and knife for 'cut'). To get a correct answer for both sequences in a pair the child has to choose the instrument that transformed an object from its initial state (in any given sequence), to the new state at the end of the sequence.

Focusing on the end states and choosing an instrument associated with one of these states will not produce consistently correct responses in the Experimental condition, although it will do so in the Control condition. If children do not relate object states in terms of transformations, but focus on the end states, then the relative SALIENCE of the two effects depicted therein (e.g. wet & cut) might influence their choice of causal instrument. That is, they might choose the instrument that was the cause of the **salient** end state, which was not always the state achieved by a transformation within the sequence.

The Gelman et al. methodology was retained for a number of reasons. First, by using similar forms of sequences the present experiment was made comparable to theirs. Secondly, possible conflicts between temporal priority and contiguity cues were reduced by using such sequences. Although the elements in the sequence were presented in the correct temporal order, the choice of instrument could not be made on the basis of priority cues. Thirdly, these sequences test children's abilities to reason about events in a more abstract manner than other methods. Unlike the mechanism and transmission experiments reported in Chapter 2, in pictorial sequences of the type used by Gelman et al. (and in the present experiment) children cannot observe a direct link between the cause and the effect as it occurs and then make judgements. Rather, accessing of past knowledge about the effect depicted, as well as attention to the beginning state is required in order to "select events that are consistent with previously presented pictures" (Schmidt et al., 1979).

Finally, it has been argued (see previous Chapter) that judgements are a fairer indication of children's competence than explanations. Sequences using the forced-choice-alternatives method (Schmidt & Paris, 1978, Gelman et al., 1980) not only minimise the verbal demands made on children, but also reduce the memory demands of the task as all the elements of the sequence are available for children to refer to at all times. Furthermore, the use of this methodology focuses on the structure, rather than on the content, of causal thinking. Structure, as defined by Kun (1978:221), being the "real or perceived relationship between events" (object states in the present case) "...that influences the nature of the causal inference". Children's judgements on such tasks may give some indication

of the type of structures they use to reason about causal events.

Predictions:

It was predicted that

1. Four-year-olds would make more causal judgements than 3-year-olds, especially in the Experimental condition, as the younger children may be more likely to focus on end states.
2. Children would give significantly more correct responses in the Control condition than in the Experimental one.
3. Within the Experimental condition all the children would make a large number of associative-causal (AC/CA) responses.

3.2 Method

(a) Subjects

Sixty children from Oxford nursery schools and play-groups participated in this experiment. There were 40 3-year-old children (mean = 3:6; range = 3:1 to 3:11), and 20 4-year-old children (mean = 4:7; range = 4:2 to 4:10). The children were randomly assigned to one of the two conditions. The experimenter was familiar to the children having spent at least a week in each classroom, as a helper, playing with the children. The experiment was introduced as a 'new game', which had to be played on a one to one basis.

(b) Design

A mixed design with repeated measures on Conditions (2: Experimental [E], Control [C]) was used. Age (2: 3+, 4+) and Sequence-set (2: X, Y) were the Between factors.

Two sets of sequences (X and Y) were created to avoid any learning or fatigue effects that might have arisen if the same material was used in both conditions. Sequence-sets X and Y were counterbalanced across conditions and trials. Each child experienced

both sequence-sets. To control for order effects, half of the children in each age group was presented with the E condition first, followed by the C condition; the other half was presented with the C condition first, followed by the E condition. Briefly, all the children performed under both conditions and experienced both sets of sequences, but in different orders and on different trials, as illustrated in Table 3.2.1.

TABLE 3.2.1 THE DESIGN OF EXPERIMENT 1

Number of		FIRST TRIAL		SECOND TRIAL		where:
children						E= Experimental
3+	4+	COND.	SEQ.SET	COND.	SEQ.SET	condition
10	5	E	X	C	Y	C= Control
10	5	E	Y	C	X	condition
10	5	C	X	E	Y	X & Y = Sets of
10	5	C	Y	E	X	sequences
N = 40		N = 20				

(c) Materials

The material created for this experiment was pilot-tested before being used. The pilot-study is presented in Appendix 1.

The materials consisted of three sequence-sets: the familiarisation sequences and the two sequence sets used in the experiment. Two sets of sequences (sequence-set X and sequence-set Y) each containing 10 sequences (i.e. 5 PAIRS of sequences) were created as a repeated measures design was being used. Since each child experienced both the Experimental and Control conditions an attempt was made to design two similar sets of sequences. The two

sets included sequences depicting the **same** transformations (e.g. wetting in the example given below) but on different objects (banana in X, cup in Y) and in different combinations (wet and **broken** in X; wet and **cut** in Y). For example -

SET X	wet cup	---?---	wet broken cup
	broken cup	---?---	broken wet cup
SET Y	cut banana	---?---	cut wet banana
	wet banana	---?---	wet cut banana

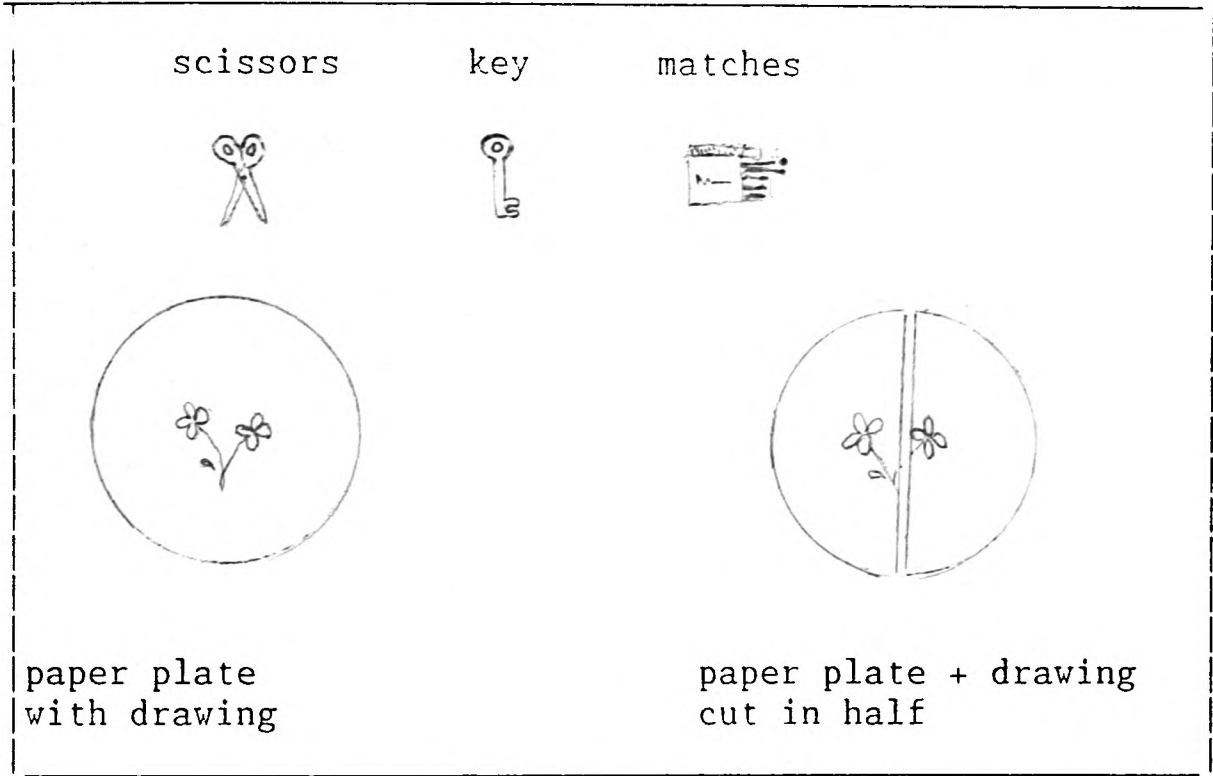
Photographs of real objects in standard and altered states were used to construct the sequences. Photographs of a variety of objects were used as choices. Full details of the materials are given in Appendix 1. Photographs were used instead of drawings in an attempt to make the representations as 'real' as possible. It was also thought that photographs would be more attractive to children and engage their interest more than line drawings.

Familiarity and experience with objects or events has been shown to be an important factor in causal reasoning (Nass, 1956; Berzonsky, 1971). Therefore, the sequences in Experiment 1 were constructed using objects and transformations which were familiar to the children. Although some objects were altered in unusual ways (for instance, an apple with a drawing on it) both the object (apple) and the transformation (drawing) were familiar to children. Familiarity with objects and transformations was ascertained in a pilot study in which children were shown photographs of whole and transformed objects and asked to name both the objects and the transformations (Appendix 1). A familiarisation procedure was included in this experiment to acquaint children with the task, materials and instructions.

Familiarisation material

Five sequences, of the form shown in Diagram 3.2.1, were used for familiarisation. This material was designed to familiarise children with the sequences to be used in the experiment and to train them to read the sequences from left to right.

DIAGRAM 3.2.1 Example of a Familiarisation sequence



The sequences used for familiarisation are presented in Appendix 1.

Experimental material

The two Experimental sequence-sets (X and Y) each contained 5 pairs of sequences. The type of choices depended on whether the set was experienced in the Experimental or Control conditions.

For all sequences children had to fill in the middle (instrument) position because Gelman et al. found that 3-year-olds did best on this position. Furthermore, it was thought that filling in this position best displayed children's abilities to infer causal instruments. Three choices were offered for the missing element. Whereas in the Gelman et al. study children were always given one appropriate (correct) choice and two inappropriate choices for

middle-position-missing items, in this experiment there were two conditions, offering different types of choices, as shown in Diagram 3.2.2.

DIAGRAM 3.2.2 EXAMPLE OF A SEQUENCE SET IN (1)THE EXPERIMENTAL AND (2)THE CONTROL CONDITON

(1) EXPERIMENTAL CONDITION				
cut banana	C H O I C E S			
	water	knife	cards	cut banana wet
	C	A	R	

(2) CONTROL CONDITON				
cut banana	C H O I C E S			
	purse	water	stamp	cut banana wet
	R	C	R	

- Where - C = correct; A = associative; R = random choices.
N.B. The transformation common to both sequences is **wetting**, in Set Y it is combined with cutting and in Set X with breaking (Wet cup ---Wet Broken cup). The transformations were paired differently in different sets in an effort to control for carry-over effects from one set to another.

The difference between the two conditions lies in the types of choices offered. In the **Experimental** the child had one **causal choice**, one **associative choice** and one **random choice**. In the **Control** condition, which was comparable to the Gelman et al. set-up, the child was given two **random choices** and one **correct choice** which could be made simply by association.

(d) Procedure

Familiarisation and testing were conducted in the schools or playgroups, either in a private room or in a bay off the classroom, depending on the facilities available. The experimenter sat beside the child either at a table or on the floor.

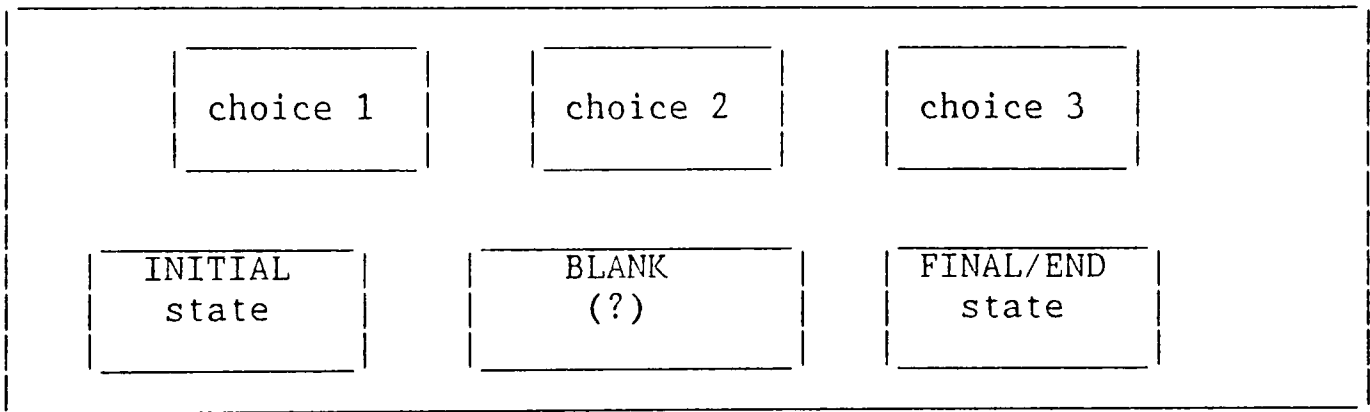
The experiment was presented as a 'picture game' which could be played with lots of different pictures. It was made clear that only two people could 'play' at any given time (i.e. the experimenter and a child) but that each child could play more than

once.

Familiarisation

First, each child was shown single photographs of all the objects to be used in the sequences and asked to name them. In this way, children's familiarity with objects was ensured. All the children were able to name all the objects. Then the familiarisation sequences were laid out, one by one, on the table or floor, in front of the child, as shown in Diagram 3.2.3. The photographs were presented with a gap between the first (beginning state) and last (end state) photographs so that the causal instrument could be inserted in between. Each child was shown how to read the sequence from left to right.

DIAGRAM 3.2.3 LAY-OUT OF MATERIALS: EXPERIMENT 1



The children were first presented with the object in its initial state (see Diagram 3.2.3) and asked to describe it. They were then shown the end state and asked if anything had happened to the object. If no change was mentioned the experimenter pointed to the first photo and mentioned the state the object was in, e.g. "Look, this plate has a flower drawn on it." She then pointed to the second photo and asked if anything else had happened to the object. If the children still did not mention the transformation that had occurred in the sequence, the experimenter pointed to the first photograph and said " Look, here it has a flower on it", then point-

ing to the second photograph she said "...and here it has a flower on it too, but it is also ____". At this stage almost all the children named the transformation that had occurred for example, in Diagram 3.2.1, they would say: "and it's cut."

The three choice objects were then placed in front of the child, who was told to pick the object that the experimenter had used to change the object in the first photo into the state shown in the final photo. Pointing to each photo in turn the experimenter asked: "What did I use to make this ____ like this?" This procedure was repeated with each sequence. The familiarisation sequences were of the same form as sequences in the Control condition.

Great care was taken to ensure that the children understood the instructions. Following each verbal instruction each child was asked if s/he knew what to do. Furthermore, whatever the choice made by the children, they were asked if they were sure of their choice and then asked what the instrument had done. Incorrect inferences were corrected. The experimenter inserted the correct instrument into the slot and then told the child what it had been used for.

The Experimental Procedure - was almost identical to the familiarisation. The only difference was that no feedback was given. Children were not asked whether they were sure of their choices and their choices were not corrected by the experimenter.

3.3 Results

Method of Scoring - Responses were coded as CORRECT, ASSOCIATIVE or RANDOM, according to the following criteria. An example of this method of coding is illustrated in Diagram 3.2.2 above.

Responses were coded:

CORRECT (C) - for the choice of the instrument that effected the transformation.

ASSOCIATIVE (A) - for the choice of the instrument associated with the continuing state of the object (i.e. the state which

is present at the beginning and end of a sequence and does not change). Wetness in Wet Cup---to---Wet broken Cup, is an example of a continuing state).

RANDOM (R) - for the choice of an object unconnected with either the transformation or the continuing state.

It was not possible to make an Associative response in the Control condition as no A choices were offered in this condition.

Single Correct (C) Responses

The mean number of correct (causal) responses for each set (X/Y) is shown in Table 3.3.1. These means were obtained from scores on the ten sequences on each sequence-set and give an overall picture of children's' performance. In general more correct responses occurred in the Control than in the Experimental condition. In both conditions, 4-year-olds made more correct responses than 3-year-olds. This difference looks most striking in the Experimental condition.

TABLE 3.3.1 MEANS AND STANDARD DEVIATIONS FOR THE NUMBER OF
TOTAL (C) RESPONSES

AGE	ORDER	MATGRP	E	C
			5.8	9.1
	I	<u>xE, yC</u>	(1.48)	(0.99)
			6.5	8.7
3+		<u>yE, xC</u>	(1.65)	(1.25)
			7.2	8.7
	II	<u>xE, yC</u>	(1.69)	(1.5)
			7.3	8.7
		<u>yE, xC</u>	(1.16)	(0.9)
			8.2	9.4
	I	<u>xE, yC</u>	(0.84)	(0.9)
			9.2	9.8
4+		<u>yE, xC</u>	(0.84)	(0.44)
			8.2	9.4
	II	<u>xE, yC</u>	(1.1)	(0.55)
			9.8	9.6
		<u>yE, xC</u>	(0.45)	(0.55)

where : E = Experimental Condition
 C = Control condition
 x/yE = Sequence set x/y in the Experimental condition
 x/yC = Sequence sets x/y in the Control condition
ORDER 1 = E on first trial, C on second trial
ORDER 2 = C on first trial, E on second trial
(Standard deviations are given in brackets, for this and following
Tables).

Calculating the Probability of Correct Responses occurring purely by
Chance

As children had a choice of three responses - Causal,
Associative or Random - there was a 33% chance of their choosing any

one of these responses. The probability that the correct (C) responses occurred simply by chance was explored using a modification of the standard hypothesis testing procedure (Marriott, 1986: personal communication).

In this method, the observed proportions of responses (C, A and R) are compared with the predicted proportions obtainable by chance (.33) using the formula:

$$Z = \frac{\text{Observed mean} - n.p}{\sqrt{n.p.q/N}}$$

where -

n = number of sequences

p = probability of any response occurring

q = (1-p)

N = Number of observations

If a Z-value is greater than 1.96, the probability of the responses observed occurring by chance is less than 0.05. If a Z-value is greater than 2.58, the probability of the response occurring by chance is less than 0.01 (all values are for a 2-tailed test).

The proportions of correct (C) responses made by both 3- and 4-year-olds were significantly ($p < .01$) greater than expected purely by chance. This indicates that they were not acting randomly.

Comparing Correct (C) scores across the two Ages

The means and standard deviations for the total number of correct (C) responses made in each condition by the two age groups were given in Table 3.3.1. This Table shows that most C-responses were made in the Control condition where no A choices were given (especially by the younger sample) regardless of the material groups and order of presentation. There is some indication that order of presentation affected the number of correct responses.

Those children who experienced the Experimental condition after the Control had higher scores in the Experimental condition than children who experienced this condition (Experimental) first. Finally, 4-year-olds made a greater number of correct responses than 3-year-olds, especially in the Experimental condition.

These trends were analysed by subjecting the raw scores for the total number of correct (C) responses to a 4-way Analysis of Variance (henceforth referred to as ANOVA) with repeated measures. Correct (C) scores in the Experimental and Control conditions were the dependent variables, with Age (2: 3+; 4+), Order of Presentation (2: E trial 1; E trial 2) and Material Group (2: Set-X; Set Y) as the Between factors. Condition (2: Experimental; Control) was the Within factor.

The two orders of presentation were (1) Experimental condition on first trial and Control on second; (2) Control condition on first trial and Experimental on second. The material groups were (1) set X in the Experimental condition, set Y in the Control; and (2) set Y in in the Experimental condition with set X in the Control (see Table 3.2.1). The results of this analysis are presented in Table 3.3.2.

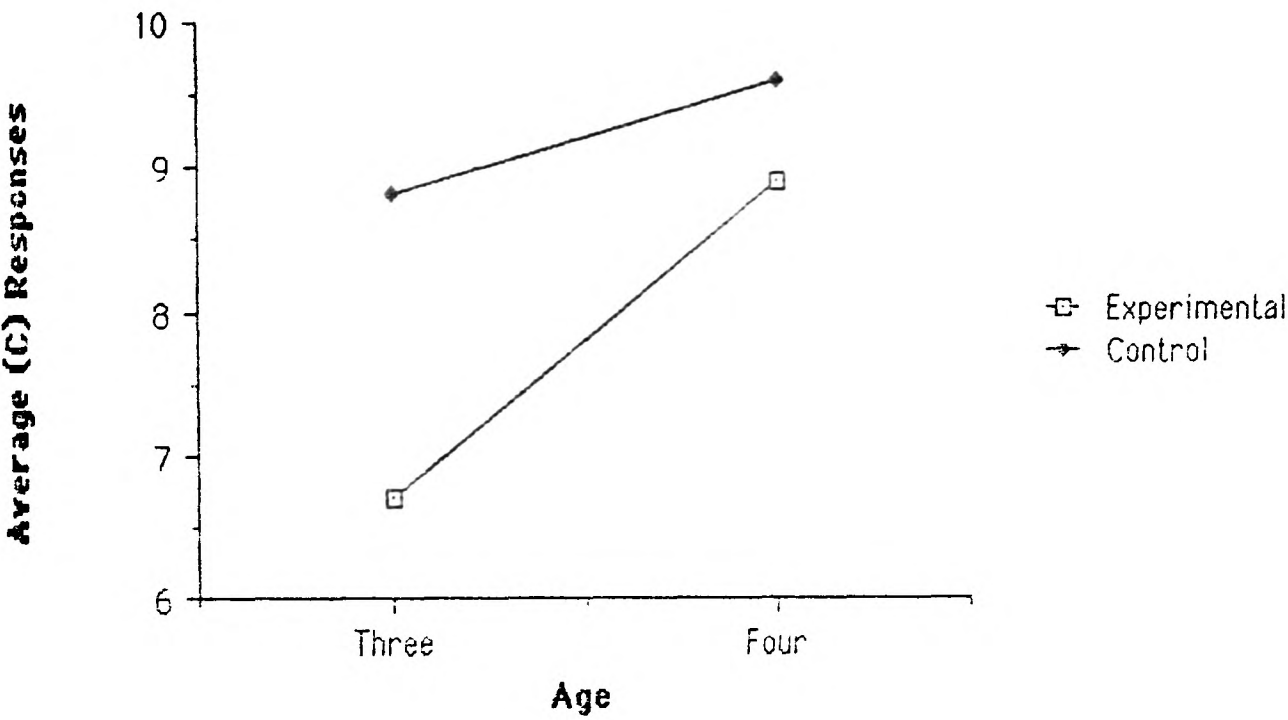
The tendency for the older children to make more correct responses than the younger ones proved to be statistically significant ($F(1,52)=32.22$, $p<.001$). The significant main effect for Condition ($F(1,52)=45.22$, $p<.001$) indicated that this variable affected correct responses. The lack of any significant main effects for Order and Matgroup showed that these variables did not significantly affect correct responses.

A significant interaction between Condition and Age ($F(1,52)=11.31$, $p<.01$) showed that the effects of Condition varied

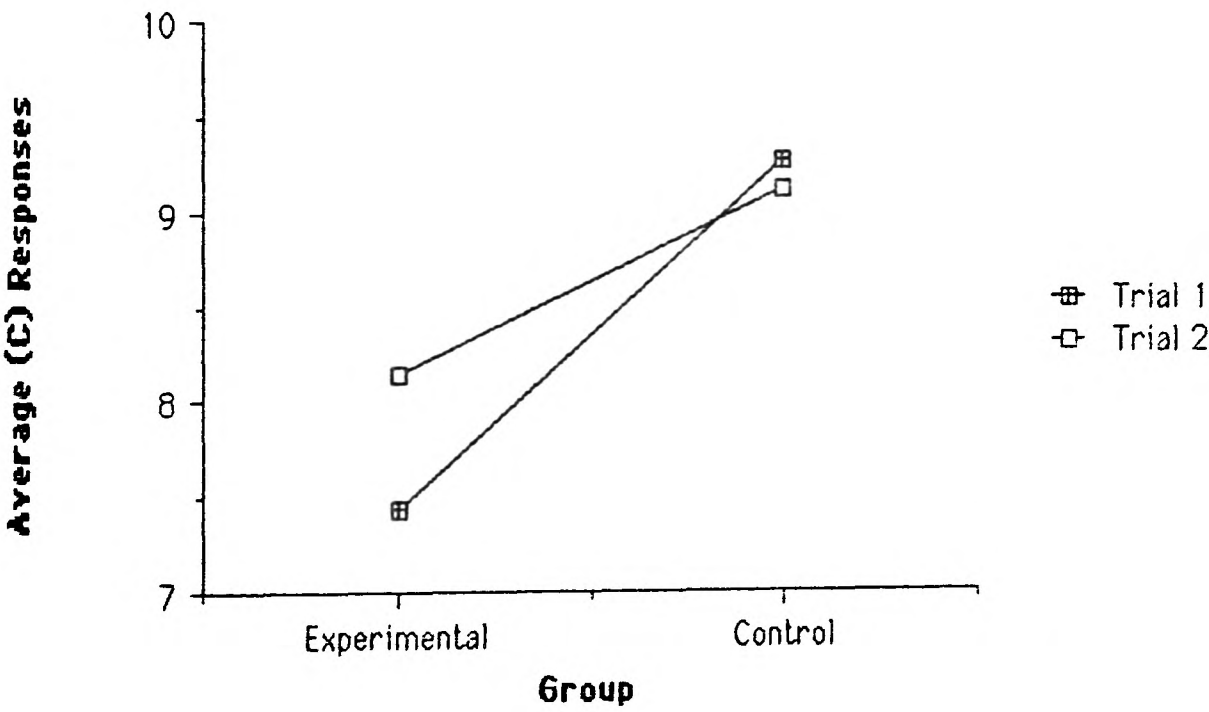
between the two age groups. This interaction was explored using the Newman-Keuls Multiple Range Test (Bruning and Kintz, 1977:119-122). A graphical representation of this comparison is presented in Figure 3.3.1. It was found that 3-year-old children made significantly more correct inferences in the Control condition than in the Experimental ($p < .01$). There was no significant difference in performance between the Experimental and Control conditions in the 4-year-old group. Age affected performance in the Experimental but not in the Control condition: the older children made significantly more correct responses than the younger ones ($p < .01$) only in the Experimental condition.

The barely significant interaction between Condition and Order ($F(1,52)=4.17, p=.05$) indicated that the effects of the two conditions varied across the two orders of presentation. The Newman-Keuls test showed that Order did not significantly affect scores on either condition ($p > .05$). That is scores on the Experimental Condition did not differ significantly whether it was experienced on the first trial (Order 1) or the second (Order 2). The same held for the Control condition.

Fig 3.3.1. Interaction: (a) Age X Condition



(b) Condition X Order



Paired Responses

Sequences were paired in order to distinguish between consistently correct (CC) and associative-causal (AC/CA) responses. Single correct responses (ie. for any one sequence within a pair) may be made by matching an instrument to a preferred end state. However, as explained below, such a method will not yield two correct (Consistently Correct) responses within a pair. In the example given in Diagram 3.3.1, it is possible to make a correct choice in (1) by matching the relevant instrument to the more striking end state (Broken). This method will produce an incorrect choice in (2) where this state is not the product of the transformation depicted in the sequence. Thus at least 5/10 single correct responses can be made by using this method. To get Consistently Correct (CC) responses children must relate initial and final states and discount the unchanging (continuous) state (broken, in (2)) to deduce the transformation that has occurred.

When single (C) responses were considered, the scores of both age groups were above chance predictions. It was also found that 4-year-olds made significantly more C-responses than 3-year-olds in the Experimental condition. Considering that there was no significant difference between the two groups in the Control, these results indicate that the Experimental condition was more difficult for the younger children to cope with. It is suggested that this is because the Experimental condition requires children to relate beginning and end states of a sequence and discount the continuing state in order to make a correct inference. An analysis of children's performance when judgements for pairs of sequences are considered may help evaluate the validity of this suggestion. Diagram 3.3.1 shows an example of coding of responses within a sequence

pair.

DIAGRAM 3.3.1 AN EXAMPLE OF CODING OF PAIRED RESPONSES:
 (Experimental Condition)

Sequence Pair A:			
	1. Wet Cup	---?---	Wet BROKEN Cup
Choices:	hammer,	water,	feather
SCORING :	C ,	A ,	R
	2. Broken Cup	---?---	Broken WET Cup
Choices:	water ,	hammer,	feather
SCORING :	C ,	A ,	R

There are 9 possible combinations of responses in the Experimental condition:

- CC AA RR
- CA AR RC
- AC CR RA

In the Control condition there are, effectively, two choices C or R and 4 possible combinations: CC, CR, RC, RR. It should be noted that the ten sequences were presented in a randomised order. Only subsequently were responses grouped according to sequence-pairs.

In the example given (Diagram 3.3.1), hammer is the correct answer for 1, and water is the correct answer for 2. If a child gets both correct she will have a CC (consistently correct) response. Similarly, choice of water for (1) and hammer for (2) is an AA response, the child is just picking an instrument associated with one of the effects shown in the sequence, but does not seem to be taking the transformation shown in the sequence into account. In an AC/CA response, the child chooses correctly for one of the sequences in the pair, but makes an associative choice for the other. This is an associative-causal response, indicating that the child has some knowledge of plausible causes, but does not always take all the given information into account when she is asked to

make an inference.

Therefore, if a child chooses hammer for (1) and water for (2), a CC-response, it appears that the child not only perceives that a change or transformation has occurred, but can discriminate between a change which has been present throughout and the actual transformation which has taken place within each sequence. As a result, she is able to choose the appropriate instruments in each sequence.

If (in the example given) a child chooses hammer for both (1) and (2), a CA response, or alternatively, water for both sequences, an AC response, this may indicate that the association between the instrument and a particular effect is so strong that she ignores the fact that another transformation has taken place.

An AA response occurs when the child chooses water for (1), and hammer for (2). This may indicate that the association between the beginning state and the instrument responsible for it is predominant and the child ignores any further change of state.

In cases where an R response is present it is difficult to tell whether or not the child is choosing responses randomly. An RR response pair indicates a totally random inference. The percentages of the various paired responses summed over five pairs of sequences, on both trials, is shown in Table 3.3.3.

Table 3.3.3 indicates that the majority of responses in the Experimental condition, for both age groups, were either of the CC or AC/CA combination. In the Control condition the majority of responses again were of the CC type, with a number of CR/RC responses occurring in the younger group.

Therefore, children's paired responses will be considered in order to see (a) how consistent the two age groups

were in their correct judgements; and (b) what their errors indicate.

TABLE 3.3.3 PERCENTAGE OF PAIRED RESPONSES IN SEQUENCE SETS
IN (1)EXPERIMENTAL AND (2)CONTROL CONDITIONS

(Numbers are given in brackets)

1.Experimental Condition

RESPONSE	THREE YEAR OLDS		FOUR YEAR OLDS	
TYPE	SET X	SET Y	SET X	SET Y
CC	36 (36)	41 (41)	64 (32)	90 (45)
CA	38 (38)	19 (19)	16 (8)	2 (1)
AC	18 (18)	23 (23)	16 (8)	8 (4)
CR	2 (2)	4 (4)	2 (1)	0 (0)
RC	0 (0)	10 (10)	2 (1)	0 (0)
AA	2 (2)	1 (1)	0 (0)	0 (0)
AR	3 (3)	0 (0)	0 (0)	0 (0)
RA	0 (0)	0 (0)	0 (0)	0 (0)
RR	1 (1)	2 (2)	0 (0)	0 (0)

2.Control Condition

RESPONSE	THREE YEAR OLDS		FOUR YEAR OLDS	
TYPE	SET X	SET Y	SET X	SET Y
CC	76 (76)	79 (79)	94 (47)	88 (44)
CR	12 (12)	3 (3)	6 (3)	2 (1)
RC	10 (10)	17 (17)	0 (0)	10 (5)
RR	2 (2)	1 (17)	0 (0)	0 (0)

(a) CC responses:

Table 3.3.4 shows the means and standard deviations for the paired (CC) responses made in each condition, under different orders of presentation and material groups. There were 5 sequence-pairs in each of the two material sets (X and Y), so all scores are out of a possible total of 5.

TABLE 3.3.4 MEANS AND STANDARD DEVIATIONS FOR THE
NUMBER OF PAIRED (CC) RESPONSES

AGE	ORDER	MATGRP	E	C
			1.3	4.1
	I	<u>xE, yC</u>	(1.16)	(0.99)
			1.7	3.7
3+		<u>yE, xC</u>	(1.42)	(1.25)
			2.3	3.8
	II	<u>xE, yC</u>	(1.64)	(0.92)
			2.4	3.9
		<u>yE, xC</u>	(1.26)	(1.45)
			3.2	4.4
	I	<u>xE, yC</u>	(0.84)	(0.89)
			4.2	4.8
4+		<u>yE, xC</u>	(0.84)	(0.45)
			3.2	4.4
	II	<u>xE, yC</u>	(1.1)	(0.55)
			4.8	4.6
		<u>yE, xC</u>	(0.55)	(0.55)

where : E = experimental Condition

C = control condition

MATGRP (Material group): x/yE = Sequence set x/y in the Experimental condition

x/yC = Sequence sets x/y in the Control condition

ORDER 1 = E on first trial, C on second trial
 ORDER 2 = C on first trial, E on second trial

The Probability of CC Responses having occurred by Chance

There were 9 possible response combinations. Thus, the probability of a child choosing any one combination would be .11. The formula presented previously was used to calculate the probability of CC responses occurring by chance. It was found that the CC responses of both 3- and 4-year-olds (in all cells of Table 3.3.4) were significantly above ($p < .01$) the level expected by chance.

Comparing CC responses across Age

Although the average CC responses of the younger children did not occur by chance, Table 3.3.4 shows that the younger children made very few CC responses in the Experimental condition. The 4-year-olds' scores, in contrast, were sometimes near ceiling. As expected, both ages made more CC responses in the Control condition. The older children made more causal responses than the younger ones in both conditions. There is some indication that order (whether E was experienced on the first or second trial) may have affected the younger children's responses.

The raw scores for the paired causal responses (CC) were subjected to a 4-way ANOVA with repeated measures. Age (2), Order of Presentation (2) and MATERIAL GROUPs (2) were the Between factors, with Condition (2) as the Within factor. The results of this analysis are presented in Table 3.3.5.

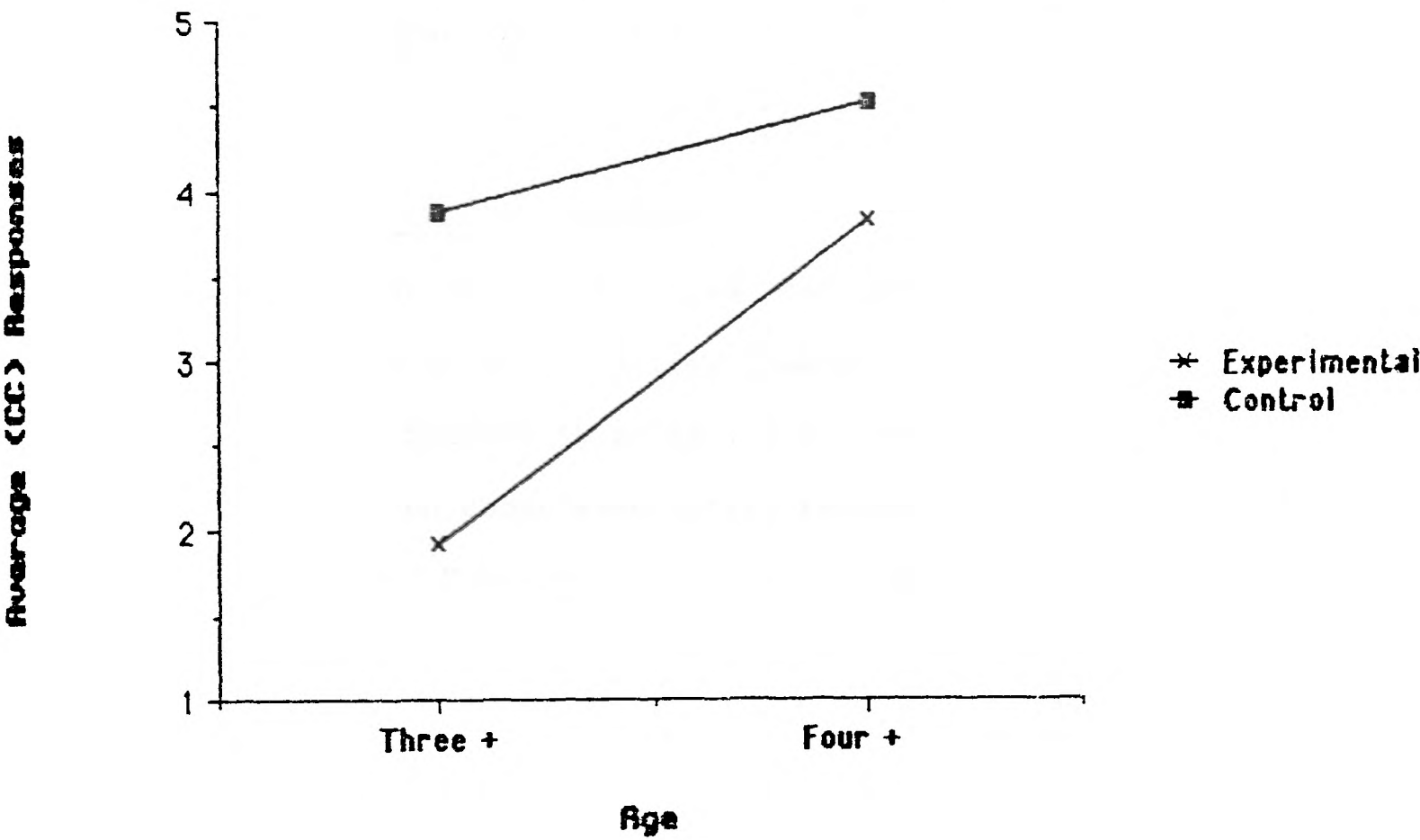
These results are almost exactly the same as those obtained for the analysis of single (C) scores except that the Condition by Order interaction is definitely non-significant here ($F(1,52)=2.71, p > .05$). The tendency for older children to give more CC responses than the younger ones was statistically significant

(F(1,52)=28.68,p<.001). Significantly more CC responses were made in the Control than in the Experimental condition (F(1,52)=45.0, p<.001). There were no significant main effects for Order or Material Group indicating that these variables did not affect CC scores.

TABLE 3.3.5 SUMMARY TABLE (ANOVA) FOR PAIRED (CC) RESPONSES IN

SOURCE		SS	DF	MS	F	PROB.	
AGE	(A)	45.06667	1	45.06667	28.68	0.000***	
ORDER	(O)	1.66667	1	1.66667	1.06	0.31	ns
MATGROUP	(M)	4.81667	1	4.81667	3.07	0.09	ns
AO		0.60000	1	0.60000	0.38	0.54	ns
AM		3.75000	1	3.75000	2.39	0.13	ns
OM		0.15000	1	0.15000	0.10	0.76	ns
AOM		0.01667	1	0.01667	0.01	0.92	ns
ERROR		81.70000	52	1.57115			
CONDITION	(C)	46.81667	1	46.81667	45.22	0.000***	
CA		10.41667	1	10.41667	10.01	0.003	**
CO		2.81667	1	2.81667	2.71	0.11	ns
CM		3.26667	1	3.26667	3.14	0.08	ns
CAO		0.41667	1	0.41667	0.40	0.53	ns
CAM		0.60000	1	0.60000	0.58	0.45	ns
COM		0.00000	1	0.00000	0.00	1.00	ns
CAOM		1.06667	1	1.06667	1.03	0.32	ns
ERROR		54.10000	52	1.04038			

Fig 3.3.2. Condition X Age Interaction (CC Responses).



A significant Condition by Age interaction indicated that the effects of Condition varied between the two ages ($F(1,52)=10.01$, $p<.01$). This interaction was explored using the Newman-Keuls test; a graphical representation is presented in Figure 3.3.2. Comparing the effects of the two conditions in each age group it was found that younger children made significantly more CC responses in the Control than in the Experimental condition ($p<.01$). There was no significant difference between conditions in the 4-year-old group. Four-year-olds made more CC responses than 3-year-olds in the Experimental ($p<.01$) but not in the Control condition.

(b) Analysis of Errors (AC/CA responses)

Pairing the responses showed that the majority of non-CC responses were of the AC or CA variety (Table 3.3.3). The AC/CA responses were analysed because (Diagram 3.3.2) such responses show whether or not children chose associative responses (when given the chance to do so) in the Experimental condition. No Associative choices are offered in the Control, so, AC/CA responses occur **only** in the Experimental condition. Table 3.3.6 presents the average AC/CA responses. Children of both ages made AC/CA responses but the 3-year-olds did so to a greater extent than the older children.

Probability of AC/CA responses occurring by Chance

Using the same method as for CC responses, the probability of either the AC or the CA response type occurring purely by chance was calculated. It was found that the proportion of CA responses made by 3-year-old children was significantly above ($p<.01$) the level expected by chance when sequence-set X was experienced in either the first or second trial. When set Y was experienced, proportions of both CA responses ($p<.05$) and AC responses ($p<.05$) were

above chance level. When Y was experienced in the second trial AC responses were significantly above ($p<.01$) the proportion expected by chance.

None of the 4-year-old's responses was significantly above the level expected by chance. This indicates that the younger, but not the older children, deliberately chose A responses.

TABLE 3.3.6 MEANS AND STANDARD DEVIATIONS OF
AC AND CA RESPONSES

AGE	ORDER	MATGRP	CA	AC
3+			2.1	0.9
	E Trial	xE	(0.99)	(0.57)
	I		1.1	1.0
		yE	(0.88)	(1.05)
			1.7	0.9
	E Trial	xE	(1.56)	(0.74)
4+	II		0.8	1.3
		yE	(0.6)	(1.1)
			1.0	0.8
	E Trial	xE	(0.71)	(0.45)
	I		0	0.8
		yE	-	(0.84)
			0.6	0.8
	E Trial	xE	(0.55)	(1.1)
	II		0.2	0
		yE	(0.45)	-

KEY: E = Experimental Condition
MATGRP (Material group): xE/yE = Sequence set x/y in the Experimental condition; E TRIAL 1 = E on first trial;
E TRIAL 2 = E on second trial.

AC and CA responses in the Two Age groups

It needs to be stressed here that sequences were presented to children in random orders and subsequently sorted out in pairs such as:

PAIR 1: (a) WET CUP -----> WET BROKEN CUP

(b) BROKEN CUP --> BROKEN WET CUP

PAIR 2: (a) PAPER+WRITING----> CUT PAPER+WRITING

(b) CUT PAPER -----> WRITING ON CUT-PAPER

Therefore, whether a response-pair was AC/CA depended to some extent on which sequences were put in (a) or (b) positions. The pairs AC and CA were collapsed into one response type (ACCA), because they were essentially the same, comprising one causal and one asssoia-tive response but in different positions (the response pattern is the same: one C and one A response, but the order of occurrence is different). Since material groups did not affect children's CC re-sponses significantly in previous analyses, in the following anlyses they were subsumed into the order group.

TABLE 3.3.7 MEANS AND STANDARD DEVIATIONS OF ACCA RESPONSES

AGE	ORDER	ACCA	where: E = Experimental
3+	E TRIAL 1	2.8	Condition
		(1.32)	E TRIAL 1 = E on first trial
	E TRIAL 2	2.1	
		(1.37)	E TRIAL 2 = E on second trial
4+	E TRIAL 1	1.6	ACCA = ACCA responses
		(0.96)	
	E TRIAL 2	0.5	
		(0.71)	

The means and standard deviations of ACCA responses are given in Table 3.3.7. Although both ages made some ACCA responses, 3-year-olds made far more of these responses than 4-year-olds. When the Experimental condition was experienced second there seemed to be a tendency for the number of ACCA responses to decrease in both age groups.

These trends were explored using a 2-way ANOVA, for independent groups, with Age(2), and Order(2: E Trial 1; E Trial 2), as the independent variables, the dependent variable being the number of ACCA responses. The results of this analysis are shown in Table 3.3.8.

Table 3.3.8 Summary Table (ANOVA) of ACCA responses

SOURCE		SS	DF	MS	F	PROB.
AGE	(A)	26.13333	1	26.13333	17.87	0.0001***
ORDER	(O)	10.80000	1	10.80000	7.38	0.0087 *
AO		0.53333	1	0.53333	0.36	0.55 ns
ERROR		81.90000	56	1.46250		

The tendency for Age to affect the number of ACCA responses proved statistically significant ($F(1,56) = 17.87$, $p<.001$).The older children made fewer ACCA responses than the younger ones. There was also a significant effect for Order ($F(1,56) = 7.38$, $p<.01$); fewer ACCA responses were made when the Experimental condition was presented in the second trial. The absence of any significant interaction indicated that Age and Order affected the ACCA responses independently of each other.

The Nature of the ACCA Responses

The majority of errors were of the AC or CA type. Examples of these response types are given below. The chosen response is

underlined.

CA RESPONSE (a) wet cup knife wet broken cup. SCORED: C

(b) broken cup knife broken wet cup. SCORED: A

[Transformation WET ignored in (b)]

AC RESPONSE (c) wet cup water wet broken cup. SCORED: A

(d) broken cup water broken wet cup. SCORED: C

[Transformation BROKEN ignored in (c)]

There is a number of possible explanations for these responses:

1) Children made inferences for the first and continuing state in one sequence in each pair (eg. in b and c above) but they made inferences for the transformation in the other sequence in the pair (a and d). It was thought unlikely that children would consistently switch methods in such a way.

2) Children were simply repeating an inference for ONE of the two final states of the object (wet or cut) which they happened to 'fixate' on for some reason. If this were the case then **either** there would have been no difference between the number of AC and CA responses for each sequence pair across the sample (as the state chosen would vary randomly from child to child) or a preferred state for each sequence would emerge, totally unconnected to the transformational information provided in the sequence. In case of the latter, it could be possible that -

3) Children were focusing only on the END photographs of sequences. If children were **not** relating object states in terms of transformations but focusing on the end states **then** the relative SALIENCE of the two effects (eg. wet & cut) depicted therein might influence their choice of causal instrument. That is, they would choose the instrument that was the cause of the **salient** state, which was not

always the relevant one.

Table 3.3.9 presents the frequency of occurrence of the AC and CA responses in each pair of sequences. This table shows that AC and CA responses did not occur in equal numbers within sequence pairs. Some pairs had more AC than CA responses and vice-versa. This pattern indicates that children were not arbitrarily fixating on any one of the two states. Rather, they seemed to be choosing causes for certain preferred states within pairs. An 'A' choice for one sequence in a pair is after all the 'C' choice for the accompanying sequence and vice versa (see Diagram 3.3.2). Therefore, the unequal numbers of AC and CA responses in each sequence-pair suggest that AC and CA responses were made because certain states appealed more to young children than others (within each pair) and the suggestion that children might be focusing on salient end states and making causal inferences for these salient states seems a viable one.

TABLE 3.3.9 FREQUENCY OF OCCURRENCE OF AC AND CA RESPONSES
IN EACH PAIR OF SEQUENCES IN THE TWO SEQUENCE-SETS

SEQ RESP		SEQUENCE PAIRS					
SET	ONSE	PR1	PR2	PR3	PR4	PR5	
3+	X	CA	13	10	11	1	2
		AC	1	0	1	5	9
	Y	CA	3	5	0	8	3
		AC	9	3	3	2	6
4+	X	CA	3	2	2	1	0
		AC	0	0	1	2	2
	Y	CA	1	0	0	0	1
		AC	3	0	1	0	0

If children were simply repeating the response made for the first sequence they had experienced within each pair whenever they were presented with the second sequence in the pair there should have been almost the same number of AC as CA responses for each pair. Table 3.3.9 shows that this is not the case. Close analysis of the sequence pairs showed that one of the sequences within a pair depicted a transformation that altered objects in a more striking way (e.g. cut) than the transformation in the accompanying sequence in the pair (e.g. wet). Indeed, most sequence pairs seemed to be comprised of one sequence depicting a very striking alteration to the object state, while the other showed a less striking alteration (or transformation). All the final photographs (of sequences) showed an object in two states one of which was relatively more salient than the other. It seemed possible that children would be more likely to infer instruments for those effects which were most striking. To find out whether this was the case, sequences were coded in terms of the transformations they depicted.

All the sequences were coded by the experimenter and an independent rater who knew nothing about the experiment. The following criteria were used:

- (1) SALIENT SEQUENCES - depict a change strikingly different from the usual form of the object. These sequences depict a transformation from the standard canonical state of an object (which had already been altered in a some way which did not significantly change the standard form of the object (e.g. wet whole banana) into an ALTERED state, strikingly different from the standard (e.g. wet and cut).
- (2) NON-SALIENT SEQUENCES - depict transformations from a strikingly altered state (e.g. cut) to a further

state. This transformation does not change the standard form of the object as dramatically (e.g. cut and wet).

There was a 100% agreement about saliency between two raters on set X, and 90% agreement on set Y sequences. It was agreed that sequences 1,3,5, and 8 showed Salient (S) transformations, in set X, while sequences 2,3,6,8, and 9 showed salient transformations in set Y. (Please refer to Appendix 1 for descriptions of these sequences). Sequence 10 in set Y was rated S by the experimenter and NS by the other rater. Therefore, a third person was asked to rate sequences according to the criteria given and a 100% agreement was reached between the three raters on set X. On set Y, the third rater also classified Sequence 10 as NS. It was decided to describe it as NS as there was 100% agreement between the two independent raters on this set.

In all the sequences rated Salient, the difference between the first and last states of the object was very striking. It may be possible that when an object is altered in a dramatic way, when it is broken, or cut, and transformed greatly from the child's ordinary experience of it, this is the change for which the child will seek a cause. Thus, in sequences where a transformation occurs which is not dramatically different from the beginning state because the first state itself is more striking, children may look for the cause of the state that is most salient to them. Furthermore, as sequences were paired it was possible that one transformation always appeared more striking relative to the other. This would certainly be the case if children focused on the END states of objects.

It should be noted that although, in relation to each other, one transformation is said to be more salient than the other

children typically mentioned both when asked to describe the photographs prior to making an inference (see Procedure). Both states were perceived but children seemed to give more importance to one than to the other.

By looking at the number of C and A responses made for sequences rated Salient and Non-Salient it might be possible to discern a pattern of preference (in terms of greater C responses) for Salient or Non-Salient sequences. Table 3.3.10 presents a summary of the sequences used in this experiment, the transformations depicted in each, the rating in terms of salience, and the number of C, A and R responses made for each sequence-type.

Table 3.3.10 shows that sequences rated as SALIENT (S) seem to have elicited a greater number of C responses than the ones rated NON-SALIENT (NS). Furthermore, it is clear that the errors made for the NS sequences were mostly of the A type: usually a response for the salient state of the object. The A response is not necessarily a repetition of a C choice for a salient transformation because often the NS sequences were experienced first (due to randomised presentation of sequences). Thus, the third explanation offered above, that the relative salience of transformations influenced childrens causal choices, seems the most probable one.

TABLE 3.3.10 FREQUENCIES OF C, A & R RESPONSES FOR EACH TYPE OF TRANSFORMATION(SALIENT/NON-SALIENT) IN SETS X AND Y

1. SET X

SEQ	STATE 1	TRF	RATED	3 YEARS			4 YEARS		
PR				C	A	R	C	A	R
1	wet cup	broken	S	19	1	0	10	0	0
	broken cup	wet	NS	6	13	1	6	3	1
2	paper+writing	cut	S	19	1	0	10	0	0
	cut paper	written	NS	9	11	0	8	2	0
3	open door	painted	S	18	2	0	8	1	1
	painted door	open	NS	8	12	0	8	2	0
4	messy hair	combed	S	13	2	5	9	1	0
	wet hair	dried	NS	8	11	1	8	2	0
5	apple+picture	cut	S	18	2	0	10	0	0
	apple+picture	erased	NS	11	9	0	5	5	0

2. SET Y

PR	STATE 1	TRF	RATED	3 YEARS			4 YEARS		
				C	A	R	C	A	R
1	wet banana	cut	S	18	2	0	9	1	0
	cut banana	wet	NS	10	9	1	7	3	0
2	painted plate	broken	S	16	4	0	10	0	0
	broken plate	painted	NS	13	6	1	10	0	0
3	dry orange	drawn on	S	18	0	2	10	0	0
	wet orange	dried	NS	9	3	8	9	1	0
4	long mess hair	cut	S	11	8	1	10	0	0
	messy hair	combed	NS	17	2	1	10	0	0
5	drawer+picture	erase	S	12	6	2	10	0	0
	open drawer+paper	shut	NS	16	3	1	10	0	0

Investigating the Effects of Salience on Correct Responses

The children's correct (C) responses to S and NS sequences are presented in Table 3.3.11. This table shows that, on the whole, Salient sequences did elicit more C responses than Non-Salient ones, especially from 3-year-olds. This was most pronounced in the Experimental condition. There was also some evidence of an order effect in the 3-year-old group as the means for C responses in the Experimental condition were higher when it was experienced on the second trial, for both S and NS sequences.

