

CHAPTER 1

INTRODUCTION

Talking to a four or five year old child, one is easily led to believe that his understanding of words and phrases such as "red", "red triangle", "cat", "animal", is the same as any adult's. He can tell you that cats and dogs are animals. He can correctly find a red triangle when given the verbal description, or can describe it when given the object. However, if he is given a set of items, and asked to put "the ones that are the same together", he fails to achieve a correct classification from an adult's point of view [Inhelder and Piaget 1964, Vygotsky 1962, Olver and Hornsby 1966].

Inhelder and Piaget [1964] give numerous examples of these inadequate classifications. They call the classifications of children between two and five years "Graphic Collections". This term subsumes a variety of behaviours, which have in common an inability to hold in mind and to use one property consistently. This leads to a constant switching, within one collection, of the property used for assessing similarity.

For example, CHRI (4;10), [Inhelder and Piaget 1964, p.23], when classifying geometrical shapes of different colours,

"starts by aligning five rectangles, the fifth of which is yellow. This leads him to select four yellow triangles, followed by two yellow semi-circles. These in turn lead to five more semi-circles in different colours."

When classifying the same materials MAR (2;11), [Inhelder and Piaget 1964, p.33],

"begins with a pile of circles, then aligns a number of squares, continuing with semi-circles and circles. A row of jumbled elements is: *A train, ch, ch, ch!*"

Similar types of collections are made when the children are given toys or pictures of meaningful objects; only here the emphasis is on telling a story.

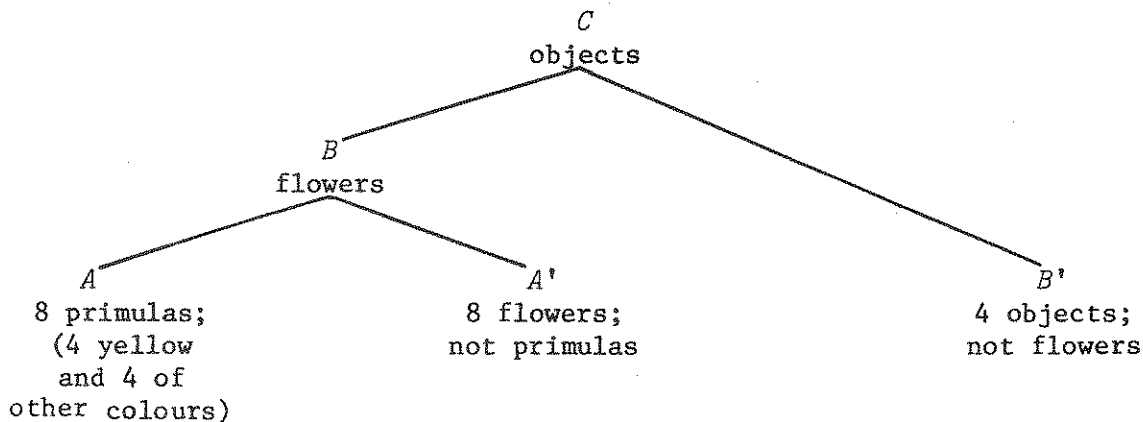
For instance when given a set of toys, CUR (4;2) [Inhelder and Piaget 1964, p.40] comments:

"Here's a woman who's bringing in all the cows and the sheep and the horses and all the chickens. He places the sheep around the seated people whom he takes for fountains and a gentleman next to them to stop the sheep going away. Finally: The bench in the middle and the trees all round just like my granny's."

These children are quite unable to sort objects into mutually exclusive classes, and to understand hierarchical arrangements of such classes. Understanding of hierarchical structures is indicated by correct answers to class inclusion questions [Inhelder and Piaget 1964, Chapter 4]. Only when the child has achieved this ability is he thought to be constructing logical classes and to be at the stage of concrete operations.

BREG (6;2) [Inhelder and Piaget 1964, p.102], when given 20 pictures sorted them into the collections (A, A', and B') whose relationships can be represented by the hierarchy in Figure 1.1.