TABLE 3.3.11 MEANS AND STANDARD DEVIATIONS OF C RESPONSES ON S AND NS SEQUENCES

CONDI TION	TRF TYPE	THREE YEARS		FOUR YEARS	
		E TRIAL 1	E TRIAL 2	E TRIAL 1	E TRIAL 2
E	SALIENT	3.9	4.15	4.8	4.8
		(0.72)	(0.88)	(0.42)	(0.42)
	NON-	2.25	3.1	3.9	4.2
	SALIENT	(1.37)	(1.45)	(0.74)	(1.03)
C	SALIENT	4.65	4.65	4.9	4.9
		(0.59)	(0.49)	(0.32)	(0.32)
	NON-	4.25	4.25	4.7	4.6
	SALIENT	(0.91)	(0.64)	(0.48)	(0.52)

where :

E = Experimental condition C = Control condition

E TRIAL 1 = E on first trial, C on second trial

E TRIAL 2 = C on first trial, E on second trial

TRF = TRANSFORMATION

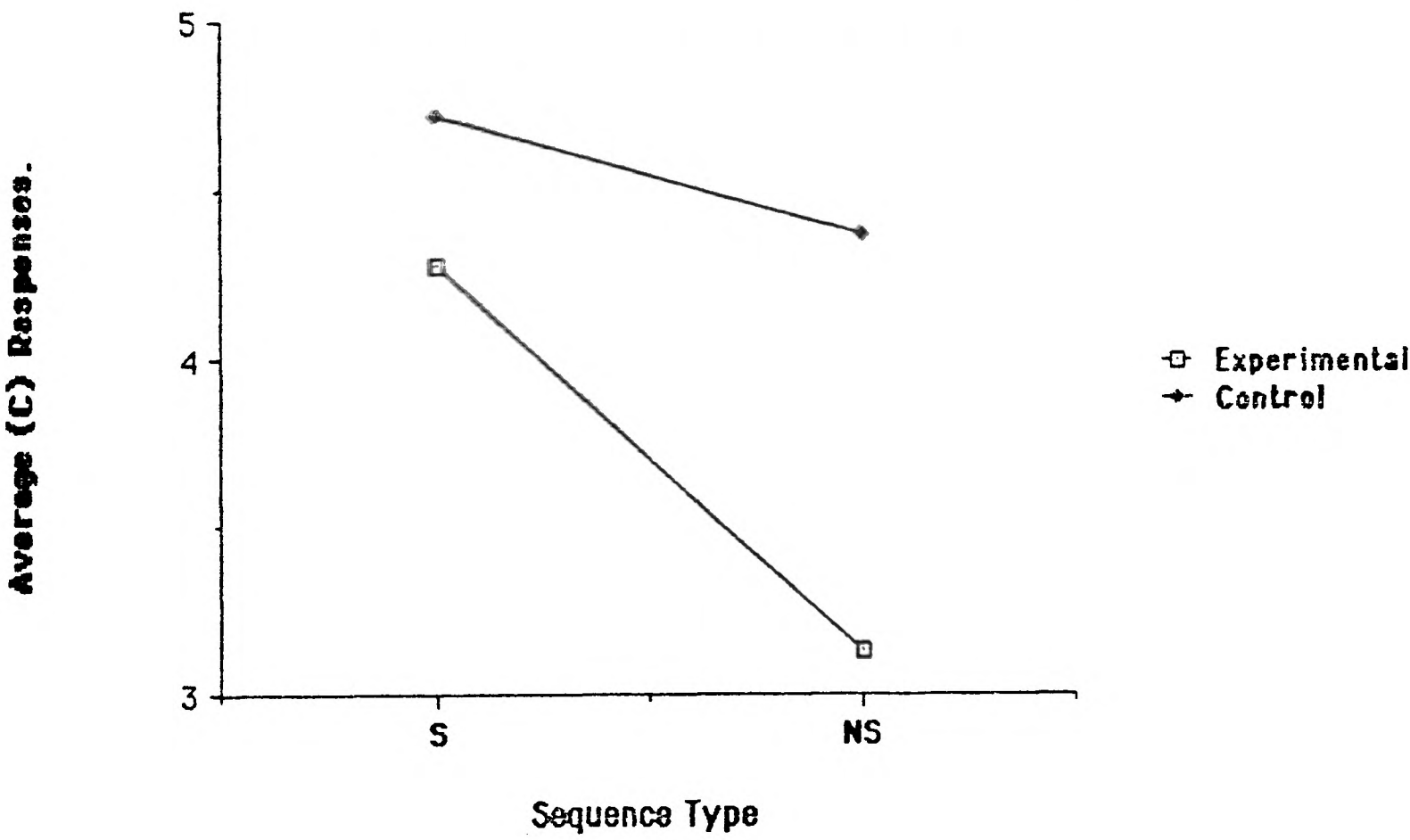
These trends were explored using a 4-way ANOVA with repeated measures, with Age(2) and Order(2) as the Between factors and Condition(2) and Sequence type(2: S, NS) as the within factors.

The dependent measure was the number of C-responses. Four scores were obtained from each child (for S and NS sequences in two conditions). The results of this analysis are shown in Table 3.3.12.

TABLE 3.3.12 SUMMARY TABLE (ANOVA) FOR CAUSAL RESPONSES ON
SALIENT AND NON-SALIENT SEQUENCES

SOURCE	SS	DF	MS	F	PROB.
AGE (A)	26.13333	1	26.13333	31.46	0.0000***
ORDER (O)	1.40833	1	1.40833	1.70	0.1983 ns
AO	0.67500	1	0.67500	0.81	0.3713 ns
ERROR	46.52500	1	0.83080		
CONDITION(C)	28.03333	1	28.03333	56.22	0.0000***
CA	7.50000	1	7.50000	15.04	0.0003***
CO	1.87500	1	1.87500	3.76	0.0575 ns
CAO	0.40833	1	0.40833	0.82	0.3694 ns
ERROR	27.92500	56	0.49866		
SEQTYPE(S)	25.20833	1	25.20833	33.27	0.0000***
SA	1.87500	1	1.87500	2.47	0.1213 ns
SO	0.53333	1	0.53333	0.70	0.4050 ns
SAO	0.13333	1	0.13333	0.18	0.6764 ns
ERROR	42.42500	56	0.75759		
CS	7.00833	1	7.00833	9.43	0.0033 **
CSA	0.67500	1	0.67500	1.91	0.3447 ns
CSO	0.83333	1	0.83333	1.12	0.2942 ns
CSAO	0.03333	1	0.03333	0.04	0.8331 ns
ERROR	41.62500	56	0.74330		

Fig 3.3.3. Condition X Sequence Type Interaction.



The difference between scores on S and NS Sequences was statistically significant ($F(1,56)=33.27$, $p<.001$). There were also significant main effects for Condition ($F(1,56)=56.22$, $p<.001$) and Age ($F(1,56)=31.46$, $p<.001$). There were significant interaction effects for Condition x Age ($F(1,56)=15.04$, $p<.001$), as well as, Condition x Sequence-Type ($F(1,56)=9.43$, $p<.01$). These interactions were explored using the Newman-Keuls test. The Condition by Age interaction was exactly the same as for the Total scores (performance was better on the Control condition ($p<.01$); older children gave more C responses than younger ones ($p<.01$) in the Experimental Condition).

A graphical representation of the Condition by Sequence-Type interaction is presented in Figure 3.3.3. There was a significant difference between responses on S and NS sequences in the Experimental condition ($p<.01$) but not on the Control. However, comparison of the two conditions showed that significantly more correct responses were given in the Control condition than in the Experimental, for both S ($p<.01$) and NS ($p<.01$) sequences.

In the Control condition, salience of transformations did not influence Correct responses. In the Experimental condition, however, far more correct responses were made in sequences depicting Salient transformations. This is not surprising if children are attending mainly to end states. Focusing on the salient state will help them get one Correct answer within each pair of sequences. This analysis shows that the salience of transformations is an important factor in influencing children's judgements.

In summary, sequences which showed Salient changes elicited significantly more Correct responses than sequences which showed Non-Salient changes. This difference was not significant in the Control condition in which a matching method could produce cor-

rect responses. In the Experimental condition where it was necessary to relate first and last states to produce correct choices, use of a matching method seemed to dispose children to choose instruments for a salient change.

3.4. Discussion

The results of Experiment 1 indicate a difference between 3- and 4-year-old children's abilities to deal with causal event-sequences of the type used in this experiment. Three-year-old children make almost as many correct responses as 4-year-olds in the Control condition which does not require them to make a relational connection between the two states of objects. In the Experimental condition, where relating the beginning and end states is essential in order to discover the transformation that has occurred in the sequence, younger children's correct scores drop significantly. There was a significant difference between the two age groups in the Experimental condition, but not in the Control (these results were identical for paired and total scores).

Thus, although a comparison of responses in the Experimental condition indicated a developmental difference, this was not supported by a comparison of the responses of the same children in the Control condition (which was similar to the Gelman et al. condition). This finding indicates that the Experimental condition allowed a differentiation between the two age groups with regard to the method they were using to find instruments for change, while the Control condition did not. The greater number of correct responses made in the Control condition supports the suggestion, made earlier on, that what Gelman et al. called a "causal response" made on the basis of transformational information may simply have been an asso-

ciative-causal one. Given exactly the same sequences in the Experimental condition as in the Control, children made fewer correct responses in the Experimental condition.

In the Control condition, it was not necessary to relate the initial and final states of the objects in order to make a correct inference. Correct responses could be achieved either by matching instruments to effects or using associative connections between instrument and effect (knife and cutting, for example, may be associated because children often see their parents using knives to cut things). The exploration of the weak Condition by Order interaction showed that for both age groups there were more correct responses in the Control condition, whatever the order of presentation. This indicates that in this condition (whether experienced first, or second), it was much easier for children (especially 3-year-olds) to make correct choices. Furthermore, the same children gave significantly more correct responses in the Control condition than in the Experimental.

Interestingly, although the Control condition improved younger children's correct scores, it had no such effect on the correct scores of the older children. There was no significant difference between 4-year-olds' correct responses on either condition. This difference between the two age groups suggests that the older group were more inclined to relate event sequences on the basis of transformations because their high performance was not tied to a particular condition. Another finding which lends some support to this conclusion comes from the analysis of correct paired-responses. The sequences were paired in order to test the consistency of children's correct (C) responses. It was only in the Experimental condition that younger children were far less consistent than the older ones.

Another reason that responses were paired was in order to investigate the type of errors made by the children. It was found that the majority of errors were of the AC/CA type. A small proportion of the errors made were of the Random variety, indicating that when children erred they did so because of a strong associative link between instrument and effect. The fact that a number of AC/CA responses were significantly above the proportions expected by chance indicate that children were not behaving in a random fashion. They chose the correct instrument responsible for the state that they chose to explain and their comments ("cut 'cause knife"; "paint, whoosh; see red") indicated that they knew that the instrument chosen could produce the effect shown. Even if such knowledge was based on constantly conjoined occurrences of instrument and effect in the past, AC and CA responses were tentatively defined as associative-causal because children seemed to be connecting particular instruments with their particular effects.

The ACCA-errors indicated that the children were giving a correct response for only one of the transformations depicted in the sequence pair. There was a strong developmental effect: older children made fewer errors of this kind compared to the younger ones. Although fewer errors of this kind were made on the second trial, especially by the older children, this difference was not statistically significant.

A number of possible explanations for the AC/CA responses were postulated. Post-hoc analysis confirmed that the relative salience of transformations depicted in the sequences affected children's correct inferences. There was a significant difference between correct responses on Salient and Non-Salient sequences. Post-hoc analyses showed that in the Experimental condition children gave a significantly greater number of correct

responses for Salient than for Non-Salient sequences. This difference was not significant in the Control condition. In general, younger children gave a greater number of correct responses in the Control condition whatever the sequence type (S/NS). The older children's scores did not vary significantly across conditions.

The greater number of correct responses on the Control, nearing ceiling in both age groups, for both total and paired responses, regardless of salience, showed that the children did understand the task. They knew that they were being asked to find an instrument for the end state of the object. Why then did the younger children's causal scores drop in the Experimental condition?

One possible explanation is that this age group were using a matching method, and choosing instruments that matched, or were associated with the effect. In the Control condition, only one instrument, the correct one, could be chosen using this method. Such a method however would not lead to consistently correct (CC) responses in the Experimental condition. Here, each choice instrument caused each of the states depicted. Thus, unless the child relates the final state to the initial state and works out the transformation that has occurred, (discounting the continuing state of the object) she will have a problem in choosing between the two choice instruments, each of which match one of the two final states. Therefore, if children are using a matching method they may well choose between the two possible instruments on the basis of which state of the object is most **salient** to them. Indeed the finding that Salient sequences elicited more causal responses overall than Non-Salient ones lends considerable support for this proposition.

Four-year-olds made less AC/CA inferences than the 3-year-olds. This may indicate that at this age they are almost at the end of a process of method change: from a matching method, to a

relational one. Being in the process of changing strategies, although they retain some elements of the former, they rely more on the latter.

The verbal explanations of the children lent support to this distinction. Whereas younger children on the whole described end states, and gave explanations for one of the two changes seen therein :

eg. "It's cut. Knives do cut". (Pointing to end photograph);

The older children usually described the whole sequence, even when they made errors:

eg. "It's wet." (looking at or pointing to first state).... "It's still wet" (looking at or pointing to second state)..... "Water done it!", or in the case of a correct inference:

"It's wet..now it's cutted as well. It's the knife..cut it."

Thus it would appear that causal reasoning in terms of transformations requires the ability to connect events into a thematic whole in order to deduce the relations within the sequence.

Before such a conclusion can be reached however, alternative explanations for the pattern of results obtained need to be considered. Firstly, children (especially 3-year-olds) might not have understood whether they were being asked to infer for the initial state of the object or for the final state. This would not affect responses in the Control condition, where only the instrument for the final state is given; however, it could lead to confusion in the Experimental condition.

Secondly, the form of the sequences required children to deal with objects in two states - the state present at the beginning of the sequence which remained unchanged and the state brought about by transformation within each sequence. Although memory demands were minimised by having all elements in the sequence accessible to chil-

dren at all times, younger children may have found it harder to deal with two object states. This is especially possible, as the structure of the task required that the first state should be discounted, or held constant, so that an inference could be made about the instrument responsible for the transformation (final state).

Finally, since the familiarisation sequences were similar to those used in the Control condition, it could be argued that greater familiarity with Control type sequences boosted children's performance in this condition.

Thus, although the results of this first experiment indicate that children who make associative choices do so because they do not treat sequences as thematic wholes, it is necessary to deal with the aforementioned problems before such a conclusion can be made. The next experiment was designed to control for these factors.

CHAPTER FOUR
INFERENCES IN EXTENDED SEQUENCES

4. Experiment 2 Methods of Choosing Causal Instruments
 in Sequence Chains

4.1 Introduction

Experiment 1 provided evidence, not previously reported, that young preschoolers (3-year-olds) prefer to use an associative Matching method (matching a plausible instrument to an effect) when making judgements about causal instruments. Older preschoolers (4-year-olds) appear to use a more Relational (causal) method relating the first and last states in any given sequence in terms of a transformation. Although the results of the first experiment clearly indicate the use of a Matching method by younger preschoolers the results were not considered conclusive for the reasons described at the end of the previous chapter.

The present experiment was designed to control for these factors and differentiate between consistently causal responses (which could only be achieved by using a Relational method) and associative-causal responses (which could be achieved by matching instruments to effects or vice-versa, on the basis either of strong associations between the instrument and the effect, or a knowledge of the causal powers of instruments).

In Experiment 1 objects were already in changed states at the beginning of a sequence (e.g. wet cup, cut banana, etc.). This departure from the standard in the first photograph (initial state) of a sequence may have triggered a search for a causal

instrument, especially if children are highly sensitive to change. When a striking change was experienced first, children may have not attended to any other change. Therefore, in Experiment 2, the departure from the standard form (e.g. Cup [standard] ----> Wet Cup [initial state]) of an object was incorporated into the sequence. Children were presented with a chain of transformations. This was done by extending the sequences of Experiment 1 one step backwards. For example, whereas in the previous experiment sequences were of the form:

Wet Cup (WC) ----?---- Wet Broken Cup (WBC)

in the present experiment they were of the form:

Cup ----?---- Wet Cup(WC) ----?---- Wet Broken Cup(WBC).

There were two reasons for extending the sequences. Firstly, it was thought that by starting sequences with the object in its standard form any confusion that arose from starting with objects which were already in an altered state would be minimised. The first change of state would be accounted for in the sequence. Secondly, by breaking down the transformation sequences (e.g. WC---->WBC) into their component parts (Cup---->WC---->WBC) the inference process was simplified. The child was now asked to deal with one change at a time and could locate the two different changes at different points in the chain if she was relating the sequence as a thematic whole. To do this children had to recognise that the underlying unity of the sequence was provided by the object. This object (cup, for example) though undergoing changes of state, was the constant unifying factor in each sequence. If children were not relating the sequence in terms of the transformations undergone by the objects, then, although they might achieve near ceiling performances on the first part of the chain (Cup--->Wet Cup or

Cup--->Broken Cup), they would not do as well on the second part of the chain (WetCup ---> BROKEN WetCup or Broken Cup ---> WET Broken Cup). This is because simple associative Matching would yield a correct choice of instrument at the first transformation point. The second transformation point, however, requires a recognition of the underlying substance (cup), the continuing state (Wetness, for e.g) which has to be discounted in order to infer the cause for the change that occurs in the second part of the chain.

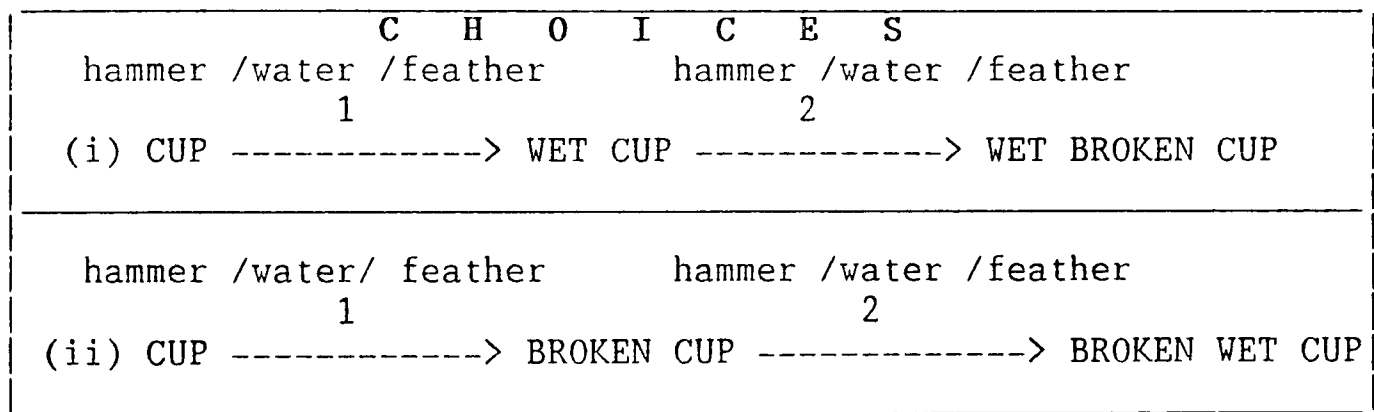
The second method requires the child to take into account the information about transformation provided in the sequence and may be more complex than the Matching method. It was not expected that extending the sequences would make the task more difficult because Schimdt and Paris (1978) successfully used 4-picture sequences with kindergarteners and pre-schoolers. Furthermore, as the sequence of photographs was always available for reference when inferences were being made, it was not thought that memory demands were being increased in this experiment. Thus it was not expected that simply extending the sequences would make this experiment more difficult than the previous one.

Moreover, since the steps of change (resulting in an object in two states) were separated, this task might be easier than the Experimental condition, Experiment 1. In the present experiment the children were asked to choose one causal instrument and then another. Having attributed for the first state of an object they could then choose the cause for the following (second) state. If children simply alternated their choices, having chosen the correct instrument for the first transformation, then they would have near ceiling scores for both transformations in a sequence. If however they were using a Matching method, a different pattern would emerge, possibly

influenced by Saliency, as in Experiment 1.

By extending the sequences used in Experiment 1, Experiment 2 (henceforth also referred to as Chains) was made directly comparable to it. The second transformations in the Chains (e.g. Wet Cup--->Wet Broken Cup) were identical to the sequences in the first experiment. This made it possible to highlight the changes, if any, which the extension of the sequences had on children's performance. As in Experiment 1, sequences were paired in order to establish the consistency and validity of correct choices. An example of a sequence pair in Experiment 2 is presented in Diagram 4.1.1.

DIAGRAM 4.1.1 A SEQUENCE PAIR - EXPERIMENT 2



There were four transformations within each pair of sequences. Exactly the same choices were given for each of the four transformations (see Figure 4.1.1). If children were simply repeating certain responses, they would repeat that response at least twice or thrice. Therefore, response patterns will show whether children are simply repeating a response, or whether there is either an associative-causal or consistently causal pattern in their responses.

The extension of the sequences used in Experiment 1 was expected to increase the number of correct responses given by children (of both age groups) on the second transformation of the Chains sequences. The number of associative-causal responses would

therefore either be eliminated, or decrease significantly. If this happened it could be argued that such responses were an artefact of the method used in the first experiment. On the other hand, if children still give large numbers of associative-correct responses, then this type of response would be shown to be genuine and not an artefact, attributable to factors other than those already accounted for.

The results of Experiment 1 also indicated that the salience of transformations influenced children's causal judgements. Since the material used in the Chains experiment was exactly the same as that used in Experiment 1, the second transformations in each sequence of this study were categorised as Salient(S) or Non-Salient(NS) on the basis of the results of the previous experiment. Only sequences from SET X (Experiment 1: 3.2 [c]) were used as all three raters reached 100% agreement in classifying these sequences S or NS.

The second transformations in the Chains study were categorised S/NS -

(a) to determine whether the extension of the sequences diminished the effect of salience on children's causal judgements and

(b) to see if the associative-causal response was in anyway connected to the salience of transformations.

Since confusion over the initial state had been controlled for, the occurrence of an associative-causal response could be attributable to children making inferences for a state of the object that was salient to them, rather than for the transformation that had changed the state of the object. For example, in the sequence:

Cup--(1)-->Broken Cup--(2)-->Wet Broken Cup

if the child finds the transformation "broken" salient, then, despite the extension, she is likely to make the same inference (hammer in this case) at points (1) and (2), especially if she is not seeing the sequence as a thematic whole, and therefore relying on associations between an instrument and a particular state to make judgements. If she is simply repeating the first response, then she should choose "water" twice, for the corresponding sequence in the pair: Cup--(1)-->Wet Cup--(2)-->Broken Wet Cup

However, by presenting extended sequences, the process of action and change was highlighted. This may make it easier for children to perceive changes taking place and make appropriate causal judgements.

Predictions:

1. It was predicted that children would do significantly better on the initial transformations of the chains sequences than on the second transformations. After the initial transformation objects in the photographs displayed one change of state (like the Gelman et al. sequences: e.g. wet cup, cut paper, etc.) and the causal instrument could easily be inferred using an associative-causal Matching method. To make a correct inference for the second transformation children **had** to relate the preceding state of an object to the end state because the change that had already occurred (first transformation) had to be discounted in order to distinguish the second change (second transformation) that occurred.

2. However, it was predicted that the extension of the sequences would lead to improved performance on the second transformations (which are exactly the same as sequences in Experiment 1) compared to the Experimental condition (Experiment 1). Extending the sequen-

ces, as explained earlier, was expected to simplify the inference process for the children. Nevertheless, it was predicted that performance would be best on the Control condition (Experiment 1) if all three 'conditions' (Experimental, Control and Chains (second transformation)) were compared because correct inferences in the Control could be achieved by using a Matching method.

It was also predicted that -

3. Older children (4-year-olds) will give significantly greater numbers of correct responses than younger children (3-year-olds).
4. Salient transformations, as defined in Experiment 1, will elicit significantly greater numbers of correct responses than Non-Salient transformations.

4.2 Method

(a) Subjects:

Seventy children were involved in this study. Forty children, 20 in each age group: 3-years (mean = 3:6; range = 3:0-3:11) and 4-years (mean = 4:4; range = 4:0-4:11) took part in the Chains Experiment.

Thirty children (twenty 3-year-olds - mean = 3:6; range = 3:2-3:10) and (ten 4-year-olds - mean = 4:5; range = 4:0-4:9) who had participated in Experiment 1 were included for comparison. As the Chains in Experiment 2 were extensions of sequence Set X, only those children who had experienced X, on their first trial in Experiment 1 (in Experimental and Control conditions) were chosen. Thus any order effects which might have occurred in the first experiment were eliminated and these scores were directly comparable to those of children in the second experiment.

The experimenter was familiar to all the children. She spent a week at the schools as a "helper" prior to starting the experiments.

(b) Design:

A mixed design with repeated measures on Transformation points (2) was used to compare 3- and 4-year olds responses on the first and second transformation points in the Chains experiment.

The effect of the extension of sequences on children's performance on Transformation 2 was investigated by comparing the Correct (CC) scores of children in Experiment 1 with the CC scores of children in Experiment 2. A 2-way, 2(Age: 3+, 4+) by 3(Condition: Experimental, Control and Chains [transformation 2]) independent groups design was used for this comparison.

(c) Material:

Two sets of colour photographs were used, one for familiarisation and one for the experiment itself. Details of the material can be found in Appendix 2.

The Familiarisation material

This consisted of five picture sequences, with two points of transformation in each sequence. An example is given in Diagram 4.2.1. Children had to make an inference about the causal instrument (what made the plate change?) at points 1 and 2. They were given 3- possible choices of a causal instrument at each point. This material was designed to familiarise children with the task and to train them to read sequences from left to right.

DIAGRAM 4.2.1 AN EXAMPLE OF FAMILIARISATION MATERIAL

Pair One		
TRANSFORMATION POINT 1	TRANSFORMATION POINT 2	
(standard)	(first change)	(second change)
(i) PLATE-----?-----	plate+drawing---	?-----cut plate+drawing
(ii) PLATE-----?-----	cut plate-----	?-----cut plate+drawing

The Experimental material:

The sequences from Set X (Experiment 1) were extended for use in this experiment. Set X items were used because there had been 100% agreement between two raters in categorising the transformations in these sequences as Salient/Non-Salient. As one of the aims of the Chains experiment was to investigate what effect simplifying the sequence had on the use of salience information in making causal inferences, it was important to use material that had been reliably categorised in the previous study.

DIAGRAM 4.2.2 EXAMPLE OF A SEQUENCE PAIR - EXPERIMENT 2

Pair One		
TRANSFORMATION POINT 1	TRANSFORMATION POINT 2	
(standard)	(first change)	(second change)
(i) CUP-----?-----	Wet Cup-----	?-----Wet Broken Cup
(ii) CUP-----?-----	Broken Cup----	?-----Wet Broken Cup

Sequences were paired to establish the consistency of the correct responses. Five pairs of sequences, of the form shown in Diagram 4.2.2, were constructed. The same choices, (in this example: water; hammer; feather;) were given at each transformation point, for both the sequences in a pair. The two sequences (i) and (ii) in each pair were not presented consecutively in an effort to control for a response bias. Please note that the second transformation points (e.g. Wet Cup--->Wet broken Cup; and Broken Cup--->Broken wet Cup) are replicas of the sequences in Experiment 1.

(d) Procedure

Familiarisation and testing were conducted in the school or playgroup. The experimenter sat beside the subject at a table or on the floor depending on the facilities available. Once again the experiment was presented as a "picture game".

The children were first shown photographs of all the items to be used in the experiment and asked to identify each object. If a child was unable to identify an object, the experimenter named it and asked the child whether she had ever seen it before. Only a couple of 3-year-olds were unable to identify certain objects but when the object was named for them, both groups indicated familiarity with it (for example: "Oh. Mummy cut my cake with that" (re: knife); or, referring to a matchbox: "Daddy does have that. For cigarette").

Familiarisation Procedure

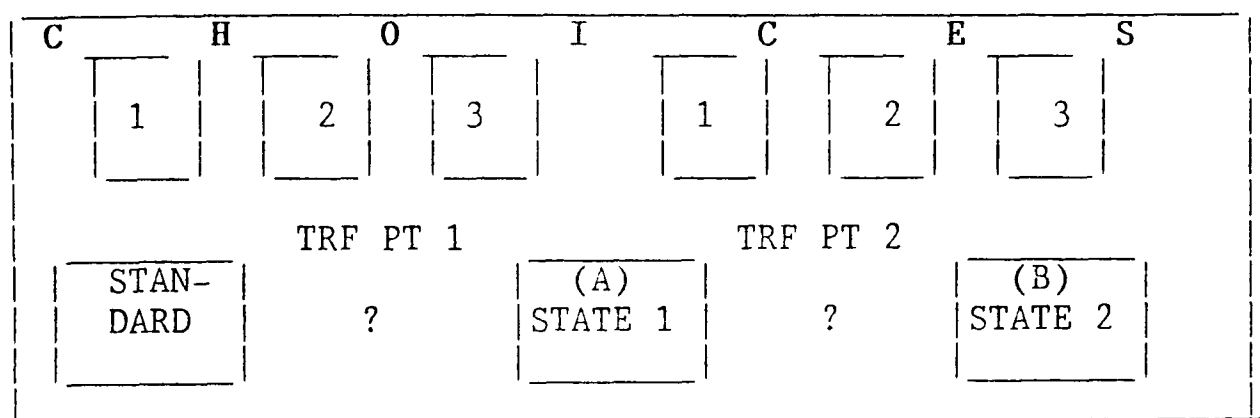
The children were subsequently familiarised with the sequence to be used in the experiment, using the familiarisation material. The procedure was exactly the same as that used in Experiment 1. For each sequence, the photographs were shown to the child one by one and laid out.

Once all 3 photographs were laid out the experimenter asked the child whether something had happened to the object at (A) and then at (B), see Diagram 4.2.3. If the answer was "Yes" (all the children answered Yes at this stage), the experimenter (E) then said:

"You said that the ___ (naming appropriate object) had changed. Look at these things" - here the experimenter presented the 3 choice photographs to the child - "and tell me what I used to make object become like this" - pointing to the first transformation. Once the

child chose an instrument for the first transformation the experimenter then directed the child's attention to the second transformation using exactly the same procedure. Three choice photographs were placed above the blank space preceding the second transformation as illustrated in Diagram 4.2.3.

DIAGRAM 4.2.3 LAY-OUT OF SEQUENCES IN EXPERIMENT 2



- where: TRF PT = Transformation Point

At each transformation point the child was shown photographs of 3 instruments. The same instrument choices were presented at points 1 and 2. Children who made errors were asked to look at the sequence again to see what had happened to the object. Most errors were made for the second transformation, especially if the first transformation had been more striking (e.g broken) compared to the second (e.g wet). In such cases the experimenter asked the child to look at the sequence again, naming the first transformation, then asking what else had happened at the end (state B in the Diagram above). If a child could not say what the second transformation was at this point, the experimenter told her what it was and asked what instrument was used to cause it. Except three 3-year-olds, all the children named both transformations by the end of familiarisation.

To check that children understood the instructions, when the last two sequences were presented they were asked if they knew what they had to do: "Do you know what you have to do now?"

All the children answered correctly, for example:

"I have to tell you what made it cut/painted etc."; or

"I have to find what made it happen"; or

"Yes. It got cut by the scissors".

Once correct inferences had been made for both transformations the experimenter 'read' the sequence out to the child (pointing to the appropriate photographs). Eg.

"I had a cup and I used this water to wash it and now it's wet. Then I banged it with a hammer and now it's broken as well."

Experimental Procedure - The actual experiment was carried out two days after the familiarisation. Each child was shown the sequences step by step, as follows:-

1. The child was shown a photograph of the standard form of the object and asked to identify it (e.g. cup). The photograph was then laid on the table (or floor) in front of the child.

2. The child was shown the object in an altered state (e.g. wet cup) and asked if anything had happened to it; all children answered "Yes". They were then asked what had happened; all children named the correct change. The photograph was then laid next to the first one (with a gap left between the two for the instrument).

3. The child was shown the object in its final state (e.g. wet and broken cup) and asked whether "anything else" had happened and what had happened to it. All the children answered correctly. This photograph was laid next to the previous two with a gap left between it and the second photograph) as illustrated in Diagram 4.2.3.

Once all 3 photographs were laid out, children were told

that they would be shown three 'things' and they had to choose which one made the given object change to become like the photograph showing the first state of the object (A in the Diagram above). The three choices were laid out above the gap between the sequence-photographs. This procedure was repeated for State B. Children's choice of causal instrument at each transformation point was noted.

The sequences were not presented in pairs in an attempt to reduce repetition of a favoured, or first chosen, instrument whenever a particular object appeared in a sequence. The sequences were presented in randomised orders with the constraint that two sequences in a designated sequence-pair were **never** presented one after the other.

4.3 Results

Method of Scoring - Responses were coded Correct(C), Associative(A) or Random (R) as in Experiment 1 (3.3). Sequences were paired in an attempt to distinguish between consistent causal inferences (CC) for transformations based on perceived changes **and** associative-causal matching of instruments to effects (AC/CA) based on association.

DIAGRAM 4.3.1 AN EXAMPLE OF CODING RESPONSES IN EXPERIMENT 2

transformation point 1			transformation point 2		
choices= (C) (R) (R)			(A) (C) (R)		
water hammer feather			water hammer feather		
1. Cup----	WATER---->	Wet Cup-----	HAMMER---->	Wet Broken Cup	
coded	C		C		
choices= (R) (C) (R)			(C) (A) (R)		
water hammer feather			water hammer feather		
2. Cup----	HAMMER---->	Broken Cup----	HAMMER---->	Broken Wet Cup	
coded	C		A		

Paired responses indicate whether children are consistent in their judgements so most of the following analyses will be

on paired correct (CC) responses. An example of the coding of a sequence-pair is given Diagram 4.3.1. A close analysis of this Diagram will show that it is not possible to get consistently correct (CC) choices within a pair of sequences at either Transformation point (1 or 2) by repeating a preferred choice. Table 1, Appendix 2, shows that the majority of responses made by children were of the CCCC variety. Repetition combinations (CAAC/CACA) were rare.

Consistently Correct Responses

In the example given in Diagram 4.3.1 the paired response for the first transformation point is coded CC, while for the second it is CA. The CC response, in this example, indicates that in both sequences (for the first transformation) the child chose the correct causal instrument. The CA response, in this example, indicates that (for the second transformation) the child made a correct choice in one sequence, and an associative-causal choice in the other. Diagram 4.3.1 shows that paired correct responses for each transformation point (1 and 2) can only be obtained if the child is following the sequence of transformations. Repetition of a response, or responding on the basis of the salience of transformations will lead to CA response-pairs, as in the example above.

The means and standard deviations of the CC responses at each transformation point are presented in Table 4.3.1. As there are 5 pairs of sequences the maximum possible CC responses at each Transformation Point is 5.

The Probability of CC responses occurring by chance

The method described in the previous chapter (3.3) was used to find out whether CC responses occurred by chance. For the First Transformation, the choices were either Correct or Random so the possible response combinations were CC, RR, RC and CR. The

probability of choosing any of these combinations was 0.25. In both age groups the proportions of CC responses made for the First Transformation were significantly above ($p<.01$) chance expectations.

TABLE 4.3.1 MEANS (out of 5) AND STANDARD DEVIATIONS FOR
PAIRED (CC)RESPONSES AT EACH TRANSFORMATION POINT

	FIRST TRANSFORMATION		SECOND TRANSFORMATION	
A 3+	3.1	**	2.35	**
G	(0.79)		(1.18)	
E 4+	4.0	**	3.2	**
S	(0.86)		(1.01)	

(N.B. ** = $p<.01$ this result occurred by chance)

Choices for the Second Transformation were Correct, Associative and Random so there were 9 possible response-pairs (see section 3.3). The probability of any one combination occurring was 0.11. It was found that children's CC responses at this transformation point were also significantly above the level expected by chance ($p<.01$). It appears that both 3- and 4-year-olds use a Relational method but the older children do so far more consistently than younger ones. This finding replicates that of Experiment 1.

Comparing CC scores on the Two Transformation Points:

Table 4.3.1 shows that more correct (CC) responses were made (by both age groups) for the first transformation than for the second. Also, older children gave more correct (CC) responses at both transformation points compared to the younger ones. The statistical significance of these findings was explored by subjecting the raw scores of the CC responses to a 2-way ANOVA with repeated measures. Correct (CC) scores on each transformation point were the

dependent variable, with Age(2: 3- and 4-year-olds) as the Between factor, and Transformation Points (2: First and Second) as the Within factor. The results of this analysis are presented in Table 4.3.2.

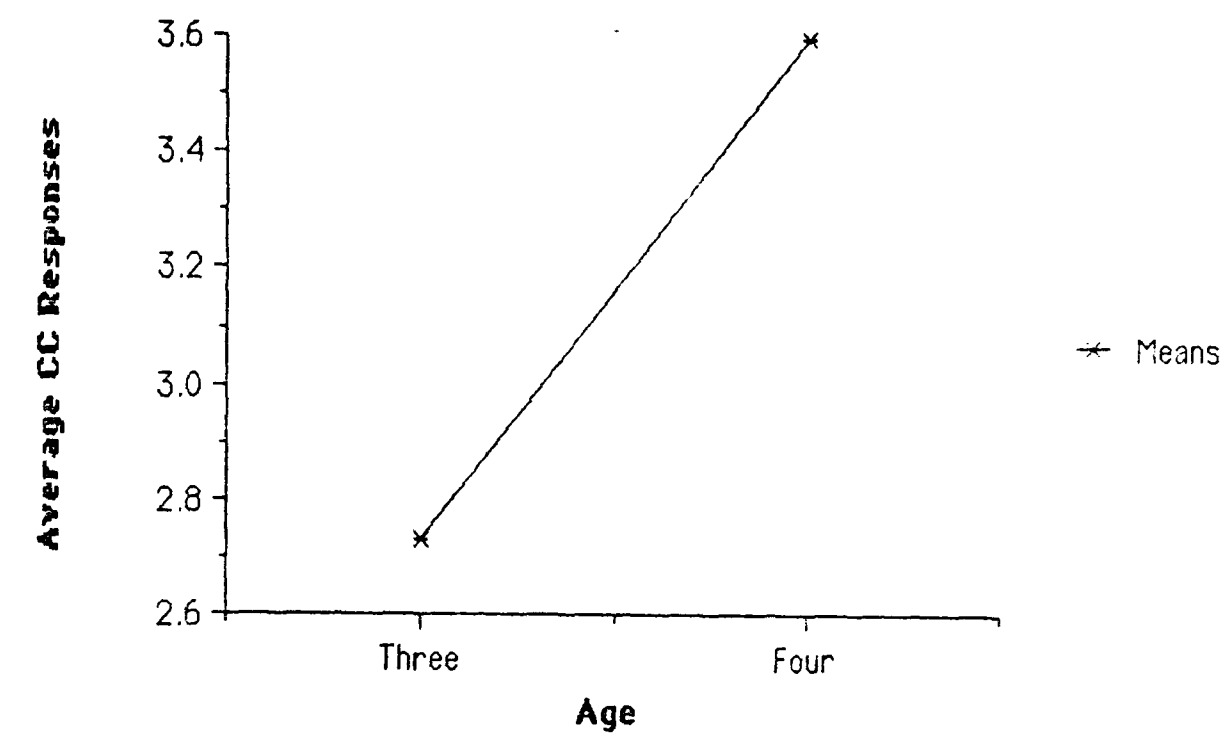
TABLE 4.3.2 SUMMARY TABLE (ANOVA) FOR CC RESPONSES AT TWO
TRANSFORMATION POINTS

SOURCE		SS	DF	MS	F	PROB.
AGE	(A)	15.3125	1	15.31250	13.20	0.0008 **
ERROR		44.07500	38	1.15987		
TRF PT	(T)	12.01250	1	12.01250	16.61	0.0002***
TA		0.01250	1	0.01250	0.02	0.8961 ns
ERROR		27.97500	38	0.72303		

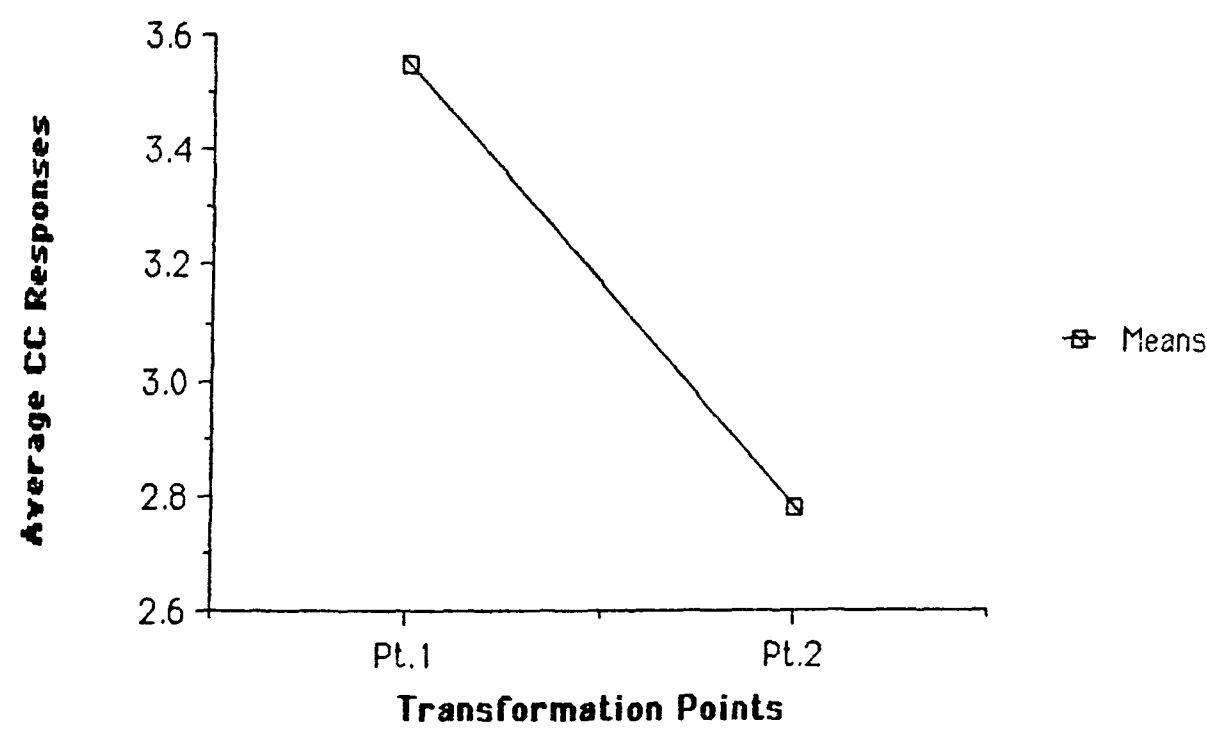
where - TRF PT = Transformation Point (First, Second).
In this and following Tables: *** = $p < .001$; ** = $p < .01$; * = $p < .05$; ns = not significant

The tendency for older children to give a larger number of correct responses proved statistically significant Age ($F(1,38) = 13.2, p < .01$). There was a significant main effect for TRF PT ($F(1,38) = 16.61, p < .001$) which showed that the tendency for a larger number of correct responses to be given for the first transformation than for the second was also statistically significant. A graphical representation of these results is presented in Figure 4.3.1. Both age groups made far more CC responses for the First transformation than for the Second. This is not surprising as a Matching method will yield correct responses for the first transformations, but not for the second. The older children made far more CC responses, overall, than the younger ones. This shows that although both age groups can use the Relational method, the older children do so much more consistently than the younger ones.

Fig 4.3.1. Effects of (a) Age



(b) Transformation Point, on CC Responses



The absence of any significant interaction between Age and Transformation point may be explained by the relatively high scores of both ages on Transformation 1. Furthermore, the differences between scores on Transformations 1 and 2 were not very different in the two age groups (3-years: 0.75; 4-years 0.8)

The Effect of Extending Sequences – Comparing Experiments 1 and 2

One of the main aims of the second experiment was to study the effect, if any, that extending the sequences of Experiment 1 had on children’s correct responses. The scores of children who experienced Set X sequences in Experiment 1 were compared with children’s CC scores on the second transformation points of sequences in Experiment 2. This was done to ensure that the scores being compared in the two experiments were strictly comparable. Thus, apart from the fact that children in Experiment 2 had been through an extended sequence, there was no difference between the three conditions compared.

TABLE 4.3.3 MEANS (out of 5) AND STANDARD DEVIATIONS FOR
PAIRED (CC) RESPONSES IN 3 CONDITIONS

	CONTRL	EXPTL	CHAINS
3+	3.9	1.3	2.35
	(1.45)	(1.16)	(1.18)
4+	4.6	3.2	3.2
	(0.55)	(0.84)	(0.98)

where - CONTRL AND EXPTL = Conditions in Experiment 1
CHAINS = Second transformation in Experiment 2.

The means and standard deviations for the number of paired correct (CC) responses in each condition is given in Table 4.3.3. Both age groups gave the most CC responses in the Control

condition. For the 3-year-old group only, extension of sequences (Chains) seemed to improve or facilitate CC responses as compared to the Experimental condition (Experiment 1). In all cases the older children gave more correct responses than the younger ones. The significance of these findings was tested by subjecting children's paired CC scores to a 2-way ANOVA for independent groups. Age (2) and Condition (3: Experimental, Control and Chains) were the independent variables with CC scores as the dependent variable. The results of this analysis are presented in Table 4.3.4.

The tendency for older children to give more correct responses than the younger ones, whatever the condition, was statistically significant: Age - ($F(1,64) = 13.19, p < .01$) see Figure 4.3.2 (a). A significant main effect for Condition ($F(1,64) = 12.25, p < .0001$) indicated that the type of condition (Control, Experimental, Chains) significantly affected children's correct responses as well. The absence of any significant interaction effect ($F(1,64) = 1.36, p > .1$) indicated that the effects of Age and Condition were independent of each other.

TABLE 4.3.4 SUMMARY TABLE (ANOVA) COMPARING CC RESPONSES IN
EXPERIMENTS 1 AND 2 (second transformation point)

	SOURCE		SS	DF	MS	F	PROB.	
	AGE	(A)	16.51429	1	16.514	13.19	0.0006	**
	CONDITION	(C)	30.66667	2	15.333	12.25	0.0000	***
	AC		3.40000	2	1.700	1.36	0.2644	ns
	ERROR		80.10000	64	1.252			

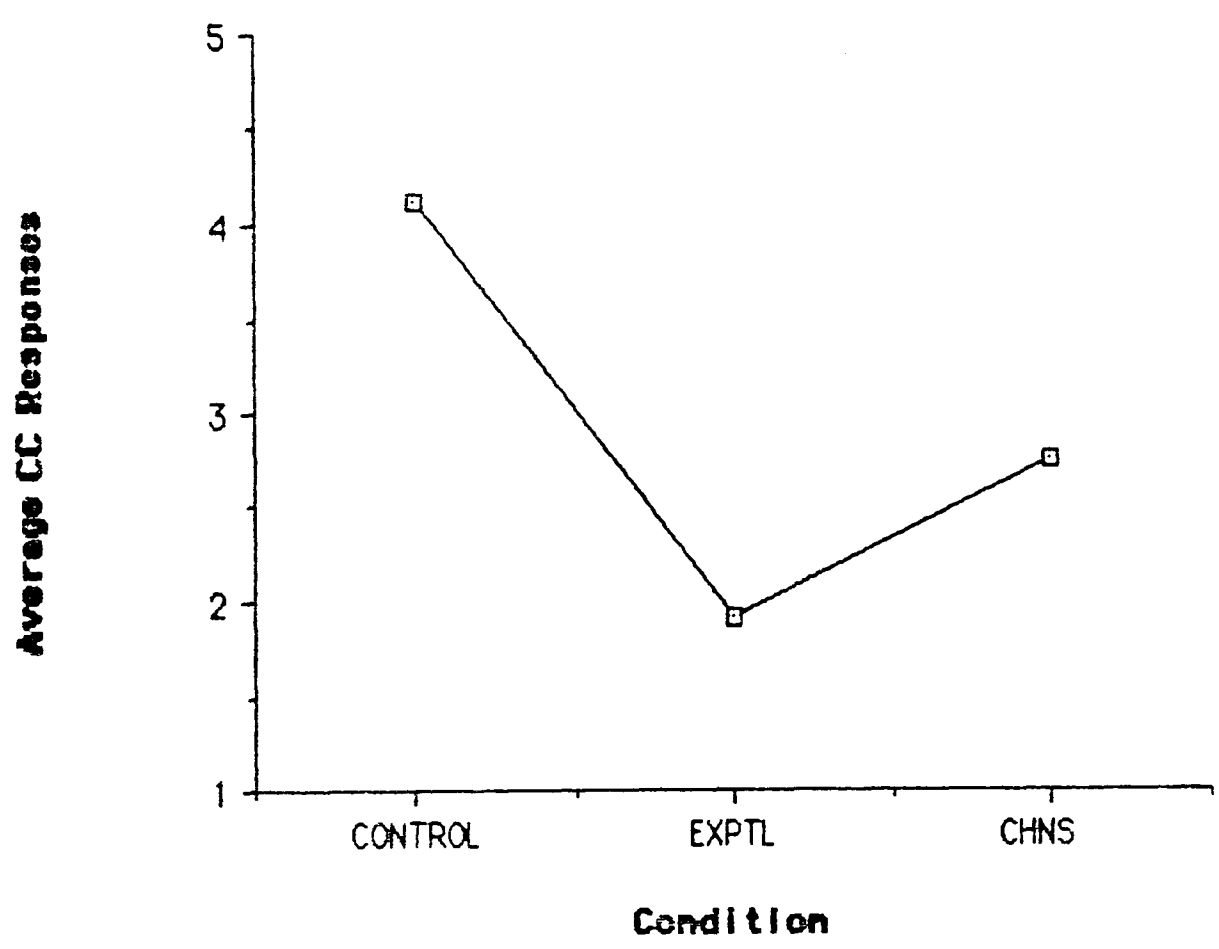
The significant main effect for Condition indicated that of the three conditions at least two differed significantly and the Newman-Keuls post-hoc test was used to explore these differences. It

was found that significantly more CC responses were made in the Control condition compared to both the Experimental ($p < .01$) and the Chains ($p < .01$) conditions. Significantly more CC responses were made for the Chains condition than for the Experimental ($p < .05$). This result suggests that extending the sequences used in Experiment 1 did facilitate correct inferences for causal instruments.

Although Table 4.3.3 shows no difference between Experimental and Chains conditions in the 4-year-old sample, the absence of any Age x Condition effect means that this difference cannot be attributed to the 3-year-olds. One reason for the absence of a significant interaction may be that the higher scores of the 4-year-olds on all conditions masked this effect. Secondly, there was an unequal distribution of subjects in the different cells of the ANOVA matrix because children from Experiment 1 (trial 1 only) were included for comparison. It is possible that because of the fewer subjects in Experimental and Control groups compared to the Chains groups the effects of these conditions in each age-group were not strong enough to contribute to an interaction.

These results indicate that when relations between objects states are pointed out explicitly (as in Experiment 2) preschoolers' performance improves. Although children may not relate object states into thematic wholes consistently, as in Experiment 1, they are more consistent when the unity of the sequence is emphasised. The ability to spontaneously relate different elements in event sequences into units may be one factor responsible for the difference in the number of CC responses made by the two age groups.

Fig 4.3.2. The Effect of 3 Conditions on CC Responses.



The Effect of Salience of Transformations on Correct responses

The results of Experiment 1 showed that if children do not relate sequences as wholes but focus on end states they may make 'salience' errors. They make more inferences for the salient (S) rather than the non-salient (NS) change depicted in the end states of objects. Although children made more correct responses in the Chains condition than in the Experimental condition, the results of the preceding analyses showed that 3-year-olds made significantly less CC responses than 4-year-olds. This is a replication of the results of Experiment 1. As it was found (in Experiment 1) that the salience of transformations significantly affected children's correct responses, the influence of salience of transformations on correct responses in Experiment 2, was also investigated.

On the basis of the categorisation scheme devised in Experiment 1 each transformation point in the chains experiment was categorised as Salient or Non-Salient. A Salient transformation was defined as one which changes an object from its standard or canonical form into a totally different non-canonical form, eg. broken; cut, etc. It is a transformation that dramatically or strikingly alters the state of an object. A **Non-Salient** transformation changes an object without changing its canonical or standard form dramatically (e.g. written on, drawn on etc.).

As all sequences were designed in pairs if the first transformation in one of the sequences in a pair was a Salient one (broken) then the second transformation was Non-Salient (**WET**) and vice-versa in the accompanying sequence. An example of a sequence-pair and the coding of transformations within it, is given in Diagram 4.3.2.

DIAGRAM 4.3.2 CODING OF TRANSFORMATION POINTS IN SEQUENCE PAIRS
IN TERMS OF SALIENCE

FIRST TRANSFORMATION	SECOND TRANSFORMATION
CUP ---to--- wet CUP (Non-Salient)	(WET CUP) ---to--- WET broken CUP (Salient)
CUP ---to--- broken CUP (Salient)	(BROKEN CUP)---to---wet BROKEN CUP (Non-Salient)

On the first transformation it was possible to make C responses solely on the basis of an association between the transformed state and the instrument. On the second transformation however, it is necessary to discount the continuing state of the object (whether Salient or not), to find the causal instrument responsible for the transformation that changed the state of the object (exactly as in Experiment 1). This can only be done if children relate each element in the sequence to the others.

It was predicted that no great difference would be found between S and NS transformations (or changes) on the first Transformation Point. If children were matching instruments to effects, rather than relating elements of the sequence into a thematic whole, salient changes would elicit more Correct (C) responses than Non-Salient ones on the second Transformation Point. Table 4.3.5 gives the means and standard deviations of correct responses for Salient (S) and Non-Salient (NS) changes at each transformation point. The word 'change' is used instead of 'transformation' to avoid confusion. The following analysis deals with both S and NS changes and the first and second Transformation Points (in the sequences) in Experiment 2.

Table 4.3.5 shows that, on the whole, Salient changes elicited more C-responses than the Non-Salient ones. C-scores on Salient changes were near ceiling point for both age groups. The

difference between the two types of change (S/NS) was almost non-existent for the 4-year-olds on the first transformation probably because, at least on this transformation, 4-year-olds were not being influenced by salience when choosing causal instruments. Interestingly, in both age groups there is very little difference between scores on the Salient changes at the two transformation points.

TABLE 4.3.5 MEANS (out of 5) AND STANDARD DEVIATIONS OF
C RESPONSES (S AND NS CHANGES) AT THE TWO
TRANSFORMATION POINTS

		<u>FIRST TRANSFORMATION</u>		<u>SECOND TRANSFORMATION</u>	
		<u>S</u>	<u>NS</u>	<u>S</u>	<u>NS</u>
A 3+		4.2	3.55	4.25	2.9
G		(0.77)	(0.76)	(0.72)	(1.07)
E 4+		4.35	4.3	4.6	3.45
		(0.67)	(0.66)	(0.5)	(0.99)

The statistical significance of these findings was tested by a 3-way ANOVA with repeated measures. Age(2) was the Between factor, with Transformation-point (2: First, Second) and type of Change (2: Salient, Non-Salient) as Within factors. The dependent measure was the number of correct (C) responses. Four scores were obtained from each child for the Salient and Non-Salient changes at each transformation-point, that is: first transformation (S); first transformation (NS); second transformation (S); and second transformation (NS). The results of this analysis are presented in Table 4.3.6.

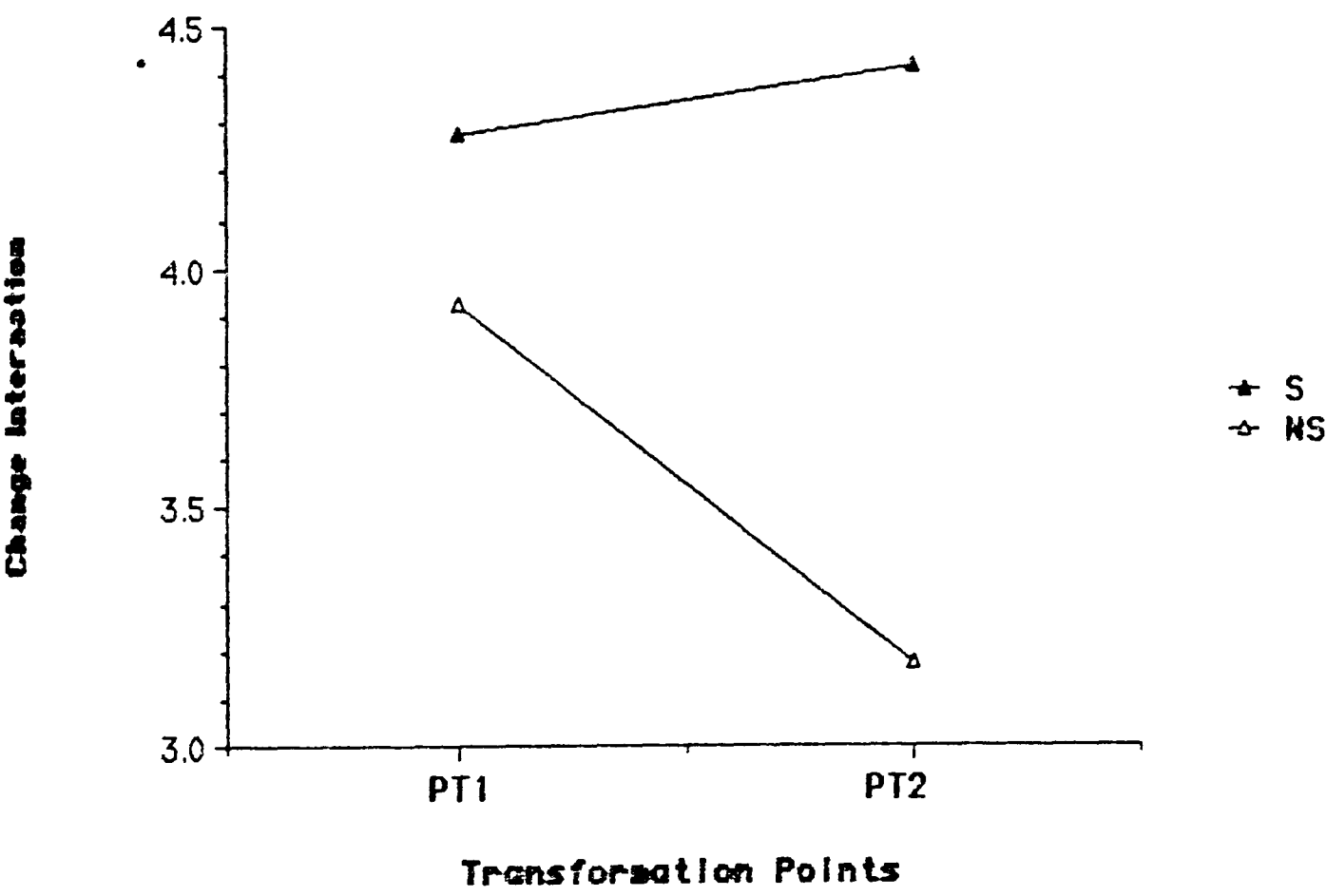
There was a significant main effect for Age ($F(1,38)=9.33$, $p<.01$) indicating that on the whole older children made far more C responses than younger ones. There were also significant main

effects for type of Change ($F(1,38)= 56.23, p<.001$) and Transformation Point ($F(1,38)= 6.87, p<.05$). The significant TRFPOINT x CHANGE interaction ($F(1,38)= 12.82, p<.01$) indicated that the effects of these variables were not independent of each other.

TABLE 4.3.6 SUMMARY TABLE (ANOVA): C-RESPONSES FOR S AND NS
CHANGES AT TWO TRANSFORMATION POINTS

SOURCE		SS	DF	MS	F	PROB.	
AGE	(A)	8.100	1	8.100	9.33	0.004	**
ERROR		33.000	38	0.868			
TRFPOINT	(T)	3.600	1	3.600	6.87	0.013	*
TA		0.000	1	0.000	0.00	1.000	ns
ERROR		19.000	38	0.524			
CHANGE	(C)	25.600	1	25.600	56.23	0.000	***
CA		1.600	1	1.600	3.51	0.069	ns
ERROR		17.300	38	0.455			
TC		8.100	1	8.100	12.82	0.001	**
TCA		0.400	1	0.400	0.63	0.431	ns
ERROR		24.000	38	0.632			

Fig 4.3.3. The Transformation-Point X Change Interaction.



The Newman-Keuls test was used to explore the TRFPOINT x CHANGE interaction. On the second Transformation point (equivalent to Experimental Condition) significantly more correct responses were made for S than for NS changes ($p < .01$). There was no significant difference however, between S and NS changes on the First Transformation. Figure 4.3.3 illustrates that relatively large numbers of Correct responses were made on Transformation point 1, whatever the type of change depicted. There was a significant difference between the Two transformation points when the change that occurred was NS ($p < .01$). When S changes were experienced however, correct scores at the two transformation points were almost identical (no significant difference).

When a Matching method can be used successfully, as for Transformation 1, the relative salience of transformations does not affect children's correct (C) judgements. However, when, as in Transformation 2, there are two end-states, children using a Matching method may choose instruments for the more salient state thereby making far less consistently causal (CC) responses than children who relate beginning states to end-states. The results of this analysis suggest that this is indeed the case as fewer correct responses were made for the Non-Salient changes than for the Salient ones.

4.4 Discussion

The results of this experiment confirmed all the predictions. Firstly, children of both ages gave far more correct responses for the first (simple) transformation in the chain (eg.: Cup---to---Wet Cup) than for the second (eg.: Wet Cup---to--- Wet broken Cup). Although older children made more correct responses at

both transformation points than younger ones, the absence of any significant Age by Transformation interaction indicated that the effects of these two variables were independent of each other.

Secondly, comparison of children's performance in the second transformation point (Chains condition) in Experiment 2 with the performance of children in the Experimental and Control conditions of Experiment 1 showed, as predicted, that performance was best in the Control condition. In this condition, as in the first transformation point in Experiment 2, an associative-matching method could be used effectively. Most interestingly, comparison of children's performances in the Experimental condition with the Chains condition (the transformations used in these two conditions were identical) showed that children made significantly more Correct (CC) responses in the Chains condition. It is possible that the extra cues provided by the extended sequence helped children to adopt a more relational method of connecting each element in a chain to the next one.

Finally, when Salient and Non-Salient changes were compared, it was found that the Salient ones elicited a far greater number of correct responses in both age groups. Children's preference for salient states at Transformation 2 where a Matching method could not produce consistently correct responses, provided support for the conclusions reached in Chapter 3.

These findings indicate that when an associative-matching method can be used successfully (eg. Control condition or Transformation Point 1) the correct responses of both 3- and 4-year-old children are very near ceiling. However, the older children are much more competent than the younger ones at making correct inferences in transformations which require the use of a Relational method.

Such a method implies that the children are relating the events portrayed in the sequence into a thematic unit.

Three and 4-year-olds made more correct responses on the first Transformation points of sequences than the second. This could be because they were associating instruments with effects, but they did not do so haphazardly. Even when they chose the wrong instrument for a transformation (eg. hammer for the transformation 'broken cup --> wet broken cup) they correctly identified the hammer's power (eg. "hammer smash it"; or "bang, bang it's smashed...hammer did it"). Although many 3-year-olds did not verbalise to this extent, when asked why they had chosen "water", for example, they either pointed to the wet bits on the cup or said: "wet". All the children, except four 3-year-olds who refused to say very much but were competent at the 'game', named the correct action of the instrument they chose. In conjunction with the fact that both age groups made very few totally random choices of instrument even at the second transformation point it seems that these children have a fair idea of the causal powers of different instruments. However, since neither of the first two experiments specifically tested children's abilities to choose correct instruments for single states, both Salient and Non-Salient, this will be done in Experiment 3.

The results of the first experiment indicated that 3-year-olds might not use a Relational method as much, or as confidently, as 4-year-olds. The finding that correct scores on transformations identical to those in the Experimental condition in the first experiment increased when these transformations were extended to begin with the standard state of an object (eg. cup) indicated that -

(1) In Experiment 1, they might have been confused, about which

state of the object (first or last) to choose an instrument for. As a result they were influenced by the salience of transformations when making judgements about causal instruments.

(2) discounting a continuing state in order to infer for the transformation depicted in the sequence may have been too difficult for the 3-year-olds. They may be capable of using Relational methods, but not when discounting is involved. Thus, in experiment 2, as they are taken through each sequence change by change, they may have found it easier to 'add' a second change to the one that had already been accounted for.

However, despite their improvement compared to the first experiment, 3-year-olds had significantly lower correct scores than 4-year-olds in the second experiment. Given that the older children too may have found 'adding' easier than the discounting required in Experiment 1, there seems to be a strong developmental influence on children's ability to deal with these transformations using a Relational method.

Nevertheless, the increase in Correct responses ~~responses~~ when the transformations were extended shows that children used the Relational method to a far greater extent in this Experiment. Even if they were 'adding' on effects they would have had to relate each successive state of the object to the preceding one in order to make a correct inference. Indeed, it is possible that going through the sequences step by step 'cued' them into thinking in a Relational way.

It should be noted that children from different schools participated in the two experiments. This may have contributed to the difference in scores to some extent. However, as the schools visited were in the same area (North Oxford), it was thought that

there would not be too much difference across schools. In addition, the familiarisation material used in this experiment was exactly the same as the experimental material whereas in Experiment 1 it had been similar to the Control material. This may have provided 'cues' for using a Relational method. Finally, the unequal numbers of children in the three Conditions and age groups may have contributed to the masking of a possible interaction effect (Age x Condition) hinted at by the means in Table 4.3.3.

Ideally, this Experiment should be replicated with equal numbers of children assigned to each Condition. Another way of doing this Experiment may be to use a before-after design. All the children would experience Set X items. Then, the Experimental group would be trained using extended sequences (from Set Y: Experiment 1) such as used in Experiment 2; the Control group would just play with photographs of different objects. Finally, both groups would be retested on Set X items. This procedure would clarify whether it was simply familiarisation with materials, or exposure to extended sequences, which increased children's CC responses.

The proportion of CC responses made by both age groups was significantly greater than the proportions expected by chance. This strongly indicates that both age groups are capable of using a Relational method. Nevertheless, even though extension of sequences improved performance, 3-year-olds still made fewer CC responses than older children on Transformation 2. Why was this?

The salience of transformations significantly affected correct scores for the more complex second transformation. This indicates that a Matching method may have been used here. Use of such a method, as explained in Chapter 3, may dispose children to focus on the most striking, or salient, state. They then find the

instrument which matches that state. It is also possible that repetition of a first response may have influenced production of AC/CA responses. If there had been consistent repetition, a large number of CACA, or CAAC responses should have occurred. Table 1, Appendix 2, shows that hardly any responses of this type occurred. Furthermore, the above chance proportions of CC responses, in both age groups, indicated that children were using a relational method quite consistently.

Shultz et al (1986, 1987) point out that children in their experiments use Humean rules when generative information is not available. Similarly, if children are not spontaneously relating events into thematic wholes, they might need some sort of cueing (as provided in Experiment 2) to do so. Despite such cues, children may be distracted by the salience of transformations. If they have a preference for simple associative-Matching, which is easier than the Relational method, this may also influence them to focus on a single salient end-state.

The results of Experiment 2 confirm that young children find it more difficult to discount even when they have been through an extended sequence of transformations. In addition, it appears that children prefer to focus on single salient states.

Siegler (1984) reported that younger children found it much more difficult to integrate multiple features than older children did. It is possible that younger children focus only on one state as they find it easier to deal with one feature at a time. In so doing they may focus on the feature (or state) which is most Salient. The next experiment (Experiment 3) was designed to test this possibility.

CHAPTER FIVEFINDING CAUSES FOR TRANSFORMATIONS WITHOUT
SEQUENCE INFORMATION5 Experiment 3 Preschool Children's Inferences for Objects
Transformed in One or Two Ways.5.1 Introduction

The results of the first two experiments suggest that young preschoolers do not always consider the relationships between initial and final object states and interpret the differences between these states in terms of transformations. They also seem to focus on the end states of objects in a sequence and choose instruments for the state most salient to them. Although the extension of sequences (Experiment 2) clarified which state children were being asked to make inferences about, the type of material used still required children to discount the first transformation that had occurred to make correct inferences for the second transformation.

In the first experiment children's errors could not be attributed only to their preference for matching instruments to salient end states although this is what the results indicated. It is possible that, despite the extension of the sequences in Experiment 2, preschool children (especially 3-year-olds) were not sure which state of the object to make an inference about, or did not realise that they had to follow the sequence and consequently chose instruments only for salient states. The above chance scores (CC) of both age groups however do not lend much support for such a conclusion.

In both Experiments 1 and 2 it was found that children

made more Correct responses for Salient transformations. It was suggested that children who are not 'discounting' (relating beginning and end states and discounting the continuing state) may focus on **one** of the two end states. The choice of state may be influenced by the relative **salience** of the two end states. Siegler's (1984) report that young children prefer dealing with single features lends support for such an assumption.

The implication of children focusing solely, or at least primarily, on salient states is that having found a cause for a salient effect they do not look for a cause for the second effect (or state). It may be that children who do consider both states are more likely to investigate whether one effect was already present in the beginning of the sequence. It is also possible that simply being able to deal with two states enables a child to 'discount' the one that does not change in the sequence and find the cause of the change that occurred in the sequence.

To see whether children could find causes for both transformations when no sequence information was present, in the Experimental Condition of the present experiment children were presented only with a series of **single** photographs which depicted objects in two states (Diagram 5.1.1). They had to find the causes of the two states of the object shown in each photograph. If children prefer to deal with single features, then, although there is no discounting involved, they will still choose only one instrument. The instrument will probably be associated with the more salient (e.g. broken) of the two states. Children who integrate features, will be able to pick out both the instruments required and 'add' or integrate them. Each instrument may be chosen by associative-causal matching of instrument to effect but a further step of 'adding' is

essential for success in this condition.

There were two advantages to presenting only the final states of objects to children. Firstly, there was no carry-over effect from the beginning state. In previous experiments, a salient beginning state (e.g. broken) might have focused the child's attention onto itself, so that in looking at the end state the child ignored the second state of the object (e.g. wet), this was not possible in this experiment. Secondly, there was no need for the children to discount the continuing states of objects, which might have been difficult for younger children to do. In Experiment 3 children simply had to choose the appropriate instruments for each transformation and 'add' them together to explain the compound state (for example, wet and broken).

Thus, if children chose to find an instrument for single salient states of objects in the Experimental condition, there would^{be} a number of important implications:

(1) Primarily, such a finding would indicate that it was not solely the ability to relate event states in sequences which affected children's correct choices in the previous two experiments. The ability to handle more than one cause for an event as well as relying on salience would also affect such choices.

(2) Secondly, it would imply that children need not attend to the sequences at all in order to make correct choices. They could easily focus on end states and be influenced by the relative salience of the end states in making choices. Such a finding would support the suggestion (Chapters 3 & 4) that younger children use Matching, rather than Relational methods in dealing with causal sequences.

(3) Finally, if 3-year-olds' responses were significantly more single-cause oriented than 4-year-olds' this would indicate that the older children are more capable of integrating two causes.

Simple choices such as those required in the Gelman et al. (1980) study, the Control condition of Experiment 1, the First Transformation points in Experiment 2 and the Control conditions in this experiment, are easier as they only require the use of an Associative-Matching method. The task in the Experimental Condition of this experiment however requires a more complex method in that it requires the encoding of two features (e.g. wet and broken) and separate choices for each which must be integrated to affect one object (e.g. cup). Although instruments may be chosen by a Matching method an integration of the two instruments responsible for the two states is also required.

FIGURE 5.1.1 EXAMPLES OF MATERIAL USED IN EXPERIMENT 3

CONDITION	MATERIAL USED	CHOICES OF INSTRUMENTS
Experimental	Wet Broken Cup	Water; Hammer; Feather
Control I	Wet Cup	Water; Hammer; Feather
Control II	Broken Cup	Water; Hammer; Feather

To ensure that children could make single correct choices for each of the states in the experimental photographs (Broken, as well as Cut, for example), two control conditions were created for this experiment: Control 1 (Non-Salient) and Control 2 (Salient). Diagram 5.1.1 presents examples of the type of material used in the different conditions. The two Controls were designed in order to investigate whether children could make correct choices for single Non-Salient states as well as single Salient states when

these were presented separately. In Experiment 1 children had to deal with objects showing two end states and although they dealt with objects in single states in the first transformation point in Experiment 2, their ability to find causes for single states, both those categorised as Salient and those categorised as Non-Salient, has not yet been investigated as a separate issue in this thesis.

The Gelman et al. experiment (1980) showed that preschoolers could find a correct instrument, given a changed state, but it did not deal with the influence, if any, that the relative salience of transformations might have on children's abilities to infer causes. Hence the two Control conditions in this experiment were specifically designed to investigate this issue. In view of preschoolers' superior performance on the first transformation points in Experiment 2, it was expected that the children in this experiment would do equally well on both the Control conditions (Salient) and (Non-Salient) as a Matching method would produce correct responses in both.

If children were able to find causes for both states in the Experimental condition, then it could be argued that they were not unduly influenced by the relative salience of these states. This would mean that the poorer performance of younger children in the previous experiments was due partly to their inferiority in relating initial and final states in sequences and/or partly to a poor understanding of the task. It would not be due to an inability to integrate two features. However, in the light of the results of the first two experiments, it was predicted that younger children would make far more single responses for objects transformed in two ways, and these choices would be mostly for the salient states.

Predictions:

1. Performance will be best on the Control conditions. Both age groups will get a high number of correct responses on the Control conditions but not on the Experimental.
2. There will be no difference in performance between the two Control conditions (Salient) and (Non-Salient).
3. There will be a significant difference between the two age groups on the number of correct responses made in the Experimental condition but not in the Control conditions.
4. In the Experimental Condition :
 - a) Older children will give a larger number of both causes (correct choices) than younger ones.
 - b) The single-cause choices of both age groups will be mostly 'salient', ie. choices for the salient state. Younger children will give a larger number of salient single causes than older ones.

5.2 Method(a) Subjects:

Eighty children - forty 3-year-olds (mean = 3:7; range = 3:2-3:11) and forty 4-year-olds (mean = 4:6; range = 4:0-4:11) participated in this experiment. The experimenter was familiar to all the children having spent a week with each class.

(b) Design:

An independent groups design (Table 5.2.1) was used to compare the performance of two Ages (3- and 4-year-old) on three Conditions (Experimental, Control 1(NS) and Control 2(S)). Children in each age group were randomly assigned to one of three Conditions.

TABLE 5.2.1 THE DESIGN OF EXPERIMENT 3

CONDITION	AGE	NUMBER OF SUBJECTS
Experimental	3+	20
	4+	20
Control 1 NS	3+	10
(NON-SALIENT)	4+	10
control 2 S	3+	10
(SALIENT)	4+	10

An independent groups design was used as the two states in the Experimental Condition (e.g. WET&BROKEN) were presented singly in the two Control conditions: (NS - WET) and (S - BROKEN). If the same children had experienced all three conditions there would have been a strong possibility of a carry-over effect, despite counterbalancing. The use of different states in the Control conditions would not have supplied any information about whether children of these ages could deal with either of the two states in the Experimental condition if presented alone.

(c) Material: Seven colour photographs of objects that had been transformed in two ways (e.g. wet and broken; cut and written-on etc.) were used in the Experimental condition. Seven colour photographs of objects that had been changed in only one way (e.g. wet, or broken, or cut etc.) were used in each of the Control conditions.

Choice of material used in Experiment 3

The photographs used in this experiment were chosen from the two sets of sequences (X and Y) used in Experiment 1 in order to make this experiment as directly comparable to the previous ones as possible. The experimenter and two independent raters went through all the end-state photographs of the two sequence-sets.

There was 100% agreement that the hair sequences from both sets (X and Y: see appendix 1) should be left out, as the end-state did not clearly indicate by itself (out of the sequence) that two changes had occurred to the object. The same happened for the drawer sequence in Set Y. It was decided that as some of these sequences had shown 'subtractive' changes, in which an effect had been removed (such as in the sequence - wet messy hair--->dry messy hair), the end state did not show two visible effects (e.g. as in the end states wet AND broken) so did not fit the structure of the rest of the material used in this experiment. In all, seven end-state photographs were selected.

The material for this experiment being taken from that used in Experiments 1 and 2, it was thought that in each of the photographs depicting two states, one state could be classified as more salient than the other using the same criteria as used in those experiments. For photographs showing two states of an object (e.g. wet and broken cup), such as used in the Experimental condition, each of the states were classified as salient (S) or nonsalient (Non-S) relative to each other. For example, broken is salient relative to wet, and wet is non-salient relative to broken. (This was done because it was suspected that children giving single choices might well be influenced by the salience of the states depicted in each photo, in choosing which state, out of the two presented, to make an inference about.) There was 100% agreement between the experimenter and an independent rater in rating states as being S or Non-S using this method.

To assign photographs to conditions Control 1 and Control 2, all states which had been categorised Non-Salient for the Experimental material were assigned to Control 1, and all states

which had been categorised Salient were assigned to Control 2. (There being 7 double state photographs in the Experimental condition this yielded 7 single-state photographs for each of the two Control conditions.) The material used in this experiment is presented in Diagram 5.2.1. In each condition, items were presented in random order to control for any carry-over effects.

DIAGRAM 5.2.1 MATERIALS - EXPERIMENT 3

EXPERIMENTAL	CONTROL 1	CONTROL 2
FAMILIARISATION MATERIAL		
cut plate+drawing	cut plate	plate+drawing
broken bottle+paint	broken bottle	bottle+paint
wet box open	open box	wet box
EXPERIMENTAL MATERIAL		
wet broken cup	wet cup	broken cup
paper+writing cut	paper+writing	cut paper
door open+paint	door open	door+paint
apple+picture cut	apple+picture	cut apple
wet banana cut	wet banana	cut banana
broken plate+paint	plate+paint	broken plate
wet orange+face	wet orange	orange+face

Three similar sets of photographs were used to familiarise children with the task. These photographs were selected from the pre-training sequences used in previous experiments. The familiarisation material is also shown in Diagram 5.2.1. For the choices given in each condition see Appendix 3.

(d) Procedure

Familiarisation

Children were familiarised with the experiment using the

familiarisation photographs. Each child was shown the photographs corresponding to the condition to which she had been assigned and was asked to describe the object. All the children being familiarised with the Control conditions were able to describe the state of the object. A few 3-year-olds needed some encouragement to speak.

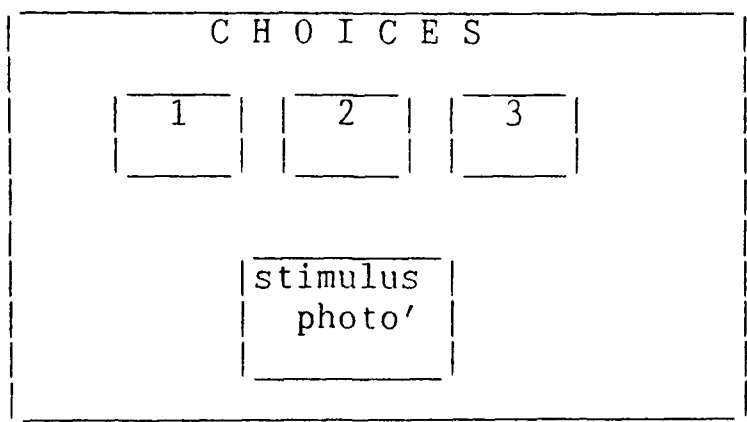
Control condition - Once children had named the state of the object, they were shown three choice photographs, and asked to choose the instrument that had caused that state. When the child had chosen an instrument she was asked why she had chosen that particular instrument. When they chose wrong instruments children answered with "I don't know". When the correct instrument was chosen, the ones who answered the question said: "'Cos it did", or mentioned the state the instrument could effect, for example, when asked why they chose scissors, children usually said "'Cos they do cut".

Then the experimenter verbally described the state to the child, e.g.: "Yes, look (putting instrument next to transformed object) the scissors cut the plate!" In cases where the child chose the wrong instrument, the experimenter asked if the child was sure that the instrument chosen could effect the state shown. This usually elicited the correct answer. Once the child had made the correction, the experimenter again asked if she was sure that this instrument could change the object in the appropriate manner. Children never changed correct choices: they answered the question with "'Course it does".

Experimental Condition - During familiarisation with this condition, if only one state of the object was mentioned, the experimenter prompted: "Has anything else happened?" This usually elicited a description of the second state of the object. In cases where it did not the experimenter asked the child to look at the

photo' again, very carefully, and tell her what had happened to it. If they still did not name both states the experimenter pointed out the two states. By the end of the familiarisation, all the children described both states. Some children still needed the prompt: "Has anything else happened?", before naming the second state. Therefore this prompt was retained in the experimental procedure.

DIAGRAM 5.2.2 LAYOUT OF THE EXPERIMENT



Once both states had been identified the children were shown photographs of the three choice instruments. These were laid out side-by-side above the photograph of the transformed object (Diagram 5.2.2). The child was told to look carefully at all three things and then to choose the things that the experimenter had used to bring the object to it's present state.

E.g. : "Look at these things (pointing to each photograph) very carefully, and choose what I used to make the name of object like this (pointing to the transformed object). You can choose as many things as you think I used from these things (pointing to choices)."

After the child had made her choice the experimenter asked for a verbal explanation for the choice:

" What did I do with the (name/s of object/s chosen) ".

In cases where two states of the object had to be accounted for (familiarisation for Experimental condition) if the child chose only one instrument she was asked if the experimenter had used anything

else on the object to bring it to its present state. This was done to ensure that children were aware that they could choose more than one instrument. If children still did not name the second instrument they were directed to look at the photo' of the transformed object again. The experimenter named the state the child had already mentioned and asked the child what else had happened: "Look, it's cut and look! has anything else happened to it?" The child then named the second state. Then the experimenter pointed out that they had chosen an instrument for one state but not for the other, and asked the child again to choose instruments: "You said scissors made it cut. Is that right? Well, what made it like this?" All the children chose the two correct instruments after this. The experimenter then placed the instruments next to the transformed object and verbally described the state to the child: "Yes, look, the pen drew on the plate and the scissors cut it!"

At the end of the familiarisation children were asked if they knew how to play the game and whether they would like to play it again. They answered in the affirmative for both and the majority of children were able to give a good verbal description of how the game should be played.

It was noticed that younger children, on the whole, became quite tense when asked to give verbal explanations for their choices. They fidgeted a lot and quite a few refused to say anything. In view of this, it was decided not to use children's verbal explanations as a response measure.

Experimental Procedure

This was similar to the familiarisation procedure and was carried out two days later. Children were asked to describe each photograph as they were presented to them (in all conditions): "Look at this

cup, and tell me about it". If there was no response to this, or only the name of the object was repeated, the experimenter prompted: "Has anything happened to this cup?", all the children responded "yes" to this prompt. The experimenter then asked the child to tell her what had happened to the object.

Control conditions - The three choices were laid out above the photograph of the transformed object and the child was asked to choose the instrument that had transformed the object.

Experimental condition - Here, if children only mentioned one state of the object, the experimenter prompted : "Has anything else happened?" Most children answered in the affirmative, though not all of these named both states. The experimenter did not point out the second state of the object if it was not mentioned by the child after the prompt. Subsequently the procedure was exactly the same as in the familiarisation, except that children who chose only one instrument were **not** asked whether any other instrument had been used. They were simply asked if they had chosen everything they needed to make the object like it was in the photograph.

The photographs in each condition were presented in different random orders to each child to control for any order or carry-over effects.

5.3 Results:

Coding of Responses - Responses were initially coded as either CORRECT or INCORRECT. In the **Control** conditions, CORRECT responses were the choices of the single instrument which had been responsible for the single state depicted in each of the photographs. In the **Experimental** condition the CORRECT response was the choice of BOTH the instruments which had caused the two states depicted in the photographs used in this condition (See Diagram 5.2.1).

INCORRECT responses in the CONTROL conditions were choices of inappropriate, random, or two instruments, for example the choice of feather, or hammer and water, as the correct instrument/s for wet cup. In the Experimental Condition, INCORRECT responses were choices of SINGLE instruments (e.g. water) for an object showing two states (e.g. wet broken cup), or the choice of two instruments, one of which was random (feather) the other correct for one state (e.g. water) of an object in two states (e.g. wet broken cup).

Choices were also coded as follows in the Experimental condition:

SALIENT - (S) - if the choice was made for the salient/state as identified in Experiment 1. (A single response)

NON-SALIENT - (Non-S) - if the choice was made for the non-salient state as previously identified. (A single response).

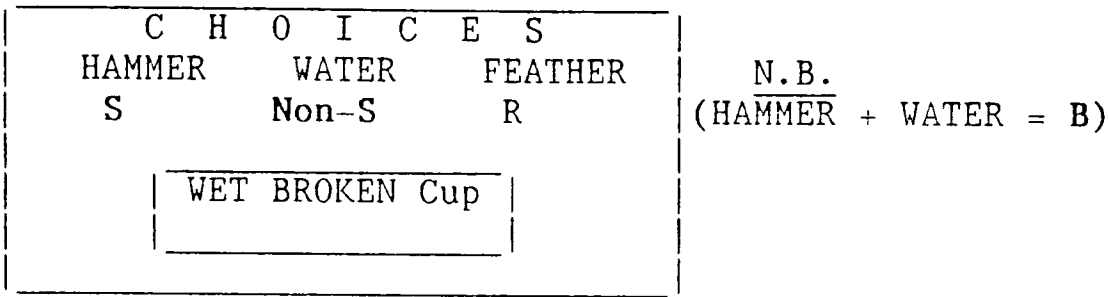
BOTH - (B) - if TWO instruments were chosen. (A 'Both' response)

RANDOM - (R) - if the random instrument, unconnected with either state, was chosen. (A single response).

Responses were either Correct or Incorrect (Random) in

the Control conditions. An example of this method of coding, for an item in the Experimental condition, is represented in Diagram 5.3.1. In the Controls, say for the item Wet Cup, the choices would be Correct (Water) and Incorrect (Hammer, Feather).

DIAGRAM 5.3.1 AN EXAMPLE OF CODING RESPONSES



The following analyses investigate -

- (a) the effect of Age and Condition on the CORRECT responses of the children and
- (b) the nature of the INCORRECT responses made by 3- and 4-year-old children.

(a) Comparing the Correct Responses of 3- and 4-year-old Children in the Experimental and Control conditions

Table 5.3.1 shows the means and standard deviations of the Correct responses in each condition. (A CORRECT RESPONSE in the Experimental condition requires choice of BOTH instruments needed to bring about the two states shown. In the Control conditions only ONE correct instrument is needed to cause the single states shown).

There is very little difference between the number of correct responses made in the Control conditions by both 3- and 4-year-olds. Both the age groups made far fewer correct responses in the Experimental condition than in either of the Controls. However, 4-year-olds gave far more correct responses in the Experimental condition than 3-year-olds.

TABLE 5.3.1 MEANS (out of 7) AND STANDARD DEVIATIONS OF
CORRECT RESPONSES

CONDITION	AGE	MEAN	S.D.	where-
Experimental	3+	1.25	1.58	S.D. = Standard Deviation
(EXPTL)	4+	3.55	2.62	
Control I	3+	6.50	0.71	
(Non-Salient)	4+	6.90	0.32	
Control II	3+	6.30	0.95	
(Salient)	4+	6.80	0.42	

The scores for the number of correct responses in each condition were subjected to a 2-way ANOVA for independent groups. Age (2: 3-and 4-year-olds) and Condition (3: EXPTL, Control 1, and Control 2) were the independent variables, with number of correct responses as the dependent measure. The results of this analysis are presented in Table 5.3.2.

TABLE 5.3.2 SUMMARY TABLE (ANOVA) FOR CORRECT REPOSSES

SOURCE	SS	DF	MS	F	PROB.
AGE (A)	20.48	1	20.48	7.82	0.0066 *
CONDITION (C)	357.24	2	178.62	68.20	0.0000***
AC	17.14	2	8.57	3.27	0.0435 *
ERROR	193.80	74	2.62		

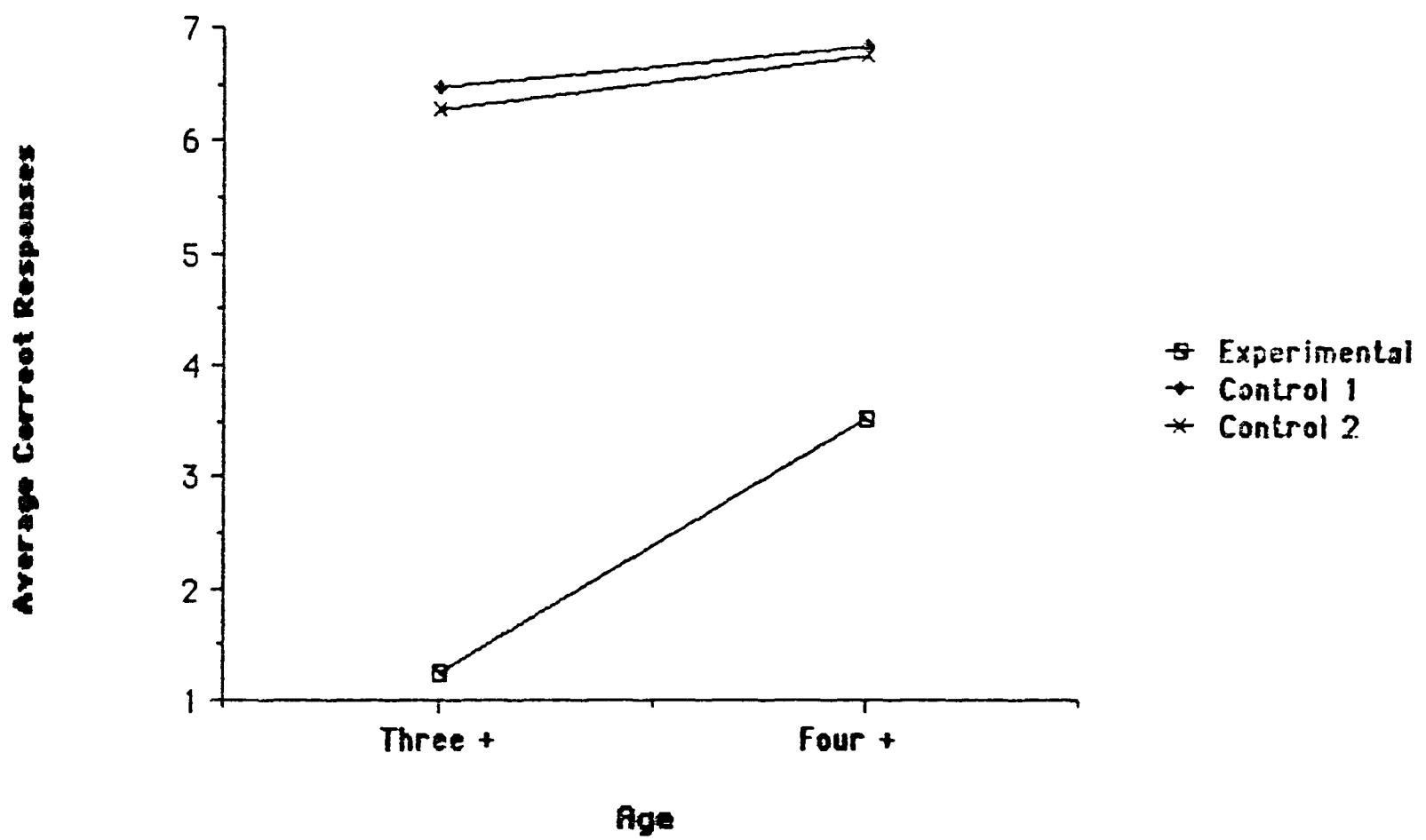
In this and following Tables: *** = $p < .001$; ** = $p < .01$; * = $p < .05$

There were significant main effects for both Age ($F(1,74) = 7.82, p < .05$) and Condition ($F(2,74) = 68.20, p < .0001$). The significant Age x Condition interaction ($F(2,74) = 3.27, p < .05$) (illustrated in Figure 5.3.1) indicates that the effects of these two variables were not independent of each other. This interaction

was explored using the Newman-Keuls test. There was no significant difference between scores on Control 1(NS) and Control 2(S) in both age groups ($p > .05$). There was a significant difference between scores on the Control conditions and scores on the Experimental Condition, with significantly higher scores ($p < .01$) occurring in the Controls, in both age groups.

Four-year-olds made significantly more Correct responses ($p < .01$) than 3-year-olds in the Experimental condition. There was no significant difference between the age groups in either of the Control conditions. This shows that although 3-year-olds are as competent as 4-year-olds at finding a cause for a single state (Controls) regardless of salience, they find it much more difficult to deal with two states. Older children are far better at 'adding' or integrating two instruments.

Fig 5.3.1. Age X Condition Interaction.



(b) Analysis of Incorrect Responses:

Very few errors were made in either of the Control conditions C1(NS) and C2(S). In the Controls errors tended to be those of choosing a totally unrelated object as the causal instrument. The near ceiling performance (Table 5.3.1) of both ages in the Control conditions indicated that these children were very good at finding the correct causal instrument for a single state.

Both age groups however, made quite a few errors in the Experimental condition. Such errors (incorrect responses) tended to be Single Responses - that is choice of only one instrument for an object showing two states. (These single choices could be totally unrelated (random) instruments or an instrument responsible for one of the two states of the object as described in the "Coding of Responses" - 5.3).

Single Responses in the Experimental Condition:

The means and standard deviations of Single (INCORRECT) and Both (CORRECT) responses in the Experimental Condition are presented in Table 5.3.3. Three-year-olds made far more SINGLE (Incorrect) responses than older children.

The difference between the number of Single responses made by the two age groups was tested using a t-test for independent measures, the results of which are also presented in Table 5.3.4. The younger children made far more single responses than the older ones ($t_{obs.} = -3.35$, $df = 38$, $p < .01$). (Correct ("BOTH") responses are not considered here as they were investigated by the analysis of variance.)

TABLE 5.3.3 MEANS (out of 7),S.D.'s, t-VALUES AND PROBABILITIES
OF SINGLE RESPONSES - EXPERIMENTAL CONDITION

Breakdown of Single Responses							
TOTAL SINGLE		SINGLE Salient		SINGLE Non-Salient			
	Mean	S.D	Mean	S.D.	Mean	S.D.	
3+	5.75	1.6	5.00	1.5	0.45	0.6	
4+	3.45	2.6	3.15	2.4	0.20	0.4	
t= -3.35, p=.002 t= -2.91, p=.006 t = -1.53, p=0.1344							

(df = 38) and S.D. = Standard Deviation
N.B. Total Single responses include Random responses. As very few responses of this type occurred they are not considered separately.

Table 5.3.3 also gives a breakdown of the means of two major types of Single responses (S and NS). The majority of single/incorrect responses made were Salient ones. Three-year-olds made more Salient responses than the older children. There was little difference between the number of NS responses made by the two age groups.

The differences between the two age groups in the number of Salient and Non-Salient responses made were explored using t-tests for independent samples. The means and standard deviations of these responses are reported in Table 5.3.4. The results of the t-tests are also presented in this Table. Three-year-olds made significantly more Salient responses than the older children (t = -2.91, df = 38, p<.05). There was no significant difference between the two age groups in the number of Non-Salient responses made. In both age groups there were very few R responses (6 in the 3+ group, 1 in the 4+ group) so these were not considered.

Not only did younger children make more errors in the Experimental condition, but they erred by choosing instruments for a

single salient state. These results provide support for the suggestion made in previous Chapters that 3-year-olds prefer to focus on a single state. When two states are present, salience is an important factor in determining which state children will attend to most.

5.4 Discussion

The analysis of variance results showed a significant difference between the Experimental and the Control groups for both ages. Although the two age-groups did not differ on the Control conditions they differed significantly on the Experimental condition. Four year-olds made far more correct responses in the Experimental condition than the younger group indicating a greater competence in integrating, or 'adding', two features.

These findings confirm the hypothesis that 3-year olds find it easier to choose an instrument for a single state than for an object in two states. Although 4-year-olds were significantly better than the younger children at dealing with objects in two states their average correct scores on the Experimental were well below the near ceiling scores on the Controls. Thus, they could choose instruments for single states but could not 'add' the two instruments needed for the double-state with the same degree of competence. This suggests that the ability to 'add' two features (causal instruments, in this case) may be in a process of development during the age span studied in this experiment.

Most errors were made in the Experimental condition. Here children had to choose **both** the causal instruments which had caused the two states depicted. All the errors made were those of choosing SINGLE causal instruments. Because they may find it diffi-

cult to encode both states of the object and then 'add' the two separate causal instruments responsible it was hypothesised that children would choose the cause of the more salient transformation. Indeed, the majority of the SINGLE errors were in the Salient category, indicating that children were very much influenced by salient transformations. This is a striking finding in view of the fact that children definitely perceived both states. Most of them even named the two states prior to making an inference about the causal instrument.

Although it could be argued that children did not understand what was expected of them, this seems unlikely in view of the fact that they understood well enough in the Control conditions. Again it could be argued that children did not understand that they had to make inferences for both states and thus decided which state to make an inference for on the basis of salience. Although this possibility cannot be ruled out, it seems unlikely because in both the familiarisation and experimental procedures the two states were emphasised and the possibility of making more than one choice of causal instrument highlighted. Furthermore, the pattern of responses of individual children was not always consistent in that not all their responses over the 7 items were of the same kind. It was quite common to have a mix of BOTH and SINGLE responses. Therefore it seems reasonable to conclude that when children made SINGLE responses it was not because they did not understand the instructions, but because they preferred to do so.

The mixture of BOTH and SINGLE responses in individual profiles may indicate that children are in a process of 'sorting out' various processing-mechanisms available to them. They may use certain mechanisms inappropriately on occasion, but with increasing

experience (witness the difference between 3- and 4-year-olds) they become more adept at using appropriate methods for given tasks.

A pattern of the preferred response modes of the two groups emerges from these results. Older children chose almost equal numbers of BOTH (mean = 3.55) and SALIENT (mean = 3.15) responses. At this age neither mode of responding is dominant, unlike the 3-year-old group where the dominant response is the Salient one. When the Salient (S) responses of 3- and 4-year-olds was compared, it was found that the younger children made significantly more S responses than the older ones. However, older children made significantly more Both responses than younger ones.

The different profiles of preferred responses of the two age groups may indicate a developing ability to deal with more than one transformation, and a corresponding ability to 'add' the causes of the two changes occurring to the same object. Siegler (1984) stresses that once people have chosen what to encode, they still have to decide on an integrative rule to use. There are a wide variety of these rules, such as conjunctive, additive, uni-dimensional etcetera (Siegler, 1984:155) but the choice of rules may depend on a number of factors, one of which is the developmental factor. A number of studies have shown that young children are much more likely to use unidimensional rules than older children or adults (Siegler, 1976; Siegler, 1981).

In relation to the findings of Experiments 1 and 2 it is possible that a developing preference for multi-dimensional inferences, allied with the ability to relate different units in a sequence into a thematic whole, contributes to the superior performance of the 4-year-old children. However, as these abilities are still developing, the 4-year-olds may be at the age when they are either

replacing one method with a more efficacious one, or learning to use rules or methods other than the favoured ones, depending on task specifications.

The results of this experiment clearly show that older children are developing a preference for multiple inferences. The development of this preference, and the corresponding ability to deal with two effects and two causes, may have helped them to discount the unchanging states of objects in the previous experiments. It is possible that an expanding cognitive capacity helps them to deal with more than one feature.

The previous experiments showed that young preschoolers do not always use all the information given (in sequences depicting transformations) when making causal-inferences. They seem to rely more on knowledge about the causal powers of objects to make causal-associations between instruments and object states (eg. water and wet). It has been hypothesised that because these children do not relate the beginning and end states of objects they rely on the relative salience of transformations depicted in the end state to choose which state of an object they will infer for. However, because previously the transformations were always presented within a sequence, it was not wholly clear whether children were inferring for salient beginning states, or the salient end state. The results of this study show that even when sequence-information is removed the majority of the younger children's inferences (mean=5.00) and a large number of the older children's inferences (mean=3.15) were for the transformations categorised "Salient".

One of the major implications of these findings is that in previous experiments children who made errors did so because they were focusing on end states. In addition to a preference for dealing

with single features, such a focus may have made them more prone to distraction by salience information. However, it is still not clear whether young children can relate object states in terms of transformations when they do not have to deal with two features in order to do so. The next experiment addresses this issue.

The results of this experiment also lend some support for the categorisation of transformations as being either salient or non-salient in relation to each other. The majority of children's SINGLE responses in the experimental condition were for the transformations categorised salient by the two raters.

CHAPTER SIXDISCOUNTING IN SEQUENCES WITH SINGLE END STATES6 Experiment 4 Preschoolers' Understanding of Discounting6.1 Introduction

The results of the first three experiments indicated that 3-year-old children - (1) do not consistently connect the initial and final states of sequences in terms of transformations; and - (2) find it difficult to deal with more than one object state when asked to find causal instruments in sequences depicting objects with a compound end state. Four-year-old children seem to be more competent than younger children in both these areas.

Experiment 4 was designed to investigate whether 3- and 4-year-old children relate beginning and end states of sequences in terms of transformations. So far, this has been referred to as a Relational method. This method involves "discounting" - a term borrowed from Attribution theory. Much work on causal discounting in social situations has been done following Thiebaut and Riecken's classic study (1955). In the Attribution framework, the discounting effect occurs when an attributor has information about an effect and several possible causes and has to ascribe the effect to one or more of these causes. As Kelley (1972:8) describes it: "The role of a given cause in producing a given effect is discounted if other plausible causes are also present".

Discounting, as referred to in this thesis, is very loosely based on the Attributional principle. In the latter, each plausible cause could be sufficient in itself to produce the given

effect. In the present experiments, "discounting" is defined as the process of relating two states of an object which has undergone transformation by discarding the unchanging features of the object in order to figure out the transformation that has occurred. In sequences such as those used in Experiments 1 and 2, objects exhibit compound (two) end states (eg. wet and cut). Each state was caused by a different instrument (water and knife), both of which are necessary to produce the final compound state. Discounting in such sequences involves holding the first state of an object (eg. wet) constant, and discounting its cause (water) when finding the cause of the change that occurred in the sequence (eg. cut in the sequence: Wet Banana ----> Wet cut Banana). DISCOUNTING as used in this thesis, is a Relational method in that both first and last states of an object **must** be considered, and the relationship which links these states apprehended, in order to make a correct causal judgement.

To control for any difficulty younger children experience when faced with two states, the sequences in this experiment were created to show only one transformation. However, to ensure that children could not achieve correct responses simply by matching an end state to an appropriate instrument using association, the transformation that occurred in the Experimental sequences, changed an object already in one state [Wet Cup] to its usual, standard state [Cup, dry]. Thus, the transformation that occurs is "drying", but the end state by itself, does not provide any clues for a correct answer as it is not an 'added' state such as "wet". The end state in the Experimental (condition) sequences of this Experiment were called 'subtracted' states. An added state, present at the beginning of the sequence (eg. wet), is taken away, or subtracted,

by a transformation (drying). Such transformations shall henceforth be referred to as 'subtractive' transformations because they remove an effect and restore the object to its usual form.

In such sequences, the continuous substance (eg. cup) is discounted and the difference between first and last states is judged by comparing these two states. This is different from discounting in sequences with two end states but is essentially a Relational method. The 'subtractive' sequences portray a reversal of change. It may be possible that the ability to comprehend the reversal of change indicates a conception of the underlying unity of the sequence: the beginning (first state) and end (last state) of the sequence being related by the transformation which **changes** the **same** object from one state to another. Such a conception is also necessary to relate elements of any of the sequences, used in the experiments reported thus far, as the object that is transformed is the unifying substance of the sequence.

The reversal of change depicted in the sequences of this experiment does not affect causal direction. Causal sequences are typically unidirectional and therefore 'irreversible' in that the effect cannot produce the cause. For example, hitting a cup can cause it to break but the breaking of the cup does not cause the cup to be hit. In Chapters 1 and 2 it was stressed that a mature understanding of causality entails an understanding of this irreversibility of causal direction. In the sequences used in this experiment causal direction remains irreversible: a cup cannot cause a wet cup. What is reversed is the change that occurred to the cup but this reversal follows the rules of causal direction - from its initial state the object is transformed, by the use of a causal instrument, to a final state. What is being tested in this experi-

ment is how children deal with transformations: whether they relate two states of the same object by the transformation that occurs, as claimed by Gelman, Bullock and Meck (1980).

Gelman et al. also used 'subtractive' transformations (my terminology). However, they asked children to read a sequence from left-to-right first and then from right-to-left, e.g.:

(cup ---> wet cup, reverse arrow, cup <--- wet cup)

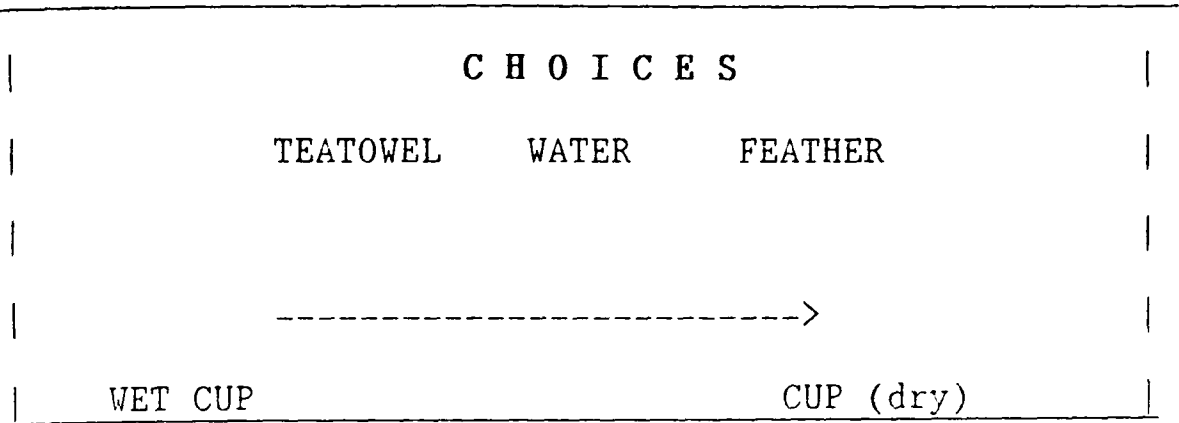
These conflicting instructions may have confused children, especially as they were pretrained with a left-right reading. Thus, in this experiment only a left-right reading is required in both conditions. Children were familiarised with a left-right reading.

To find out whether children were using a Matching method or a Relational method, three choices of causal instrument were offered in the Experimental (Relational) condition which was composed of 'subtractive' sequences. One instrument was responsible for the initial, visibly altered, state of the object (associative), another for the final state (the correct answer), the remaining instrument was totally unrelated. An example of such a sequence and the choices offered is given in Diagram 6.1.1.

Here it is vital that children take account of the change that has occurred in the sequence. Using an associative-matching method will not work as the end state of the object cannot really be matched with any instrument. As the object is in its standard state at the end of the sequence (e.g. Cup, Paper) there is no marked effect with which to match an instrument. Matching the instrument to the effect shown in the beginning state of the object will likewise not produce a correct answer. Only use of a Relational method will produce correct answers.

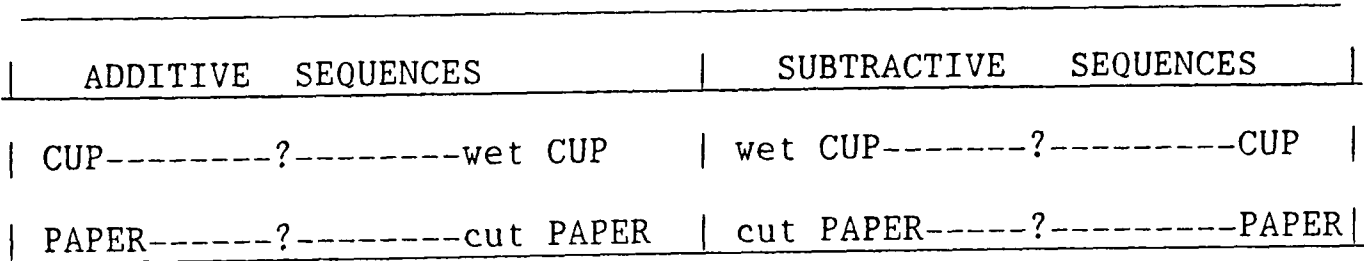
DIAGRAM 6.1.1 EXAMPLE OF A 'subtractive' SEQUENCE

(N.B. The arrow indicates the direction of transformation)



Whereas sequences used in previous Experiments depicted 'additive' transformations, that is, an object in one state had another state 'added' to it, the sequences used in the Experimental (Relational) condition of Experiment 4 depict 'subtractive' transformations: the transformation of objects already in a changed state to their usual, standard, forms. Examples of the two types of sequences are presented in Diagram 6.1.2.

DIAGRAM 6.1.2 'ADDITIVE' AND 'SUBTRACTIVE' SEQUENCES



To see whether sequences in which a state was perceptibly 'added' to the object ('additive' transformations) facilitated correct responses more than sequences in which changed objects were transformed to their standard states ('subtractive' transformations) a Control (Matching) condition was designed using the same objects but depicting the type of transformations ('additive') used in previous experiments. For the sequences in the Control condition, children were given one correct choice (e.g. water) and two incor-

rect choices (e.g. teatowel, feather).

It was predicted that all the children would give a greater number of correct answers in the Control (Matching) condition as they could use an associative-matching method. However, on the basis of past results, it was predicted that the 4-year-olds would give more correct responses in the Experimental (Relational) condition than 3-year-olds.