Figure 1.1: The hierarchical relationships between three classes of items.



BREG has progressed beyond the stage of graphic collections; however the following questions indicate that he does not fully understand these hierarchical relationships and thus has not yet reached the stage of concrete operations. He is asked:

"A little girl takes all the yellow primulas and makes a bunch of them, or else she makes a bunch of all the primulas. Which way does she have the bigger bunch? — *The one with the yellow primulas will be bigger* (he counts the others), *Oh no, its the same thing* ($4 = 4$). — And which will be bigger: a bunch made up of the primulas or one of all the flowers? — *They're both the same.* (He compares the 8As with the 8A's.)"

The young child's inability to construct and manipulate hierarchically related classes is well replicated [e.g. Kofsky 1966, Nixon 1971] but there is disagreement about the reason for this inability, and about the factors involved in the development of mature classificatory behaviour.

The different theoretical approaches seem to revolve around the role of language in classification. There are two opposing points of view. There are those who maintain that linguistic ability is dependent on the development of cognitive structures, while others argue that cognitive development is dependent on the acquisition of the appropriate linguistic structures. Piaget and his followers maintain the former position, while Bruner and his co-workers uphold the latter. Vygotsky's view seems to be intermediate to these two. These different theoretical approaches will be discussed in turn.

Inhelder and Piaget's work on classification is based on Piaget's theory of development. The stages of development advanced by Piaget, and the behaviour they encompass, are so well known that they need not be reviewed in detail. A very brief, general summary will be given, however, to identify the foundations on which the detailed discussion of directly

relevant aspects of the child's developing classificatory ability can be built.

Piaget's theory of development concerns the structures responsible for progression through a sequence of stages. Each stage, while deriving from the previous one, involves a qualitatively different adaption to the environment [Piaget 1950, 1960].

The first two years of his life the child is said to be at the Sensori-motor stage. At birth he is endowed with basic reflex actions, e.g. sucking, grasping, kicking; by the end of this stage the child is capable of complex co-ordinated actions, such as making a detour to reach a goal. Each action is the result of assimilation of the environment to a general internal scheme, and the accommodation of the scheme to unique aspects of the situation. Sensori-motor schemes are self-regulating and development progresses towards increasingly higher order co-ordinations. However, throughout this stage, the child's knowledge of an object or event is confined to his on-going perceptions and actions. He has no ability to think of an object in its absence.

At about two years of age, transition to the stage of Preoperational Thought occurs. This lasts until seven or eight years. During the final part of the sensori-motor period the child achieves the concept of a permanent object. Deferred imitation also becomes possible. These provide the foundations for the symbolic function which is developed rapidly during the next few years [Piaget 1951]. The preoperational stage involves the progressive interiorisation of sensori-motor schemes. This enables the child to think about what, at the previous stage, could only be overtly performed. However, the child is still limited to thinking about what is physically possible. Thus with the class inclusion problem cited above, BREG can mentally separate the eight

primulas into the two groups of four yellow ones, and four differently coloured ones, but he cannot think simultaneously of the combination of these: all the primulas; presumably because this is not possible physically.

When a child can combine two classes to form a higher order class ($A + A' = B$) and simultaneously subtract one class from the higher order class ($B - A' = A$) (reversibility), he is at the stage of Concrete Operational Thought. Operations do not exist in isolation, they are co-ordinated with one another to form a structured system.

Finally, around twelve years of age the child reaches the stage of Formal Operational Thought.

"The formal logical stage ... is characterised by hypothetico-deductive strategy, and the potential for utilising all possible transformations of classes and relations." [Inhelder, Bovet, Sinclair and Smock 1966].