6.2 Method

(a) Subjects:

Sixty children participated in this experiment. There were thirty 3-year-old children (mean= 3:5; range= 3:0 - 3:10) and thirty 4-year-old children (mean= 4:5; range= 4:0 - 4:11).

(b) Design:

An independent groups design was used, with Age (2: 3+, 4+) and Condition (2: Additive, Subtractive) as the independent variables and the number of correct choices as the dependent measure. Half of the children (n = 15) in each age group were randomly assigned to one of the two conditions as shown in Table 6.2.1.

TABLE 6.2.1: THE DESIGN OF EXPERIMENT 4

CONDITION	AGE	NUMBER OF CHILDREN
SUBTRACTIVE	3+	15
TRANSFORMATIONS	4+	15
ADDITIVE	3+	15
TRANSFORMATIONS	4+	15

(c) Material:

DIAGRAM 6.2.1 SEQUENCES USED IN EXPERIMENT 4

FAMILIARISATION SEQUENCES		
Subtractive Condition		Additive Condition
CHOICES		CHOICES
knife glue card		glue knife card
1. CUT BANANA---?---WHOLE BANANA		1. BANANA---?--- CUT BANANA
water spoon towel		water towel spoon
2. WET HAIR-----?--- HAIR (DRY)		2. HAIR---?--- WET HAIR
-----EXPERIMENTAL SEQUENCES-----		
A. <u>SUBTRACTIVE CONDITION</u>		
FIRST STATE	CHOICES	LAST STATE
1. Wet cup	teatowel/water/feather	Dry cup
2. Broken mug	hammer/glue/matchbox	Whole mug
3. Paper written-on	pen/eraser/flowers	Blank paper
4 Cut paper	scissors/cellotape/toy	Whole paper
B. <u>ADDITIVE CONDITION</u>		
FIRST STATE	CHOICES	LAST STATE
1. Cup	teatowel/water/feather	Wet cup
2. Mug	glue/hammer/matchbox	Broken mug
3. Paper	pen/eraser/flowers	Paper written-on
4. Paper	scissors/cellotape/toy	Cut paper

Eight photographic sequences were used altogether. Four showed objects already changed in some way (e.g. wet) being transformed to their standard form (e.g. dry). These were used for the Experimental (Relational) condition. The other four showed objects in their standard forms (e.g. whole-dry-cup) being changed in some

way (e.g. wet) these were used for the Control (Matching) condition. Three choices of causal instrument were offered for each sequence. In each condition, two sequences using different objects, were constructed as familiarisation material. All the sequences used in this experiment are presented in Diagram 6.2.1.

(d) Procedure:

The experimenter spent a week in each classroom, playing with the children and assisting the teachers. Familiarisation and testing were carried out in a bay adjoining the main classroom, or in a secluded corner of the room.

Familiarisation

Children were taught to read the sequences from left to right. First they were asked to describe each photograph as it was laid out before them, then to say what had happened to the object in the photograph and choose the instrument of transformation. Once the sequence was laid out before the child, to stress the direction of the sequence, the experimenter said :

"Look, first the (naming the object) was like this, (pointing to first photograph) and then it became like this (pointing to photograph of transformed object)."

Children who made incorrect inferences were taken through the sequences again, stressing the direction of causal action. This was done until the child made the correct choice, at which point the sequence was read out to the child. Generally, only one repetition of the sequence was required. After the familiarisation each child was asked if they knew what to do. All of them said that they had to find what had caused the object to change, or to "find what did it!"

Experimental Procedure

The actual testing was done a day or two after the familiarisation. The procedure was exactly the same as the familiarisation procedure, except that children who made incorrect inferences were not taken through the sequences a second time. The lay-out of the sequences was exactly the same as in previous experiments. Sequences were presented randomly in order to control for carry-over effects.

6.3 Results

The responses in each condition were initially coded as either correct or incorrect. CORRECT choices were choices of instruments which transformed the object from its first to its last state in any given sequence. INCORRECT choices were all choices which could not have transformed the object from its first to its last state.

Correct responses will be analysed first, followed by analysis of Incorrect responses.

(a) CORRECT RESPONSES:

Do correct responses occur purely by chance?

The same procedure, as previously (see 3.3), was used to calculate the probability of responses occurring by chance. The probability of a correct response occurring by chance was 0.33 as three choices were given to the children. It was found that:

1. The 3-year-olds made significantly more correct responses than expected by chance ($p < .05$) in the (Relational) condition and so did the 4-year-olds ($p < .01$).

2. In the Control (Matching) condition both groups made more

correct responses than expected purely by chance ($p<.01$).

Comparing the Two Age Groups on the Two Conditions

The means and standard deviations of the correct responses made by the different groups are presented in Table 6.3.1. Three-year-olds made more correct responses in the Matching condition than in the Relational one. The difference between the two conditions was less pronounced in the 4-year-old group. There was also a greater difference between the scores of 3- and 4-year-olds in the Relational than in the Matching condition.

TABLE 6.3.1 MEANS (out of 4) AND STANDARD DEVIATIONS
OF CORRECT RESPONSES

<u>CONDITION</u>	<u>AGE</u>	<u>CORRECT</u>
RELATIONAL	3+	1.87 (1.4)
(Subtractive)	4+	3.47 (0.6)
MATCHING	3+	3.53 (0.7)
(Additive)	4+	3.87 (0.4)

N.B. (Standard Deviations are given in brackets)

These differences were explored by subjecting the correct responses to a 2-way ANOVA for independent groups. Age (2: 3+, 4+) and Condition (2: Relational, Matching) were the grouping factors, with the number of Correct responses as the dependent variable. The results of this analysis are presented in Table 6.3.2.

There were significant main effects for both Age ($F(1,56) = 19.18, p<.001$) and Condition ($F(1,56) = 21.91, p<.0001$) indicating that both factors affected the number of correct responses. The significant Age by Condition interaction ($F(1,56) = 8.23, p<.05$) indicated that the effects of Age and Condition were not independent of each other as illustrated in Figure 6.3.1.

TABLE 6.3.2 SUMMARY TABLE (ANOVA) COMPARING TWO
AGE GROUPS ON TWO CONDITIONS

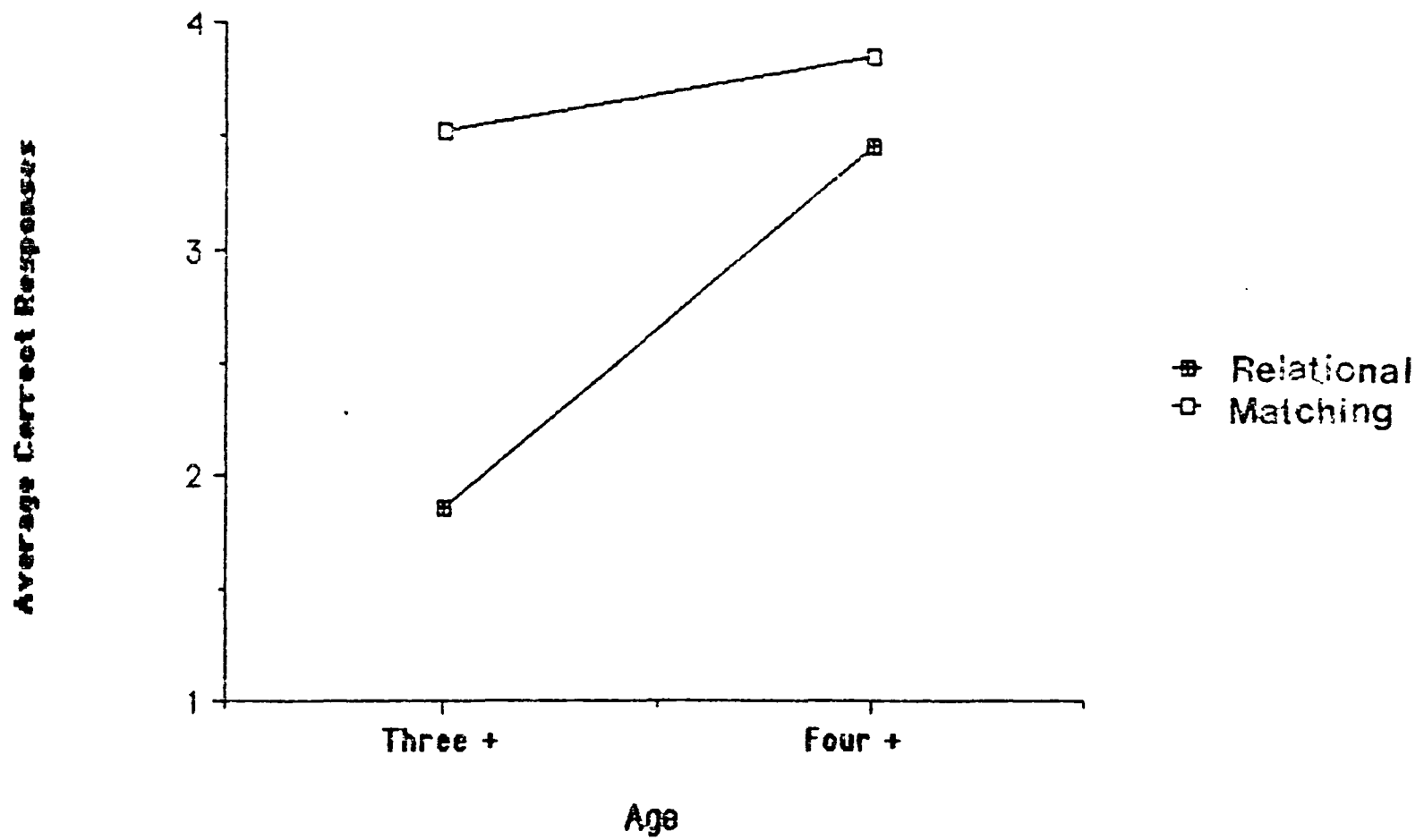
SOURCE	SS	DF	MS	F	PROB.
AGE	14.01667	1	14.01667	19.18	0.0001***
COND	16.01667	1	16.01667	21.91	0.0000***
AC	6.01667	1	6.01667	8.23	0.0058**
ERROR	40.93333	56	0.73095		

In this and following Tables: *** = $p < .001$; ** = $p < .01$; * = $p < .05$

The Age x Condition interaction was explored using the Newman-Keuls test. Although there was a significant difference between the two Conditions (Relational and Matching) in the 3-year-old sample ($p < .01$) with more correct responses in the Matching condition, there was no significant difference between Conditions in the 4-year-old sample ($p > .05$). The two age groups only differed significantly in the Relational condition ($p < .01$) where older children made more correct responses than the younger ones.

Three-year-olds do use a Relational method, as their Correct choices in the Relational Condition are above chance expectations. Nevertheless, they fare better when they can use a Matching method (Matching/Control condition). As in previous experiments, the results show that although 3-year-olds use a Relational method, they use it less consistently than 4-year-olds. Despite the presentation of single features 3-year-olds still made significantly fewer Correct responses than older children.

Fig 6.3.1. Age X Condition Interaction.



If 3-year-olds do not consistently connect the first and last states of an object in a sequence, on what basis do they choose causal instruments? An analysis of the type of incorrect responses made by these children might provide an answer to this question.

(b) INCORRECT RESPONSES:

Incorrect choices in the matching condition were called 'random' because they were inappropriate for the transformation depicted. There were two types of Incorrect responses in the Relational condition-

- 1. ASSOCIATIVE-CAUSAL (AC) - choices of instrument which matched the altered (initial) state of the objects in the sequences. Such choices indicate that children are paying more attention to **changed** states, than to the transformation sequence, and matching instruments to the change perceived.
- 2. RANDOM - choices of inappropriate instruments.

TABLE 6.3.3 MEANS (out of 4) AND STANDARD DEVIATIONS OF
AC and R RESPONSES

N.B. Standard Deviations are given in brackets.

CONDITION	AGE	AC	RANDOM
RELATIONAL	3+	1.33 (1.35)	0.80 (0.94)
(Subtractive)	4+	0.47 (0.64)	0.06 (0.26)
MATCHING	3+	-	0.47 (0.64)
(Additive)	4+	-	0.13 (0.35)

The means and standard deviations of Incorrect responses made in each condition by the two age groups are presented in Table 6.3.3. In the Relational condition, 3-year-olds made far more AC and

R responses than 4-year-olds. The younger children also gave more R-responses in the Matching condition compared to the older ones.

Do errors occur purely by chance?

The probability of either the AC or the R responses occurring purely by chance was 0.33. Using the same procedure as for the Correct responses (above) it was found that the Random responses in both age groups were significantly below chance level ($p < .05$). The proportion of AC responses made by older children was also significantly below chance level but the proportion of AC responses made by 3-year-olds did not differ significantly from the proportions expected by chance. One third of the 3-year-olds' total responses (20/60) were of the AC type compared to 7/60 in the 4-year-old group.

6.4 Discussion

As predicted, the results of this experiment showed that older children (4+) were more competent than younger ones (3+) at choosing causes for subtractive transformations (Relational Condition). The older children were equally competent on both the Matching and Relational conditions. Younger children however, fared much better when choosing causes for a transformation that added an effect (e.g. CUP----> Wet CUP), than for transformations which removed or 'subtracted' effects, (e.g. WET Cup----> dry Cup).

In both conditions, the proportion of Correct responses made by both age groups were significantly above the level expected by chance. The majority of errors in both groups were of the AC type indicating that children preferred to choose instruments for the initial state. However, it was found that in both 3- and 4-year-old groups the proportion of AC responses made were not significantly

above the level expected by chance. Thus, although there may be a tendency to focus on the initial, changed state, this tendency was not strong enough to be significant. These results show that children as young as 3-years can reliably use the Relational method.

What do these results mean? It is clear that given causal transformations leading to visible change (additive), when only one change is effected, 3- and 4-year-olds' Correct scores are near ceiling. However, as has been argued earlier, this may be because in this condition it is very easy to simply match an instrument to the effect given at the end of the sequence. The initial and final states of the sequence need not be related by the transformation that has occurred in order to gain a correct response. All that is required is the knowledge of the powers of given instruments to produce certain effects.

When the causal transformations (as in the Relational condition) restore a changed object to its standard form, the end state of the object does not depict a marked change. In such cases, children have to relate the first and last states of the object in the sequence in terms of the transformation that has occurred within the sequence in order to choose the correct causal instrument. A matching method will not succeed because the end state of the object is its standard form (e.g. cup, or paper). Only by taking into account that the cup was wet first and that now it is not, can the child seek the cause of what made it "not wet" (dry).

One reason for the 3-year-olds poorer performance in the Relational condition could be that they were not reading the sequences from left to right, and therefore were not following the correct causal direction. It seems unlikely, however, that children of the same age focused on the end state at the right in the Matching

condition as evidenced by their near ceiling performance in this condition. Nevertheless, when asked to choose the instrument that made the object change from its first state to the end state, in the Relational condition 20/60 of the younger children's responses, and 7/60 of the older children's responses were the instrument which had caused the initial state of the object (AC response).

Gelman et al. (1980) suggest that 3-year-olds prefer a right-left reading. However, as pointed out previously (Chapter 2), in their Experiment they had not accounted for associative-causal matching. The preference for a right-left reading may simply have been a preference for matching to a changed state. In addition, Gelman et al. asked children to make left-right and then right-left readings for the same sequence. It is possible that their methodology may have confused children to some extent.

While not dismissing the possibility that children were not reading the sequences from left to right, it seems that this is not a very good explanation for the results. If children had been consistently reading sequences from right to left, AC responses should have been above chance level. In any case, if the children were reading from left to right in the Matching why not in the Relational condition? It appeared to the experimenter that the children were following the sequences from left to right even in the Relational condition. When asked what had happened to the object in the final photograph, they mentioned the the transformation that had occurred in the sequence (e.g. Wet CUP ---> CUP: "It's dried"; or "There's no water"; or "Gone. All gone wet"). In the familiarisation phase the children were able to say what they had to do. Furthermore, in Experiment 4, children were familiarised with reading sequences from left-to-right.

One possible explanation for the results is that visible, or immediately perceptible, change may be a very important cue for causal reasoning. A basic feature of the ability to find causes is the ability to perceive change and then look for the cause of that change. Our ability to perceive and react to change is crucial for adaptation. Thus it is possible that for adaptational purposes this is one of the abilities that develops before many others, if it is not an innate, 'a priori', category which we are born with, as Kant intimated. If this were the case, then children will immediately respond to any change that alters objects from their standard forms. It may well be this propensity to look for the cause of the change from the standard form that leads 3-year-olds to attribute for that change, rather than for the change that has occurred in the sequence.

Another possible factor that may buttress this tendency is that the younger children react more to change information than to sequence information. Thus, already having a propensity to infer for any change from normal, in the Relational condition of this experiment children may be disposed to make AC responses. The AC responses of the 3-year-olds did not differ significantly from chance expectations. This may indicate that by this age children are taking transformational information into account although they do not use this information as consistently as 4-year-olds.

The results of this experiment show that even when only one transformation or change of state occurs, 3-year-olds make significantly more correct responses in the (Matching) condition in which an associative-matching method can be used successfully. The implications of this finding are that they perform better when the sequence is such that they do not have to relate the first state to

the last.

This finding replicates the results of Experiments 1 and 2. However previously one argument against this interpretation was that younger children might be unable to deal with the combined end-states that were always presented. In this experiment only one end-state was presented. What was tested was simply whether or not the child follows the causal direction of the sequence, relating the first state of the object to the last.

The results of Experiment 4 suggest that young children have the ability to perceive and make inferences about change. They are also able to relate initial and final states of sequences in terms of transformation. However, there seems to be a developmental shift between the ages of 3- and 4-years. Both age groups demonstrate the use of a Relational method, but older children use it more consistently and extensively than younger ones.

Younger children succeed in causal inference tasks which use abstract sequences but make more Correct responses when they are not required to relate the initial and final states of an object to make an inference (Matching Condition). Thus, although they have causal knowledge and know what instruments cause what particular effects, they are only beginning, at age three, to relate the different elements in a sequence into a cohesive whole on the basis of the transformations that have occurred.

CHAPTER SEVEN

METHODS USED IN PROBLEMS INVOLVING CAUSAL REASONING

7 Experiment 5 Preschool Childrens Use of Different Methods for Inference and Prediction

7.1 Introduction

Experiment 5 was designed to test the hypotheses that arose from the findings of the first four experiments. The results of these experiments suggested that there may be two major ways of dealing with pictorial sequences of the forms used in these experiments:

- (1) The Associative-Causal Matching method, and
- (2) The Relational Method.

The Matching method consists of 'matching' relevant instruments to given effects or vice-versa. This method does not require that both the initial and final states shown in a sequence should be considered before making a causal judgement. The Relational method, on the other hand, is the truly causal one and requires that first and last states of objects in a sequence should be related in terms of the transformation that is depicted in the sequence. The results of Experiments 1 and 2 indicate that 3-year-olds prefer the Matching method to a Relational method. In Experiment 4 children's performance on tasks where the Matching method would produce Correct responses (Additive Condition) was compared to a task which required the use of a Relational method (Subtractive Condition). However, the 'relational' task did not involve the discounting of a continuing state which was required by the tasks in

Experiments 1 and 2 (see 6.1). Experiment 5 was designed to compare performance on tasks that required the use either of a Matching method (AC task) or of a Relational method which involved discounting a continuing state (DISC task).

The results of the first two experiments also suggested that 3-year-olds find it more difficult to deal with two states. This assumption was supported by the results of Experiment 3. Even when no discounting is involved, 3-year-olds prefer to focus on a single salient effect and find a cause for it. The older children (4-years) are much more competent at 'adding' or integrating the two causes required to bring about the two end states. Hence the ability to 'add' or integrate features may also been important factor affecting younger children's performance on these experiments.

The relative importance of the Matching Method, the Relational Method (involving discounting) and the ability to deal with more than one feature at a time has not yet been investigated in one experiment. Therefore, in Experiment 5, three tasks were designed to compare these methods directly. The AC task could be adequately tackled simply by using a Matching method, the DISC task required the use of a Relational method and the ADD task involved the 'adding' or integration of two separate features. The requirements for getting Correct responses on these tasks are outlined below:

1. THE ASSOCIATIVE-CAUSAL (AC) TASK :

requires a simple matching between instruments and effects, assuming knowledge of the specific powers of specific causal instruments.

2. THE DISCOUNTING (DISC) TASK :

requires that the state of an object **present at the beginning of a sequence** be discounted in order to find the cause of the change or transformation present at the **end** of the sequence.

3. THE ADDING (ADD) TASK:

requires that when two different changes or transformations are present, the two causes of those changes should be combined or added in order to explain the effects. To succeed in this task children must be able to deal with more than one cause at a time; that is, they must be able to integrate two features.

As explained in Chapter 3, the consistency of responses in tasks involving discounting is very important. Children may make single correct responses simply by matching instruments to Salient end states. Only by checking children's performance on both Salient and Non-Salient sequences (as defined in Experiment 3) is it possible to judge whether children consistently relate beginning and end states of sequences in terms of the transformation that has occurred (see 3.1). Therefore sequences in both AC and DISC tasks were paired, as in Experiment 1, to investigate the consistency of children's correct choices.

When objects are transformed in two ways (e.g. wet and broken) an understanding of multiple causality, or at least an understanding that two instruments have affected the same object, is essential for total comprehension of what a sequence is depicting. Such comprehension is important for discounting; DISC sequences not only require children to use a Relational method, they also require that the two states shown at the end of the sequence are integrated.

Previous results (Experiments 1 and 2) showed that younger children tend to focus on the more **Salient** of the combined (two) end states. One explanation suggested for this finding was that children found it difficult to deal with two features in a sequence.

The results of Experiment 3 support this explanation. However, in this Experiment children had to put two instruments together physically (picking two separate photographs) as well as mentally (integrating knowledge of these instruments and their effects) in order to make a correct (Both) response in the Experimental condition. It is possible that some children may have wanted to make a BOTH response, but found it difficult to first pick out the two instruments and then put them together (add). Therefore, the ADD task in this experiment, offered a conjunctive (JOINT) choice instead of a Random choice so that children could choose two instruments without having to pick them out singly and then add them together. The JOINT choice was a photograph of two instruments (e.g. hammer and water) as opposed to the choices of single instruments presented in previous experiments.

It should be noted here that the ADD task does not necessitate the use of a relational method. To get Correct responses on ADD sequences children may match instruments to relevant effects but they **MUST** also integrate or 'add' the two instruments (or effects) chosen. Even if children are relating initial and final states in the ADD tasks, if they do not 'add' the two different transformations that occur, they will not make correct choices. A detailed description of each task is given in section 7.2 (Materials).

Schmidt and Paris (1978, see 2.5) found that 5-year-olds found it much easier to predict effects than to infer antecedents.

To find out whether this is the case in object sequences, two Conditions were designed:

(I) **The INFERENCE CONDITION (INF)** -

in which children had to infer the cause of the end state/s of objects, given the first and last states of the objects.

(II) **The PREDICTION CONDITION (PRED)** -

in which, given the objects and instruments, children had to predict the end states of the object.

Within each of these conditions there were three types of tasks (sub-conditions) which required the use of one of the three methods described earlier:

- (a) The Associative-Causal (AC) task
- (b) The Discounting (DISC) task and
- (c) The Adding (ADD) task.

Examples of the sequences used for these tasks can be found in Diagram 7.2.1. A description of each type of task, in the two conditions (INFERENCE and PREDICTION) is given in section 7.2 (Materials).

The two conditions (Inference and Prediction) were designed to investigate whether these two abilities were disparate. It was argued that if children were using any of the methods postulated here then they should be able to apply them just as effectively for inferring causes as for predicting effects.

It was thought that, by designing different tasks which obliged children to use specific methods in order to make correct responses, some information about the methods most preferred by preschool children would emerge. Furthermore, comparison of performance on DISC and ADD tasks would indicate which of these tasks was most problematic for children. To ensure as much similarity between tasks as possible, the same objects (e.g. Cup, Paper, etc.) and

transformations (breaking, wetting, cutting, etc.) were used to construct sequences in all 3 tasks. The choices given for sequences were the same across tasks (see Diagram 7.2.1).

Predictions

(1) Children of both ages will make most correct responses on the AC tasks. There will be no significant difference between ages on this task. Although 4-year olds will do well on all 3 tasks, in both Conditions, 3-year-olds will do best on the AC tasks and worst on the DISC and ADD tasks which either require that first and last states of objects should be related in terms of a transformation (DISC) or that two features must be integrated (ADD).

(2) Children will do far better on the PREDiction tasks than on the INFERENCE ones.

7.2 Method

(a) Subjects:

One-hundred-and-twenty children from Oxford nursery schools and play-groups: sixty 3-year-olds [mean = 3-6; range = 3-0 to 3-11] and sixty 4-year-olds [mean = 4-6; range = 4-0 to 5-0] participated in this experiment.

(b) Design:

An independent groups design was used. Age (2: 3+, 4+), Condition (2: INF, PRED) and Task (3: AC, DISC, ADD) were the independent variables. Correct responses were the dependent variable. Children in each age level were randomly assigned to each of the six independent groups: INF-AC, INF-DISC, INF-ADD, PRED-AC, PRED-DISC and PRED-ADD as illustrated in Table 7.2.1.

TABLE 7.2.1: THE DESIGN OF EXPERIMENT 5

CONDITION	TASK	AGE	N
INFERENCE	AC	3+	10
		4+	10
	DISC	3+	10
		4+	10
	ADD	3+	10
		4+	10
PREDICTION	AC	3+	10
		4+	10
	DISC	3+	10
		4+	10
	ADD	3+	10
		4+	10

KEY: N = Number of children; TASKS: AC = Associative-Causal; DISC = DISCounting; ADD = ADDing.

An independent groups design was used because the same objects (e.g. cup) and transformations (e.g. wetting) were used in the different tasks and conditions. The use of a repeated measures design, with different objects and transformations in the different tasks and conditions, was rejected. If different materials had been used any significant difference between Conditions or Tasks could have been attributable, at least in part, to the different materials. A repeated measures design, using the same materials could have produced a learning effect. A between groups design cut out the possibility of such effects. Between group variance was controlled to some extent by only including children from schools in one area (North Oxford). Children from each school were randomly assigned to

each of the experimental groups.

(c) Material:

The sequences were created by adapting material used in previous experiments, in order to maintain consistency across experiments. The experimenter and an independent rater went through the two Sequence-sets used in Experiment 1 and coded transformations as being Salient and Non-Salient, only sequences on which 100% agreement was reached between raters were retained for Experiment 5.

Sequences such as the drawer and hair sequences (Set Y) were discarded because raters did not agree about the saliency of effects. The the hair sequences (Set X) and the orange sequences (Set Y) were discarded because they showed 'subtractive' transformations. The results of Experiment 4 indicated that 3-year-olds did not do as well on such transformations as on 'additive' ones. Hence only 'additive' transformations were used in Experiment 5. In all, 5 pairs of sequences were chosen for this experiment, as shown in Appendix 5, 3 from Set X (Cup, Paper, Apple) and 2 from set Y (Banana, Plate).

The same objects (Cup, Paper, etc.) were used to construct sequences for the 3 tasks in each condition, as illustrated in Diagram 7.2.1. The difference between tasks was minimised by using the same objects (e.g. Cup), transformations (wetting) and choices in each task. The major difference remaining was the different structure of sequences in each task. Each task necessitated the use of different methods. General descriptions of the three tasks are given below:

- (a) AC TASKS - only require use of the simple Associative-matching method to get a correct response. (Although children may relate beginning and end states here, it is not

necessary to do so in order to make a correct response.)

In the INFerence Condition children had to find the instrument that matched the effect shown - e.g.

Cup----?----WET Cup [CHOICES = hammer/water/hammer&water]

In the example given above, the correct choice, water, could be attained simply by finding an instrument which matched the end state. This task (INF-AC) is similar to the Gelman et al. task and the Control condition in Experiment 4. The INF-AC task differs from the other two in that a **conjunctive choice** comprising two causal instruments (hammer&water) was offered instead of a purely random choice. The conjunctive choice was presented to see whether children preferred multiple explanations to single ones. In some tasks (PRED-DISC and ADD) the conjunctive choice is the correct one, but it is incorrect in all the other tasks.

In the PREDiction Condition children had to find the effect that matched, or could be produced by the instrument shown -

Cup--water--?-- [CHOICES: Wet Cup/Broken Cup/Wet Broken Cup]

This task (PRED-AC) is similar to the prediction tasks in the Gelman et al.. (1980) experiment, but the materials and transformations used are different, as is the conjunctive choice that was offered to children.

(b) DISC TASKS - here it is essential to relate the first state of the object to the last, in both INF and PRED Conditions. For example, in the INF Condition, for the sequence -
Broken Cup---?---Wet Broken Cup

[CHOICES: hammer / water / hammer&water]

using an AC method would result in the choice of instrument for the state (Broken). In order to distinguish whether an AC method was being used, and to control for this, sequences were paired as in Experiment 1. The corresponding sequence to the one given above would be -

Wet Cup----?----Wet **Broken** Cup

These sequences are exactly the same as those used in Experiment 1 except that for each sequence a **conjunctive choice** was offered instead of a random one.

Similarly, in the PRED condition, the DISC task requires use of a relational strategy. For example, in the sequence-

Wet Cup---hammer---?---

[CHOICES: Wet Cup / Wet Broken Cup / Broken Cup]

if children do not encode the first state of the object, they may well choose Broken Cup, simply by matching the appropriate state to the instrument given (hammer). Alternatively, children could choose the state similar to the first state (e.g. Wet Cup). To find out whether a matching method was being used and whether children were being influenced by similarity, all sequences were paired. Thus, for the sequence-

Broken Cup--water--?--

[CHOICES: Wet Cup / Wet Broken Cup / Broken Cup]

(which, with the previous sequence, makes up the Cup pair of sequences) if a child chose Wet Cup, this would indicate that she was matching the instrument to the effect. If she chose Broken Cup, she was simply choosing on the basis of similarity. If children consistently chose the correct

states for both sequences in a pair this would indicate that they were discounting the first state. The correct response of **Wet Broken Cup** could only be achieved if the first state was taken into account.

Both AC-INF and DISC-INF tasks have been used in previous experiments presented in this thesis: the DISC task in Experiments 1 (Experimental Condition) and 2 (Second Transformation), the AC task in Experiment 4 (Control). The PRED-AC and PRED-DISC sequences were designed especially for this experiment.

(c) ADD TASKS - were created for this experiment. These tasks required an ability to integrate two features. In the INF condition, children will choose only one instrument for objects transformed in two ways, if two causes are not integrated in order to account for two effects. For example, in the sequence-

Cup----?----Wet Broken Cup

CHOICES: hammer / water / **hammer&water**

children may make a single choice of **either hammer or water** and may rely on the salience of transformations to make these single inferences. They must be able to integrate two causes to make the correct choice of **hammer&water**.

Similarly, in the PRED condition, children who do not integrate the effects of two instruments may predict only one effect. They may do this by simply finding the matching effect for a preferred instrument, or by matching a salient effect to one of the two instruments given. In the sequence-

Cup---hammer&water---?---

CHOICES: Wet Cup / Wet Broken Cup / Broken Cup

use of a matching method would lead to choices for either Wet Cup, or, in the latter case, Broken Cup. Only children who 'add' the effects of both the given instruments would make the correct prediction of Wet Broken Cup.

DIAGRAM 7.2.1. EXAMPLES OF SEQUENCES IN EXPERIMENT 5

N.B. - Choices are the same in each of the three tasks in each Condition (ie. H/ W/ H&W - for all INF tasks; WC/ BC/ WBC for all PRED tasks) in this example.

INFERENCE			PREDICTION		
AC TASK					
(1/ 2 / 3) <-----choices----->			(1 / 2 / 3)		
Cup	H/ W/ H&W	Wet Cup	Cup	--water--	WC/ BC/ WBC
Cup	---"---	Broken Cup	Cup	--hammer-	---"---
DISC TASK					
Broken Cup	(1/2/3)	Broken Wet Cup	Broken Cup	--water--	(1/2/3)
Wet Cup	(--"--)	Wet Broken Cup	Wet Cup	--hammer--	(--"--)
ADD TASK					
CUP	(1/2/3)	Wet Broken Cup	Cup	-hammer&water--	(1/2/3)

where: 1/2/3 = the 3 choices H/ W/ H&W in the INFerence condition, and WC/ BC/ WBC in the PREDiction condition.
H = hammer; W = water; H&W = hammer and water;
WC = wet-cup; BC = broken-cup; WBC = wet-broken-cup.

There were 10 sequences (5 pairs) in the AC and DISC tasks in each condition, and 5 sequences in the ADD tasks (see Appendix 5). There were only 5 sequences in the Add tasks because the nature of these sequences were such that they incorporated the two transformations which occurred separately within the paired sequences. As in previous experiments, sequences in the AC and DISC tasks were paired to ensure that children made consistently correct responses. Additionally, paired sequences in the AC task would provide information as to whether children could deal with each of the two single transformations that had to be integrated in the ADD tasks.

Three choices were given for each sequence. In the INF

condition these were choices of instruments (e.g. hammer/ water/ hammer&water). In the PRED condition the choices were 'effects' (e.g. wet cup/broken cup/wet broken cup).

Four familiarisation sequences were constructed for each condition to familiarise children with the task and to train them to read the sequences from left to right. Details of all materials are provided in Appendix 5.

(d) Procedure:

The experimenter spent two weeks in each classroom playing with the children and assisting the teachers. The experiment was introduced as a "new game". Testing was conducted either in a secluded corner of the classroom, or in a bay adjoining the room, depending on the facilities available.

Familiarisation

Sequences used for familiarisation corresponded to sequences used in the experimental group to which the child had been assigned. Thus, children in the INF-AC group were familiarised with sequences similar to the INF-AC sequences, those in the PRED-DISC group were taken through PRED-DISC type sequences, and so on. The photographs that made up each sequence, and the relevant choice photographs, were laid out in front of the child. The different lay-outs used in the two conditions (INF and PRED) are shown in Diagram 7.2.2.

Children assigned to the INF condition were asked to name the object at the beginning of the sequence (initial photograph). They were then shown the final photograph and asked what had happened to the object. The 3 choice-photographs were then laid out, and the children were asked to name the object or objects in each photograph. This was done to ensure that children realised that one

photograph (conJOINT choice) showed two objects. They were then asked to pick the photograph of the instrument/s that had changed the object.

DIAGRAM 7.2.2 LAYOUTS OF SEQUENCES PRESENTED IN EXPERIMENT 5.

CONDITION	
INFERENCE	PREDICTION
choice of instruments	choices of end states
1 2 3	1 2 3
begin photo ? end photo	begin photo instrument ?

(N.B. The lay-out was exactly the same for all 3 tasks (AC, DISC, and ADD) in each condition.)

This procedure was identical to the procedures used in previous experiments for the AC and DISC groups. In the ADD condition, if children chose a single instrument which accounted for only one of the two states of the object, the experimenter asked them if anything else had happened to the object. All children acknowledged that something else had happened. The experimenter then asked each child to say what else had happened. Once the child had named the second change the experimenter asked the child to look at the choices again and to pick the photograph that showed the "best" instrument/s responsible for changing the object [to the final state]. Some children (mostly 3-year-olds) still did not choose the conjoint instruments. When this happened, the experimenter went through the sequence, pointing out the two states, and then the two instruments responsible for those states and asked the child again to pick the photograph which showed "best" how the object had been changed in two ways, explicitly mentioning the two states: "Now, tell me what I used to make this (object) wet and broken?"

This had not been done previously but, in view of the

results obtained thus far, it was thought that the TWO end states should be emphasised. The two states and two possible causes or effects in the ADD tasks were highlighted during familiarisation to ensure that children were aware that they were being asked to give two causes or two effects (depending on the condition - INF or PRED). Indeed, it could be said that the children were 'trained' to look for two causes/effects. This procedure was repeated for each familiarisation sequence.

The procedure for the PRED tasks was similar, except that children were asked to tell the experimenter what would happen if the instrument given was used on the object. Children in each task group were first shown a picture of the object and then asked to name the object (AC and ADD tasks) and state (DISC task). They were then shown the photograph of the instrument (AC and DISC) or conJOINT instruments (ADD). Care was taken to ensure that each instrument in the JOINT photograph was named. The choice photographs were then laid out in front of the children and they were asked to describe the states of the objects in each photograph. They were then asked to choose the photograph that showed what would happen if the experimenter used the given instrument on the initial photograph: "Now, look carefully at these things (choice photographs) and tell me what this cup (pointing to initial photograph) will look like if I use this hammer to hit it."

In the DISC group, children who predicted a single end state were taken through the sequences again, but this time it was pointed out by the experimenter that the object had been altered in some way (name first state) and then an instrument was used. The child was asked to choose the photograph that showed "best" what would happen to the object when the given instrument was used.

Children who predicted only one end state in the ADD group, were taken through the sequence again. The experimenter pointed out that there were two instruments and asked what would happen if first one, then the other, was used. When the child had predicted the two states, she was asked to choose the photograph that showed "best" what would happen to the object.

The children were taken through all the sequences. The experimenter pointed out information they might have disregarded. If they still did not answer correctly, the experimenter picked out the correct response. The experimenter then 'read' through the sequence with the child (e.g. "Look! This cup is wet, and there's a hammer. I hit this wet cup with the hammer and now the cup is broken and wet"). This procedure was used to ensure that children not only understood what was being asked of them in each condition but also had been shown how to work out the correct answer.

Experimental Procedure

This was practically the same as the familiarisation, except that no corrections were made and the two states/instruments in the ADD tasks were not emphasised as much as in familiarisation. In the DISC and ADD tasks, in both the INF and PRED conditions, care was taken to ensure children noticed the first state. They were asked to describe the first photograph. If they did not mention the first state (e.g. wet) the experimenter asked if anything had happened to the object. This was rarely necessary with the older children. After the prompt younger children always correctly identified the first state (e.g. " 'Course. It's wet! You must washed it."). The experimental conditions were administered the day after the familiarisation.

7.3 Results

Initially, children's responses were coded as either CORRECT or INCORRECT. Choices of either the instruments which effected the transformation depicted in the sequence (INF condition) or the end-state that would ensue, given certain object states and instruments (PRED condition), were coded CORRECT. Choices of instruments which could not produce the end state/s shown (INF) or of end-states which were not compatible with the instrument and object states given (PRED) were INCORRECT. Examples of coding of responses, in each pair of sequences, in the INF and PRED tasks is presented below (CORRECT answers are in **bold type**, the rest are INCORRECT):

INF-AC: Cup---H/W/H&W----Wet Cup

Cup---H/W/H&W----Broken Cup

PRED-AC: Cup --water--**WC/BC/ WBC**

Cup--hammer--**BC/WC/WBC**

INF-DISC: Broken Cup--H/W/H&W--Broken Wet Cup

Wet Cup-----H/W/H&W---Wet Broken Cup

PRED-DISC: Broken Cup--water----- **WC/BC/**WBC****

Wet Cup----hammer----- **BC/WC/**WBC****

INF-ADD: Cup H/W/**H&W** Wet Broken Cup

PRED-ADD: Cup --hammer&water-- **WC/BC/**WBC****

- where - H = hammer; W = water; H&W = hammer and water;

WC = wet-cup; BC = broken-cup; WBC = wet-broken-cup.

In the AC and INF-DISC tasks particular SINGLE choices were Correct in each sequence. In the PRED-DISC and ADD tasks the JOINT choice (Hammer **and** water/ Wet Broken Cup) was always the Correct one.

Correct (C) Responses

The means and standard deviations of the total (i.e. not paired) Correct responses (out of 10 in all tasks, as the scores on the ADD tasks were doubled to make them comparable to the other tasks) are presented in Table 7.3.1. The range of Correct (C) responses made by the younger children (2.2 to 7.5) was wider than that of the older children (7.4 to 9.1) indicating that while older children did relatively well on all tasks younger children found some tasks and conditions easier than others.

TABLE 7.3.1 MEANS (out of 10) AND STANDARD DEVIATIONS OF
CORRECT RESPONSES - including chance levels

CONDITION	TASK	AGE	MEAN	S.D.	PROBABILITY
INFERENCE	AC	3+	7.5	1.3	p < .01
		4+	9.1	1.3	p < .01
	DISC	3+	6.1	1.2	p < .01
		4+	7.6	1.8	p < .01
	ADD	3+	3.2	2.6	ns
		4+	7.4	2.1	p < .01
(N = 60)	AC	3+	5.9	1.3	p < .01
		4+	8.1	1.7	p < .01
	DISC	3+	4.6	2.2	p < .01
		4+	7.6	1.3	p < .01
	ADD	3+	2.2	1.5	ns
		4+	7.6	2.1	p < .01

N.B. All means in ADD tasks are adjusted means. The ADD scores were doubled in order to make them comparable to the AC and DISC scores as there were only 5 scores for each of the ADD tasks (ADD-INF and ADD-PRED) and 10 scores for each of the DISC and AC tasks. The adjusted scores were used to compute the Analysis of Variance. The p-levels were calculated for the actual means.

Three-year-old children made far more CORRECT responses in the INF condition than in the PRED. Their highest scores, in each condition, were made in the AC task, followed by the DISC task. They seemed to make the least number of Correct responses in the ADD task. This pattern was found in the 4-year-olds responses too, although, for this age group, there seemed to be less of a difference between the two conditions (INF and PRED). In all cases older children made more Correct responses than younger ones.

Did Correct responses arise by chance?

Using the same procedure as described in Chapter 3 the proportions of the observed average Correct responses made by each group was compared to the proportion expected purely by chance. Three choices were offered for each sequence, two Incorrect, and one Correct. The probability of a Correct response being chosen was 0.33. The probabilities of these responses having arisen by chance are also shown in Table 7.3.1.

It was found that 3-year-olds Correct responses were significantly above chance level ($p < .01$, in all cases) in the AC and DISC tasks in both conditions. However, in the ADD tasks, in both conditions, these children's average Correct responses did not vary significantly from those expected by chance ($p > .05$). The 4-year-olds Correct responses were significantly above chance level, on all tasks, in both INF and PRED conditions.

Comparing C responses across age

The total Correct responses were subjected to a 3-way ANOVA for independent groups. Age (2: 3+, 4+), Condition (2: INF, PRED) and Task (3: AC, DISC, ADD), were the grouping factors, with number of Correct responses as the dependent variable. The results of this analysis are presented in Table 7.3.2.

There was a significant main effect for Age ($F(1,108)=89.2, p<.001$). This indicates that the 4-year-olds had far more Correct scores, overall, than the 3-year-olds as illustrated in Figure 7.3.1(a). There was also a significant main effect for Condition ($F(1,108)=6.68, p<.05$), which showed that the INF condition elicited a greater number of Correct responses than the PRED condition (Figure 7.3.1(b)).

TABLE 7.3.2 SUMMARY TABLE (ANOVA) FOR TOTAL CORRECT RESPONSES

SOURCE		SS	DF	MS	F	PROB
AGE	(A)	267.008	1	267.008	89.20	0.0000 ***
CONDITION	(C)	20.008	1	20.008	6.68	0.0111 *
TASK	(T)	130.317	2	65.158	21.77	0.0000 ***
AC		9.075	1	9.075	3.03	0.0845 ns
AT		50.117	2	25.058	8.37	0.0004 **
CT		4.117	2	2.058	0.69	0.5050 ns
ACT		1.050	2	0.525	0.18	0.8394 ns
ERROR		323.300	108	2.994		

In this and following Tables: * = $p<.05$; ** = $p<.01$; *** = $p<.001$;
ns = non-significant

The non-significant AGE x CONDITION and CONDITION x TASK interactions, indicated that the effect of Condition was independent of the effects of both Age and Task; the INF condition elicited more Correct responses than the PRED condition, regardless of age or task. The significant main effect for Task ($F(2,108)=21.77, p<.01$) indicated that at least one of the tasks had a significant effect on the number of Correct responses.

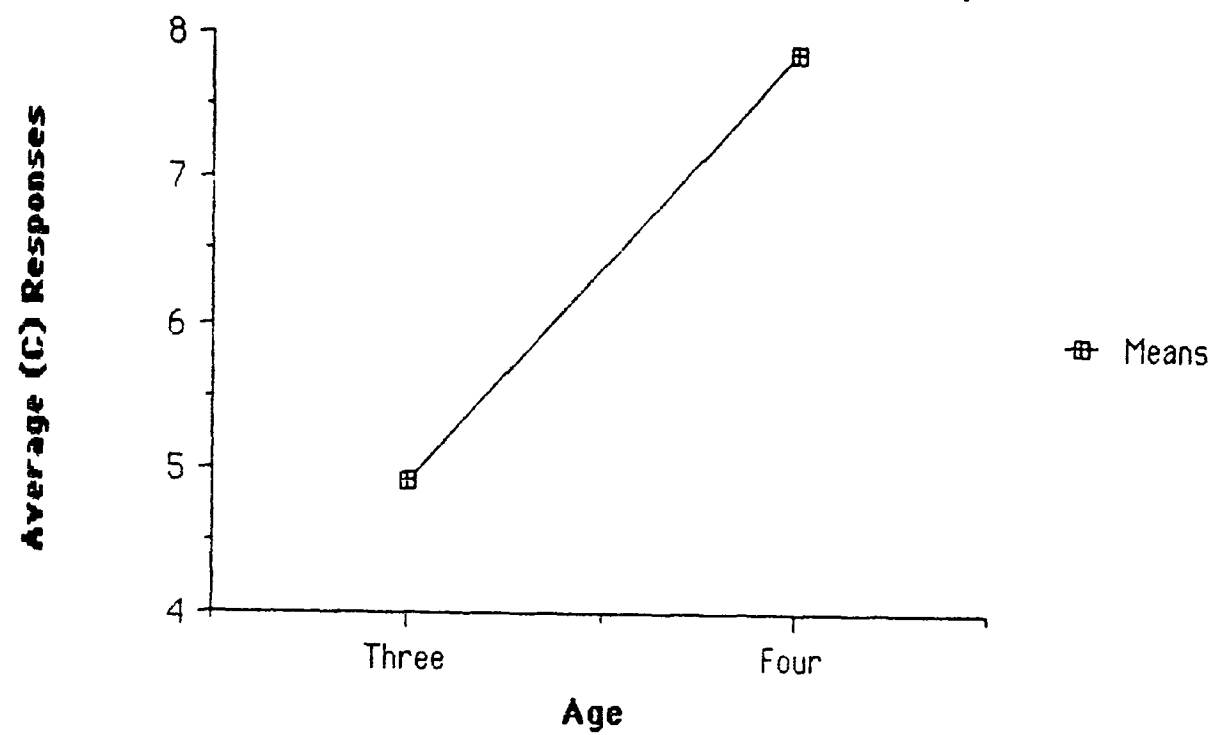
The significant AGE x TASK interaction ($F(2,108)=8.37, p<.01$) indicated that the effects of the different tasks depended on

the age of the children as illustrated in Figure 7.3.2. Post-hoc comparisons (Newman-Keuls) showed that on all 3 tasks the 4-year-olds made far more Correct responses than the 3-year-olds: (AC Task - $p < .01$; DISC Task - $p < .01$; ADD Task - $p < .01$). Thus, even on the AC task older children made significantly more correct answers than younger ones. The difference between the two age groups on this task may be due to the drop in younger children's Correct responses in the PRED-AC task (Table 7.3.1).

Three-year-olds made more Correct choices on the AC tasks than on either the DISC ($p < .05$) or ADD ($p < .01$) tasks. They also made significantly more Correct responses in the DISC tasks than on the ADD tasks ($p < .01$). The pattern that emerges for the 3-year-olds is that the (AC) Matching method is the most preferred, followed by the Relational one (DISC), but they found it most difficult to deal with two features (ADD).

No such pattern emerged in the 4-year-old group. As Table 7.3.1 shows these children made a large number of Correct responses on all tasks and there was no significant difference between the three tasks in the 4-year-old sample.

Fig 7.3.1. Effects of (a) Age on Correct Responses.



(b) Condition on Correct (C) Responses.

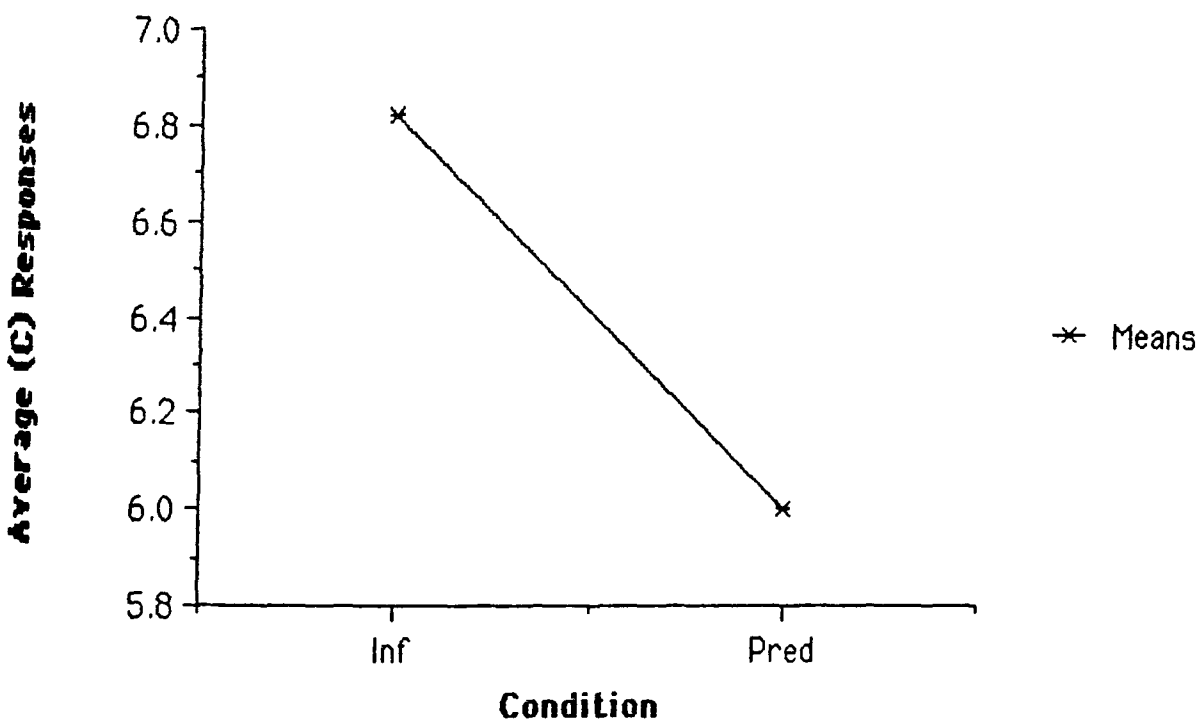
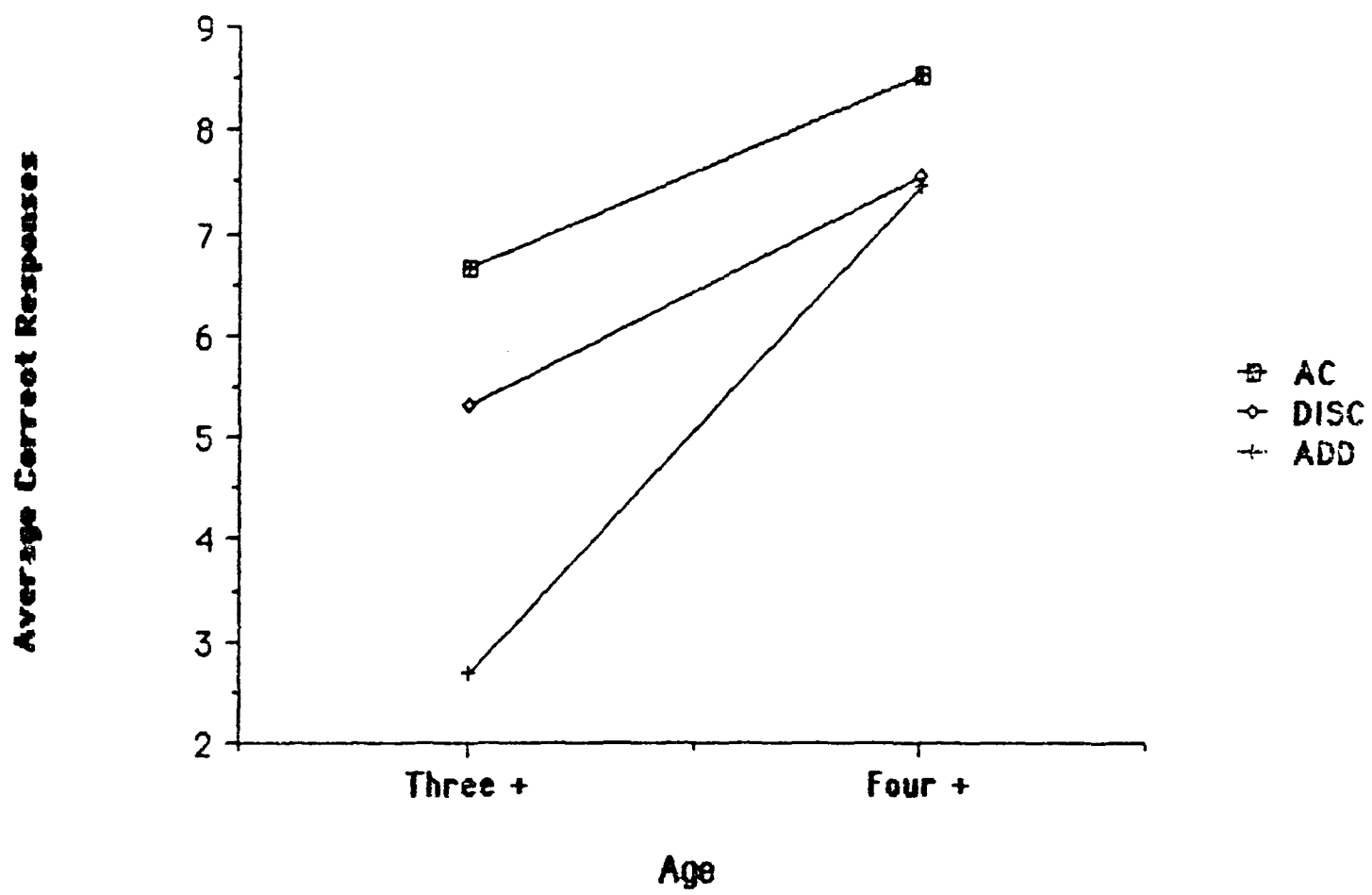


Fig 7.3.2. Age X Task Interaction.



In conjunction with the finding that on the ADD tasks the proportion of Correct responses obtained could have occurred by chance, the results of the analysis of variance and post-hoc tests strongly suggest that 3-year-olds are better at discounting than adding. The 4-year-olds seem to be equally competent at both.

However, as pointed out previously, Single Correct responses on the INF-DISC task may be made by using a Matching-method. Therefore, it is necessary to look at the pattern of paired responses in the two age groups before any conclusions can be made.

Consistently Correct Responses

Sequences were paired (as in Experiments 1 and 2) to distinguish whether children were being consistent in making Correct choices. Consistent CORRECT choices (CC), in the DISC tasks, can be made **only** if children relate the beginning and end states of objects. In ADD tasks, CC responses can only be made if both transformations depicted in the sequence are accounted for. Even if a Matching method is used, the two instruments that match the given effects must be 'added' to make a Correct choice. In the AC tasks, CC choices can be made simply by matching end states to instruments. Although a SINGLE Correct response, within a sequence-pair, may be achieved by matching an instrument to an end state in AC tasks, the use of this method in both DISC and ADD tasks will not produce consistently correct (CC) paired responses. Therefore the following analyses were conducted on the paired CC responses made in each task to see how this more stringent coding affected children's responses.

Responses were paired because, on DISC tasks, in pairs such as:

(a) Wet Cup ----H, H&W, W ---- Wet Broken Cup

(b) Broken Cup ----H, H&W, W ---- Wet Broken Cup

it is possible to make a 'correct' choice in (a) by matching the relevant instrument (H) to the Salient (as defined in previous experiments) end state (Broken). This method will produce an incorrect choice in (b) however, because here, the salient end state is not the product of the transformation shown in the sequence. Since all sequence pairs used in this experiment comprised one Salient and one Non-Salient sequence (as described in 7.2) it was possible to make at least 5 Correct choices (out of 10) by matching instruments to Salient end states. Thus, at least 50% (well over the chance level of 33.33%) of the single Correct choices in the DISC task could have been made by using a Matching method. For this reason paired responses were considered a more accurate measure of the Relational method. To make correct choices on both the (a) and (b) sequences given in the example above children had to relate the beginning and end states in terms of the transformations depicted in each sequence (Broken in (a) and Wet in (b)).

Sequences in the ADD tasks were not paired because they contained both the transformations which were dealt with separately in the AC and DISC tasks. Nevertheless, the ADD tasks require an integration of two transformations. Therefore responses on the 5 ADD tasks in each condition were considered comparable to the 5 paired responses on the AC and DISC tasks in each condition.

The maximum number of CC scores in the AC and DISC tasks is 5, as there are five-pairs of sequences. This tallies with the actual scores in the ADD tasks, which are out of 5. These, although not CC scores in the same way as scores in the other two tasks, will be counted as such because **two** inferences, or **two** predictions are required in each sequence in order to gain a score categorised CORRECT.

The means and standard deviations of the CC paired responses are presented in Table 7.3.3. This Table shows that on all 3 tasks, in both INF and PRED conditions, 4-year-olds made more CC responses than 3-year-olds. Both age groups made the greatest number of CC responses in the AC condition.

TABLE 7.3.3 MEANS (out of 5) AND STANDARD DEVIATIONS OF
CONSISTENTLY CORRECT RESPONSES
(including chance levels)

CONDITION	TASK	AGE	MEAN	S.D.	CHANCE LEVELS
INFERENCE (N = 60)	AC	3+	3.1	0.88	p < .01
		4+	4.3	0.95	p < .01
	DISC	3+	1.3	1.06	p < .01
		4+	2.8	1.40	p < .01
	ADD	3+	1.6	1.26	p > .05 ns
		4+	3.7	1.06	p < .01
PREDICTION (N = 60)	AC	3+	1.5	1.27	p < .01
		4+	3.4	1.26	p < .01
	DISC	3+	1.0	1.25	p < .05
		4+	2.7	1.06	p < .01
	ADD	3+	1.1	0.74	p > .05 ns
		4+	3.8	1.03	p < .01

The Probability of CC Responses Occuring by Chance

The procedure used for (C) responses was utilised to find out whether the CC responses obtained could have arisen by chance. In the AC and DISC tasks, 3 choices were offered in each sequence, so, for a pair of sequences, there were 9 possible response combinations. Thus, the probability of any one pair (such as the CC pair) being chosen was 0.11. In the ADD task the probability

of choosing the Correct response in each sequence was 0.33.

The 4-year-olds' Correct-responses in all 3 tasks (INF and PRED) were significantly above the proportions expected by chance ($p < .01$) as shown in Table 7.3.3. Except for the ADD tasks (in both Conditions) the younger children's Correct responses were significantly above chance level as well. On the INF-ADD task the proportion of Correct responses made by this group did not differ significantly from the proportion expected by chance. This indicates that these children may have been performing in a random manner. However, on the PRED-ADD task, Correct-responses were significantly less than expected by chance intimating that children were not behaving randomly on this task.

Comparing CC responses across age

Although most of the CC responses made by the 3-year-olds did not occur by chance their scores were far lower than those of the 4-year-olds in all the groups (Table 7.3.3). Both age groups made less CC responses in the PRED than in the INF condition. In both age groups, the largest number of CC responses occurred in the AC tasks and 4-year-olds made more CC responses in ADD than in DISC tasks.

The statistical significance of these findings was investigated using a 3-way ANOVA for independent groups. Age (2: 3+, 4+), Condition (2: INF, PRED) and Task (3: AC, DISC, ADD) were the independent variables, with number of correct (CC) responses as the dependent measure. The results of this analysis are presented in Table 7.3.4.

There was a significant main effect for Age ($F(1,108) = 82.32$, $p < .001$); 4-year-olds made significantly more CC responses than 3-year-olds (Figure 7.3.3(a)). There were also significant main

effects for Condition ($F(1,108) = 7.28, p<.05$) and Task ($F(2,108) = 10.16, p<.001$).

TABLE 7.3.4 SUMMARY TABLE (ANOVA) FOR CORRECT RESPONSES

SOURCE		SS	DF	MS	F	PROB	
AGE	(A)	102.675	1	102.675	82.32	0.0000	***
CONDITION	(C)	9.075	1	9.075	7.28	0.0081	*
TASK	(T)	25.350	2	12.675	10.16	0.0001	***
AC		1.875	1	1.875	1.50	0.2228	ns
AT		4.550	2	2.275	1.82	0.1663	ns
CT		7.350	2	3.675	2.95	0.0568	ns
ACT		0.350	2	0.175	0.14	0.8692	ns
ERROR		134.700	108	1.247			

The significant Condition effect shows that children did best on the INF condition (Figure 7.3.3(b)). There was no significant Age x Condition interaction. Table 7.3.3 shows that 4-year-olds made almost the same number of CC responses on each Task in both Conditions whereas 3-year-olds CC scores dropped on all tasks in the PRED condition. It is suggested that the lower scores of both age groups on the PRED-AC task (as compared to the INF-AC task) masked any possible interaction effect.

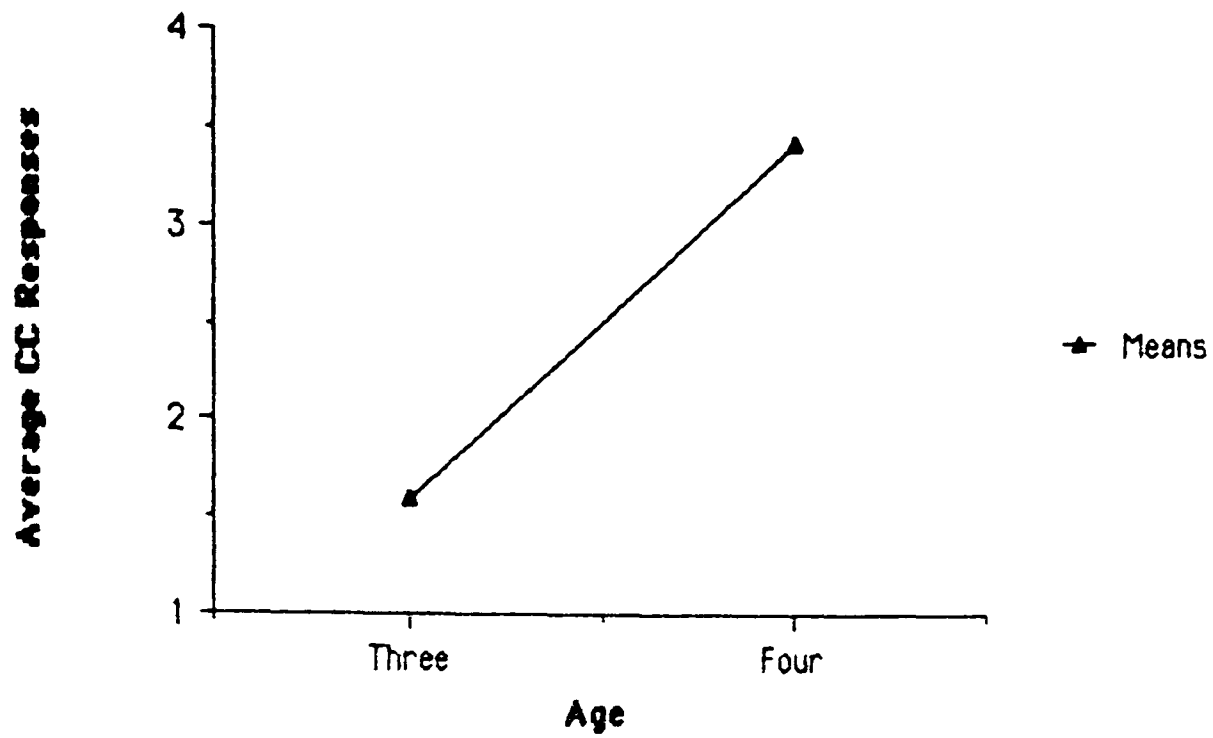
The significant main effect for Task indicated that there was a significant difference between at least two of the three Task groups. Differences between the means of the three groups AC, DISC and ADD was tested using the Newman-Keuls test. A graphical representation of this comparison is presented in Figure 7.3.3 (c). There was a significant difference between the AC task and both the DISC ($p<.01$) and ADD ($p<.05$) tasks. The majority of CC responses were made on the AC task, and the least on the DISC task. Signifi-

cantly fewer correct responses were made on the DISC task than on the ADD task ($p < .05$).

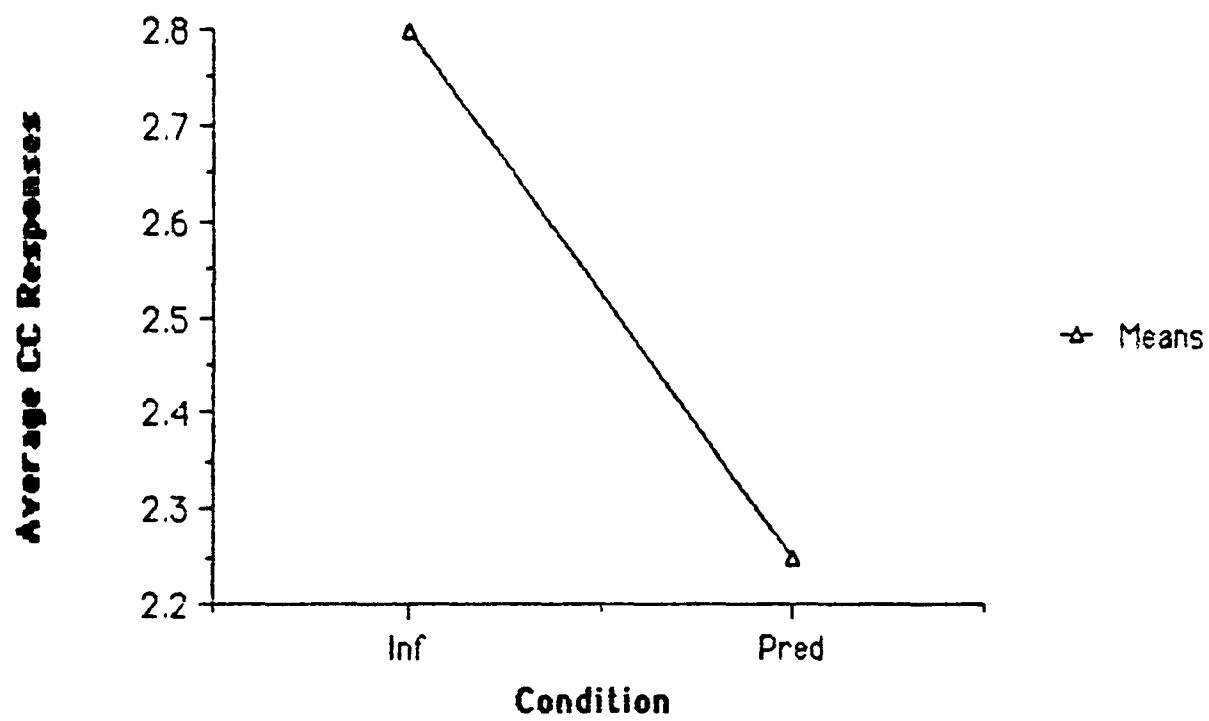
These results are contrary to the results of the analysis of single Correct responses, which not only showed that 4-year-old's responses on all 3 tasks were equivalent, but also indicated that 3-year-olds did better on DISC than on ADD tasks. However, the analysis of paired responses indicates that both age groups show the same pattern of responses, but 4-year-olds make more Correct (CC) choices than 3-year-olds on all tasks (Age main effect). Figure 7.3.4 shows the pattern of responses made by the two age groups on the 3 tasks. This figure simply illustrates that although there were no significant interaction effects, the pattern of results in the two age groups is different. The difference between the ADD and DISC tasks is much smaller in the younger group.

The different pattern of results obtained from the two analyses was possibly influenced to a large extent by performance on DISC tasks. As previously mentioned, the fact that children are using a relational method in DISC tasks can only be gauged by considering paired responses. A comparison of Tables 7.3.1 and 7.3.3 shows that the 'correct' scores of both age groups drop dramatically when responses are paired, especially in the DISC tasks. This indicates that children were possibly using Matching methods in the DISC tasks and the high single Correct scores (Table 7.3.1) could be result of this. An investigation of the types of INCORRECT responses made by children will show whether this is a viable proposition.

Fig 7.3.3. Effects of: (a) Age on CC Responses.



(b) Condition on CC Responses.



(c) Task on CC Responses.

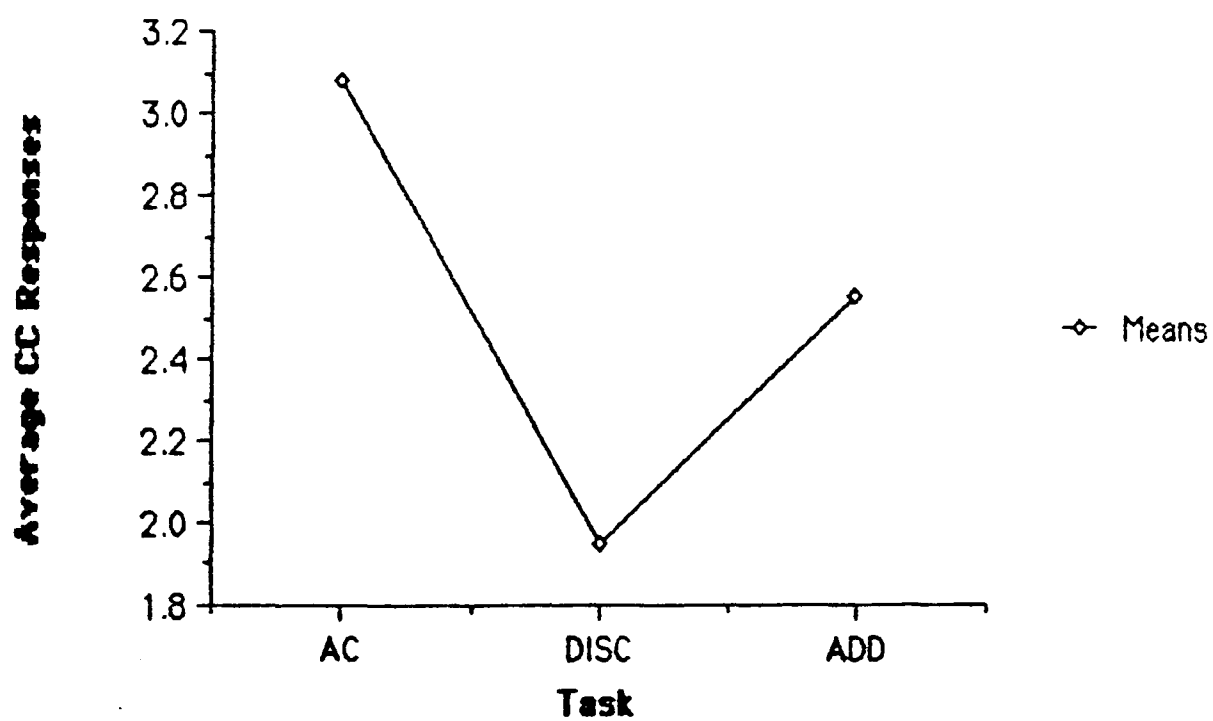
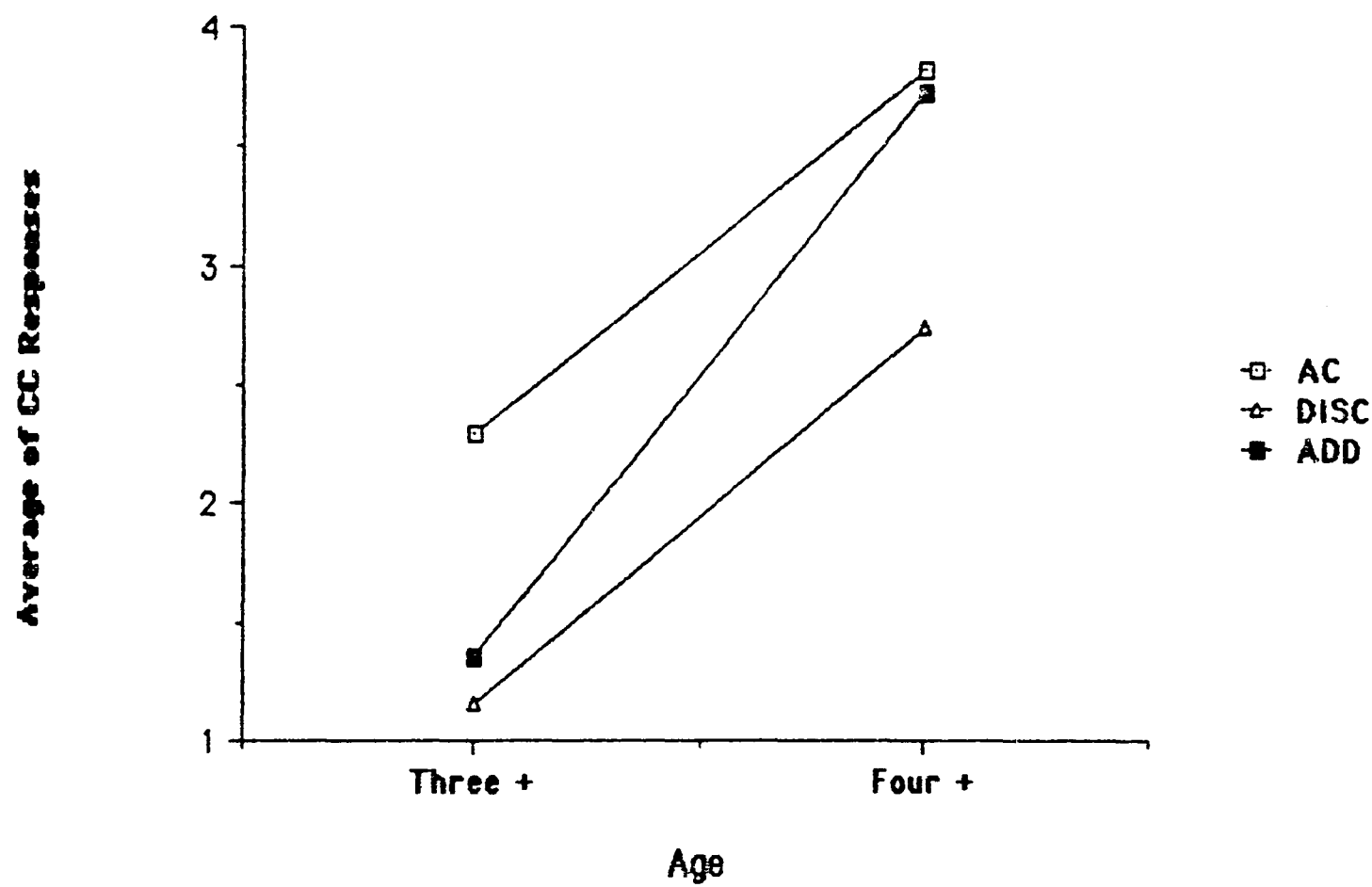


Fig 7.3.4. Pattern of Responses of Two Age Groups on the 3 Tasks.



It was suggested that a large number of errors arise because children focus on end states and match instruments to effects. Results of previous Experiments indicate that children who behave in this way seem to concentrate on the Salient end state (when two end states are present). The findings of previous experiments also suggest that children find it difficult to use the discounting method consistently. They also seem to prefer choosing single causes to 'adding' two separate causes to explain a combined effect (Experiment 3). To find out whether the errors they made were random ones, or were influenced by either of the factors described above, an analysis of the types of errors children made, on each task in each condition, was carried out.

Incorrect Responses

Responses were initially coded as CORRECT or INCORRECT but the INCORRECT responses were divided up into choices of SINGLE (e.g. water/ wet cup etc.) and JOINT (hammer and water/ wet-broken cup, etc.) instruments or effects. Since the Tasks used in this experiment used different types of sequences the nature of the errors varied from task to task. In some tasks a SINGLE response is correct whereas in others the JOINT response is correct. Therefore errors made within each task and condition will be described separately.

Due to the proportional nature of the data, as well as the small numbers of responses made under each of the categories of responses in certain Tasks and Conditions, statistical analyses of errors was not viable. The probability that errors arose randomly was calculated and a purely descriptive approach was taken in dealing with the Incorrect responses.

I. AC TASKS:

INF-AC - Sequences in this task were of the form:

- (a) Cup---H/**W**/H&W---Wet Cup
- (b) Cup--**H**/W/H&W---Broken Cup

In these and following examples the letters in **bold** type are the **Correct** responses. S and NS refer to the type of transformation shown in the sequence (broken is a Salient transformation whereas Wet is relatively Non-Salient.) This categorisation is exactly the same as in previous experiments.

Errors in this task consist of choice of the wrong instrument (H in (a); W in (b)) or conjoint instruments (H&W). There being three choices, the probability of an incorrect response arising by chance is 0.33. Using the same procedure as for the Correct responses, the probabilities of the incorrect responses occurring by chance were calculated. The average incorrect responses are presented in Table 7.3.5. The proportions of INCORRECT responses obtained were all significantly less than the proportions expected by chance ($p<.05$).

TABLE 7.3.5 MEAN (out of 10) INCORRECT CHOICES: AC-TASKS

INFERENCE					PREDICTION				
JOINT		SINGLE			JOINT		SINGLE		
MEAN	S.D	MEAN	S.D.		MEAN	S.D	MEAN	S.D.	
3+	1.4	1.3	1.1	1.1	2.4	1.6	1.7	1.9	
4+	0.7	1.1	0.2	0.4	1.6	1.4	0.3	0.7	

PRED-AC - The sequences in this task (PRED-AC) were of the form:

- (a) Cup--water--- ? **WC**/WBC/ BC
- (b) Cup--hammer---? **WC**/ WBC/BC

Errors consisted of choosing either a conJOINT state or the wrong state (e.g. WBC or BC for (a)). The wrong state is the state which cannot be produced by the instrument given in the sequence. The mean number of INCORRECT responses are given in Table 7.3.5. Again, the probability of choosing an incorrect response is 0.33 and it was found that all the errors made in the PRED-AC task, by both age-groups, were significantly below the proportions expected by chance.

Very few errors were made in the AC tasks. Almost equal numbers of JOINT and SINGLE responses were made in the INF Condition by the 3-year-olds. In the PRED condition, both age groups mostly erred in choosing a JOINT end-state (e.g. WBC for sequence (b) above). Their errors, however, were significantly below ($p < .01$) the proportions expected by chance indicating these children were not acting randomly. The majority of JOINT errors suggest that these children may have been attracted by the two states in these photographs simply because they were different from the single state photographs. Another possibility is that they saw the appropriate instrument/state in the JOINT photograph and chose it despite the additional instrument.

In order to check this children were asked why they had chosen the JOINT photograph. The 3-year-old's answers were very inconsistent. The majority replied with: "I don't know" or "Because it is" (16/24); others (8/24) pointed to the correct effect in the JOINT photograph. The 4-year-olds almost always (10/16) mentioned the correct instrument/effect in the JOINT photograph. Thus, it seems that the JOINT choice may have distracted the children to some extent.

II. DISC TASKS:

INF-DISC - The sequences in this task were of the form:

(a) Wet Cup---H/W/H&W---WetBroken Cup

CODED: C I J

(b) Broken Cup---H/W/H&W---WetBroken Cup

CODED: I C J

Responses could be coded Correct (C), INCorrect (I), or JOINT (J), as shown in the examples above. Both I and J were incorrect responses. The I-errors consisted of choosing the wrong instrument, associated with one of the states in the end photograph, which was not the result of the transformation depicted in the sequence (e.g. W for (a), or H for (b)). The mean number of errors is presented in Table 7.3.6.

Three choices were given to the children, C/I/J, in each sequence. The probability of choosing any one of these is 0.33. The JOINT errors of the 3-year-old group were significantly below chance level. The proportions of I errors made by this group were not significantly different from the proportion expected by chance; 4-year-old's I errors were significantly less than expected by chance.

It has been proposed that errors of the I-type occurred because children were not relating the beginning and end states of the sequence, but focusing simply on end states. Although the majority of errors made by both groups were of the I-type, this proportion could have been obtained by chance in the younger group. Children may have been making choices at random either because they were not relating the elements in the sequence or because they found it difficult to discount.

TABLE 7.3.6 MEAN (out of 10) INCORRECT CHOICES: INF-DISC

INFERENCE - DISC TASK				
JOINT ERROR		I-ERROR		
	MEAN	S.D.	MEAN	S.D.
3+	0.2	0.4	3.7	1.2
4+	0.8	1.7	1.6	0.7

Interestingly, very few JOINT errors were made in this task. When asked why they chose a JOINT photograph all the children replied with: "I don't know" or, " 'Cause I did!" The relatively minimal proportion of JOINT errors in this task compared to the PRED-AC task suggests that children were distracted by these choices in the latter task because they found the PRED condition more difficult to deal with than the INF condition. This speculation is supported by the finding that performance was significantly better in the INF than in the PRED condition.

PRED-DISC - The form of sequences in this task were:

- (a) Wet Cup--hammer--- ? WC/WBC/BC
CODED: S C A
- (b) Broken Cup--water--- ? WC/WBC/BC
CODED: A C S

In this condition, there was effectively one correct (C) and two incorrect choices. The incorrect choices were both SINGLE. Single choices were coded for SIMILARITY (S) or ASSOCIATION (A), as shown in the example above, because children could choose either the single state Associated with the given instrument (e.g. BC in (a); WC in (b)), or the end state Similar to the first state (e.g. WC in (a); BC in (b)). Table 7.3.7 presents the average S and A choices made in this task.

Almost all the errors in this task were of choosing the single state associated with the given instrument. In the 3-year-old group, the Association errors were significantly greater ($p<.01$) than expected by chance. In the older group these errors were significantly below the level expected by chance ($p<.01$). These results suggest that children were not behaving in a random manner, neither were they taking the beginning state into account in these sequences.

TABLE 7.3.7 MEAN (out of 10) INCORRECT CHOICES: PRED-DISC

PREDICTION - DISC TASKS				
SIMILARITY		ASSOCIATION		
	MEAN	S.D.	MEAN	S.D.
3+	0.6	0.9	4.8	1.8
4+	0.3	0.5	2.1	1.3

Discounting in the PRED condition is slightly different from discounting in the INF condition. Both conditions require the child to hold the first state constant, but, whereas in the INF-DISC task the child has to find the cause of the added effect (broken in (a)), in the PRED-DISC task the child has to hold the first state constant and 'add' on the effect produced by the given instrument. It was thought that both these methods were 'discounting' methods according to the definition presented in section 7.1 since they both require that the first state should be taken into account and held constant. In addition, the first state must be related to the last in both conditions. In the INF condition this is the only way to figure out the transformation that has occurred in the sequence. In the PRED-DISC condition if the effect of the given instrument is not added to the first state then there will be no transformational rel-

ation between the beginning and end states.

The data in Tables 7.3.6 and 7.3.7 suggest, however, that children (especially 3-year-olds) find the PRED-DISC task more difficult than the INF-DISC one. Futhermore, their errors in the PRED-DISC task are more systematic than errors in the INF-DISC one.

III. ADD TASKS:

INF-ADD - Sequences in this task were of the form:

(1) Cup---H/W/H&WATER---Wet Broken Cup

CODED: S/NS/C

The correct choice was JOINT (H&W) as the Cup became both Wet and Broken. Errors consisted of choosing single instruments (either H, or W, in this example) to account for the two end states. Choice of single instruments indicate that children were not taking both beginning and end states into consideration when making their choices of causal instrument. Errors in this task were categorised as: S - choice of instrument for the salient transformation, or NS - choice of instrument for the non-salient transformation.

The mean number of incorrect responses are given in Table 7.3.8.

TABLE 7.3.8 MEAN (out of 5) INCORRECT CHOICES: ADD-TASK

		INFERENCE				PREDICTION			
		SAL-CHOICE		NSAL-CHOICE		SAL-CHOICE		NSAL-CHOICE	
		MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
3+		2.7	1.2	0.7		2.6	0.8	1.3	1.1
4+		1.3	1.1	0	-	0.9	1.1	0.3	0.5

Most of the errors were of the S variety. The S-errors made by 3-year-olds were significantly above chance expectations (p<.05). The older children's S-scores did not vary significantly

from chance expectations. Although the two instruments responsible are presented together (unlike Experiment 3) children, especially 3-year-olds, do tend to choose the single instrument associated with the salient end state (H in the example given above) when asked to find the instruments which could have caused the two end states. Relatively few NS choices (significantly below chance expectations ($p < .01$) - 3+) were made, again indicating that children focused on the more salient of the two end states.

This finding is especially striking in this Task because there is no potentially confusing first state. The object is presented in its standard form. Because of this, children are not required to discount the first state. Furthermore, conJOINT instruments were offered to make it easier for children to pick two instruments if they wished to do so. This data supports the findings of Experiment 3, in that, although one of the problems in dealing with sequences such as those used in Experiments 1 and 2 may be that discounting is difficult, younger children also find it difficult to deal with TWO states. They seem to prefer to focus on one.

PRED-ADD - The sequences in this task, were of the form:

(1) Cup---hammer&water--- ? WC/WBC/BC

Again, the correct response was JOINT (WBC), the combined effects of the two instruments. Errors consisted of choosing single states associated with only one of the instruments given. These errors were classified as:

S - choosing a salient state (BC, in the example given), or

NS - choosing a non-salient state (WC, in this example).

Table 7.3.8 shows that, again, the majority of errors were of the S variety. This is especially striking in the 3-year-old

group, where the number of S-errors (significantly more than expected by chance, $p < .01$) were double the number of NS errors (not significantly different from chance expectations). All errors made by the older children were significantly below ($p < .01$) the proportions expected by chance. Once again, these data lend support to previous findings and indicate that younger children prefer to deal with single features and in so doing, choose the most salient ones.

7.4 Discussion

The results of the analyses of both the SINGLE and CONSISTENT CORRECT responses confirmed the predictions that Age and Task significantly affect these responses. The prediction that children would do better on the PRED condition was not supported by the results. Children of both ages actually made more Correct (C and CC) responses in the INF condition. It is possible that children deal differently with object sequences than with narrative sequences, such as used by Schmidt and Paris (1978).

Analyses of both single (C) and consistently correct (CC) responses showed significant main effects for Age, Condition and Task. However, although there was a significant Age by Task interaction for (C) responses, this interaction was non-significant for (CC) responses. It was suggested that pairing responses, especially in the DISC tasks, produced lower average CC responses in both age groups, thereby making the overall patterns more similar in the two groups and overriding the differences which would contribute to such an interaction.

Figure 7.3.4 shows that while 4-year-olds ADD and AC scores were much higher than their DISC scores, in the 3-year-old

group, the DISC and ADD scores were both far lower than AC scores. The possible Age by Task interaction suggested by the figures in Table 7.3.3 (and Figure 7.3.4) may have been masked because the overall pattern (AC easiest---ADD---DISC hardest) was the same in both age groups. Although 4-year-old's scores on ADD and DISC tasks were more disparate than 3-year-old's, the younger children did make less correct responses on DISC than on ADD tasks overall.

Both 3-and 4-year-old's average CC scores in DISC tasks were significantly above chance expectations. Although fewer CC choices were made by younger children on this task, those that were made did not occur by chance. On the ADD tasks, however, 3-year-olds' average Correct responses may have been chosen at random (not significantly different from chance expectations). So, although slightly more Correct choices were made by 3-year-olds on ADD than on DISC tasks (Table 7.3.3) they performed more 'randomly' on the ADD tasks. This finding lends some credence to the suggestion that the greater discrepancy between these two tasks in the 4-year-old group, in conjunction with the similar overall pattern of results in the two groups, largely contributed to the significant Task effect and may have masked a possible interaction. Furthermore, the high scores in the AC tasks made by both ages may also have contributed toward masking an Age by Task interaction effect.

The finding that the PRED Condition was more difficult than the INF one was surprising and is difficult to explain theoretically as both Conditions require children to use the same methods (matching, or relational, or adding) to deal with the sequences. A closer look at the Tables of means (7.3.1 & 7.3.3) show that the greatest difference between Conditions was on the AC-tasks where the children made a number of JOINT errors. It is possible that it was

this difference which largely contributed to the Condition effect. One way to check this would be to replicate this study either leaving out the AC task altogether, or substituting the JOINT choices with Random ones.

The analysis of Incorrect responses showed that both age groups made fewest errors on the AC-tasks. Errors made by 4-year-olds were significantly below chance expectations on all tasks. These findings support the hypothesis that young preschoolers make most correct responses when a Matching method can be used successfully (AC task). Although both 3- and 4-year-olds can discount (as witnessed by their above chance responses on DISC tasks), the 3-year-olds also made a significant number (above chance) of Association errors (matching the given instrument to the effect it could cause, such as water to wet, rather than choosing an end state after discounting the first state given) on the PRED-DISC tasks. This indicates that they were using a Matching Method rather than a Relational one.

Interestingly, the 3-year-old's errors in the ADD tasks, too, were significantly above the level expected by chance. Children tended to match a single, salient effect to the instrument capable of producing that effect, regardless of the fact that TWO instruments, or TWO effects, were presented (in the different conditions). It seems that children prefer to choose SINGLE responses even when conJOINT ones are available, as the correct (JOINT) choices on these tasks were not significantly different from chance expectations.

The results of this experiment support the hypothesis that Matching methods are preferred to Relational ones. It was also shown that although both age groups can discount, they were generally better at 'adding'. However, for the reasons discussed above,

these results were not totally conclusive. In order to clarify whether adding is easier than discounting, for both age groups, this experiment should be rerun, leaving out the AC task, as high scores on this task may swamp differences between the other two tasks.

As it has been shown that children do better on Inference tasks than on Prediction tasks, it may be a good idea to run two separate experiments, one focusing on 3- and 4-year olds' performance on INF-DISC and INF-ADD tasks, the other focusing on their performance on the PRED DISC and ADD tasks. This might highlight any significant differences between the two age groups on these two tasks which did not come out in the present analysis.

The results of this experiment also provide support for the view that children as young as 3-years can use a Relational method. However, they do not use this method as consistently as older children. Older children are also better at 'adding' or integrating two features. Overall these results suggest a preference for associative-matching in the 3-year-old group.

CHAPTER EIGHTYOUNG CHILDRENS PRODUCTION OF 'STORY' SEQUENCES: CAUSAL OR
ASSOCIATIVE ORDERING8 Experiment 6: Preschoolers' Ordering of Sequences8.1 Introduction:

The results of the previous experiments showed that although the younger children can easily find causes when an associative-matching method could be used, they have more difficulty in doing so on tasks involving discounting or adding. One possible explanation for these findings was that young children did not consistently relate the object states shown in the sequence in terms of transformations. This suggestion received some support from the results of Experiments 4 and 5. Experiment 6 was designed to investigate how children relate elements into a sequence when given the opportunity to structure sequences.

It was suggested that younger children may use a more associative-causal mode of reasoning than older children. Not only is this simpler than causal reasoning involving discounting, but also, this may be the earliest mode of ordering events used by children. Although causal knowledge may be rooted in associative knowledge, it is ultimately very different. The difference lies in the way objects and events are related to each other (see Chapter 1).

How do young children relate objects and events in their world? Do they relate objects and events primarily because - (1) they are associated to each other in some way, or (2) because they

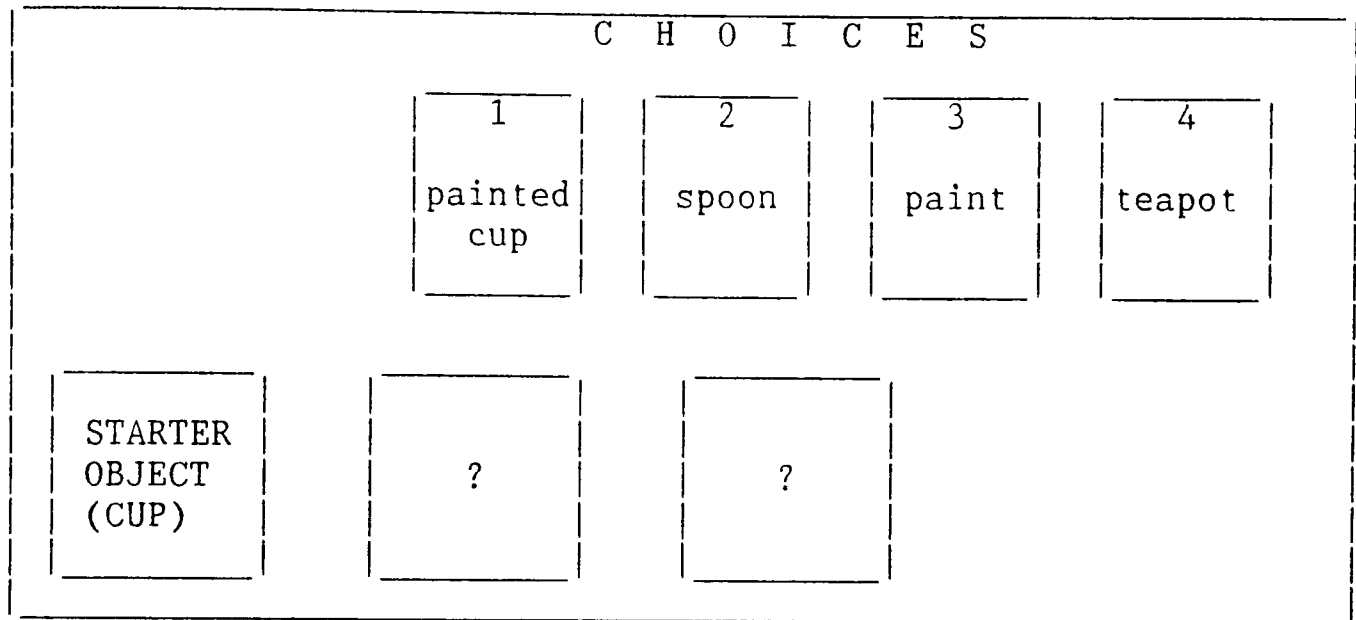
are related by transformation or change? The way children spontaneously relate objects or events could be a good indicator of the way they structure events. If it was found that at different ages children's preferred methods of structuring were different, for example, if 3-year-olds preferred associative structures to causal ones, this could explain why, in previous experiments, the younger children made a large number of associative choices despite displaying an ability to make causal choices. Thus, the present experiment was designed in order to investigate children's preferred ordering of objects and events. Three to six year old children were asked to construct 'stories' about different objects, using photographs, in an attempt to find out whether these children spontaneously organised the photographs into a causal structure. Photographs were used in order to minimise any verbal load.

The children who participated in this experiment were presented with six Problems. These Problems consisted of sets of photographs. Each set contained the photographs of a starter object and four choice objects. Children were required to choose two photographs which, when combined with the photograph of the starter object would tell a story about it. For example, they would be shown a starter object (eg. cup) and then asked to make a story about something that happened to it. Four choice photographs, from which they could only choose two, were presented to the children to help them make their stories as illustrated in Diagram 8.1.1. Full details of the Problems used in this experiment are given in Section 8.2 (Materials).

In the previous experiments the children were presented with sequences that were already causally structured and they had to follow that structure. By allowing them to choose their own struc-

ture on a series of objects, it was thought that their preferred structures would emerge. These structures might give some indication of preferred methods of relating objects at different ages. On the basis of the previous results, a developmental difference was expected. It was hypothesised that 3-year-olds would make the greatest number of associative choices ('stories') while 5- to 6-year-olds would make the greatest number of causal choices.

DIAGRAM 8.1.1 AN EXAMPLE OF PROBLEMS USED IN EXPERIMENT 6



Each of the Problems comprised a starter object (S0) and four choices. Therefore, there were 12 possible 3-element combinations, or 'stories'. For example, using the Problem depicted in Diagram 8.1.1, the combinations shown in Diagram 8.1.2, are all possible. Each story, or 3-element combination, has a particular structure (see Diagram 8.1.2). (N.B. The same structures and categories were possible for all the problems used in this experiment, as shown in Appendix 6 (B). As Diagram 8.1.2 shows, it is possible to distinguish two major types of stories from these constructions: the Causal and the Associative.

DIAGRAM 8.1.2 THE POSSIBLE 'STORY' COMBINATIONS

STORY COMBINATION	STRUCTURE	CATEGORY
1. CUP - paint, painted cup	C P PC	CAUSAL
2. CUP - painted cup, paint	C PC P	CAUSAL
3. CUP - paint, spoon	C P S	ASSOCIATIVE-RANDOM
4. CUP - spoon, paint	C S P	ASSOCIATIVE-RANDOM
5. CUP - paint, teapot	C P T	ASSOCIATIVE-RANDOM
6. CUP - teapot, paint	C T P	ASSOCIATIVE-RANDOM
7. CUP - painted cup, spoon	C PC S	ASSOCIATIVE-SIMILAR
8. CUP - spoon, painted cup	C S PC	ASSOCIATIVE-SIMILAR
9. CUP - painted cup, teapot	C PC T	ASSOCIATIVE-SIMILAR
10. CUP - teapot, painted cup	C T PC	ASSOCIATIVE-SIMILAR
11. CUP - spoon, teapot	C S T	PURELY ASSOCIATIVE
12. CUP - teapot, spoon	C T S	PURELY ASSOCIATIVE

KEY: C = cup; PC = painted cup; S= spoon; T = teapot; P = paint

A CAUSAL STORY is one in which the starter object is transformed, and the cause of the transformation is given (stories 1, and 2). Although, the ordering of elements is different, both stories show that a change has taken place, and provide the causal instrument. Although the causal instrument (paint) may be related to the effect (painted cup) either by the similarity of cause and

effect (red paint), or by a causal-association between cause and effect (ie. paint is used to paint things, and can, by virtue of its nature, colour objects). The important thing in this experiment however, is that by choosing paint and painted cup, the child **chooses a causal structure** in her ordering of the elements.

Only the choice of the transformed starter object and the causal instrument was considered as a causal choice. The order in which the children placed these elements (see Diagram 8.1.2:(1) SO - Instrument - Transformed SO; or (2) SO - Transformed SO - Instrument) was not considered important if the children verbally expressed the causal relation correctly: eg. "The cup got painted; you painted it with this paint". Ordering (instrument before, or after, effect) was not given much significance in this experiment. It was thought that young children may not use the notion of the temporal priority of cause to effect when ordering their pictures, simply because they have not been taught to order pictures or photographs in that way. They would have to be aware that something had changed the cup, choose the correct instrument and describe the order of events properly for their stories to be rated causal however.

The second causal sequence (2) in Diagram 8.1.2 does not follow a temporal order such as the first. There is a cup, a painted cup and an instrument - how can we say this ^{is} a causal ordering using the definition given above? It was thought that children might know the correct temporal order the sequence follows but might not place their photographs in the way the experimenter wanted (1). Because it was suspected that (for the same reason) adults too might use order (2) to make causal stories, ten adults were tested on the same sequences as the children (see Appendix 8). It was found that 20% of

adults' stories were of the order (2) type although they described the sequences in the correct temporal order. So it was decided to categorise these as causal stories if children's verbal justifications indicated a knowledge of temporal order. To check this all children who made stories using order (2), but did not give spontaneous verbal descriptions of their stories, were asked to describe what happened in their story.

An ASSOCIATIVE STORY is one in which elements are combined because of similarity (cup and painted cup, are similar because they are both cups), because they all belong to the same category (eg. fruit: apple, orange, banana), or because of their utility. Utility is used here in the sense that objects which are used together and thus often experienced contiguously, or conjunctively (eg. cup and spoon, teapot and cup and spoon) may be associated in terms of usage (for example, in the words of one four-year-old girl, "cup and spoon go together because you have to mix your tea").

The Associative stories shown in Diagram 8.1.2 are of different types: Associative-Random, Associative-Similar, or Purely Associative. The common element in all these associative stories is that at least one element was chosen on the basis of an association between that element and the Starter Object (SO), the remaining element could be chosen on the basis of similarity (with the SO), association (with other elements), or at random.

The CAUSAL stories are asymmetrical, involving change and some notion of production and priority. The ASSOCIATIVE stories on the other hand are symmetrical, and do not require any notion of change, production, or priority. They are symmetrical in the sense that any one element may be associated with any other (this is especially true of the Purely associative stories), in any time order.

The causal stories are asymmetrical because there is a fixed time order cup then painted cup and all the elements are not associated to each other. Cup is not associated to painted cup. Rather, the cup is transformed, an action has taken place to make it change, and this action (painting) was effected by use of paint. Paint is not associated with cup, but paint---painted may well be an Associative-Causal link.

In previous experiments it was found that the salience of transformations influenced children's causal inferences. Salient transformations were those in which objects were dramatically changed from their common forms (eg. broken, or cut), that is, like Humpty Dumpty, the object was intrinsically altered. Non-Salient transformations were those in which objects retained their common forms, but had things added to them (eg. wet [whole] banana, painted [whole] cup, etc.). This distinction was retained in this experiment.

In an attempt to control for the effects of salience, two sets of Problems were designed:

Salient Problems contained photographs of the starter objects transformed such that their common form was altered:

eg. SMARTIES - knife; CUT box Smarties ; sweets; chocolates

Non-Salient Problems contained photographs of the starter objects transformed in unusual ways, but such that their standard form (whole) was **not** altered:

eg. CUP - paint&brush; PAINTED (whole) cup; teaspoon; teapot

Thus, in the Salient problems, transformations altered the standard forms (whole cup---broken cup) of the objects, while in the Non-Salient problems, the standard form (whole), was retained, but transformations were **added onto** the standard form:

In previous experiments, the effect of salience was found when two **end** states were present. In this experiment, although objects were only altered in one way, the two sets of Problems were designed in order to investigate whether Problems containing Salient transformations (PS) would elicit more causal stories (simply because there was a striking departure from a standard state) than problems containing non-salient transformations (PNS).

As this experiment required children to follow more complex verbal instructions than in previous experiments, as well as asking them to construct 'stories', a test of verbal skills was administered. This was the British Picture Vocabulary Scale (BPVS) which is a test of children's receptive vocabulary. It was predicted that verbal skills would not affect children's construction of causal stories as causal reasoning and causal ordering were thought to be cognitive functions which should be relatively independent of language, especially as verbal justifications were not compulsory for success in the task.

Predictions

It was predicted that:

1. Older children would make far more causal stories than the younger ones; that is, 5-year-olds would make the most causal stories, followed by the 4- and 3-year-olds, respectively. Three-year-olds were expected to make far more associative stories than the 4-year-olds. It was expected that 5-year-olds would make the least number of Associative stories.
2. The Salient Problems would elicit a greater number of Causal stories than the Non-Salient ones.
3. Verbal skills would not significantly affect the production of Causal story sequencing.

8.2. Method

(a) Subjects:

Seventy-seven preschool and first-school children participated in this experiment. There were 26 3-year-old children (range = 3-1 to 3-11; $x = 3-7$), 30 4-year-old children (range = 4-1 to 4-11; $x = 4-6$); and 21 5-year-old children (range = 5-0 to 6-0; $x = 5-7$) in this sample.

(b) Design:

A mixed design with repeated measures on Problem-Type (2: Salient, Non-Salient) was used. Age (3: 3+, 4+, 5+) was the Between factor.

(c) Material:

- (1) The British Picture Vocabulary Scale (BPVS) was administered. The children were tested individually in the same area where the experiment was conducted. The BPVS was presented as a picture game.
- (2) The 6 sets of Problems were divided into 3 Salient problems (PS) and 3 Non-Salient Problems (PNS). Each problem consisted of a starter photograph of a whole object (cup, towel, apple, etc.) and 4 choice photographs. Two of the choice photographs could be combined with the starter to make a causal story.

In addition, 4 problems were created to familiarise the children to the procedure as well as to help them understand what they had to do in this experiment. Two familiarisation problems were of the PS type, and the other 2 were of the PNS type to ensure that children had equal familiarity with both types of problems. All Problems designed for this experiment, including the familiarisation materials, are presented in Diagram 8.2.1.

DIAGRAM 8.2.1 THE PROBLEMS USED IN EXPERIMENT 6

-----Familiarisation Sequence-----				
STARTER OBJECT	CHOICES FOR COMBINATION			
	(1)	(2)	(3)	(4)
1. PAPER	scissors;	cut paper;	[pen;	ruler]
2. CUCUMBER	knife;	cut cucumber;	[onion;	potato]
3. PLATE	water;	wet plate;	[fork;	knife]
4. DRAWING	eraser;	partially erased drawing;	[pen;	colours]
-----Experimental Sequences-----				
STARTER	NON-SALIENT CHOICES			
	(1)	(2)	(3)	(4)
1. CUP	paint&brush;	painted cup;	[teaspoon;	teapot]
2. WOOD	tomato sauce;	sauce on wood;	[hammer	nails]
3. APPLE	pen;	apple+picture;	[orange;	banana]
	SALIENT			
4. SMARTIES	knife;	cut box Smarties;	[sweets;	chocolate]
5. TOWEL	scissors;	cut towel;	[soap;	tap water]
6. CUP	hammer;	broken cup;	[plate;	spoon]

N.B. In this Diagram, the first two choices for each problem are the Causal ones. The choices in [] brackets are the purely associative choices.

(d) Procedure: The experimenter spent a week with each group of children, assisting teachers and playing with the children, prior to starting the experiment. The BPVS was introduced as a picture game, and each child was tested individually by the experimenter. The parents of some of the children declined permission for their children to be tested on the BPVS although they were willing to allow them to participate in the experiment. Thus, although 77 children participated in this experiment it was only possible to get BPVS scores for 62 children (20 3-year-olds, 25 4-year-olds and 17 5-year-olds). The children were familiarised with the experiment in a second session.

An attempt was made to record the verbal stories of the children but, unfortunately, this was not viable due to poor recording facilities as well as classroom conditions in the schools visited.

Familiarisation - The materials were introduced as a "new game". The child was told that in this game she would be asked to make stories about lots of things and that to help her make these stories she would be shown 4 photographs. She was told that she must look carefully at these photographs and then choose the two photographs, which, when combined with the starter object, made the best story about something that happened to that object.

Having been given this general introduction, the child was then shown the starter photograph for the first of the familiarisation problems. She was asked to name the object in the photograph. Then, she was asked to make a story about that object, with the help of any two of the 4 choice photographs that the experimenter proceeded to lay out in front of her -

E: "Look, here are some other photographs to help you make the story. I want you to look carefully at all of them (here the experi-

menter pointed to each choice photo and asked the child to describe it); now, choose two of these (pointing to the choices) to make a story of what happens to the (name of starter object)".

Once the child had chosen the two objects, the experimenter told them to place these *next* to the starter photograph. Then, the child was asked to tell the experimenter what happened in her story. Younger children mainly named each of the components, eg.

"Cup, paint, its got paint on"; or "Cup, spoon, paint."

Interestingly, when the children produced Causal stories they all stated that the instrument had produced the effect - "Painted with the paint". For the Associative stories quite a few of the younger children (mainly 3-year-olds) did not give a verbal answer at all. When asked what their story was, they simply pointed at the photographs they had chosen, and said: "There". Others just listed (named) each of the 3 elements in their story. When asked *why* they had combined those particular elements they replied " 'Cause I did" or "' Cause it's a story".

Older children gave more connected answers, eg.

"It's a cup, and then there was this paint, and it did get painted, see." or - "There's a cup, and another one and it's got red on it, and the tea was put in". As there was a great variability in the verbal responses, even among older children, it was decided not to analyse the verbal responses of the children separately, especially as it was also difficult to obtain recordings. The verbal responses were used to check that children were not responding randomly for purposes of categorisation of responses. Thus, children were always asked for a verbal version of the story they had constructed, but were not pressed to give one if they appeared reluctant.

When the child completed a familiarisation problem (FP) she was asked to tell the experimenter the story. The experimenter 'read' out the story that the child had constructed if no adequate verbal response was forthcoming. Reading the story involved naming the various elements and trying to connect them to each other, for example:

E: "Look, in the beginning you have a piece of paper, and then you chose a pen, and a ruler. All these things go together, don't they?"

or - E: "Look, in the beginning you have a piece of paper, and you chose some scissors, and a cut piece of paper. Did these scissors cut the paper up?"

This was done in order to make it clear to the children that the 3 elements should be connected together in some way and indeed that they could be combined to make a story about something that had happened to the starter object.

It should be noted that only the stories that children had constructed were read out to them. The experimenter never offered an alternative construction. This procedure was followed in an attempt to ensure that the children were not influenced to make constructions which they otherwise might not.

Experimental Procedure - The experiment was conducted a couple of days after familiarisation. All 6 problems (3 PS and 3 PNS) were presented to each child in the same session. The problems were presented in random orders. The PS and PNS problems were not presented as different sets in order to control for any response bias that might have been established if children had experienced either 3 salient or 3 non-salient problems in succession. The two Problem sets were separated for the analysis of responses.

The procedure itself was much the same as the familiarisation, exactly the same protocol being used. The only difference was that the experimenter did not 'read' any of the completed stories back to the child. Each child was asked to tell the experimenter what had happened in her story. Children who replied "I don't know", or did not respond verbally, were then asked why they had chosen the two objects to combine with the starter. If no adequate verbal response was given at this point, the experimenter complimented the child on her story, and presented the next problem. This approach was taken because it was noticed, during familiarisation, and in previous experiments, that some children became distracted and uncomfortable when pressed for verbal responses which they were either unwilling or unable to give. As it was thought that they might become tense about the experiment and see it as a testing situation in which they were unable to perform adequately an attempt was made to reassure them that making a story with the pictures was what was important, and the verbal explanation did not matter.

Only the photographic sequences constructed by children were coded as a 'stories', not their verbal explanation. From henceforth the term 'stories' refers only to these sequences.

8.3 Results

The stories made by the children were coded as either Causal (C) or Associative (ASS) using the following criteria:

C-STORIES - contained a photograph of the transformed starter object and a photograph of the instrument responsible for the transformation, for example: (SO) = TOWEL (CHOICES = SCISSORS, CUT TOWEL).

ASS-STORIES - contained choices of at least ONE object associated

with the starter, for example: SO = TOWEL (CHOICES = WATER, SCISSORS).

Two independent raters and the experimenter coded the stories made by the children. There was 100% agreement between raters. The Causal stories will be considered first.

(1) CAUSAL STORIES:

Table 8.3.1 shows the means and standard deviations (in brackets) of the number of stories made in each category, for the two problem types (PNS and PS), by the 3 age groups.

TABLE 8.3.1 MEANS (out of 6) AND S.D.'S OF CAUSAL STORIES

PROBLEM TYPE			
AGE	PNS	PS	
3+	0.85	1.31	
	(1.01)	(1.26)	
4+	1.23	1.63	
	(1.07)	(1.23)	
5+	2.62	2.71	
	(0.67)	(0.56)	

KEY: PNS = NON-SALIENT PROBLEMS; PS = SALIENT PROBLEMS

The Probability of Causal Stories Arising by Chance

For each Problem children had 4 choices and were allowed to choose only 2 to construct a story. As 4 choices were given, there were six possible combinations of choices one of which is the Causal combination. The probability of the children choosing this one combination purely by chance is 0.17, and was tested using the procedure described in section 3.3. It was found that the proportions of C-stories made by children in each of the three age groups was significantly higher than expected purely by chance ($p<.01$), for

both PNS and PS. Children between 3-5-years reliably (ie. not by chance) make causal stories. Therefore these children are capable of constructing causal structures.

Age, Problemtype and Causal Stories

Reference to Table 8.3.1 shows that 3-year-olds made the least number of C-stories, and 5-year-olds made the greatest number of this type of story. Indeed the 5-year-old's scores were very near ceiling for both Salient (PS) and non-salient (PNS) problems. In general, however, there was a difference in the number of C-stories made for PS and PNS: PS seemed to elicit a greater number of C-stories than PNS.

The statistical significance of these findings was investigated by subjecting the raw scores to a 2-way analysis of variance for repeated measures with one Between factor (Age (3): 3+, 4+, 5+) and one Within factor (Problem Type (2): PNS, PS). The results of this analysis are presented in Table 8.3.2.

TABLE 8.3.2 SUMMARY TABLE (ANOVA) - CAUSAL STORIES

SOURCE	SS	DF	MS	F	PROB.
AGE (A)	63.306	2	31.653	18.63	0.0000 ***
ERROR	125.759	74	1.699		
PRBLMTYPE (P)	3.833	1	3.833	9.23	0.0033 **
PA	0.877	2	0.437	1.05	0.3540 ns
ERROR	30.736	74	0.415		

Where: * =p<.05 ** =p<.01 *** =p<.001 ns = non-significant

There was a significant main effect for Age (F(2,74) = 18.63, p<.0001), indicating that at least one of the 3 age groups differed significantly from the others in the number of Causal sto-

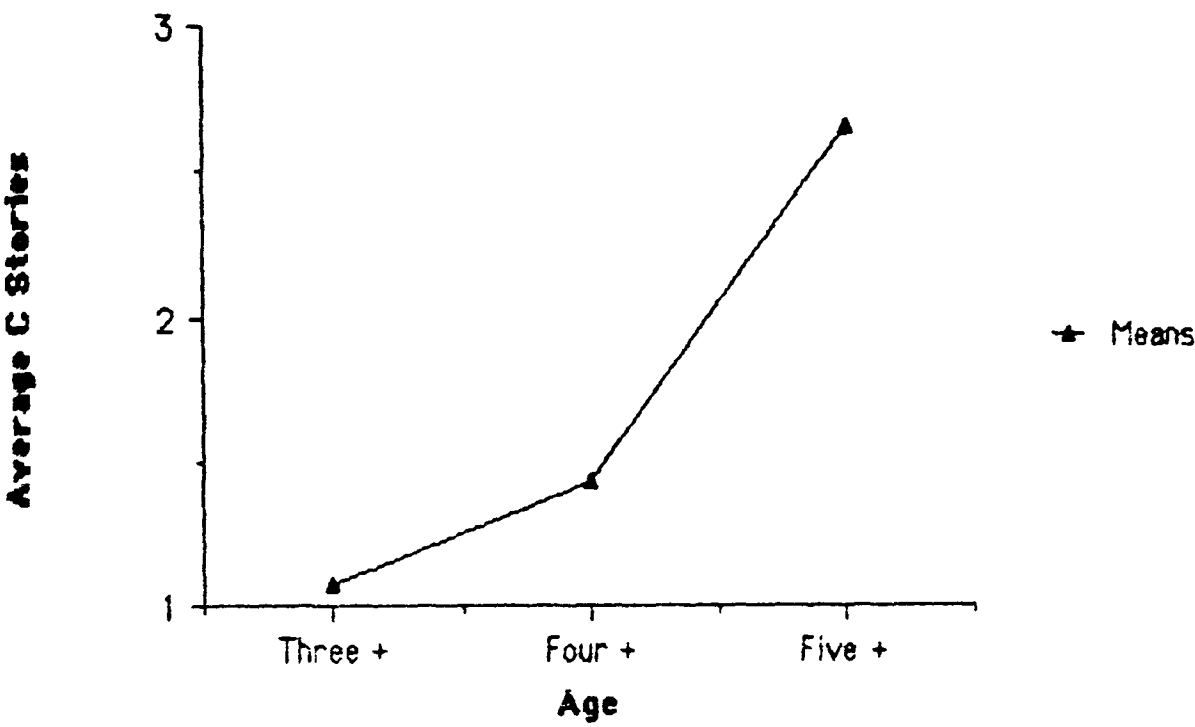
ries constructed. Post-hoc analysis (Newman-Keuls) showed that although there was no significant difference between the number of causal stories produced by 3 and 4-year-olds ($p > .05$), there was a highly significant difference between the number of causal stories produced by 3 and 5-year-olds ($p < .01$), with the older children making a greater number of C-stories. There was also a significant difference between the 4 and 5-year-olds ($p < .01$), with the older children again making a greater number of C-stories than the 4-year-olds. A graphical representation of these results is given in Figure 8.3.1(a).

There was also a significant main effect for Problem Type ($F(1,74) = 9.23, p < .01$). This indicated that more causal stories were made for one problem type (PS) than for the other (PNS) as shown in Figure 8.3.1(b). As the same children experienced PS and PNS (order randomized), it appears that Salient Problems (PS) definitely elicited more C-stories than Non-Salient ones (PNS).

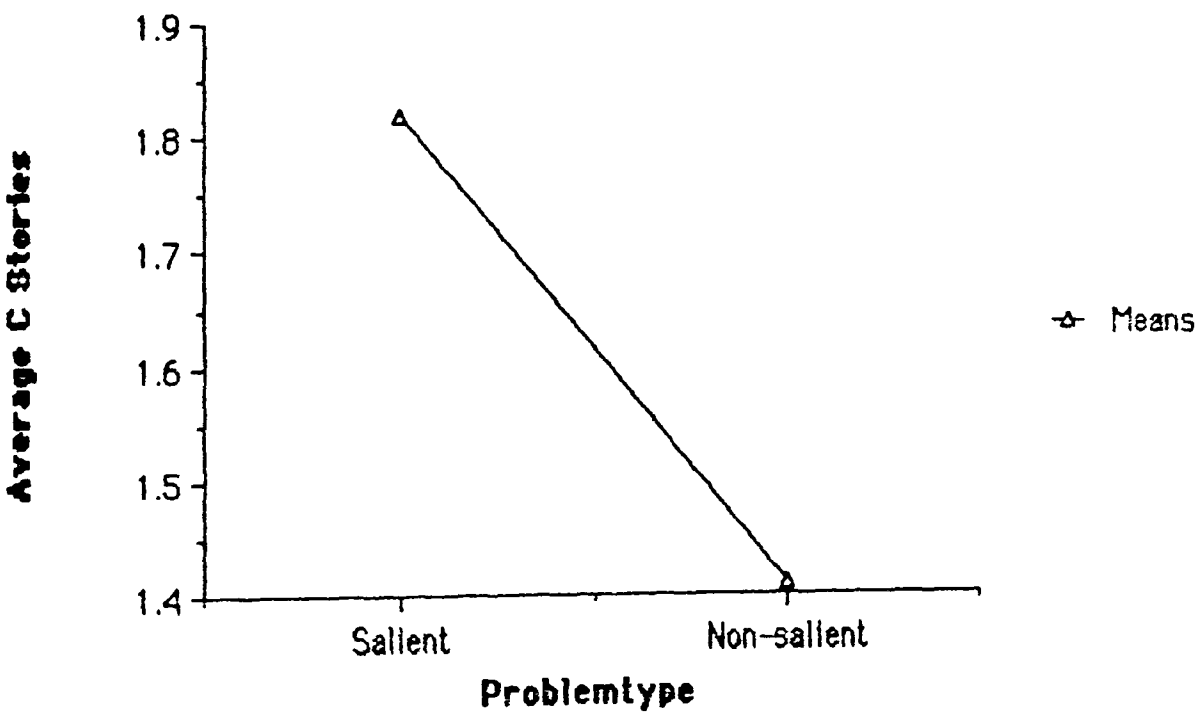
The Influence of Verbal Skills on Causal Structuring

Verbal skills were not expected to affect the number of causal stories made by the children significantly as very little verbal output was required for the tasks in this experiment. In relation to the children's understanding of the instructions, it was thought that the familiarisation procedure would be sufficient for children to understand what was required of them in this experiment. However, there was a possibility that children might use linguistic markers (names of objects and transformations) to construct sequences mentally before making their choices, or even in the process of making the choices. If children verbally constructed sequences, then their verbal ability would be an important factor in construction of causal stories, as verbal reasoning might improve their performance.

Fig 8.3.1. Effects of:(a) Age on Causal Stories.



(b) Problemtype on Causal Stories.



In order to investigate the effect of verbal skills on causal story construction, a verbal skills measure (B.P.V.S.) was included.

Only 62 of the 77 children were tested using the B.P.V.S., for the reasons explained above (8.2(d)). There were 20 3-year-olds, 25 4-year-olds, and 17 5-year-olds with B.P.V.S. scores. A stepwise multiple regression, with AGE and B.P.V.S. as the independent (predictor) variables, and causal-scores as the dependent variable, was conducted. This was done in order to test how much of the variance in the number of causal stories produced by the children was explained by chronological age, and how much was affected by the verbal skills of the children. Two multiple regressions were computed: one for the Non-salient Problems, one for the Salient Problems.

In each of the multiple regressions the child's chronological age at the time of testing was entered first. This indicated how much of the variance in the causal-scores could be explained in terms of how old the child was. The B.P.V.S. standardised score was entered next to determine how much of the variance in causal-scores was due to verbal skills after the variance accounted for by age had been removed.

Table 8.3.3(a) presents the first of these multiple regressions. The two steps were (1) Age and (2) B.P.V.S., for both the regressions on PNS and PS. The most striking feature of Table 8.3.2(a) is that the child's age accounted for the majority of the variance (30%, $p < .001$) in the children's causal-scores for PNS. Only 0.4% of the remaining variance was accounted for by verbal skills (B.P.V.S.), and this was non-significant ($p > 0.1$). These results indicated that the chronological age of children significantly affected the number of causal stories made for PNS, whereas verbal

skills (B.P.V.S. scores) had no significant effect.

TABLE 8.3.3 REGRESSION RESULTS - EXPERIMENT 6

(a) NON-SALIENT PROBLEMS (PNS)

VARIABLE	STEP	MultR	RSq	RSqCHANGE	FCh	SIG
AGE	1	.5461	.2983	.2983	25.503	.000
BPVS	2	.5497	.3022	.0039	.330	.568

(b) SALIENT PROBLEMS (PS)

VARIABLE	STEP	MultR	RSq	RSqCHANGE	FCh	SIG
AGE	1	.4459	.1988	.1988	14.888	.000
BPVS	2	.5240	.2745	.0757	6.160	.016

A different picture emerges for the Salient problems (PS), as Table 8.3.2(b) shows. Again a strikingly large and highly significant percentage of the variance in causal stories was explained by the Age variable (20%, $p<.001$), but, unlike PNS, 7.6% of the remaining variance was explained by verbal skills ($RSqChange = .0757$, $p<.05$). It appears therefore, that verbal skills affect causal stories for the Salient Problems, but not for the Non-Salient ones. Nevertheless, even here, most of the variance in causal scores was explained by age (20%). Although a small but significant amount of variance is explained by verbal skills, this is to be expected from a purely statistical point of view: as age explains less variance, another factor (in this case, verbal skills) is more likely to account for the remaining variance.

One possible reason why verbal skills affect causal

story production for PS but not for PNS is that the younger children are prompted to make causal stories by the salience of the transformations presented. If they are also using verbal markers to reconstruct the sequences mentally, the use of a marker such as 'broken' may trigger a search for a causal instrument, while the marker 'paint', or 'red' (NS) may not. Another possible explanation may be that as the B.P.V.S. is highly correlated with some intelligence tests, an intelligence factor is at work: children with a high B.P.V.S. scores are able to deduce the causal relations far more than children with lower B.P.V.S. scores. This may hold for both PNS and PS, but the more striking transformations in the salient problems may well facilitate this education process. The following analysis was conducted in order to see if any support for this explanation could be found.

The Effect of Age and Verbal Skills on Production of Causal Stories:

To investigate the relationship between age, high or low verbal skills and causal stories, when Problems were Salient and Non-Salient, children were divided into two B.P.V.S. groups within each age group by dichotomising their B.P.V.S. standardised scores. The two groups established were -

- (1) HIGH - the group of children with scores **above** the median for that age group; and
- (2) LOW - the group of children with scores **below** the median for that age group.

The means and standard deviations of the causal stories made by the different groups are presented in Table 8.3.4. The children in the HIGH verbal skills groups made more causal stories than children in the LOW groups. In general more causal-stories were made for Salient Problems than for Non-Salient ones but this difference appears mini-

mal except in the 3-year-old HIGH and 4-year-old LOW groups. Finally, there seems to be an overall increase in the number of causal stories made for both types of Problems, in both HIGH and LOW verbal groups, across age, from minimal causal stories by 3-year-olds in the LOW group for PNS to ceiling performance by the HIGH 5-year-old group for the same type of Problem.

TABLE 8.3.4 MEANS (out of 3) AND STANDARD DEVIATIONS OF CAUSAL
STORIES - GROUPED BY AGE AND B.P.V.S. SCORES

		PROBLEM TYPE	
AGE	B.P.V.S.	NON-SALIENT	SALIENT
3+	HIGH	1.2	1.8
	(n=10)	(1.4)	(1.4)
	(N=20)		
	LOW	0.6	0.9
4+	(n=10)	(0.79)	(0.91)
	HIGH	1.42	1.75
	(n=12)	(1.08)	(1.14)
	(N=25)		
5+	LOW	0.92	1.54
	(n=13)	(0.9)	(1.3)
	HIGH	3.00	2.94
	(n=8)	(0.00)	(0.4)
(N=17)	LOW	2.22	2.44
	(n=9)	(0.83)	(0.73)

(N.B. Standard Deviations are presented in brackets)

The statistical significance of these trends was investigated using a 3-way analysis of variance (3x2x2) with AGE (3: 3+, 4+, 5+) and B.P.V.S. (2: high, low) as the Between factors, and Problem Type (2: PNS, PS) as the Within factor. The number of causal stories made was the dependent measure.

TABLE 8.3.5 SUMMARY TABLE (ANOVA) – CAUSAL STORIES MADE BY
CHILDREN GROUPED BY AGE AND B.P.V.S. SCORES

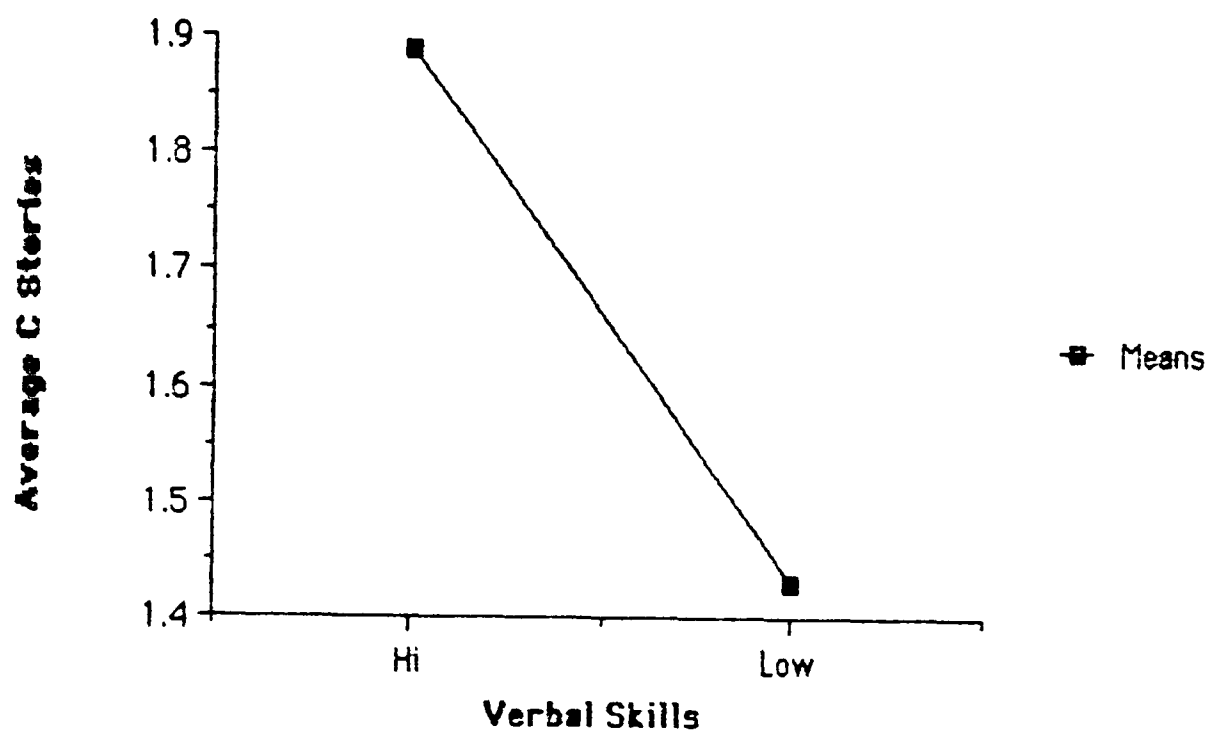
SOURCE		SS	DF	MS	F	PROB	
AGE	(A)	46.872	2	23.436	14.89	0.0000	***
BPVS	(B)	9.769	1	9.769	6.21	0.0157	*
AB		0.911	2	0.456	0.29	0.7497	ns
ERROR		88.136	56	1.574			
PROBLEMTYPE (P)		3.175	1	3.175	7.31	0.0091	*
PA		1.062	2	0.531	1.22	0.3023	ns
PB		0.091	1	0.091	0.21	0.6492	ns
PAB		0.632	2	0.316	0.73	0.4879	ns
ERROR		24.337	56	0.435			

- where - * =p<.05 ** =p<.01 *** =p<.001 ns = non-significant

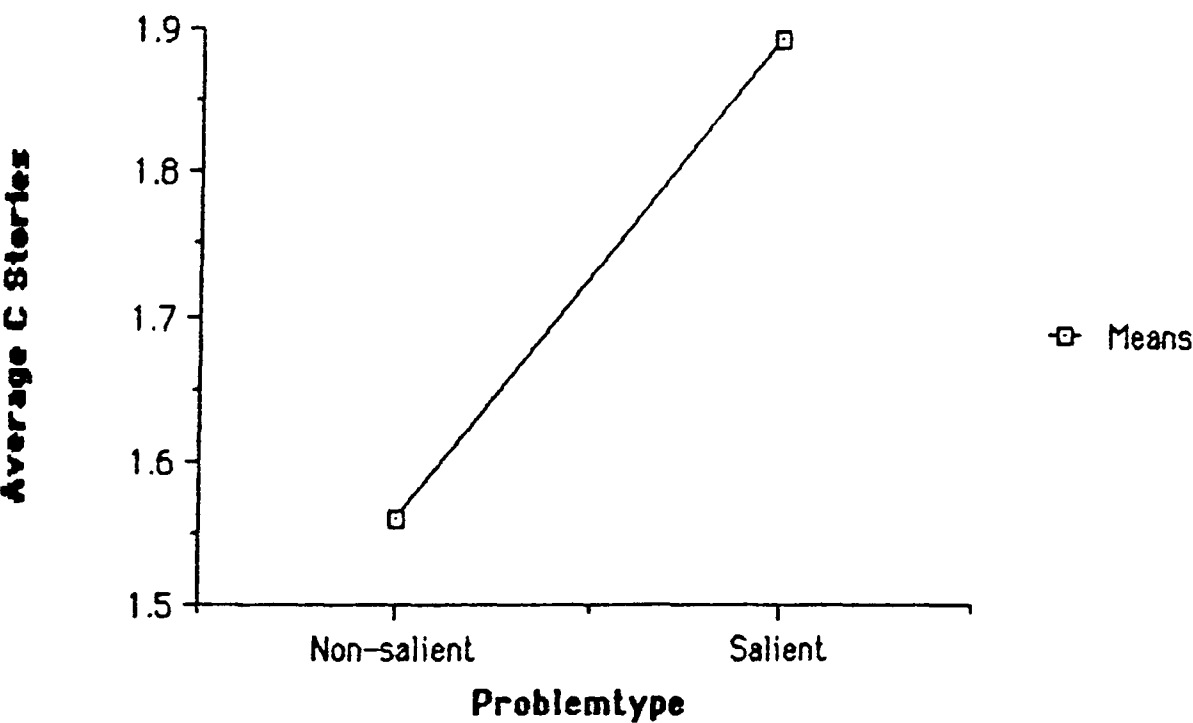
Table 8.3.5 shows that there was a significant main effect for AGE ($F(2,56) = 14.89, p<.0001$) which indicated that causal scores increase with age. Post-hoc analysis (Newman-Keuls) showed significant differences between the 3- and 5-year-old groups (NK $p<.01$) and the 4- and 5-year-old groups (NK $p<.01$). There was no significant difference between 3- and 4-year-old groups.

There was a significant main effect for verbal skills, indicating that the HIGH group made significantly more causal stories than the LOW group, as shown in Figure 8.3.2(a). There was also a significant main effect for Problem Type ($F(1,56) = 7.31, p<.05$) indicating that Salient Problems did indeed elicit more causal stories than Non-Salient ones (Figure 8.3.2(b)).

Fig 8.3.2. Effects of:(a) Verbal Skills on Causal Stories.



(b) Problemtype on Causal Stories.



The absence of any significant interaction effects indicates that although each of the independent variables had some influence on the causal scores, its effects were not modified by the other variables. Most significantly, verbal skills (BPVS) did not interact with any of the other variables ($F < 1.0$ in each case) thus, it can be argued that verbal skills did not significantly affect the production of causal stories for PS alone. Higher verbal skills increased production of causal stories in all age groups, for both PNS and PS. The salient problems elicited larger numbers of causal stories than the non-salient ones and this effect (PRBLMTYPE) was independent of both AGE and B.P.V.S..

(2) ASSOCIATIVE STORIES:

The Associative stories may be subdivided into the three following categories, as shown in Diagram 8.1.2. The following categorisation scheme was devised by the experimenter and is a very tentative one, based on some of the ideas discussed in Chapter 1.

1) The PURELY ASSOCIATIVE (A) stories are associated on the basis of utility (Cup, spoon, teapot), or category (orange, apple, banana). Such stories were categorised A because all three elements are in an associative relation with each other. **A-STORIES** - contain photographs of two objects, each of which is associated to the SO and each other. For example, in the story below, towel is associated to water and soap because of utility, water and soap are

SO = TOWEL (CHOICES) = SOAP, WATER

associated to each other by utility too. Thus, each element is associated with the others.

2) The ASSOCIATIVE-SIMILAR (AS) stories contain two elements that are similar in nature (eg. CUP-painted CUP) and have

features in common. The third element in such stories is associated with the others because of utility (eg. water), or category. These stories were categorised as AS, because at least one element could have been included by virtue of its similarity with the starter, while the other was associated with the starter either because of utility or category. **AS-STORIES** contained a photograph of the transformed S0 and an object associated with S0 (not the causal instrument). The transformed S0 could be chosen for the similarity between it and the starter. For example:

S0 = TOWEL (CHOICES) = CUT TOWEL, WATER

(The towel and cut towel are identical except for the fact that one is cut and the other whole).

3) The ASSOCIATIVE-RANDOM (AR) stories contain two elements which are associated by utility or category, and a third which is unrelated to either of these elements. These stories were categorised AR because one element appears to have been chosen at random, while the other may have been chosen because of some association with the starter object. **AR-STORIES** - contain a photograph of an object associated with the S0 and the third choice is totally unrelated to either the S0 or the second object. For example, in the story below there is no relation between scissors and the other two objects.

S0 = TOWEL (CHOICES) = WATER, SCISSORS

Thus, it can be seen that the twelve possible combinations for each problem (Diagram 8.1.2) can be reduced to four categories of stories: CAUSAL, PURELY ASSOCIATIVE, ASSOCIATIVE-SIMILAR, and ASSOCIATIVE-RANDOM. Two independent raters and the

experimenter coded the stories made by the children. There was 100% agreement between raters.

TABLE 8.3.6 MEANS (out of 3) AND STANDARD DEVIATIONS OF
DIFFERENT CATEGORIES OF STORIES

N.B. - There were 3 Salient and 3 Non-Salient problems.

PROBLEM					TYPE				
NON-SALIENT (PNS)					SALIENT (PS)				
CATEGORY					CATEGORY				
AGE	C	A	AS	AR	C	A	AS	AR	
3+	0.85	0.57	1.31	0.27	1.31	0.23	1.08	0.38	
	(1.01)	(0.70)	(0.97)	(0.60)	(1.26)	(0.51)	(1.61)	(0.75)	
4+	1.23	0.30	1.03	0.43	1.63	0.67	0.33	0.37	
	(1.07)	(0.65)	(1.07)	(0.68)	(1.23)	(0.84)	(0.55)	(0.76)	
5+	2.62	0.14	0.24	0.00	2.71	0.24	0.05	0.00	
	(0.67)	(0.48)	(0.54)	0.00	(0.56)	(0.54)	(0.22)	0.000	

KEY: C = causal story; A = purely associative story; AS = associa-
tive-similar story; AR = associative-random story

The means and standard deviations (in brackets) of the number of stories made in each category for the two problem types (PNS and PS), by the three age groups (including all 77 children), is presented in Table 8.3.6. This Table shows that both AS and A-stories were made by all age groups, with 3- and 4-year-olds making the most AS stories. Three-year-olds made more AS-stories for PNS than C-stories, while for PS they made almost as many AS stories as C-stories. Although 4-year-olds made almost as many AS as C-stories for PNS, the number of AS-stories made dropped for PS. Comparitively few A-stories were made. The number of AR-stories was also minimal, with 5-year-olds making no AR-stories at all.

The Probability of Associative Stories Arising by Chance - The same procedure was used, as for the C-stories. However, the probability of any of the AS or AR-stories occurring was 25% as there were two possible combinations for both these stories (Diagram 8.1.2). The probability of the A-stories occurring purely by chance was exactly the same as for the C-stories, as only one combination yielded this category.

(i) AS-Stories - The proportions of AS-stories made by the 3-year-olds were significantly greater than expected by chance for both PS ($p < .05$) and PNS ($p < .01$). The 4-year-olds made significantly more of these stories than expected by chance for PNS ($p < .05$), but for PS they made significantly less ($p < .01$) AS-stories than expected by chance. Five-year-olds made far less of these stories than expected by chance ($p < .01$) for both Problem Types (PS and PNS).

(ii) AR-Stories - Only 3- and 4-year-old children made any of these stories. In both groups, the proportions of AR-stories were significantly less than expected by chance for both PNS (3+ - $p < .01$; 4+ - $p < .05$) and PS (3+ - $p < .05$; 4+ - $p < .01$).

(iii) A-Stories - The proportions of A-stories made by all ages were either significantly less than (3+ PS, $p < .05$ and 5+ PNS, $p < .01$), or were not significantly different from (3+ PNS; 4+ PS and PNS; 5+ PS) chance expectations. The only Associative story structures significantly above chance level were the AS-stories so further analysis will only concern these stories.

Associative Similar Stories - A 2-way repeated measures ANOVA, One Between (AGE (3)), and one Within (PROBLEM TYPE (2)), was computed to compare the number of AS stories made by each age group for salient (PS) and non-salient (PNS) problems. The results of this analysis are presented in Table 8.3.7.

TABLE 8.3.7 SUMMARY TABLE (ANOVA) FOR AS STORIES

SOURCE		SS	DF	MS	F	PROB.	
AGE	(A)	25.648	2	12.824	15.13	0.0000 ***	
ERROR		62.703	74	0.847			
PROBLEMTYPE (P)		5.264	1	5.264	9.04	0.0036 **	
PA		2.183	2	1.092	1.88	0.1606 ns	
ERROR		43.077	74	0.582			

Where - * = $p<.05$ ** = $p<.01$ *** = $p<.001$ ns = non-significant

There was a significant main effect for Age ($F(2,74) = 15.13, p<.0001$). This indicated that at least one age group differed from the others in the number of AS stories made. Post-hoc analysis (Newman-Keuls) showed a just significant difference between the 3 and 4-year-olds ($p<.05$). Significant differences were found in the number of AS stories made by 4- and 5-year-olds ($p<.05$) and 3- and 5-year olds ($p<.01$); in both cases, the 5-year-olds made far fewer AS stories than the younger children. The significant main effect for Problem Type indicated that far more AS stories were made for the Non-Salient Problems than for the Salient ones

8.4 Discussion

The results of this experiment show a shift in ordering sequences between the ages of three and five. Five-year-olds made far more causal stories than either 3- or 4-year-olds. Although there was no significant difference between 3- and 4-year-olds on the number of causal stories made, all the 3-year-olds AS-stories were significantly above chance level while only AS-stories in the

PNS condition were above chance level in the 4-year-old group. Three-year-olds made the most AS stories. These results suggest that 4-year-olds may be at a stage where, although they may prefer Causal ordering they fall back on an AS ordering if the cues (salience of a transformation, for example) are not strong enough.

That 3-year-olds too can make causal stories is demonstrated by their above chance choices of causal structures. However, their AS stories too are significantly above chance, which seems to indicate that both modes of structuring are attractive to this age group. The C and AS stories were by far the most common and only stories in these two categories were significantly above the proportions expected by chance. Thus, it appears that by age three, it is the causal ordering and the ordering on the basis of similarity and association (AS) which are the most prevalent.

It could be argued that AS stories are very akin to Causal ones as an AS construction may show an awareness of change (a child chooses cup and painted cup). This is possible, but the choice of spoon (or teapot) which completes this type of story, seems to indicate that while the child may find the change interesting, he still prefers an associative structure. On the other hand, children might well have been choosing two cups (similarity) and a spoon (associated with cup). Because children's verbal responses were not always available, it was not always possible to be certain of the basis on which they had chosen the AS combinations. Thus it was decided to err on the side of caution and call the category "Associative-Similar", in order to guard against imputing a causal tendency when none may be present.

It was also found that Salience affected the production of causal stories. In all the age groups, more causal stories were

made for Salient than for Non-salient problems. The presence of transformations categorised as 'Salient' in the choices offered to the children obviously prompted causal ordering. Why was this?

As hypothesised, this may be because the Salient Problems (PS) depict objects changed in a drastic way; drastic in that the wholeness of the object is destroyed. The Non-Salient Problems (PNS), however, although the transformations shown may be striking because they are unfamiliar (tomato sauce on wood), objects retain their wholeness. The results of this experiment suggest that the change from "WHOLE" to "NOT WHOLE" (ie. Broken or cut) prompts causal stories to a greater extent than additive changes (WHOLE + change) in the younger age groups. By the age of five, however, children in this experiment were making almost as many causal stories for PNS as for PS (Table 8.3.1, Table 8.3.5). Although there was no statistically significant Age by Problem Type interaction, it is possible that it was overridden by the large Age effect. The Age effect however does show that 5-year-olds made the most Causal stories (near ceiling) and this may indicate that the preferred mode of story construction for the 5-year-olds is the causal one and they are therefore not distracted by salience cues. The younger children, on the other hand, may not have fixed upon a preferred mode, and need prompts, such as Salience cues, to produce causal stories.

A verbal skills measure (B.P.V.S.) was administered in order to investigate the effects of verbal skills on the production of causal stories. The results of the analysis of verbal skills casts an interesting light on the general results, especially on the effect of salience.

The results of the stepwise multiple regression showed that the majority of variance in causal scores (number of C-stories

made) was accounted for by Age. However, for Salient Problems, a very small but significant ($p < .05$) percentage of the variance was accounted for by verbal skills. But why do verbal skills influence performance for PS but not for PNS? Two possible explanations were offered. It was suggested that children with higher B.P.V.S. scores may do better on both PNS and PS, but the drastic changes depicted in PS problems not only prompt causal ordering, but also some form of verbal intelligence which helps in the deduction of the causal relation. The significant main effect (see ANOVA, Table 8.3.) for B.P.V.S. (verbal skills) simply indicated that the HIGH verbal group made more causal stories overall compared to the LOW verbal group. This finding indicates that verbal skills significantly influence causal story production.

The speculation that children may be verbally reconstructing their stories, or at least using mental verbal markers in constructing stories, seems possible in the light of these findings. If children do use some verbal process in story construction, then the labelling of objects as "broken" or "cut", words implying causal transformation, may trigger a causal structuring. For the Non-Salient Problems, no words with a causal implication need be used. For example, the painted cup may be described as "red cup", or "got paint on", and frequently was by the children. A large number of AS stories were made for NS problems, and this may be because children, although they had described the transformed object correctly, seemed to ignore the transformation and group the transformed object with the starter on the basis of similarity (eg. "Here's a cup, and here's another cup, and some tea"). Similarly, in the wood problem, when describing the transformed photograph children would say - "It's got some sauce on it", or "There's red on it". Such descriptions, it

is argued, may not trigger causal sequencing as effectively as the word "broken", for example.

In Salient Problems descriptions of the transformed object were always made by using words with a causal implication - "it's smashed", or "its cutted". It is possible that when direct causal markers indicating drastic changes are used a causal story is more likely to be produced as the child will then search for the causal instrument. For PNS, although children may initially react to the transformed object and choose it as a component for their story, the verbal marker used may not be as effective in triggering a search for the causal instrument. As a result, there might be some sort of competition between searching for and choosing a causal instrument, or choosing an object associated with the other components. As the latter is simpler this may be the AS choice is made. To clarify whether children perceive the changed object as being the same as the Starter Object ~~this~~ children's verbal descriptions should be noted (see below).

It may be argued that perhaps children do not respond to the causal transformation in PNS because the transformations are unusual. The same argument should also apply to PS as the transformations depicted there are just as unusual. Nevertheless, to control for this possibility, it would be interesting to design materials showing 'familiar' and 'unfamiliar' transformations, which were either salient or non-salient.

There is a number of ways in which this experiment could be improved. Firstly, the sequences could be designed using associations elicited from the children. The Problems were designed using associations proposed by the experimenter. It may be that children have stronger and different associations of objects with, for exam-

ple, cup. It would also be interesting to record the verbal explanations that children did offer for their stories. If a sufficient number of such records could be obtained it might be possible to investigate whether children gave more verbal explanations for the Salient problems, than for the Non-Salient ones. The purpose of such an analysis would be to find some support for the explanation offered above that Salient verbal markers are more effective in producing causal stories than non-salient ones.

Recording verbal explanations would also enable analysis of children's utterances to determine on what grounds they chose the components for their stories. This would be especially useful for the non-causal categories. For example, if for an AS story children chose - CUP, Painted Cup and Spoon - and said that they chose the painted cup because the first cup got painted, this would indicate that they were responding to a change in the starter object, but did not search for the cause, as they did when making a causal story. If they said that they chose the cups because they were both 'cups' however then they would be constructing their story on the basis of similarity rather than a perception of change. This would be interesting theoretically, as it has been proposed that the relation of change is one of the most important relations to apprehend in order to understand that a causal transformation has occurred. Only after such an apprehension does a search for the causal instrument ensue.

In conclusion, the results of this experiment support the hypothesis that a preference for causal as opposed to associative structuring develops with age. Salience of transformations affects production of causal stories, as does verbal skills. Age, however, seems to emerge as a major factor in the development of this preference.

CHAPTER NINEPRESCHOOLERS' ABILITY TO DEAL WITH A TWO FEATURE TASK

9 Experiment 7: Dealing with One or Two Features
 in a Motor Task

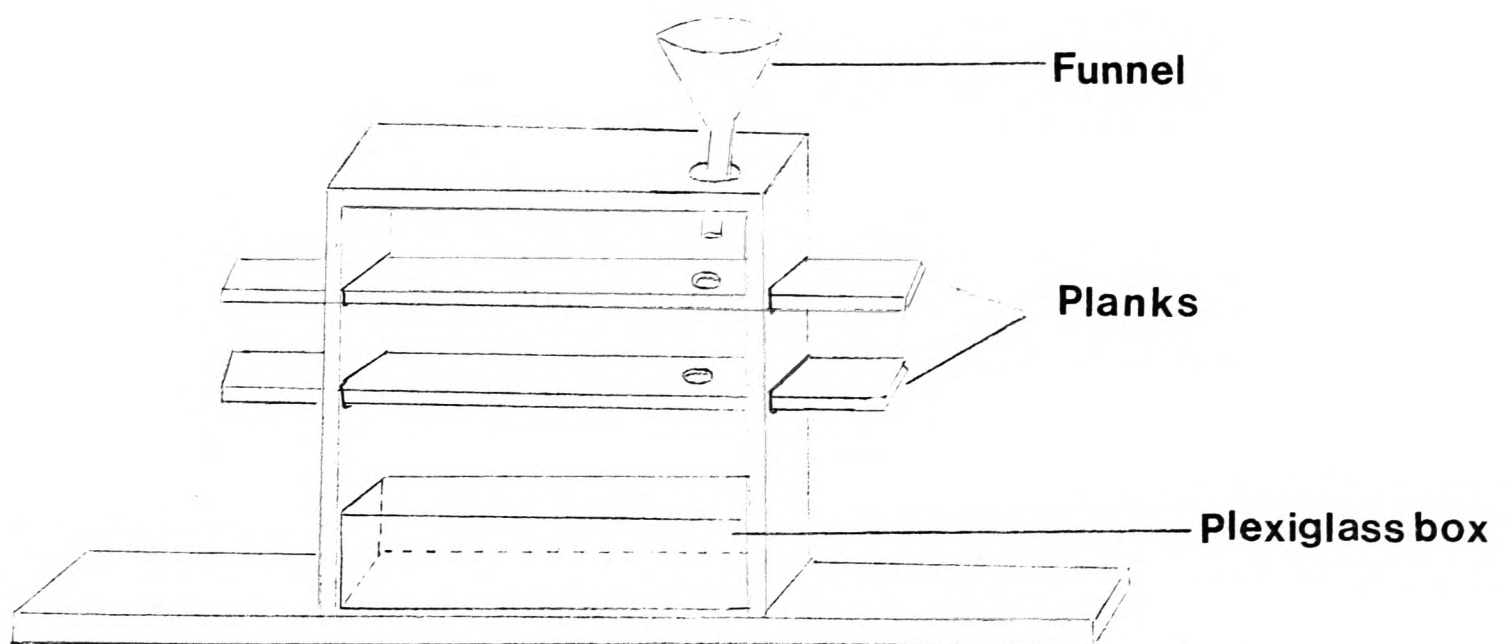
9.1 Introduction

One question arising from the results of Experiments 1, 2, 3, and 5 concerned the reasons for the relatively poor performance of 3-year-olds on sequences involving compound (two) states. One possible reason proposed was that these children found it difficult to deal with two features. The results of Experiment 5 certainly indicate that 'adding' two states or instruments was far more difficult for 3-year-olds than dealing with single features. However it can be argued that the tasks given were too 'abstract' since photographic sequences were used. Children may be able to deal with two features in real life situations but find the mental integration of two features more difficult. In using photographic material it is possible that the experiments tapped the child's ability to use some form of abstract reasoning in addition to feature integration. If concrete physical objects were used children might be more competent at integrating, or 'adding', two features. Furthermore, two states, one of which always appeared more salient than the other, were often used in previous experiments. It can be argued that children would be more competent at integrating features which did not 'compete' with each other (in terms of saliency).

Experiment 7 was designed to investigate these possibilities. In this experiment the child has to make something happen

rather than make a judgement about a representation of something that has already happened. A procedure involving a motor-task was adopted to reduce the abstract reasoning load. This task required children to fill a plexiglass box with sand by pouring the sand through a funnel after dealing with one, or two, obstructions (wooden planks). Each plank had a hole in it. Children had to position the hole under the funnel allowing the sand to fall through into the box. Using two planks which were exactly the same, except for the position of the holes, should also minimise any 'competition' between features - Figure 9.1.1 illustrates the basic apparatus used and the two conditions (One Plank or Two Planks) are illustrated in Figure 9.2.1.

FIGURE 9.1.1 THE BASIC APPARATUS USED IN EXPERIMENT 7



In the ONE PLANK condition, children had to figure out that the hole had to be under the funnel for the sand to go through. In the TWO PLANK condition they also had to figure out that both the holes (in the two planks) had to be under the funnel for the sand to go through. Thus, in the latter condition, they had to 'add' the two

holes under the funnel; in other words they had to deal with two features - each hole in the two planks - to achieve the desired end state. This is roughly similar to the ADD tasks in Experiment 5.

Although it would have been ideal to use the same sorts of objects and transformations as used in the photographic sequences, this was not possible in practice. It might have been possible to get children to wet things but cutting, especially using a knife, was not very practical. Some of the younger 3-year-olds could not use scissors properly so that alternative was not feasible as manual dexterity might have influenced results. Furthermore, a lot of raw materials would have been required. Therefore, a roughly comparable task was designed simply to test whether the problem in dealing with two features was a general cognitive problem or a task specific one. If younger children needed more trials than older ones to get the sand through two planks then this might indicate that successful dealing with two features is less common in the 3-year-old group. The fewer trials a child needed to get the sand into the box (in the two plank condition) the quicker she was to integrate both planks.

Assuming, on the basis of past results, that younger children find single feature tasks much easier than tasks with two features, 3-year-olds were predicted to need a greater number of trials in the TWO PLANK condition than in the ONE PLANK condition. It was also predicted that 4-year-olds would require fewer trials on both conditions than 3-year-olds.

9.2 Method

(a) Subjects:

Sixty children from Oxford nurseries and play-groups participated in this experiment. There were 30 3-year-old (mean= 3-

5; range=3-0 to 3-11) and 30 4-year-old children (mean= 4-6; range = 4-0 to 4-11) in this sample.

(b) Design:

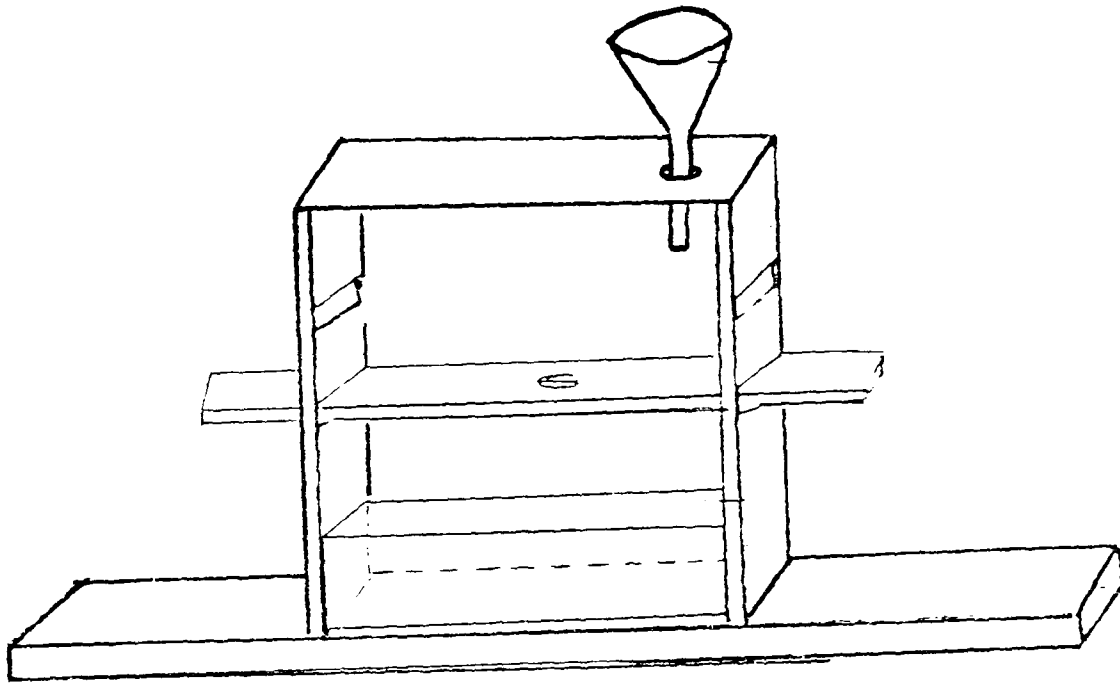
A 2(Age: 3+, 4+) by 2(Condition: One Plank, Two Plank) independent groups design was used. The dependent variable was the number of trials needed to put sand into the box. An independent groups design was used because, when the material was pilot tested (with counter-balanced conditions) to see if children understood the task (see Appendix 7) it was found that children who experienced the TWO PLANK condition first were much faster ($p < .01$) on the ONE PLANK condition. Furthermore, significantly more trials were taken for the TWO PLANK condition when this condition was experienced first (compared to the ONE PLANK). When the TWO PLANK condition was experienced second there was no significant difference between the number of trials needed on the two conditions.

The findings of the Pilot study suggested that there might be a learning effect. Therefore, an independent groups design was chosen to eliminate carry-over effects. In each age group, half the children were randomly assigned to the ONE PLANK condition and the other half to the TWO PLANK condition.

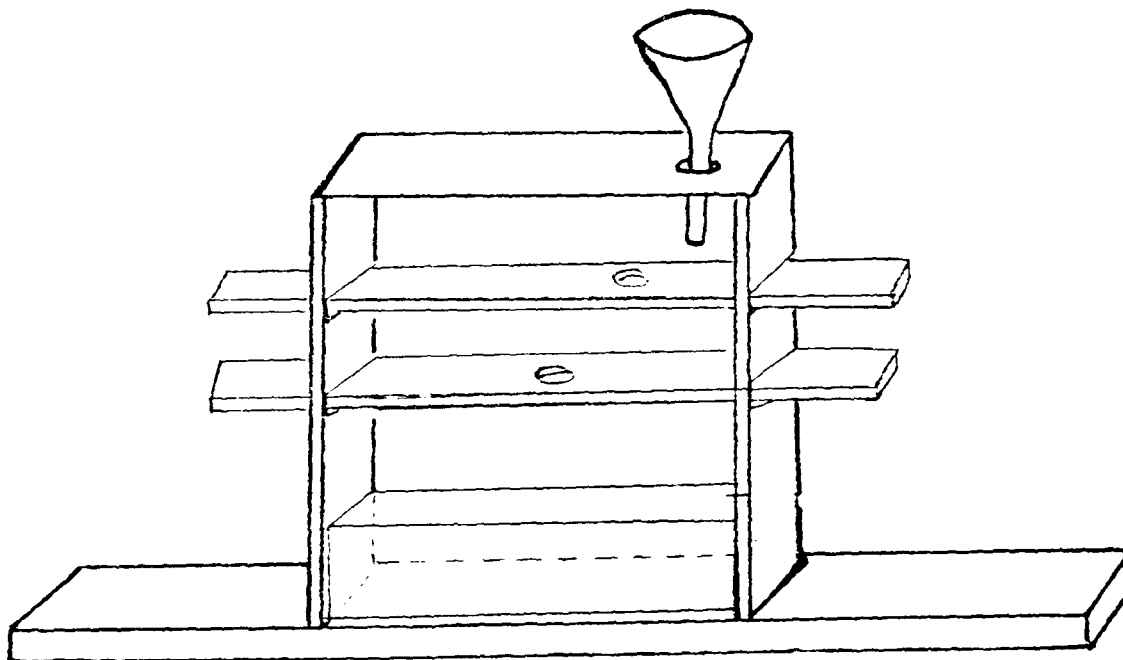
(c) Material:

A red wooden frame was constructed (base - 28"; sides 13"; top bar 10.3") with two slots cut into each side 2" apart through which wooden planks could be inserted (see Diagram 9.1.1). A large white funnel was inserted through a hole on the top bar of the frame and a rectangular plexiglass container was placed on the base of the frame. A box of fine industrial sand and a red sand scooper were provided.

FIGURE 9.2.1 THE DIFFERENT CONDITIONS IN EXPERIMENT 7



ONE PLANK



TWO PLANKS

Four wooden planks (26" long), painted blue, were used: one for Familiarisation, and the remaining three for the Experiment proper. All the planks slid easily through the slots in the frame. Each plank had a hole cut into it (1.5" in diameter). The hole was at a different position on the second plank.

The hole on the Familiarisation plank was positioned so that when the plank was inserted through the slots, with equal lengths protruding at each end, the hole was directly under the funnel. When the three Experimental planks were positioned so that equal lengths protruded at each end of the frame, the hole was 7" to the left of the funnel on ONE PLANK (A), 3" to the left of the funnel on the other plank (B) and 5" to the left of the funnel on the last plank (C). Planks (A) and (B) were used in the TWO PLANK condition and PLANK (C) on the ONE PLANK condition.

(d) Procedure

The experimenter spent two weeks in each classroom playing with the children. The experiment was introduced as a "sand game" which could be played by a single child and the experimenter. The apparatus was placed on a table in front of the child who sat beside the experimenter.

Familiarisation - The children were familiarised with the apparatus using the familiarisation plank. They were asked to put sand into the plexiglass box with the plank in the top slot and then with the plank in the bottom slot or vice versa. They were also shown how to move the plank within the slots, thus displacing the hole from under the funnel. Each child was then allowed to play with the apparatus by him/herself for a few minutes.

Experimental Procedure - Immediately after familiarisation the experimenter asked the child to play the game with her again (all

the children were very willing and enthusiastic). Each child was asked to fill the plexiglass box with sand. Children had been randomly assigned to one of the two conditions. Each child was tested individually. The child was asked to fill the box with sand just as she had been doing before (ie. during familiarisation). Depending on the Condition, either one or TWO PLANKs were then inserted into the empty frame and the child was told to start filling the box with sand.

ONE PLANK CONDITION - After the child had put in one scoop of sand the experimenter asked the child to see if the sand had gone into the box. The child was asked why the sand had/had not fallen into the box. In the latter case, she was asked if she would like to try to fill the box again. (All the children wished to continue.) Whenever the child tried to pour sand into the box this was counted as one trial. The answers given by the children at the end of each trial and the number of trials needed to get the sand into the box were recorded.

TWO PLANK CONDITION - Exactly the same procedure as for the ONE PLANK Condition was followed.

In both conditions, if children started shaking the plank in order to shift sand into the box, or tried to put sand directly in the box, ignoring the funnel and hole, they were told that they had to get the sand in the box by pouring it through the funnel.

9.3 Results

Subjects scores consisted of the number of trials needed to get sand into the box. If children got the sand into the box the first time they were asked to this was scored as "0 trials". The

next trial was counted as the first, and so on. All the children who participated in this experiment persevered until they got the sand into the box.

Number of Trials taken to Complete the task

The mean number of trials needed by each age group in the two conditions is presented in Table 9.3.1. Although 3-year-olds needed more trials than 4-year-olds in both conditions this difference is most numerically striking in the TWO PLANK Condition. Furthermore, 3-year-olds needed fewer trials in the ONE PLANK Condition than in the TWO PLANK Condition. The difference between Conditions for the 4-year-olds seems negligible.

TABLE 9.3.1 MEANS AND STANDARD DEVIATIONS FOR THE NUMBER OF TRIALS IN EACH CONDITION

	3-YEARS	4-YEARS
ONE PLANK	2.67	2.07
Condition	(1.23)	(1.16)
TWO PLANK	4.27	2.0
Condition	(1.53)	(0.93)

To test the statistical significance of these findings the raw scores (number of trials) were subjected to a 2-way ANOVA for independent groups. Age (2: 3+, 4+) and Condition (2: ONE PLANK, TWO PLANK) were the independent variables with number of trials as the dependent measure. The results of this analysis are presented in Table 9.3.2.

There was a significant main effect for Age ($F(1,56)=20.26, p<.001$) indicating that the older children needed significantly fewer trials to complete the task than the younger ones. There was also a significant main effect for Condition

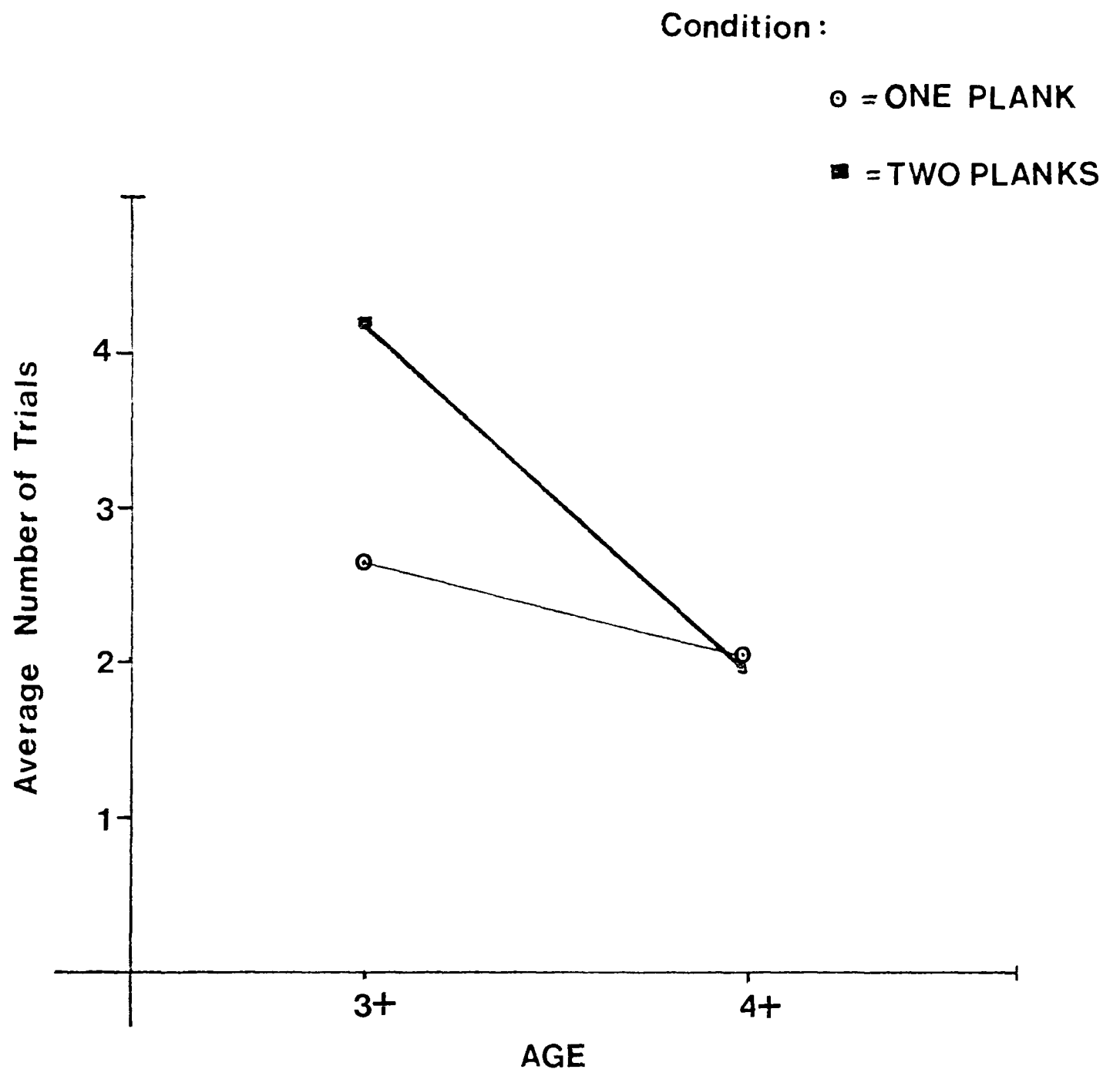
($F(1,56)=5.79$, $p<.05$), indicating that the ONE PLANK condition was easier (required fewer trials) than the TWO PLANK condition.

TABLE 9.3.2 SUMMARY TABLE (ANOVA) FOR NUMBER OF TRIALS TAKEN BY
THE TWO AGE GROUPS IN TWO CONDITIONS

SOURCE	SS	DF	MS	F	PROB.
AGE	30.81667	1	30.81667	20.26	0.000***
CONDITION	8.81667	1	8.81667	5.79	0.019 *
AGE x COND	10.41667	1	10.41667	6.850	0.011 *
ERROR	85.20000	56	1.52143		

The significant Age x Condition interaction indicated that the effect of Condition was influenced by the age of the children. Figure 9.3.1 depicts this interaction and shows that both age groups performed equally well in the ONE PLANK condition (Newman-Keuls post-hoc test for differences between means $p>.05$, non-significant.) The effect of adding the second plank was apparent in the 3-year-old group, who needed significantly more trials to pour the sand into the box in the TWO PLANK condition than in the ONE PLANK condition ($p<.01$). There was no significant difference between the two conditions in the 4-year-old groups. The older children did needed significantly fewer trials than younger ones in the TWO plank condition.

The the two plank condition was apparently more difficult for 3-year-olds, but not for the older children, compared to the ONE PLANK condition. The younger children can eventually complete the TWO PLANK task successfully but the fact that they needed more trials may indicate that they are either not as prompt as older children to use an 'adding' method, or that they prefer to concentrate on one feature at a time.

FIGURE 9.3.1 AGE BY CONDITION INTERACTION

A look at the verbal explanations given by the children may give some indication of the processes used by these children to solve the problem.

Explanations

The children's explanations for their failures and success in getting the sand into the box were categorised as shown in Table 9.3.3.

TABLE 9.3.3 DIFFERENT CATEGORIES OF EXPLANATIONS GIVEN BY
CHILDREN FOR: (1) FAILURE, AND (2) SUCCESS

(1) Reasons for Failure

<u>TYPE OF EXPLANATION</u>		<u>FREQUENCY</u>	
		3+	4+
1	EXPLANATIONS MENTIONING OBSTRUCTION eg. "it's stuck"; "It's on the wood"...etc.	6	1
2	EXPLANATIONS MENTIONING ABSENCE OF HOLE/S IN PLANK eg. " 'Cause there's no hole";	3	4
3	EXPLANATIONS MENTIONING POSITION OF HOLE IN RELATION TO POSITION OF FUNNEL eg. " 'Cause the hole/s isn't there..." (pointing under funnel)	0	4
4	EXPLANATIONS MENTIONING POSITION OF HOLES AND ACTION REQUIRED TO GET SAND IN BOX eg. " 'Cause there's no hole/s...I move this [and this]." (pointing to plank/s) or: "It can't go fru wif no holes...move this.."	0	4
5	NO EXPLANATION - STATEMENT OF ACTION REQUIRED eg. " I want to move this hole"; " I needta move it".	5	0
6	REPETITION OF WHAT HAPPENED eg. " 'cause it didn't go".	3	2
7	"I DON'T KNOW" (IDK)/ NO ANSWER	11	5

2. Explanations for Success

TYPE OF EXPLANATION	FREQUENCY	
	3+	4+
1 EXPLANATIONS IN TERMS OF OWN ACTIONS eg. "'Cause i move it there"; "'cause I push it"	15	5
2 EXPLANATIONS MENTIONING HOLES eg. "'Cause its got hole/s to go through"; "'Cause its got hole/s there now".	3	9
3 EXPLANATIONS MENTIONING POSITION OF HOLE IN RELATION TO POSITION OF FUNNEL eg. " 'Cause the hole/s is under there" (pointing under funnel)	2	5
4 EXPLANATIONS MENTIONING POSITION OF HOLES AND OWN ACTIONS eg. "'Cause I put it (hole) there..Else it wont go through."	1	8
5 EXPLANATIONS INFERRING MOTIVE TO SAND eg. "'Cause it wants to go in"; "'Cause it did"	3	0
6 DESCRIPTION OF WHAT HAPPENS eg. "It's going down the hole"	0	1
7 NO EXPLANATION, POINTS AT HOLE OR POURS SAND IN	5	0
8 IDK / NO ANSWER	1	2

Table 9.3.3 shows that on the whole very few explanations were given. Children's explanations sometimes varied from trial to trial but are included here because they give some indication of how children viewed the task.

(1) Explanations for Failure

The majority of 3-year-olds responded with "I don't

know" when asked why the sand had not fallen into the box. Their next most favoured response was either to mention the plank as the reason why the sand could not go through (6), or to give no explanation but state their intent for the next trial (5), eg. "I want to move this". Four-year-olds gave a wider variety of responses. Most of their responses were of the "I don't know" variety, closely followed by responses mentioning either the specific reason (absence of a hole) why the sand was stuck (Category 2 - $n=4$), or the position of the hole in relation to the funnel (Category 3 - $n=4$). They also made as many responses (Category 4 - $n=4$) which included the reason why the sand did not go through as well as the action required to make it do so. Category 4 was the most complete explanation but none of the 3-year-olds and very few of the 4-year-olds responses fell in this category.

(2) Explanations for Success

The majority of 3-year-olds explained their success in terms of their own actions (15). Again 4-year-olds gave a wider variety of responses the majority being explanations which mentioned the presence of holes in the planks (9), followed by explanations including a mention of their own actions as well as the position of the holes.

In general, younger children seem to find it more difficult to give verbal explanations for failure, as the large number of "IDK" answers showed. However they appear to understand the task, as evidenced by the explanations in categories 1 and 3. The younger group tended to explain success mostly in terms of their own actions, eg. "[It went in the box], because I moved it[plank/hole]." This type of answer however, may be due simply to a lack of insufficient vocabulary or fluency. Their actions in dealing with the sand

game did not indicate that they believed that merely pushing the plank would enable the sand to go through : the majority of three year olds pushed the hole under the funnel.

Observation

The most striking difference between the 3-and 4-year-old's behaviour was in the two plank task. Once a 4-year-old figured out that she had to move the hole under the funnel, she would (in general) move both planks under the funnel simultaneously (9/15 4-year-olds behaved in this way). Younger children typically (11/15) moved the first plank (hole) under the funnel, then tried to pour the sand through. When they found the sand would not go through, they either moved the second hole under the funnel, or repeated previous erroneous moves. Thus, 3-year-olds seemed to prefer to deal with one plank at a time, whereas older children dealt with both at once.

9.4 Discussion

The hypothesis that prompted this experiment was that 3-year old children would find single feature tasks much easier than two-feature tasks, and that 4-year olds would perform better on both types of tasks. The findings showed that although there was a significant difference between the ONE and TWO PLANK conditions in the 3-year⁷old group, this difference was non-significant for the 4-year-olds. Furthermore, the two age groups did not differ significantly in the ONE PLANK condition, but did so in the TWO PLANK condition. These findings clearly show that younger children do find it much more difficult to deal with two features (TWO PLANK), than with one feature (ONE PLANK).

It can be argued therefore, that it is not just dealing with abstract photographic material which produces this phenomenon. Even in a task where they can interact with the materials younger children find it difficult to integrate two features. Once the older children established that the hole needed to be under the funnel they quickly applied this to both planks. The younger ones however seemed to deal with one plank at a time. In the TWO PLANK condition 4-year-olds were more likely to mention both the planks or holes than were 3-year-olds, who described each obstruction as or after they dealt with it. The explanations of both age groups showed that they could identify the cause (which is an inhibitory one) of the sand not falling into the box (see Table 9.3.3 - Reasons for Failure - Category 1).

The results of this experiment lend strong support to the claim that 3-year-olds prefer, or find it easier, to deal with single features. It appears that dealing with two features may be a general cognitive problem at this age level and not a task specific one. These findings are consistent with Siegler's (1984) account of feature selection and integration. The implications of these results will be discussed in greater detail in the next and final chapter.

CHAPTER TEN10 GENERAL DISCUSSION AND CONCLUSIONS10.1 Introduction

The issues raised in this thesis will be discussed in this chapter in the light of the results obtained. The implications of these results will then be considered within the context of the literature on causal development. This is followed by a section outlining the limitations of the experiments reported in this thesis. Finally, suggestions and implications for further research are offered.

10.2 The Basic Issue - Difference between Causal and Associative-Causal Reasoning

The examination of different viewpoints on causal and associative relations (Chapter 1) ended with a distinction being drawn (section 1.5) between causal-associations and causality in terms of transformations. Causal-associations share certain characteristics with the causal relation: they are unidirectional, dynamic and specific (specific instruments become associated with specific effects). They differ from association based on similarity, for example, where objects are associated on the basis of similar attributes such as size or shape or colour. Causal-associations need not imply the whole causal relation in terms of transformation.

Comprehension of the causal **relation** must incorporate some knowledge of transformation. A causal event depicts the transformation of a **first state** (A) at time₁, to a subsequent state (A')

at time₂ (section 1.5). To understand this event, the two states (A and A') must be connected by the transformation. In addition to a perception of change a prerequisite of causal understanding is an (at least, implicit) assumption of an underlying continuous substance. A basic understanding of causality may be composed of both causal and associative knowledge. In conjunction with an ability to relate object states or events in terms of transformations, knowledge of specific properties of objects (causal-associations) may be used to make causal judgements in specific situations.

A review of the literature on physical causality (Chapter 2) indicated that past research, on the whole, either ignored the causal/associative distinction or dichotomised it. A number of studies focused solely on children's understanding of the Humean rules of causality - Contiguity, Priority and Constant conjunction - without clarifying whether they accepted his basic premise that causality was no more than a special type of associative relationship. Other researchers (Bullock, 1981, Shultz, 1982) focused on the generative and mechanistic aspects of causality. Furthermore, none of the research on causal reasoning appears to have differentiated causal-associations from other types of association. This distinction helped separate causal-associations from the causal relation - primarily in terms of priority and transformation which are essential to the causal relation but not to the associative-causal.

Study of the literature raised one central question - whether an understanding of causality is totally divorced from associative knowledge? Consideration of philosophical accounts (Chapter 1) led to the conclusion that although causality may be a 'higher order' relation it is grounded in an associative-causal data base. If, however, perception of the causal relation is direct (Michotte,

1963) causal reasoning may involve more than a system of associative-causal links.

Gelman, Bullock and Meck (1980) asserted that preschoolers' understanding of causal relations was "more than a memory for contiguously associated events". As pointed out earlier however, they did not show that these children were not reasoning associatively. Gelman et al. claimed that young preschoolers related object states in terms of transformations. The question their experiments raise is: "Do preschool children relate object states in terms of transformations, or do they simply 'match' instruments associated with given effects on the basis of associative-causal knowledge?".

10.2.1 INVESTIGATING THE BASIC QUESTION (EXPERIMENTS 1 AND 2)

Experiment 1

Experiment 1 was designed to investigate how children reason when faced with event sequences, similar to that used by Gelman et al. (1980), if they are given the opportunity to make associative responses. There were two conditions: Experimental - in which children had to relate first and last states to figure out the transformation which had occurred, and Control - where it was possible to 'match' an associated instrument with an end state to make a Correct choice.

Although both 3- and 4-year-olds' Correct responses in both conditions were significantly above the proportions expected by chance, the younger children made significantly less Correct responses than 4-year-olds in the Experimental condition. Only the younger children made significantly fewer Correct responses in the Experimental condition than in the Control.

These results suggest that whilst 3-year-olds were able

to relate first and last states and deduce the transformation that had occurred they also may have been using some other method to choose instruments for transformation. This conclusion was supported by the finding that 3- and 4-year-olds did equally well on the Control condition in which associative-causal 'matching' produced correct answers.

The pattern of errors made by the two age groups in the Experimental Condition provided some confirmation for this speculation. The younger group in particular, made a large proportion of Associative-Causal (AC/CA) responses (3.3.2). These responses intimated that children were making at least one judgement (within a pair of judgements) on the basis of an association between instrument and effect.

Significantly more correct responses were made for SALIENT (S) transformations (see 3.3.3) than for NON-SALIENT (NS) ones in the Experimental Condition only. This finding is important because it implies that it is far easier to make correct choices in the Control even though two states, one of which is more salient relative to the other, are also present. This implies that salience in itself may not be a problem when only one of the 3-fixed-choices has a causal-association with one of the end states. Furthermore, these results imply that children attended more to the salient END state regardless of the transformation depicted in the sequence in the Experimental condition where associative-causal matching would not produce a correct choice.

In addition, children may not have been discounting the initial state when choosing instruments for transformation. Because of either, or both, ^{of} these factors the child may have been struck by the salience of one state, relative to the other, in the final

photograph of a sequence. Consequently, the child would choose an instrument for the state which she perceived as being 'important' or salient. Therefore, at the end of Chapter 3 it was suggested that children who made errors might do so because they were using an associative-causal matching-method in preference to a 'relational' method (i.e. relating first and last states to figure out the transformation that occurred in the sequence). A rationale for the existence of these methods is presented below.

10.2.2 TWO PROPOSED METHODS OF REASONING IN CAUSAL SEQUENCES

(Experiment 1, continued)

The Relational Method is conceptualised as the more causal one in terms of the definitions offered by Gelman et al. (1980) and extended in this thesis. Preschool children's superior performance in conditions where only one Correct and plausible causal choice is offered (Control condition, Experiment 1) indicate that they have a good associative-causal data base. They know that water will wet things, that a knife is used to cut and so on. They rarely choose instruments which could not possibly produce the given effect/s. What I shall attempt to show here is that demonstration of such knowledge does not necessarily imply a relational method of reasoning rather than an associative one.

Rumelhart and Ortony (1977:119) identify one typical reasoning strategy as an essentially matching strategy. In their words, the process is to

"fill certain variables of a schema and then search for cases which match these variables and assume that the unspecified variable has the same value as the instance we found".

In the sequence - Wet Banana -----> Wet CUT Banana, for example, the correct answer would depend on the schema that the child chooses to fill in. If, for example, she chooses the CUT schema because she is focusing on the end state, she will try to find the instrument which matches this state and decide that this is the unspecified variable (instrument) which brought about the effect. However, if a CHANGE schema is used, first and last states have to be compared to fill in what the change is, then the specific schema related to the transformation (CUT, for example) can be used to find the instrument used to cause that change.

Each child was asked to choose the instrument that I had used to change object A into object A'. Children could scan the whole sequence, relating A to A' in terms of transformation, by discounting the continuing state. Alternatively, they could either focus on the final state of the whole sequence OR scan the sequence, but because they find it difficult to deal with two (end) states, focus on the salient end-state. The last two processes would produce similar results. The diagrams overleaf illustrate how, given the same problem situation and objective, different results are obtained depending on the method chosen to 'solve' the problem.

A close look at Diagrams 1a and 1b shows that, in order to make the correct judgement for the problem given, it is necessary to discount the continuing state of the object. If children focus on the final state in the sequence (1b) then a choice must be made between the two end-states. It is suggested that children perceive both states, but they choose a cause for the more dramatic change (Cut in this case) because it is more salient. Focus on the salient state may inhibit processing of the second state.

The existence of such methods, however, cannot be accep-

ted on the basis of the results of the first experiment alone. First, the child may have been unsure which state, initial or final, she was being asked to make an inference about. The familiarisation procedure was designed to minimise confusion about the task but a degree of uncertainty is always possible, especially with younger children. Some children may have always made inferences for salient beginning states when the transformation depicted in the sequence was non-salient. Secondly, the younger children (3-year-olds) may not have had the cognitive or information-processing capacity to deal with two object states. Thus they may have used the simpler Matching method. Finally, the familiarisation sequences were all exactly the same as in the Control condition and greater familiarity with such sequences may have contributed to higher scores on the Control. (Familiarisation sequences were not like the Experimental Condition sequences in order to rule out the possibility that children might learn to use a Relational Method through familiarisation). Experiment 2 was designed to control for these factors.

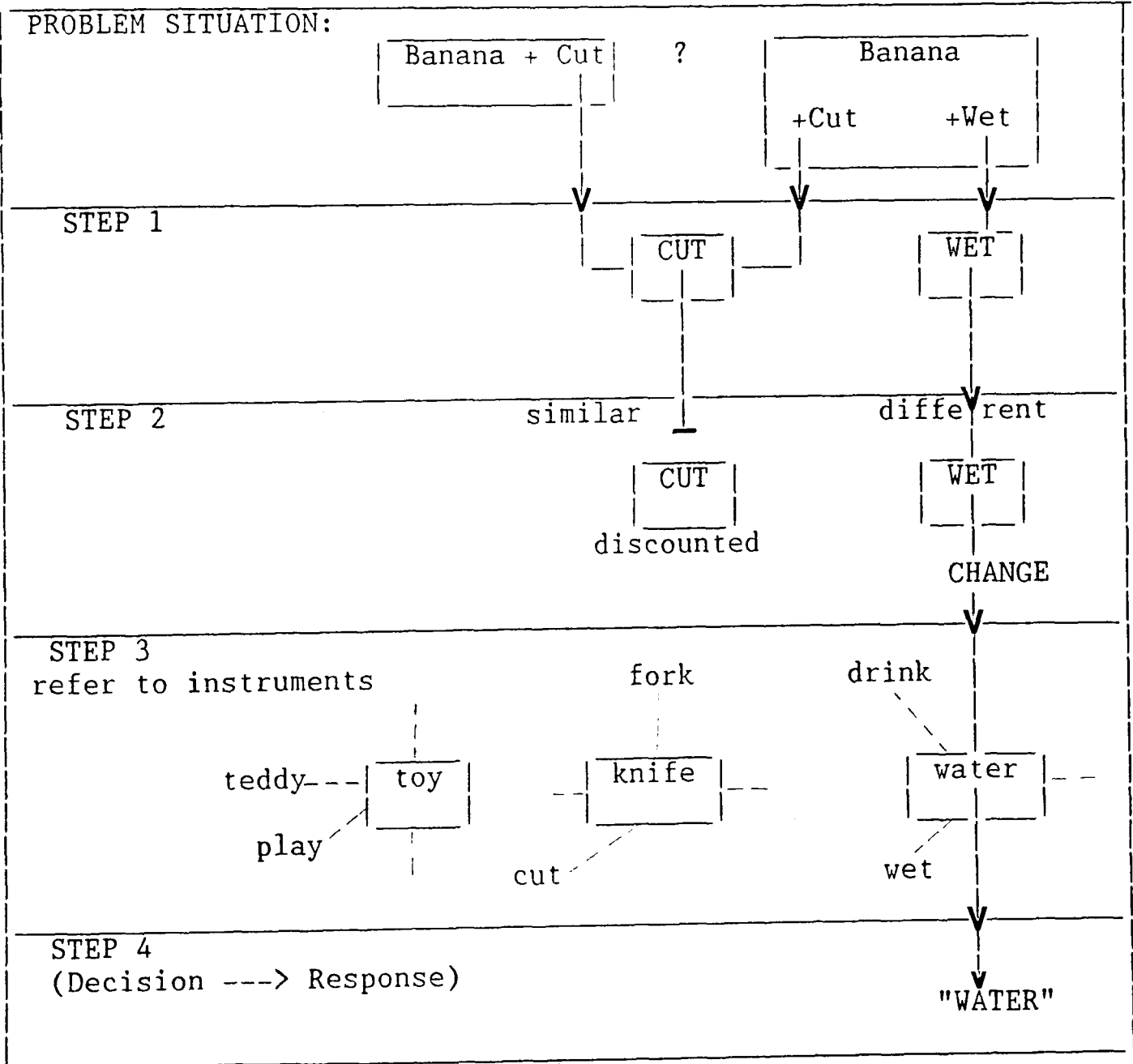
Diagram 1 TWO METHODS OF CHOOSING CAUSAL INSTRUMENTS

PROBLEM SITUATION	OBJECTIVE
(A) BANANA + cut ----> (A') BANANA + cut + WET	Determine cause of CHANGE from A to A'.

METHOD

- 1. Scan first and last states.
- 2. Discount similarities and determine difference (CHANGE).
- 3. Find instrument that can cause that change from choice array.
- 4. Choose instrument of transformation.

(a) CAUSAL (RELATIONAL) METHOD

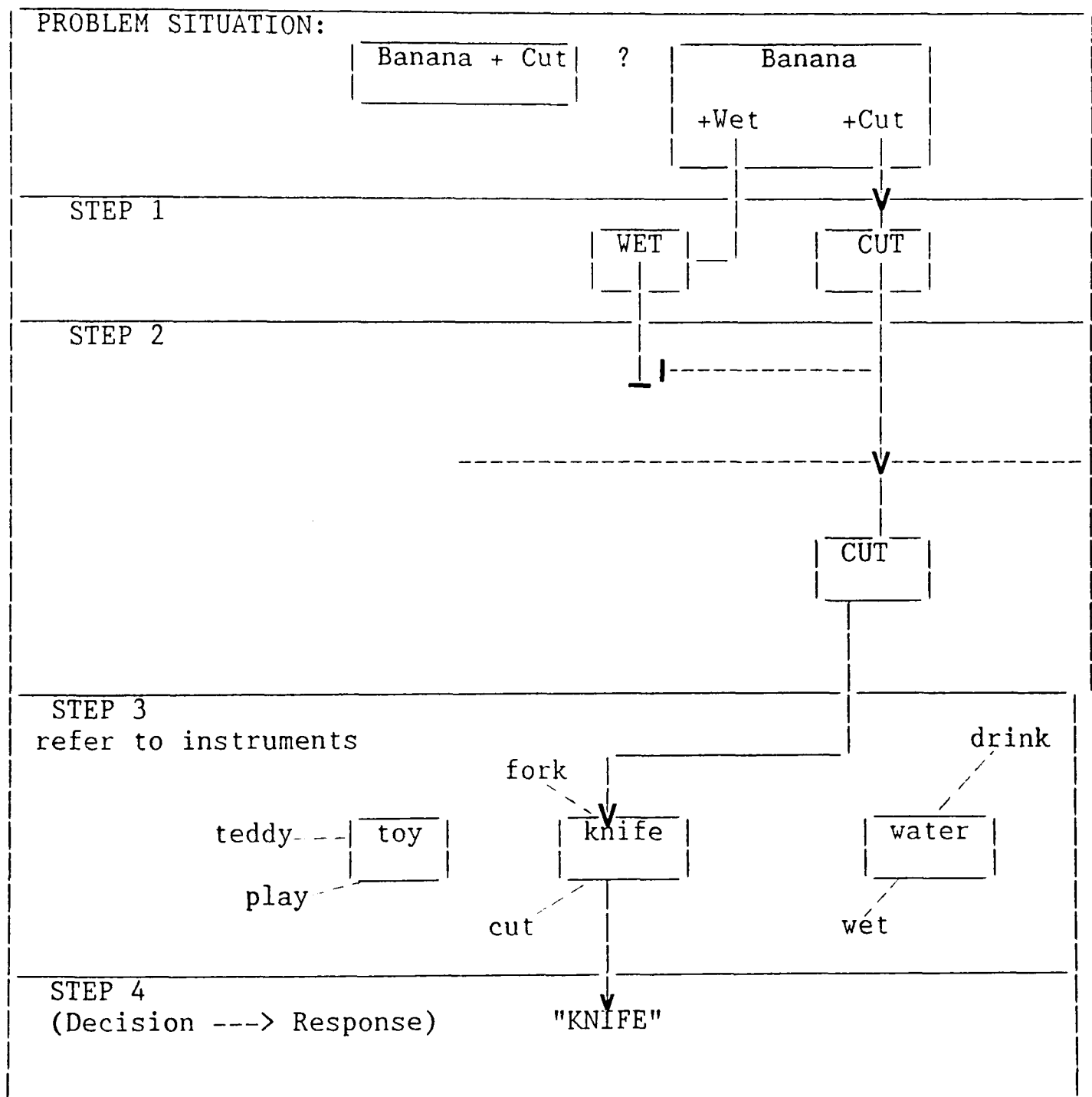


where - ———| = inhibited
 ———> = activated

PROBLEM SITUATION	----->	OBJECTIVE
(A) BANANA + cut----->	(A') BANANA + cut + WET	Determine cause of CHANGE from A to A'.

- METHOD
- 1. Scan last state to identify change/*by reference to prototype*
 - 2. Two end states - one activates processing.
 - 3. Find instrument that can cause that state from choice array.

(b) ASSOCIATIVE-CAUSAL (MATCHING) METHOD



where - ———| = inhibited
 ———> = activated

Experiment 2

In Experiment 2 sequences were extended to start with an object in its standard state (i.e. whole and unaltered in any way, e.g. whole cup) to ensure that children were clear which state they were being asked to make an inference about. It was thought that going through each transformation that resulted in the compound end states might help children to use a Relational method, relating each element in the sequence to the other in terms of a transformation. Although all the sequences contained S and NS transformations it was thought that the effect of salience might be reduced because each transformation (S and NS) was dealt with individually. Finally, the same type of sequences were used for the familiarisation as for the experiment proper, so that children were familiar with the sequences and procedure used in the experiment. (This was the case for all subsequent experiments.)

Although 3- and 4-year olds correct responses (CC) were significantly above the level expected by chance, the younger children made significantly fewer CC responses than the older ones. Both age groups made significantly more CC responses for the first transformation (banana--->cut banana) than for the second (cut banana--->cut WET banana). As Correct responses for the first transformation could be made by using a Matching Method, whereas a Relational Method had to be employed for the second, these results were consistent with the conclusions of the previous experiment.

Comparison of the two Conditions (Experimental and Control) of Experiment 1 with the second transformation (Chains Condition) of Experiment 2 showed that both age groups did best in the Control Condition. This finding confirmed the assumption that

when a Relational method was required (Experimental and Chains conditions) children made more mistakes than when a Matching method could be used successfully (Control). Also, compared to the Experimental condition, significantly more correct responses were made on the Chains condition. When information about the first state of the object was provided (Experiment 2 sequences) all the children made more correct responses for transformations identical to those in the Experimental condition.

Despite modifications the results of Experiment 2 were remarkably similar to those of Experiment 1. It seems that when children have to relate first and last states and have to discount a continuing state (Experimental Condition, Chains Condition), they make more errors than in a condition where it is possible to match or use a causal-association between an instrument and an effect (Control Condition).

These results provide support for the two methods proposed earlier: the Relational method and the Associative-causal Matching method (Matching method for short). The similarity of the overall response patterns in Experiments 1 and 2 also lends some credence to the suggestion that both Relational and Matching methods are available to 3- and 4-year-olds but that the difference between the two ages lies in their use of these methods. The older children, who made more CC responses overall, seem to use the Relational method more consistently.

10.3 Investigating issues raised by Experiments 1 and 2

The question raised by the results of Experiments 1 and 2 is why young children made associative-causal (ACCA) errors although they demonstrated the ability to use a relational method?

Two possibilities have been suggested:

1. Young children do not consistently relate initial and final states, preferring to focus on final states. Perhaps the ability to relate initial and final states is still nascent.
2. Young children can in principle relate initial and final states consistently but are unable to deal with compound end-states because of limited information processing capacity. Therefore, they choose to focus on the more salient state.

Since children name both end states when prompted to do so, why do they only decide to find the cause for one? Possibly younger preschoolers have difficulty in dealing with two features at a time as Siegler (1984) has suggested. If this is the case, then, when faced with two end states children may be tempted to find the cause for the most dramatic one first and may either 'forget' to process the second state or may dismiss it as unimportant.

The next experiments were designed to investigate these possibilities. They can be divided into studies which investigate children's ability to deal with two states or features (Experiment 3, Experiment 5 [ADD condition], Experiment 7) and studies which investigate children's abilities to relate object states in terms of transformations (Experiment 4, Experiment 5 - DISC condition, Experiment 6).

10.3.1 DEALING WITH ONE OR MORE FEATURES AND THE EFFECT OF SALIENCE

Experiment 3

To avoid any problems created by having to deal with sequences, only the final photographs (of sequences) were used. In the Experimental condition, a compound end-state was presented (e.g.

WET and BROKEN cup). In the Control conditions final photographs depicting a single state were used (e.g. WET cup). It was hypothesised that although children might be able to choose the correct single causes for both S and NS items in the Controls, the younger children might find it difficult to integrate, or 'add' the two relevant causal instruments to account for the compound end-states presented in the Experimental condition.

The results of Experiment 3 provided strong support for this hypothesis. Three- and 4-year-olds' correct scores on the Control conditions (S and NS) were near ceiling, but only the 3-year-olds made significantly fewer correct choices (both instruments) in the Experimental condition than on either of the Controls. The two ages differed significantly only in the Experimental Condition.

Correct scores in the Control conditions can be achieved by a simple Matching Method. In the Experimental condition each instrument may be chosen by 'matching', but a further step of 'integrating' or 'adding' is also required. The results of Experiment 3 indicate that 3-year-olds preferred choosing a single instrument - for the Salient state - to 'adding'.

Three-year-olds made significantly more single Salient choices than 4-year-olds. Although salience by itself does not influence young children's single causal judgements (Control conditions), it seems to be used to decide which of two states to focus on. Thus, in a situation where a relatively salient and Non-Salient state are 'competing' for attention (Experimental condition), the younger child seems to decide that the Salient state is the more important.

Whereas younger children made predominantly Single re-

sponses, older children made almost equal numbers of Correct and Single responses in the Experimental Condition. The different profiles of preferred responses of the two age groups may indicate a developing ability to deal with more than one transformation, and a corresponding ability to integrate the causes of the two changes occurring to the same object. Siegler (1984) points out that a number of studies have shown that young children are much more likely to use unidimensional rules than older children or adults (3.4): this seems to fit the results of the 3-year-olds. However, 4-year-olds display the capacity to 'add' two features as well as a tendency to choose single instruments. It would seem that at this age neither mode of responding is dominant, unlike the 3-year-old group, where the dominant response is the single Salient one.

This finding is congruent with the view that although different modes of operating may be available to children, certain methods may be preferred to others, perhaps because they are easier to use. The results of this Experiment show a clear difference between 3- and 4-year-olds in their handling of two object states. The increasing tendency to take both states into account may help 4-year-olds to discount the unchanging, continuous states in sequences such as those used in Experiments 1 and 2.

One possible implication of these findings is that in previous experiments children who made errors did so because they were focusing on final states rather than relating the initial and final states of objects in the sequence in terms of the transformation that had occurred. Hence they were more likely to be influenced by the salient state when deciding which of the two end-states they would find a cause for.

Experiment 5 - (ADD Task)

Children had to select two photographs from the choice array in Experiment 3 (Experimental Condition). This may have inhibited their choosing both instruments as they had to pick two objects physically as well as integrate them mentally. Young children may have chosen the instrument for the most salient transformation because it was the most important and in their eagerness to move on to the next item, 'forgotten' to, or neglected to pick out the second instrument as well. Thus, in the ADD Task in Experiment 5, children were presented with a JOINT choice, a photograph of both the instruments required to effect the two transformations shown. To see whether the same pattern of results as obtained in Experiment 3 would pertain within a sequence, the two states were presented within a sequence in the ADD condition. Sequences were of the form:

INFERENCE CONDITION

(JOINT choice)

CUP -hammer/ water/ hammer+water - WET BROKEN CUP

PREDICTION CONDITION

(JOINT choice)

CUP - HAMMER+WATER - wet cup/ broken cup/ wet broken cup

(Choices given in lower case)

In both INF and PRED conditions, children who were not predisposed to 'add' features were expected to err by making Single choices.

Older children made significantly more Correct responses overall, than younger ones. Additionally, although 4-year-olds' correct responses on the ADD tasks were significantly above the level expected by chance, the proportions of younger children's Correct scores were at chance level. These results suggest that while older children attend to and integrate both features in a consistent manner, younger children do not.

This finding is especially striking because there is no potentially confusing first state in ADD-sequences. The object is in its standard form (e.g. CUP) in the initial photograph. Thus, even when no discounting is required within a sequence, 3-year-old children appear to prefer end states and SINGLE features. When faced with a task involving two features this preference may influence them to focus on a single feature on the basis of some criterion such as Salience. It is possible that focusing on the Salient state 'inhibits' the processing of the Non-Salient one. The finding that 3-year-old's correct responses in ADD tasks could have arisen by chance intimates that this age group does not 'add' or integrate features in any consistent fashion as the 4-year-olds seem to do.

Nevertheless, the Salience factor could have influenced these results. Though 3-year-olds may be inclined (as much as 4-year-olds) to 'add' two given features, they may also be distracted from doing so by the Salient one and tend to focus on it to the exclusion of the other feature. In addition, it can be argued that the tasks used in these experiments were quite abstract as children had to make judgements on the basis of photographs. Although young children may be competent at integrating two features in a real-life situation, they may find it more difficult to implement this ability on abstract tasks.

Experiment 7

Therefore, Experiment 7 was designed to control for salience as well as to provide a more active task situation. Children were required to make something happen rather than to make judgements about things that had already happened. Furthermore, the two features that were used (Two Planks) were exactly like each other in shape, size and colour. The only difference between the two

planks lay in the position of the holes through which the sand could be poured into the box (9.2 -Two Plank Condition). There were two conditions: ONE PLANK and TWO PLANK. On the basis of the results of Experiments 3 and 5 it was predicted that 3-year-olds would need fewer trials on the ONE Plank condition than on the TWO Plank one because they find it easier to deal with single features.

The results confirmed this prediction. The younger children needed significantly fewer trials to complete the ONE plank task than the Two Plank task. Although there was no significant difference between the two age groups in the number of trials taken in the ONE PLank Condition, 4-year-olds needed significantly fewer trials than younger children in the TWO Plank condition. Younger children could eventually integrate both planks to get the desired effect but required more trials, than the older children, to do so. This was because the younger children typically only moved one plank at a time. Four 4-year-olds usually moved both planks within the same trial once they had worked out that the hole had to be under the funnel in order for the sand to fall into the box.

It is significant that even when a more active task was designed, with no potentially conflicting salience information, the results were remarkably similar to those of the more 'abstract' tasks. The findings of Experiment 7 provide considerable support for the suggestion that one of the major differences between 3- and 4-year-old's performance in these experiments is that older children integrate two features much more readily than younger ones.

The implication of the findings of Experiments 3, 5 (ADD) and 7 is that the ability to deal with multiple features is developing during the preschool years. Three-year-olds can solve a two-feature problem (Sandbox task) at their own pace. However, they

seem to be less competent at doing so in more abstract sequences where a more abstract mode of integration is required. It is therefore possible that their preference for dealing with SINGLE features predisposes them to focus on single states. When two altered states are present, they will therefore choose one to focus on. This choice seems to be influenced by salience.

The question that arises is whether the results obtained thus far can be explained solely in relation to young children's difficulties in dealing with two features. I think not. The problem of choosing between two end states only arises if children are not using a Relational method to deal with sequences. If children are relating initial and final states they should be able to discount the initial, continuing, state. However, discounting in these two experiments does involve the ability to deal with more than one feature. In Experiments 1 and 2, discounting and integration of two states are rather entwined. Therefore an experiment where no integration is required, but use of a relational method is essential was designed (Experiment 4).

10.3.2 WHY DO PRESCHOOLERS MAKE ASSOCIATIVE-CAUSAL RESPONSES?

Experiment 4

To avoid any difficulties arising from presenting two end states, in Experiment 4 sequences were created involving only one transformation. The cause of this transformation however could not be inferred by matching the end state with a plausible instrument because sequences were of the form:

Wet Cup -----?----- Cup (dry)

Two Conditions (Relational and Matching) were designed to see whether children would do better when they could match to end states

(Matching condition) than when they had to heed transformational information (Relational condition). The types of errors made on the experimental (Relational) condition would indicate whether children would fixate on visible change (find the cause for the initial state) or extract the relationship and find the cause for the transformation.

Younger children made far more Correct responses on the Matching condition than on the Relational. Both age groups however made significantly more Correct responses than expected by chance on both Conditions. Between the two age groups there was a significant difference in the Relational condition but not on the Matching. Thus, although 3-year-olds can relate initial and final states to extract the transformational relation they do not use this method as consistently as 4-year-olds. What do the younger children do?

Errors made in the Relational condition were largely associative-causal. These errors may indicate that children are attending to specific states rather than to information about the type of transformation that occurred. However, the proportions of these errors did not differ significantly from the proportions expected purely by chance. This finding is promising because it intimates that children as young as 3-years can relate object states in terms of transformations, given a relatively simple task. Furthermore, they may be making associative-causal judgements at random.

The 3-year-olds' inferior performance in the Relational condition suggests that it is not only a difficulty in dealing with two features which contributed to the significant age effects in previous experiments. Younger children do not use Relational methods consistently enough to get large numbers of Correct responses, even when only single states are used.

Nevertheless, it is important to stress that the results of Experiments 1, 2 and 4, all indicate that children as young as 3-years of age **can** make Correct responses **above** the level expected purely by chance in tasks which require the use of the Relational method. Their inferior scores compared to the 4-year-olds may be due to a preference for a simpler method rather than a complete inability to relate object states in terms of transformations. The younger children seem to use the Relational Method far less consistently than the older ones, especially when the Salience of transformations may 'activate' a Matching process.

10.4 Comparing Adding, Discounting and Associative-Matching

Experiment 5

Experiment 5 was designed to investigate the hypothesis that 3-year-olds would make more Correct choices in sequences where a Matching method would yield Correct responses than in Sequences which involved Discounting or Adding. Three types of task (AC, DISC and ADD - see 7.2 for details) were designed. In AC tasks, Correct responses could be obtained simply by using a Matching Method, in DISC tasks it was essential that a Relational Method was used in order to make Correct Choices. In the ADD tasks, as discussed earlier, children were required to integrate two object states/instruments. There were two Conditions: INFERENCE and PREDICTION.

Both 3- and 4-year-olds made the most Correct choices on tasks which did not require the use of either a Relational Method, or integration of two features (AC-tasks). Although significantly fewer Correct answers were made on the DISC tasks than on the ADD tasks, the proportions of Correct choices made on DISC tasks was

significantly above the level expected by chance. This suggests that children were using a Relational method on this task but did not use it consistently enough to get a large number of Correct responses.

No consistent errors were made by either age group on the INF-DISC tasks. However, on the PRED-DISC task, the proportion of Associative errors made by 3-year-olds were significantly above the level expected purely by chance. Associative errors consist of choosing the end state associated with the given instrument (e.g. "broken" for hammer). The majority of 3-year-olds errors were of this type and indicated that they were not relating initial and final states, but were choosing effects that matched the given instruments. This finding lends further support for the hypothesis that at age three children may be using both Matching and Relational methods but they err because they sometimes use an inappropriate method for the task given. Older children, on the other hand, seem to be more consistent and accurate in their choice of methods.

In conjunction with the findings of Experiments 1 and 2, the results of Experiment 5 suggest that while 3-year-olds may prefer associative relations, older children may prefer causal relations. However, although it can be concluded from these experiments that younger children definitely do better when only associative-causal Matching methods are required this does not really show what type of relations they prefer.

10.5 Do children prefer Causal or Associative Relations?

Experiment 6

Experiment 6 was designed in an attempt to answer this question. Children (3+ - 5+) were asked to construct sequences given an initial photograph and four choice photographs. It was thought

that by allowing children to structure their own sequences some clues about their preferred mode of relating objects might emerge. Since the children were instructed to "make a story" about each object, a verbal skills measure (BPVS) was also administered.

The different possible story structures have been described in detail in Chapter 8 (see Diagram 8.1.2). In the CAUSAL story the starter object was transformed, and the instrument of transformation was included in the sequence, for example:

Cup -paint- Painted Cup

In all three age groups, the proportion of CAUSAL stories (for both Salient (PS) and Non-Salient problems (PNS)) was significantly above the level expected by chance. The number of Causal stories increased significantly with age: 5-year-olds made significantly more causal story-structures than 3- and 4-year-old children. Children made far more Causal stories for PS than for PNS. This suggested that Salient transformations elicited causal structuring. The non-significant interaction between Verbal Skills and Problem-type (S/NS) indicated that children with higher Verbal skills tended to make more causal structures no matter what type of problem they were faced with.

Three types of associative stories (Associative-Similar [AS], Associative-Random [AR] and purely Associative [A]) were identified (8.3). The proportions of AS stories were the only ones above chance expectations in the two younger age groups. Three-year-olds made significant numbers of AS stories for both PS and PNS while 4-year-olds AS stories were significantly above chance level only for PNS. This finding seems to indicate that 3-year-olds prefer the AS structure more than 4-year-olds. The older children use it for Non-Salient problems where the transformation may not be salient enough to elicit a causal story.

In answer to the question raised in this section, the results of Experiment 4 showed that 3-year-olds made fewer Relational judgements than 4-year-olds. The results of Experiment 6 indicate a shift (between the ages of 3+ and 5+) from a preference for associative structures towards a preference for causal structuring.

10.6 Limitations of Experiments in this Thesis

Specific limitations of each experiment have been outlined in the discussion section of each experimental chapter therefore only general criticisms will be made here.

One major limitation of the experimental work in this thesis is that whenever objects were presented in two states (e.g. cut and wet) one state was always more salient than the other. The material had been created to ensure that two distinct changes could be seen, and thus salience was a discriminating feature. However, perhaps because of a preference to focus on changed end states, salience became a cue for processing one state rather than another. One way to check whether children still prefer the Matching method when salience is not a cueing factor would be to design material in which the two states depicted were equivalent in salience.

It should be noted that Salience can be conceptual as well as perceptual. For example, a broken cup is both conceptually and perceptually salient. It looks very striking and the child is aware that 'breaking' things is "bad". Additionally, cups are usually broken by dropping, so the choice of 'hammer' in a way contributes to the salience of 'broken' because of its novelty. On the other hand, cut paper is not conceptually very salient because it is a familiar everyday activity in nursery classes and perhaps at home. Thus, 'cut' is perceptually salient compared to 'written' but not

conceptually salient in itself. If both conceptual and perceptual salience of various transformations are taken into account and a set of material designed in which both end states are almost equally salient, for example:

Cut Paper + writing in red ink

it would be possible to control for the effect of salience. Thus it would be possible to find out whether Salience actually prompts or inhibits Relational thinking. Perceptual and conceptual salience should also be taken into account when creating such materials.

Another possible criticism of the material used in this thesis is that the same types of objects and transformations were used throughout. This was done so that there was some consistency across experiments. Also, pilot testing showed that children were familiar with transformations such as 'cut', 'write', 'break' etc., and it was thought that by using familiar material children would be given more of a chance to demonstrate whether or not they were able to use certain basic causal principles. Having shown that 3- and 4-year-olds can use a Relational method of reasoning, the next step may be to see what they do when unfamiliar instruments and transformations are used. However, in using unfamiliar materials one has to be aware that children may be thrown by the fact that they do not have any knowledge about a specific event. After all, even adults can come up with magical or irrational reasons for events beyond their sphere of knowledge.

The material used could also be improved by using different choice-instruments. For instance, water (from a tap or in a jug) is always the instrument of 'wetting', hammer the instrument of 'breaking', and so on. As these instruments are often used in the familiarisation sequences as well as the in experimental ones, it is

possible that associative-causal links between certain instruments and effects are strengthened during the experiment itself. Therefore, if three different (but plausible) instruments were utilised for each transformation (e.g wet $\rightarrow$ water/ tea/ orange juice) there would be less chance of a "water $\leftrightarrow$ wet" associative link being strengthened.

It would also be a good idea to elicit associations from the children themselves. For example, a child could be shown a broken plate and asked to say what could make it happen. Especially in Experiment 6, it would have been an advantage to have used associations elicited from children. The advantage of using elicited associations is that there is a degree of certainty that children do 'group' certain things together and this not just the theoretical imposition of an adult.

10.7 Present Results in the Light of Previous Research

Despite these limitations the results of the experiments reported in this thesis indicate that when familiar materials are used and when the verbal load of tasks is reduced children as young as 3-years of age demonstrate that they can reason causally. Contrary to Piagets's claims (see Chapter 2) preschool children demonstrated an understanding of the causal relation in terms of change in abstract photographic sequences.

These results also indicate that we should not assume that 3-year-olds, or even 4-year-olds, reason in a purely Relational (causal) way when faced with event sequences. Given a number of similar sequences children may opt for either a Relational Method, or a Matching Method, or often, both. What seems to develop between the ages of 3- and 4-years is the ability to choose and use the relevant

method in a fairly consistent way.

10.7.1 CAUSAL RULES (Shultz)

The present results are consistent with recent claims that "children as young as 3 years have at their disposal a diverse array of rules for making causal attributions" (Shultz, Fisher, Pratt and Rulf, 1986:143). Shultz et al. proposed that the generative transmission rule which specifies that "an effect is attributed to a cause that is capable of directing the appropriate sort of transmission to the effect" (1986:143) is the overriding principle because of "its greater adaptational success in accounting for causal phenomena". However, when the generative transmission is not obvious, other rules - the "secondary principles" - are used.

One such principle is that of 'facility' which is connected with the information-processing demands of specific causal rules. Shultz et al. suggest that:

"For each causal rule there is information that needs to be remembered and analyzed. When that information exceeds the capacities of the observer, the facility principle specifies that the rule requiring that information will not be used.." (1986:148)

They argue that as working memory processes increase in efficiency with development, the facility principle would have "a differential impact on children of different ages". To test this assumption they created a conflict between rules of covariation and temporal contiguity. The amount of information required by the covariation rule was varied over conditions. They found that although the covariation rule was predominant in all age groups (3- 5- and 7-years) when covariation information was simple, in the complex information condition the younger children (3 and 5 years) abandoned the covariation rule and opted for the simpler temporal contiguity rule. These

results are consistent with the facility principle.

If the facility principle is applied to the two methods of reasoning with causal sequences proposed here, it is clear that the Matching Method (Diagram 1b) is definitely the simpler one. It is possible that sequences such as those used in this thesis produce some degree of conflict between choice of Relational and Matching methods. If 3-year olds are at an age where both strategies are accessible, but they have not yet developed a preference for the Relational method, it is possible that they may use the Matching method when it is more facilitatory.

Although children in the Shultz et al. experiments could watch an event happening and then make a judgement about it, children in my experiments were typically presented with representations of events that had already happened and asked to make judgements about these events. Judgements, in the latter case, had to be made on the basis of the informational constraints that they were given. In this respect, the work done using pictorial sequences differs significantly from other types of experiments where the phenomena can be observed directly. Reasoning about pictorial sequences is a more abstract process, and although memory and verbal demands may be reduced, such sequences require the abstraction of relations based on assumptions about priority and generation. Thus, the fact that 3-year-olds can reason successfully about such sequences implies that they do make these assumptions. This view is consistent with the findings of recent research on children's causal understanding (Shultz, 1982, Baillargeon and Gelman, 1980, Keil, 1979, etc.).

However, the results also show a developmental difference between the ages of 3-years and 4-years. Essentially, although

younger preschoolers use the Relational method they do so far less than older ones. Even when possible influences such as competing salience information and having to deal with two features are removed (Experiment 4) this pattern persists. The question raised is why this is so.

The results of Experiment 6 suggest that 3-year-olds prefer associative groupings to causal ones whereas older children show a marked preference for causal grouping. This preference, tied to the fact that the Matching method is more facilitatory than the Relational one, may have influenced children's responses.

If, however, apprehension of change is one of the major prompters of causal reasoning (as suggested in Chapters 1 and 2), then, the predominance of AS stories over other associative structures is understandable. It may indicate that although very young children are aware of change they are also interested in grouping things (things that "go together"). Indeed, in all the nurseries and playgroups I visited, categorisation of objects that "go together" was a regular exercise. Therefore, although young children may encode the fact that something has changed and are intrigued by it, they do not always go on to search for the instrument of change and include it in their story. They may prefer to choose another object associated with the starter object instead.

10.7.2 CAUSAL AND ASSOCIATIVE 'COMPLEXES' (Vygotsky)

If preschoolers had shown a marked preference for associative ordering, the possibility that causal ordering is a result of formal/informal learning would have been very strong. However, children as young as 3-years performed above chance level in producing causal stories. The next most common ordering was the AS one, which

included a changed object. Taken together, there seems to be an indication that perception of change does influence ordering of sequences.

Vygotsky's (1962) described a type of thinking used in concept formation which he called "thinking in complexes", and defined thus:

"In a complex, the individual objects are united in the child's mind not only by his subjective impressions but also by bonds actually existing between these objects"
(Vygotsky, 1962:61)

These bonds were based on similarity, contrast and associations the simplest complex being "the associative complex". Objects are included in this complex because of similarity in shape, size, or any other attribute. Contrast, and temporal or spatial contiguity, also influence inclusion of objects into this complex. This complex is very similar to the Associative-Similar category in Experiment 6.

The "collection complex" identified by Vygotsky, was more advanced than the simple associative complex in that some sort of superordinate ordering seems to be involved. In this complex "collections of complementary things often form a set or a whole...the collection complex is a grouping of objects on the basis of their participation in the same practical operation - of their functional operation" (1962:63). This complex is akin to the Purely Associative story category. Very few Associative stories were made in Experiment 6.

From the Vygotskian position this is not really surprising as the purely associative ordering is what Vygotsky (1962) called a "collection complex". This type of complex is more advanced than the simple "association complex" which is more akin to AS stories. There may have been some conflict between causal ordering and

purely associative ordering, with the causal ordering being chosen in favour of the latter simply because the instructions were to make a story about what **happened** to objects. The real choice shift appears to be between making C and AS stories. It is possible that the AS story is the simplest one. Both C and purely A stories are more complex, and involve the imposition of some kind of **relation** such as causality or functionality which connects the different elements into a whole **on the basis of this relationship**. Thus, the shift may be from simpler to more complex structuring. As the causal structure may be more preferred than the Associative, especially in 'making a story', it is the causal structure that is chosen.

Such an explanation intimates that 3-year-olds cannot really make a causal ordering, but the results of this experiment suggest otherwise. One way to see if children are able to perform a task (i.e. to see whether they have the cognitive capacity to handle the task) is to train them. If they improve with training then this may indicate that although they are able to order things causally, for example, they did not do so spontaneously for a number of reasons. That is, they might not have understood exactly what the experimenter wanted them to do. They might have preferred things that go together and chosen that grouping because they were more familiar with it, and so on. Thus, if this experiment is rerun using a before-after design, with training in making causal stories, it can be seen whether 3-year-olds find it easier to make AS stories than Causal ones, or whether they just prefer to make such stories when the constraints of the task are not strictly spelt out.

Zaporozhets, Zinchenko, and Elkonin (1971) point out that although adults often view the child's inability to solve a problem in a specific way as a function of his inability to master

certain intellectual operations "in reality, a distinctive solution is given because the child has changed the perception of the problem to correspond with the motivation stimulating him" (p. 234). In situations where the task is not strictly constrained, preschoolers may be guided by motivational factors such as liking for a particular item or past experience. Such factors may influence the child's choices. If children can be encouraged to give verbal explanations for their choices, some very interesting insights may be gained. For example, Zaprozhets et al.. relate how a preschool child solved an object classification problem (cup, glass, saucer, slice of bread) where they had to choose the object which was the odd one out. The child chose to eliminate "glass" because if he was to have breakfast he would drink a cup of milk and eat a slice of bread. This is a logical, functional relation, based on experience. As Zaprozhets et al.. (1971:235) point out, "from the point of view of logical operations, the..reasoning is irreproachable. Only the child's relationship to the problem, which leads him to substitute a mental solution of a lifelike problem for classification, is original". This seems a point well worth keeping in mind when interpreting results of Experiment 6. Adult 'bias' in interpretation may be greatly reduced if verbal data of this sort is elicited from preschoolers.

10.7.3 IMPLICATIONS AND SPECULATIONS

The findings reported here may throw some light on the sometimes contradictory conclusions about children's capabilities made on the basis of past research in this area. If young preschoolers have a generalised difficulty in integrating multiple features, then they will not do well in causal reasoning tasks which make such demands. Much of the past research has pitted different types of

information (e.g. covariation against contiguity) but children's choice of simpler principles may be governed not so much by an inability to grasp or use the more complex principle as by a difficulty with integrating two or more features and with discounting the irrelevant one.

Essentially, the results of all these experiments provide support for the notion that the preschool child has access to a number of 'rules' or strategies for dealing with certain problems. What seems to be developing is the ability to apply these methods relevantly.

Leslie and Keeble (1987:286) suggest that causal perception may be an initial "processing device to introduce a cause-effect format for internally representing events". It is possible that this cause-effect format is what helps children distinguish causal relations from associative ones. This may even be the basis of the CHANGE schema described earlier on. Causal associations are thus specific instances of causation which help children build up elementary notions of the powers of things. These notions may be altered and extended by experience but may constitute an initial knowledge base. Reasoning about causal events may be facilitated by accessing the Change schema. This view is compatible with claims that "children's concepts are constrained in terms of what information is attended to and how it is organised at the representational level...(developmental) change occurs more in the acquisition and use of information specific to each content domain than in the acquisition of new conceptual structures" (Bullock, 1984:5).

These speculations need to be confirmed by further research. Some ideas for future research, aiming to address such

issues, are presented in the next section.

10.8 Suggestions for Future Experiments

It was proposed that children may be using two methods to deal with event sequences. One factor that inhibited use of the Relational method, and discounting in particular, was the difficulty that children may have when dealing with two end states. The results of Experiment 4 indicated that although 3-year-olds may use the relational method to a lesser extent than 4-year-olds, their associative errors could have arisen by chance. This result raises the issue of whether it is mainly a difficulty in dealing with two states which triggers associative matching. In order to test this, more sequences such as those designed for Experiment 4 could be created using a greater variety of transformations. By using a repeated measures design in which the same children would have to deal with single feature sequences (Wet Cup---->Cup (dry)) as well two feature sequences (Wet Cup---->Wet Broken Cup), it may be possible to find out which sequences are more difficult for children to deal with, and which, if any, elicit associative matching responses to a significant degree.

Another question raised by the results was whether an ability to deal with two features directly affected children's use of the Relational method. I suggest that children who process both end states, refer back to the sequence and scan it in a relational way when they realise they can only choose one instrument of transformation. One way to test this speculation would be to design an experiment to check the correlation between an ability to deal with two features and the consistent use of a relational method.

For example, an experiment could be designed in which

there are two conditions: Features and Sequences. In the Features condition children would be presented with joint end states (e.g. wet cut banana, as in Experiment 3). In the Sequences condition, children would be presented with sequences such as those used in the Experimental condition of the first experiment (cut banana ---> wet cut banana). Using a repeated measures design, with counterbalanced conditions, it should be possible to test for correlation between the two conditions. Creating a totally different set of materials in which ends states were equally salient would be advantageous, as any effect of salience would be controlled for to some extent. Additionally, if, in a corresponding experiment, sequences were designed where two states were either equally salient or very different in salience then a comparison of performance on the two types of sequences might provide evidence about whether salience is inhibitory to the processing of two states (as suggested by Diagram 1b). The results of such experiments may indicate (1) whether there is a direct connection between the ability to integrate features and the tendency to use a relational method; and (2) to what extent salience information influences different types of processing of information.

10.9 Conclusions

There has been considerable controversy about the notion of causation for centuries. One of the main issues debated by philosophers is the notion of causal necessity. In this thesis, this notion has been largely taken for granted, the viewpoint adopted being that of Hawkins (1937, Harre and Madden, 1975, and Shumaker, 1980). This approach takes the view that causal instruments, or agents, have in their nature, because of certain properties, the

ability to bring about specific effects.

Psychologists have focused on a number of issues in relation to the development of causal understanding. The development of the acquisition of knowledge about causal relations which can be articulated (eg. Piaget, 1930) or inferred from behaviour (eg. Keil, 1979) have been studied. The conditions under which a causal relation (between inanimate objects) is perceived have been demonstrated (Michotte, 1963) and children's knowledge of causal laws such as priority, contiguity and covariation have also been researched extensively (reviewed in Sedlak and Kurtz, 1981).

Some of the more recent work has focused on children's reasoning about causal events (Gelman, Bullock and Meck, 1980). The focus of the present thesis has been on the way in which children reason about causal event sequences and the methods they may use to process such sequences. Two such methods were postulated: the Relational and the Associative-Causal Matching methods. There is evidence that children may rely on an associative-causal data base to make inferences about specific instruments or effects. Correct judgements (in certain sequences) could only be made by accessing some sort of higher-order 'relational schema' which specifies that a causal relation involves change from one state to another. The postulation of such a schema is very speculative, but the results of experiments in this thesis provide some support for this speculation.

The study of the existence and development of such a schema among preschool children and infants poses a complex and intriguing research problem. Connecting events which could be interpreted as isolated occurrences into a relationship mediated by transformation or change is a basic yet complex process. Neverthe-

less, it seems essential for an understanding of causality. Whether infants prefer such a relation over relations of association is an interesting question. Preference for causal relations may point to some sort of adaptational pressure to encode the relevant temporal and spatial cues necessary for causal comprehension as Leslie and Keeble (1987) intimate. Such pressure may predispose infants to attend to 'change relations' in preference to any other type of relation when both types of relations are present. Such a tendency would help them build some sort of associative-causal data base which they could apply to their environment. These speculations arise from ideas presented in this thesis and have been presented here as possibilities for future research.

There is still much to be learned about the development of causal understanding as well as about the processes underlying causal reasoning. Some of the most interesting developments seem to occur during infancy and early childhood and more work with very young children may broaden our conception of their capabilities, not only in causal reasoning but in other areas. As Moses Maimonides stated centuries ago:

"It is..impossible to infer from the nature which a thing possesses after having passed through all stages of its development, what the condition of things has been in the moment when this process commenced...If you make this mistake, and attempt to prove the nature of a thing in potential existence by its properties when actually existing, you will fall into great confusion."

(Guide for the Perplexed, ca. 1185 A.D.)

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APPENDIX 1

A PILOT STUDY - Experiment 1

Introduction

The pilot testing of materials used in Experiment 1 was done in two stages. First children's familiarity with each object and transformation to be used in the experiment was tested to ensure that all the children recognised them. Secondly the same children were tested on sequence sets X and Y respectively to

- (i) ensure that they understood the task
- (ii) ensure that the two sequence sets were comparable.

Method

(a) Subjects - were twenty children from Oxford College creches and nurseries. There were ten 3-year-old children, ranging in age from 3-2 to 3-10 and ten 4-year-old children age range 4-4 to 4-11.

(b) Design An independent groups design was used. Half the children in each age group (5) experienced Set Y sequences and the other half experienced Set X sequences.

(c) Material Colour photographs of objects in standard (eg. apple, cup, etc.) and altered forms (eg. cut apple, cut wet apple, broken cup, etc.) were used to test familiarity with objects and transformations. The same photographs were then used to construct the two sequence sets.

(d) Procedure

1. Testing for Familiarity

This was done over three or four sessions with each child, depending on individual attention spans. Each child was shown over a hundred photographs of objects in their standard states (apple), objects transformed in one way (broken cup) and objects

transformed in two ways (wet cut banana).

Recognition of objects:

The children were first asked whether they recognised the object:

"Do you know what this is?" (Children responded with either yes, a nod, or the name of the object). In the first two cases the experimenter (E) then asked:

"What is this?", or, "What is this called?" - pointing to the photo of the object.

All photographs which children did not recognise were discarded at this stage.

Recognition of transformations:

Children were asked to name the transformation that the object had undergone:

"What has happened to this _____?"

Where two transformations had occurred and only one was named, children were prompted to name the second transformation :

"What else has happened to this _____?"

Testing Understanding of Sequences

Both age groups were tested on sequence sets X and Y. Each sequence was laid out before the child and s/he was told to pick the instrument that had changed the object from its beginning state to its end state:

"Look at these three things, and tell me which ONE I used to make this cup" (pointing to beginning photograph)" become like this?" (pointing to end photograph).

After giving the instructions E asked the child - "What do I want you to do?". Over half the four year old children responded with - "Say what did it", or "Find what made it ____". The rest of the four

year olds and the majority of the three year old children either, did not give any verbal reply but simply chose an instrument, or said - " I don't know". In the latter case the experimenter repeated the instructions and then asked - "Do you know what to do now?", when the child nodded or said -"Yes", they were again asked - "What do I want you to do", at this stage all the children either told the experimenter verbally or actually chose an instrument. Because of this initial difficulty in comprehending instructions in Experiment 1 children were familiarised with a number of practice sequences to ascertain that they knew what was expected.

Results

1. Familiarity

Table 1 shows the percentage of correct responses given by three and four year old children for naming objects and transformations. The majority of children's responses were correct on this simple naming task.

TABLE 1 NUMBER AND PERCENTAGES OF CORRECT RESPONSES IN NAMING
OBJECTS AND TRANSFORMATIONS.

AGE	OBJECTS	OBJ. ONE TRF	OBJ. TWO TRF'S
3	95.5	91%	82.5
	(640)	(182)	(165)
4	99.6%	95%	90%
	(667)	(190)	(180)

2. Sequences

Childrens scores on the two sequence sets (X and Y) were compared. The sequences were presented in the Experimental Condition as this was expected to best discriminate between the two sets of

materials, being the more difficult condition. The number of correct responses made by the two age groups is given in Table 2.

TABLE 2 NUMBER OF CORRECT RESPONSES (out of ten) ON
TWO SEQUENCE SETS

<u>SEQUENCE SET</u>	<u>3-YEARS</u>	<u>4-YEARS</u>
SET X	22	40
SET Y	19	35

The chi-square test (Everitt, 1977) showed no significant difference ($p>.05$) in the proportions of correct responses given on the two sequence sets by three and four year old children. This indicated that the two sets were roughly comparable, ie. neither was easier nor more difficult than the other.

Conclusions

Preschool children demonstrated familiarity with the objects and transformations depicted in the pilot photographs. These photographs were used to construct sequences for Experiment 1. Although no difference was found between the two sets of sequences, since they were tested on such a small sample it was decided to keep them separate for the statistical analyses. They were however assumed to be roughly equivalent. It was on this assumption that they were used in the experiment.

B. Materials Used in Experiment 1

TABLE 3 TRANSFORMATIONS AND INSTRUMENTS IN EXPERIMENT 1

TRANSFORMATION	CAUSAL INSTRUMENT
<u>Familiarisation</u>	
cutting	scissors or knife
shutting	hand
breaking	hammer
erasing	eraser
<u>Experimental</u>	
wetting	water
cutting	knife/scissors
marking	paintbrush/pen/pencil
breaking	hammer
combing	comb
drying	towel
erasing	erasor
shutting	hand

1. AN EXAMPLE OF PHOTOGRAPHS USED IN EXPERIMENT 1

EXPERIMENT 1 - Set Y

BANANA PAIR

INITIAL STATE



FINAL STATE



SEQUENCE 1

INITIAL STATE



SEQUENCE 2

FINAL STATE



2. DESCRIPTION OF SEQUENCES USED IN EXPERIMENT 1

N.B. Choices given in each Condition are presented separately: (c)

(A) FAMILIARISATION SEQUENCES

FIRST STATE	-----CHOICES -----	END STATE
1. Plate+drawing	----scissors, matches, toy----	Plate+drawing cut
2. Wet box	-----hand, keys, card-----	Wet box open
3. Smaries box+ribbon	----knife, rug , book,----	Cut Smarties box + ribbon
4. Bottle+paint	----hammer, candle, newspaper----	Bottle+paint smashed

(B) EXPERIMENTAL SEQUENCES

SEQUENCE SET X:

TRANSFORMATION		
1. WET CUP	breaking	WET BROKEN CUP
2. BROKEN CUP	wetting	WET BROKEN CUP
3. PAPER+WRITING	cutting	PAPER+WRITING CUT
4. CUT PAPER	writing	PAPER+WRITING CUT
5. DOOR AJAR	painting	DOOR AJAR+PAINT
6. DOOR+PAINT	opening	DOOR AJAR+PAINT
7. WET HAIR+COMB	drying	DRY HAIR+COMB
8. WET TOUSLED HAIR	combing	WET COMBED HAIR
9. APPLE CUT+PICTURE	erasing	CUT APPLE (no picture)
10. APPLE+PICTURE	cutting	CUT APPLE+PICTURE

SEQUENCE SET Y

TRANSFORMATION		
1. CUT BANANA	wetting	WET CUT BANANA
2. WET BANANA	cutting	WET CUT BANANA
3. PLATE+PAINT	breaking	BROKEN PLATE+PAINT
4. BROKEN PLATE	painting	BROKEN PLATE+PAINT
5. WET ORANGE+FACE	drying	DRY ORANGE+FACE
6. WET ORANGE	drawing	WET ORANGE+FACE
7. LONG TOUSLED HAIR	combing	LONG COMBED HAIR
8. LONG TOUSLED HAIR	cutting	SHORT TOUSLED HAIR
10. OPEN DRAWER+PAPER	shot	CLOSED DRAWER+PAPER
9. OPEN DRAWER+DRAWNON PAPER	erasing	OPEN DRAWER+BLANK PAPER

Different choices were offered in the Experimental and Control conditions for the same sequences. The choices offered for each sequence set, in each of the two Conditions is given overleaf:

I. CHOICES IN EXPERIMENTAL CONDITION

SET X	SET Y
1. hammer, water, feather	knife, water, flowers
2. hammer, water, feather	knife, water, flowers
3. scissors, pen, matches	paint, hammer, keys
4. scissors, pen, matches	paint, hammer, keys
5. hand, paint, book	towel, felt pen, spider
6. hand, paint, book	towel, felt pen, spider
7. towel, comb, spoon	comb, scissors, cards
8. towel, comb, spoon	comb, scissors, cards
9. eraser, knife, newspaper	eraser, hand, rug
10. eraser, knife, newspaper	eraser, hand, rug

II. CHOICES IN CONTROL CONDITION

SET X	SET Y
1. hammer, matches, feather	water, flowers, keys
2. water, ribbon, postcard	knife, magazine, box
3. scissors, umbrella, book	paint, chair, biscuits
4. pen, tin, spoon	hammer, cards, bottle
5. paint, newspaper, plate	towel, toy car, telephone
6. hand, sweets, plant	felt pen, keys, cup
7. towel, ruler, glue	comb, spider, post-card
8. comb, shoes, crayons	scissors, stamp, sellotape
9. eraser, soap, ribbon	hand, dishcloth, coke can
10. knife, purse, envelope	eraser, rug, batteries

APPENDIX 2

Materials Used in Experiment 2

1. AN EXAMPLE OF PHOTOGRAPHS USED IN EXPERIMENT 2

(PERIMENT 2

A CUP SEQUENCE



TRF 1

2. DESCRIPTIONS OF SEQUENCES IN EXPERIMENT 2

A. FAMILIARISATION SEQUENCES

TRANSFORMATION 1		TRANSFORMATION 2	
1. Plate	---?---	Plate + PICTURE	---?--- Plate + picture CUT
2. Box	---?---	WET box	---?--- Wet box OPEN
3. Bottle	--?---	Bottle + PAINT	---?--- Bottle + paint BROKEN
4. Smarties	--?--	CUT Smarties	---?--- Smarties cut + BOW

CHOICES - were the same as in Experiment 1. Same choices at both Transformation Points.

B. EXPERIMENTAL SEQUENCES

N.B. In each pair of sequences, choices were exactly the same, at each transformation point.

Transformation 1		Transformation 2	
1. CUP	WET CUP	WET BROKEN CUP	
2. CUP	BROKEN CUP	WET BROKEN CUP	
Choices: Hammer, water, feather			
3. PAPER	PAPER+WRITING	PAPER+WRITING CUT	
4. PAPER	CUT PAPER	PAPER+WRITING CUT	
Choices: pen, scissors, umberella			
5. DOOR	DOOR AJAR	DOOR AJAR+PAINT	
6. DOOR	DOOR+PAINT	DOOR AJAR+PAINT	
Choices: paint, hand, tin			
7. MESSY WET HAIR	NEAT WET HAIR	NEAT DRY HAIR	
8. MESSY WET HAIR	MESSY DRY HAIR	NEAT DRY HAIR	
Choices: towel, comb, crayons			
9. APPLE+PICTURE	CUT APPLE+PICTURE	CUT APPLE - no PICTURE	
10. APPLE+PICTURE	APPLE (no picture)	CUT APPLE	
Choices: knife, eraser, spider			

TABLE 1 THE NUMBERS OF MAJOR ERROR TYPES IN EXPERIMENT 2

ERROR TYPE		AGE GROUP	
		3+	4+
	CCCA	15	10
	CCAC	2	0
	CCAA	1	5
	CACC	8	7
	IACC	1	5

APPENDIX 3

EXAMPLE OF PHOTOGRAPHS USED IN EXPERIMENT 3

EXPERIMENT 3 - APPLE AND PLATE ITEMS



CHOICES IN EACH CONDITION

The same choice photographs were presented for the relevant items in each condition.

<u>EXPERIMENTAL</u>	<u>CONTROL 1</u>	<u>CONTROL 2</u>
wet broken cup	wet cup	broken cup
paper+writing cut	paper+writing	cut paper
door open+paint	door open	door+paint
apple+picture cut	apple+picture	cut apple
wet banana cut	wet banana	cut banana
broken plate+paint	plate+paint	broken plate
<u>wet orange+face</u>	<u>wet orange</u>	<u>orange+face</u>

CHOICES

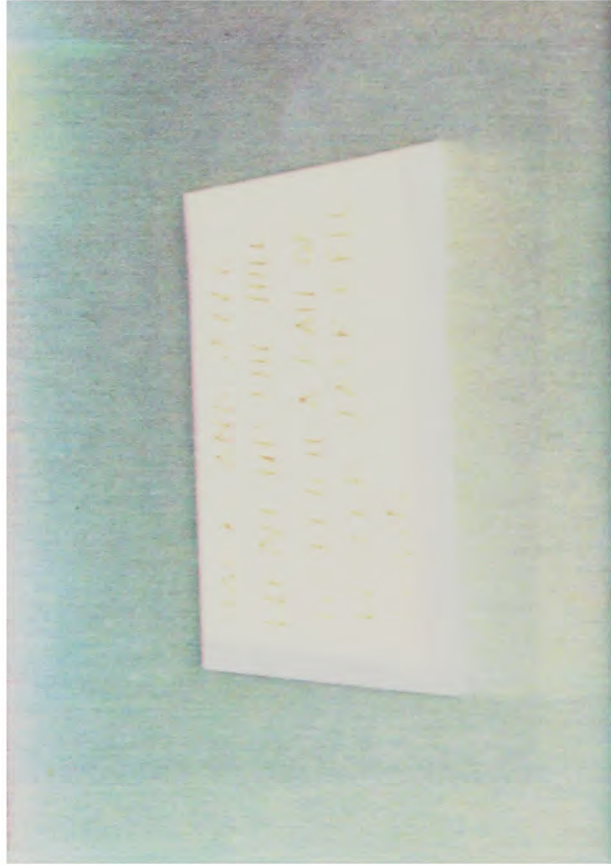
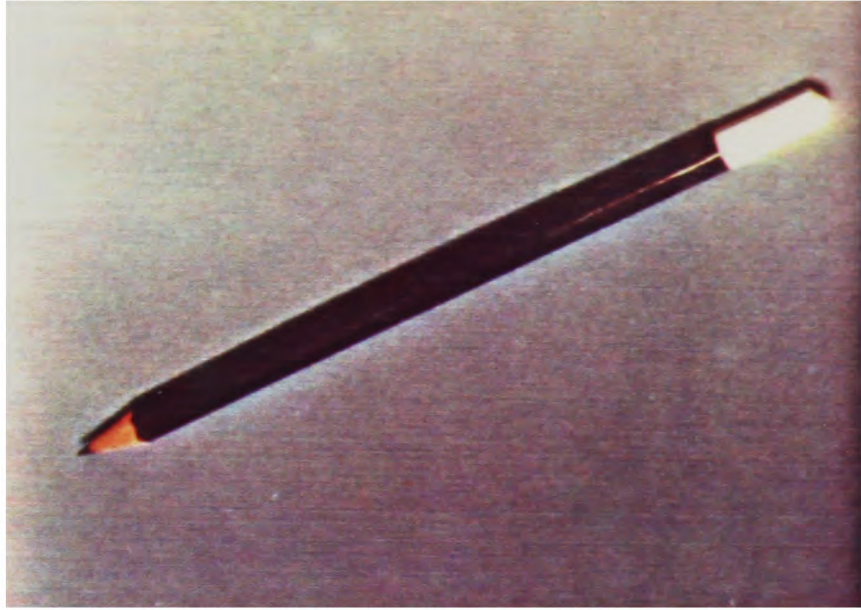
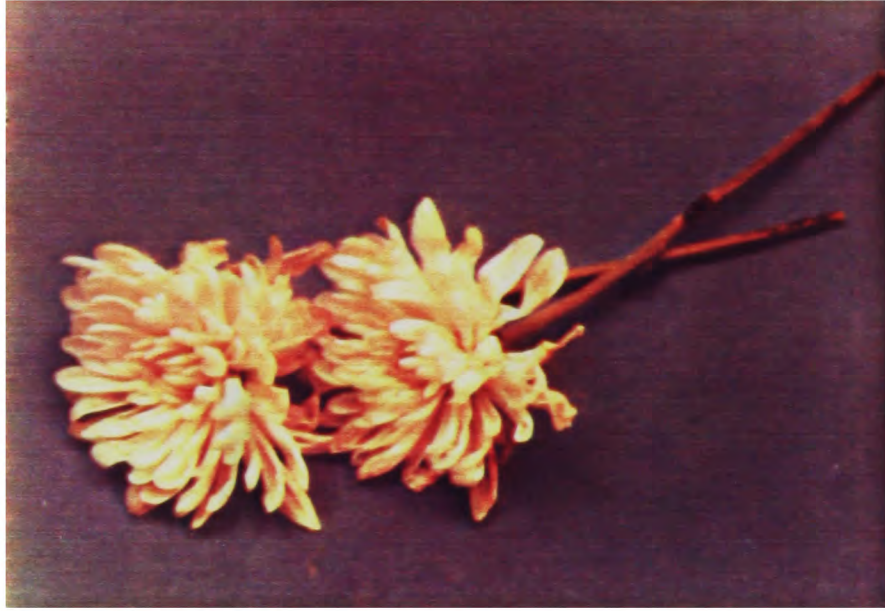
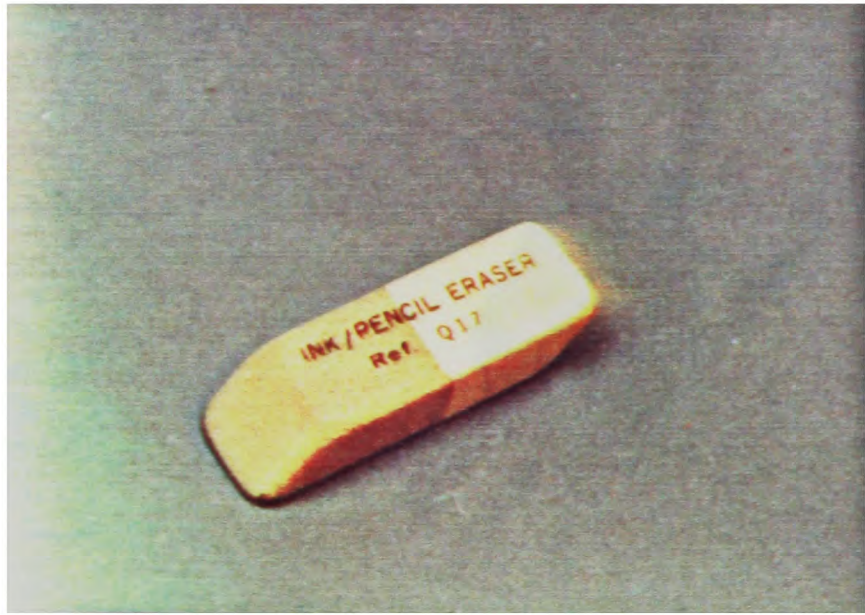
hammer, water, feather
scissors, pen, matches
hand, paint, book
eraser, knife, newspaper
water, knife, flowers
hammer, paint, keys
crayon, water, cards

APPENDIX 4

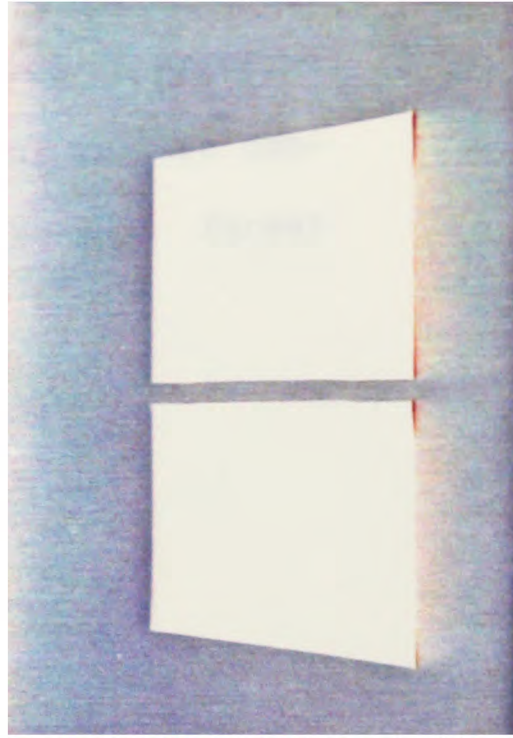
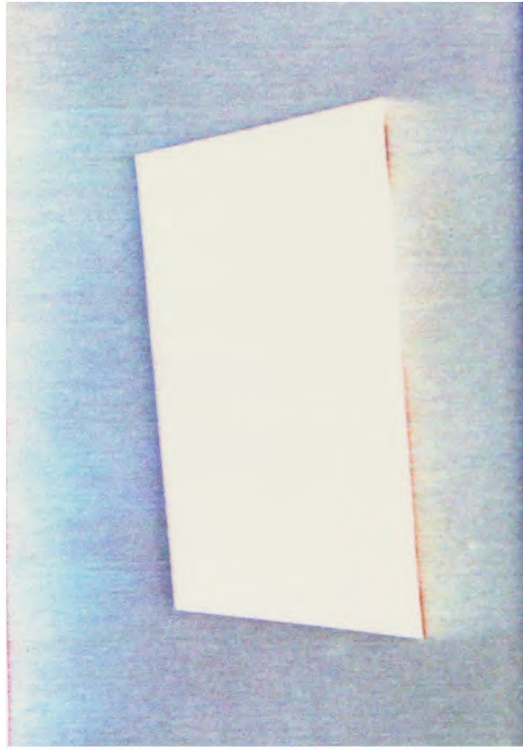
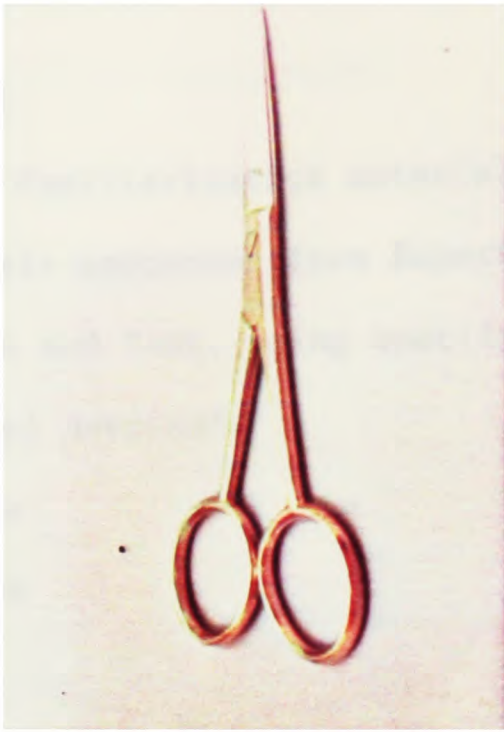
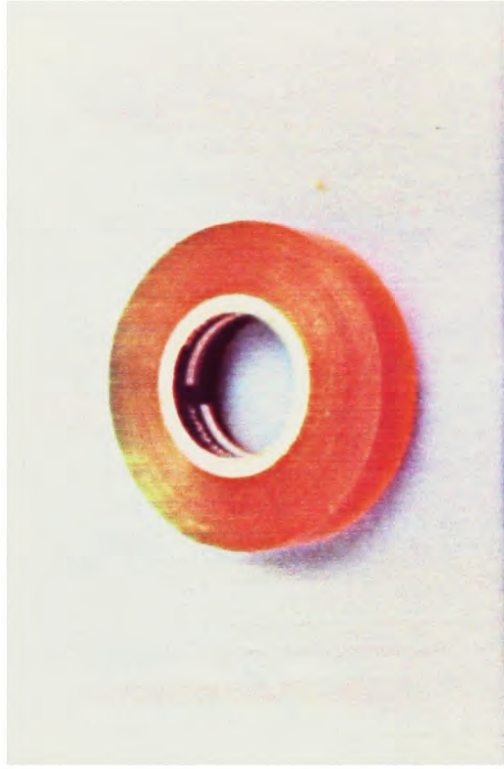
AN EXAMPLE OF PHOTOGRAPHS USED IN EXPERIMENT 4

EXPERIMENT 4-

A PAPER SEQUENCE (Subtractive)



A PAPER SEQUENCE (Additive)



APPENDIX 5

DESCRIPTION OF SEQUENCES USED IN EXPERIMENT 5

A. Familiarisation Material

Sequences from Familiarisation material used in previous experiments, plus the hair-sequence from Experiment 1, were constructed for each Condition and Task, using exactly the same format as the Experimental Material overleaf.

1. Plate sequence
2. Bottle sequence
3. Hair sequence
4. Smarties sequence

B. Experimental Material

Exactly the same choices were offered in the 3 tasks (in each Condition) for the different sequences.

INFERENCE CONDITION:

INF-AC TASK

<u>FIRST State-----C H O I C E S-----END State</u>	
1. CUP	WET CUP
2. CUP	BROKEN CUP
hammer(H), water(W), hammer+water(H+W)	
3. PAPER	CUT PAPER
4. PAPER	PAPER+WRITING
pencil(P), scissors(S), pencil+scissors(P+S)	
5. APPLE	CUT APPLE
6. APPLE	APPLE+DRAWING
knife(K), pen(P), knife+pen(K+P)	
7. PLATE	BROKEN PLATE
8. PLATE	PAINTED PLATE
hammer(H), piant(P), hammer+paint(H+P)	
9. BANANA	CUT BANANA
10.BANANA	WET BANANA
knife(K), water(W), knife+water(K+W)	

INF-DISC TASK

<u>FIRST State-----C H O I C E S-----END State</u>		
1. WET CUP		WET BROKEN CUP
2. BROKEN CUP		WET BROKEN CUP
	hammer(H), water(W), hammer+water(H+W)	
3. CUT PAPER		CUT PAPER+WRITING
4. PAPER+WRITING		CUT PAPER+WRITING
	pencil(P), scissors(S), pencil+scissors(P+S)	
5. CUT APPLE		CUT APPLE+DRAWING
6. APPLE+DRAWING		CUT APPLE+DRAWING
	knife(K), pen(P), knife+pen(K+P)	
7. PLATE+PAINT		BROKEN PLATE+PAINT
8. PLATE BROKEN		BROKEN PLATE+PAINT
	hammer(H), piant(P), hammer+paint(H+P)	
9. WET BANANA		CUT WET BANANA
10. CUT BANANA		WET CUT BANANA
	knife(K), water(W), knife+water(K+W)	

INF-ADD TASK

<u>FIRST State-----C H O I C E S-----END State</u>		
1. CUP	H, W, H+W	WET BROKEN CUP
2. PAPER	P, S, P+S	CUT PAPER+WRITING
3. APPLE	K, P, K+P	CUT APPLE+DRAWING
4. PLATE	H, P, H+P	BROKEN PLATE+PAINT
5. BANANA	W, K, W+K	WET CUT BANANA

PREDICTION CONDITION:

PRED-AC TASK

<u>FIRST</u>	<u>State</u>	<u>INSTRUMENT</u>	<u>C</u> <u>H</u> <u>O</u> <u>I</u> <u>C</u> <u>E</u> <u>S</u>
1.	CUP	water	WET CUP
2.	CUP	hammer	BROKEN CUP
			WET BROKEN CUP
3.	PAPER	scissors	CUT PAPER
4.	PAPER	pencil	PAPER+WRITING
			CUT PAPER+WRITING
5.	APPLE	knife	CUT APPLE
6.	APPLE	pen	APPLE+DRAWING
			CUT APPLE+DRAWING
7.	PLATE	hammer	BROKEN PLATE
8.	PLATE	paint	PAINTED PLATE
			BROKEN PLATE+PAINT
9.	BANANA	knife	CUT BANANA
10.	BANANA	water	WET BANANA
			CUT WET BANANA

PRED-DISC TASK

<u>FIRST State</u>	<u>INSTRUMENTS</u>	<u>-----CHOICES-----</u>
1. WET CUP	hammer	WET BROKEN CUP
2. BROKEN CUP	water	BROKEN CUP
		WET CUP
3. CUT PAPER	pencil	CUT PAPER
4. PAPER+WRITING	scissors	CUT PAPER+WRITING
		PAPER+WRITING
5. CUT APPLE	pen	CUT APPLE+DRAWING
6. APPLE+DRAWING	knife	CUT APPLE
		APPLE+DRAWING
7. PLATE+PAINT	hammer	BROKEN PLATE+PAINT
8. PLATE BROKEN	paint	BROKEN PLATE
		PLATE+PAINT
9. WET BANANA	knife	CUT WET BANANA
10. CUT BANANA	water	CUT BANANA
		WET BANANA

PRED-ADD TASK

N.B. Choices are exactly the same as for the corresponding sequences in AC and DISC tasks, but only the correct choice is presented here.

<u>FIRST State</u>	<u>INSTRUMENTS</u>	<u>CHOICES</u>
1. CUP	hammer and water	WET BROKEN CUP
2. PAPER	pencil and scissors	CUT PAPER+WRITING
3. APPLE	knife and pen	CUT APPLE+DRAWING
4. PLATE	hammer and paint	BROKEN PLATE+PAINT
5. BANANA	W, K, W+K	WET CUT BANANA

APPENDIX 6

A Pilot Study for Experiment 6

Introduction

This pilot study was carried out to ensure that children could understand what they were required to do in Experiment 6. As children had not been asked to construct sequences in previous experiments, all the material designed for Experiment 8 was tried out in this study. A few adults were also tested in order to check that the experimenter's expectations of how causal stories should be ordered were shared by other adults. The adults and children were given exactly the same instructions. Another reason for testing adults was to see whether they would make large numbers of causal stories and what sort of order they would impose on their causal stories.

Causal stories could either be ordered temporally, for example: Cup -hammer- broken cup, or not follow a strict temporal order, for example: Cup - Broken Cup - hammer. Because it was expected that children might use the latter order, it was thought important to check if adults, who could demonstrate knowledge of the correct temporal ordering of the sequence verbally, might nevertheless structure their sequences in a non-temporal order. If adults did construct 'non-temporal' looking sequence, but, explained the story in the correct temporal order, this could be taken to indicate that young children who construct this type of sequence (which contains all the correct elements but not in the specified order) may also know the correct temporal order of events in such sequences.

Method

(a) Subjects - Ten adults (mean age = 24, range = 20-28) and fifteen children. There were 5 children in each of the three age groups (3-years, 4-years and 5-years) tested in Experiment 7.

(b) Material - All the material used in Experiment 7, including the familiarisation material was piloted in this study. Detailed description of the material is given in Chapter 8 (8.2 - Materials). The material was not divided into Salient and Non-Salient problems here as the main reason for doing this study was to see if children could understand the task. Children were simply presented with all 6 problems.

(c) Procedure - Exactly the same procedure was followed as for the experiment (see 8.2 - Procedure). Adults and children received exactly the same instructions.

Results

As the main focus of this study was to see if children could tackle the problems, the mean number of stories in each of the 4 categories (see Chapter 8 for details) - Causal, AS, AR and A were recorded. The mean number of stories made by adults and children is presented in Table 1.

The majority of 5-year-olds' (significantly above proportions expected by chance - $p < .01$) and all the adults' stories were of the Causal variety. The 4-year-olds' causal stories, too, were above the level expected by chance ($p < .05$), but proportion of Causal stories made by 3-year-olds was not significantly different from the proportions expected by chance. The youngest groups AS stories however were significantly above the proportions expected by chance. All the children picked only two photographs, as instructed,

in the 'experimental' phase but some children, especially 3-year-olds showed a tendency to pick more than two photographs during familiarisation. They had to be told, again, that they could only pick two.

TABLE 1 MEAN (OUT OF 6) OF STORIES MADE IN PILOT STUDY

	<u>C A T E G O R Y of STORY</u>				
<u>AGE</u>	<u>CAUSAL</u>	<u>AS</u>	<u>AR</u>	<u>A</u>	
3+	1.6	2.0	1.4	1.0	
	(1.4)	(1.2)	(1.5)	(0.7)	
4+	2.4	2.2	0.6	0.6	
	(1.1)	(0.8)	(0.9)	(0.6)	
5+	5.4	0.2	0	0.4	
	(0.9)	(0.5)	=	(0.6)	
Adult	6.0	-	-	-	

Adults' Causal stories - When the order of adult's story structures were analysed, it was found that 20% (12/60) of their stories were constructed using a non-temporal structure (as defined in Chapter 8) such as:

Cup --- Painted Cup--- Paint

When asked to describe their story verbally, however, they used a temporal order: eg. "You used the paint to paint the cup red". Adults who made 'non-temporal' sequences were asked why they had structured their stories in that way. Typicallly they said that they did not think it mattered. However, four of the adults who had made this type of sequence said that they thought they had preserved the temporal order because first there was a cup and then it got pain-

ted. The instrument used to paint it was the paintbrush and paint. They did not see why the instrument had to be placed as the middle element.

The children too, were asked to describe the Causal stories verbally, but only the 5-year-olds and two of the 4-year-olds did so. All these children mentioned the transformation that changed the starter object in describing their stories. The other children replied with "I don't know" when asked what the story was that they had constructed. All the children who constructed causal stories used the correct temporal order.

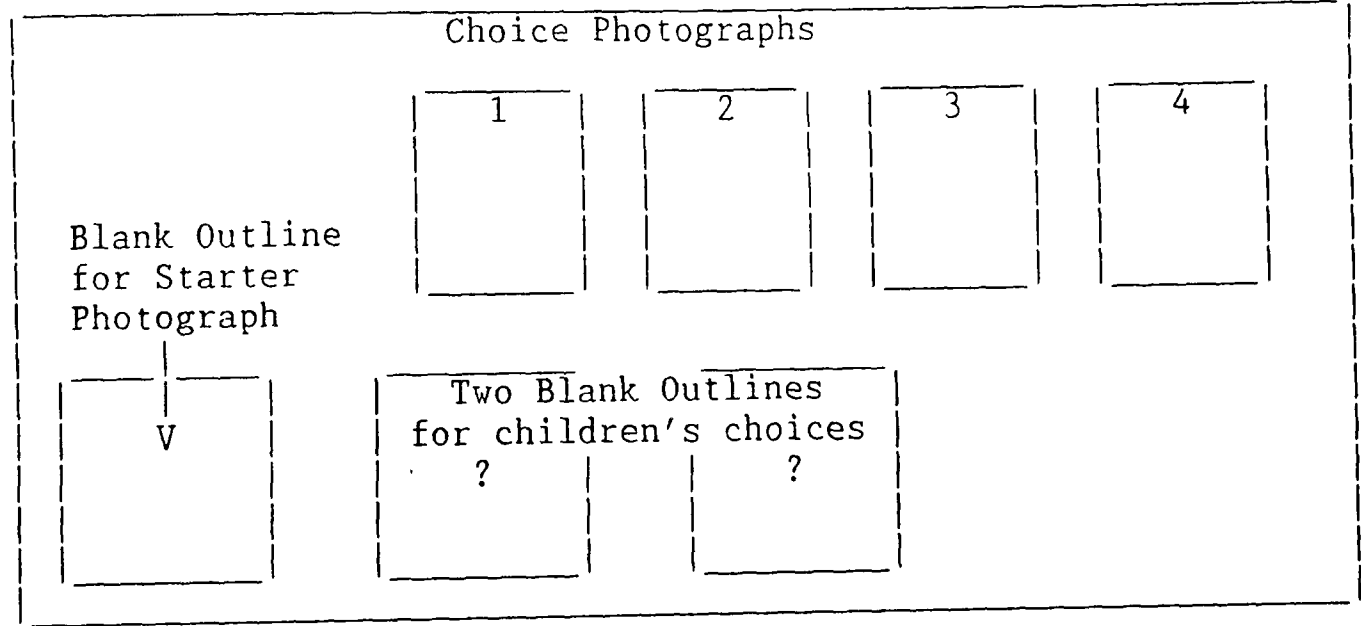
Discussion

The results of this study indicated that 3- to 5-year olds should be able to deal with the problems in Experiment 6. It was very interesting that some adults arranged their sequences in a non-temporal order. They obviously knew the correct temporal order but did not see why the sequence had to be structured in the way the experimenter wanted. Although only a small proportion of adults stories were 'non-temporal' it was thought that children might well make similar constructions. If they did so, it would not be correct to categorise these sequences as non-causal because these children might well know the correct temporal order, but, like some of the adults, prefer to arrange the photographs into a non-temporal sequence. The finding that adults made some Causal stories using a non-temporal order prompted the experimenter to ask any child who constructed such a story in Experiment 6 to describe it verbally. It was decided that children who could not give correct verbal descriptions of such stories would not have their stories categorised causal. Stories which contained all the elements necessary for a

Causal story but were constructed into a non-temporal sequence and for which no adequate verbal explanation was given were to be scored Peri-Causal (bordering on Causal).

Because it was noticed that the younger children tended to choose more than two photographs it was decided that in the Experiment (6) problems would be presented on a sheet of paper (as shown in Diagram 1) which had 3 rectangles drawn in for the 'story'. The choices were placed above these rectangles. The first rectangle contained the starter photograph, and the remaining two had to be filled with the two choices.

DIAGRAM 1 PROPOSED FORMAT FOR EXPERIMENT 6



These results also indicated that 4- and 5-year-old children could construct Causal stories (above chance expectations). Although the proportion of such stories in the 3-year-old group could have occurred by chance, the above chance proportions of AS stories indicated that 3-year-olds knew they had to construct a sequence.

B. Materials Used in Experiment 6
and Possible Combinations of Stories

1. AN EXAMPLE OF PHOTOGRAPHS USED IN EXPERIMENT 6

EXPERIMENT 6 - SMARTIES ITEM (PS)



CUP ITEM (PNS)



2. DESCRIPTION OF MATERIAL IN EXPERIMENT 6

The material used in Experiment 6 is presented in Diagram 2. A detailed categorisation of the Cup sequences is presented in Chapter 8, therefore, only abbreviations are used here to represent possible combinations. Please refer to Diagram 2 for the original abbreviations used in Diagram 3.

DIAGRAM 2 MATERIAL USED IN EXPERIMENT 6

-----Experimental Sequences-----				
<u>STARTER</u>	<u>NON-SALIENT</u>		<u>CHOICES</u>	
	(1)	(2)	(3)	(4)
1. CUP (C)	paint&brush;	painted cup;	[teaspoon;teapot]	
	(PB	PC	S	T)
2. WOOD (W)	tomato sauce;	sauce on wood;	[hammer nails]	
	(TS	SW	H	N)
3. APPLE (A)	pen;	apple+picture;	[orange; banana]	
	(P	A+P	O	B)
-----SALIENT CHOICES-----				
4. SMARTIES(S)	knife;	cut box Smarties;	[sweets; chocolate]	
	(K	CS	Sw	Ch)
5. TOWEL (T)	scissors;	cut towel;	[soap; tap water]	
	(Sc	CT	Sp	W
6. CUP (C)	hammer;	broken cup;	[plate; spoon]	
	(H	BC	P	S

N.B. The abbreviations used for categorisation are given in

brackets.

DIAGRAM 3 THE POSSIBLE 'STORY' COMBINATIONS

CAT	CUP	WOOD	APPLE	SMARTIES	TOWEL	CUP	
C	C, PB, PC	W, T, SW	A, P, A+P	S, K, CS	T, Sc, CT	C, H, BC	
	<u>C, PC, PB</u>	<u>W, SW, T</u>	<u>A, A+P, P</u>	<u>S, CS, K</u>	<u>T, CT, Sc</u>	<u>C, BC, H</u>	
AS	C, PC, T	W, SW, H	A, A+P, O	S, CS, SW	T, CT, Sp	C, BC, S	
	<u>C, T, PC</u>	<u>W, H, SW</u>	<u>A, O, A+P</u>	<u>S, SW, CS</u>	<u>T, Sp, CT</u>	<u>C, S, BC</u>	
AS	C, PC, S	W, SW, N	A, A+P, B	S, CS, Ch	T, CT, W	C, BC, P	
	<u>C, S, PC</u>	<u>W, N, SW</u>	<u>A, B, A+P</u>	<u>S, Ch, CS</u>	<u>T, W, CT</u>	<u>C, P, BC</u>	
AR	C, T, PB	W, H, T	A, O, P	S, SW, K	T, Sp, Sc	C, P, H	
	<u>C, PB, T</u>	<u>W, T, H</u>	<u>A, P, O</u>	<u>S, K, Sw</u>	<u>T, Sc, Sp</u>	<u>C, H, P</u>	
AR	C, S, PB	W, N, T	A, B, P	S, Ch, K	T, W, Sc	C, S, H	
	<u>C, PB, S</u>	<u>W, T, N</u>	<u>A, P, B</u>	<u>S, K, Ch</u>	<u>T, Sc, W</u>	<u>C, H, S</u>	
A	C, T, S	W, H, N	A, O, B	S, Sw, Ch	T, Sp, W	C, P, S	
	<u>C, S, T</u>	<u>W, N, H</u>	<u>A, B, O</u>	<u>S, Ch, Sw</u>	<u>T, W, Sp</u>	<u>C, S, P</u>	

APPENDIX 7

PILOT STUDY for EXPERIMENT 7

Introduction

The apparatus designed for Experiment 7 was pilot tested to ensure that 3- and 4-year-old children understood the task and would be able to do it. This apparatus is described in detail in Chapter 9.

As it was possible that using a repeated measures design might create learning effects, it was decided to use such a design in this preliminary study. If there were any significant order effects then it was decided that an independent groups design would be used for the experiment proper. There were two conditions. In one only ONE PLANK obstructed the sand from flowing into the box. In the other condition TWO PLANKs obstructed the flow of sand. It was predicted that the two plank condition would require more trials. The material and conditions are described in detail in Chapter 9.

Method

(a) Subjects - Twenty four preschoolers aged 3-years (mean = 3:4) and 4-years (mean = 4:7).

(b) Design - A mixed design was used with two between factors (Age and Order of Presentation) and one within factor (Condition). Children were randomly assigned to each Order group:

ORDER A - ONE Plank Condition first; TWO Plank condition second

ORDER B - TWO Plank Condition first; ONE Plank Condition second

There were 12 children in each age group and within each age group 6 children were assigned to Order A, the other 6 to Order B.

(c) Material - as described in 9.2 (Materials).

(d) Procedure - Children were shown the apparatus. The pouring of sand was demonstrated by the experimenter using one of the planks. Each child was allowed to play with the apparatus for a while and was shown how the planks could be pushed about through the slots.

In the ONE PLANK condition the experimenter inserted ONE PLANK into the frame and asked the child to pour the sand into the box. In the TWO PLANK condition, two planks were inserted and the child was again asked to fill the box with sand.

After each Condition, each child was asked to explain to the experimenter how to play the game. This was done to see if children could understand what they were being asked to do. The experimenter said to the child -

"Now you tell me how to play this game and then let's see if I can do it".

The children usually found this funny and were willing to tell me what to do. Except for two 3-year-olds who replied with "I don't know", all the children said that I had to put the sand into the box through the funnel, the details are given in the Results section.

Results

(1) Effects of Order and Age - The number of trials needed by children to get the sand through the holes was recorded. If children got the sand through the very first time this was scored as zero, subsequent trials were numbered from 1 onwards. Table 1 presents the means and standard deviations of the number of trials needed in each condition.

TABLE 1 MEANS AND STANDARD DEVIATIONS FOR THE NUMBER OF
TRIALS IN EACH CONDITION

		C O N D I T I O N			
<u>ORDER</u>	<u>AGE</u>	<u>One Plank (OP)</u>	<u>Two Plank (TP)</u>		
	3+	2.7	3.2		
A		(1.03)	(1.47)		
(OP, TP)	4+	2.5	1.3		
		(1.38)	(0.52)		
	3+	1.7	4.0		
B		(0.41)	(1.41)		
(TP, OP)	4+	0.7	2.5		
		(0.82)	(1.05)		

where - OP = ONE PLANK Condition and TP = TWO PLANK Condition

ORDER A = OP first, TP second; ORDER B = TP first, OP second.

Younger children needed more trials on the Two Plank condition in both order groups. The older children needed less trials than the younger ones in the two conditions in both order groups, although this difference looks numerically non-significant in the OP condition, group A.

Children needed less trials for the One Plank condition than for the Two Plank one. Furthermore, when the Two Plank condition is presented first (B) far more trials are needed than when it is presented second (A) indicating that order affects performance on this condition at least.

The statistical significance of these findings was tested using a 3-way ANOVA with repeated measures. Age (2: 3+, 4+) and Order (2: A, B) were the Between factors with Condition (2: One

Plank, Two Plank) as the Within factor. The number of trials needed to get sand into the box was the dependent variable. The results of this analysis are presented in Table 2.

TABLE 2 SUMMARY TABLE (ANOVA) - SAND PILOT STUDY

<u>SOURCE</u>	<u>SS</u>	<u>DF</u>	<u>MS</u>	<u>F</u>	<u>PROB.</u>	<u></u>
ORDER (O)	1.3333	1	1.3333	1.29	0.269	ns
AGE (A)	12.0000	1	12.0000	11.61	0.003	**
OA	0.0000	1	0.0000	0.00	1.000	ns
ERROR	20.6667	20	1.0333			
CONDITION(C)	12.0000	1	12.0000	9.23	0.007	*
CO	21.3333	1	21.3333	16.41	0.001	**
CA	5.3333	1	5.3333	4.10	0.056	ns
COA	0.3333	1	0.3333	0.26	0.618	ns
<u>ERROR</u>	<u>26.0000</u>	<u>20</u>	<u>1.3000</u>			

There was a significant main effect for Age ($F(1,20)=11.61$, $p<.01$) indicating that 3-year-olds needed more trials than 4-year-olds to succeed in the task. There was also a significant effect for Condition ($F(1,20)=9.23$, $p<.05$) but the significant Condition x Order interaction ($F(1,20)=16.41$, $p<.01$) indicated that the effects of Condition were not independent of Order. This interaction was analysed using the Newman-Keuls post hoc test.

It was found that Order had a significant effect on the One Plank Condition. Children needed significantly more trials ($p<.01$) when this condition was experienced first (Order A) than when it was experienced second (Order B). Order did not signifi-

cantly affect the Two Plank condition however. It was also found that within Order A there was no significant difference between the two Conditions. That is, when the One Plank Condition is followed by the Two Plank one, there is no significant difference between the number of trials needed in each Condition. However, when the Two Plank Condition is experienced first (B), significantly more trials are needed on this condition than on the One Plank ($p < .01$).

These results indicate that there is some carryover effect when the two conditions are presented to the same children. The Two Plank condition does seem to be more difficult to deal with than the One plank, but this difference is significant only when the Two Plank condition is experienced first. Nevertheless, whatever the order, numerically more trials were needed on the two plank condition.

(2) Children's Understanding of the Task - All the 4-year-olds and ten out of twelve 3-year-olds were eager to tell the experimenter what to do. Of these children 7 of the older children and all of the younger children said -

"You have to take this (picking-up or pointing to sand scoop) and put some sand in the box".

The experimenter then asked which box she had to put sand in and all the children were able to tell her. The other children (five 4-year-olds) gave more detailed instructions, pointing to the funnel and saying that the sand had to be poured through there. Two of these children warned the experimenter that she would not be allowed to shake the planks to make the sand go through (they had been told not to do so).

Discussion

The results of the Pilot study indicated that both 3- and 4-year-old children could do the task. The children's verbal responses indicated that they understood what they had to do and their results indicated that although the younger children might need more trials on Two Plank condition even they could successfully complete the task.

The use of a repeated measures design showed that there were some significant 'learning' or carryover effects between the two Conditions. Therefore it was decided to use an independent groups design in the experiment proper in order to avoid these effects. Use of an independent groups design would enable the experimenter to draw clearer conclusions about children's abilities to deal with one or two features in a novel task.