In their analysis of the development of classification, Inhelder and Piaget [1964] are concerned with the transition from preoperational to concrete operational thought. They divide the development of classification into three main stages. At Stage I (ages two to five years), the child constructs graphic collections. At the second stage (ages five to seven years), the child's initial classifications appear logical, but he does not fully understand the hierarchical relationships involved. BREG, whose behaviour was described above, is at this stage. From seven to eleven years, the child correctly answers the class inclusion questions and he is considered to be constructing logical classes.

To explain development through these stages, Inhelder and Piaget make use of the distinction between the intension and the extension of a class. Intension is the common property of a class, e.g. red things,

animals. Extension is a list of the particular members of an individual class, e.g. cat, horse, tiger, rabbit. The differentiation and co-ordination of intension and extension provides the mechanism for the development of classification.

They argue that in the infant there is an early, if rudimentary appreciation of intension, based on sensori-motor assimilations. For instance, the infant sucks a variety of objects. Assimilation of each one to the general sucking scheme confers this common property on them. However, they do not form a simultaneous collection for the child because his only knowledge of an item is the act of sucking it. He is limited to one object at a time.

Interiorisation of these schemes enables thought of an object when it is not being perceived, or acted on. Hence two objects can be compared and united in thought if they are both assimilated to the same interiorised scheme. The interiorised scheme is the intension, the two particular objects the extension. However, the thought of the preoperational child is tied to what is physically possible and is not sufficiently dissociated from the consequences of an action to enable reversibility to be achieved. In this instance, the intension is not sufficiently dissociated from its application to the comparison of two particular objects (extension), to enable understanding to be achieved of how other new objects should be compared in order to join the existing collection. For instance, if the child has put a red square and a blue square together, the intensive property "square" is tied, in thought, to those two objects, and this thought is not general enough to predict that all future items to be included in that collection must be squares. The child may add a differently shaped item because it is similar on another property (e.g. red colour). If he does, he has no way of thinking

simultaneously about all of these actions (classifying by square shape and then by red colour), except by the spatial configuration he has constructed (extension). This will guide future actions, e.g. to make a "train". At this point the extension is completely unrelated to any intensive concept of similarity.

The mechanisms of retroaction and anticipation, which enable a co-ordination of past actions with those anticipated in the future, are responsible for the growing relationship between intension and extension. In logical classifications, intension and extension are fully co-ordinated and interdependent.

Language plays no major role in the elaboration of these structures. In fact Inhelder and Piaget maintain that comprehension of linguistic concepts is dependent on the actions and operations of the child. They argue that their investigations of the use of "all" and "some" [Inhelder and Piaget 1964, Chapter 3], and of the class inclusion problem, showed that children only understand verbal concepts to the extent that they can structure the situation cognitively [Inhelder and Piaget 1964, p.284].

Piaget argues that language is dependent on operational structures, and not vice versa, for cognitive development in general, up to and including the concrete operational stage; and he cites a number of investigations which support this view [Piaget 1963, pp.128-130, in Furth 1969]. Additional support is provided by Furth [1966] and Sinclair [1969].

Furth [1966] tested deaf and hearing children on tasks which were presented non-verbally and he found that in many tasks the deaf children exhibited logical thinking that was on a par with that exhibited by hearing children. He argued that in those tasks where the deaf were retarded, their failure could be attributed to inadequate social

experiences rather than to their lack of language *per se*.

Sinclair [1969] found that concrete operational children gave more sophisticated comparative descriptions than did preoperational children. However, while training of the preoperational children in the use of comparatives improved their linguistic performance, it had very little effect on their ability to conserve.

Such findings support Piaget's position that linguistic factors are not decisive in the development of concrete operational behaviour. However, the role of language in formal operations is less clear. Piaget seems to feel that language is a necessary but not a sufficient condition for formal operations. It is necessary because the operations no longer bear upon objects as do concrete operations, but on propositions which are expressed verbally. However, language is not sufficient since formal operations

"go beyond language in the sense that the operational propositional structures constitute rather complex systems that are not inscribed as systems in the language even though the elaboration of the structures needs the support of verbal behaviour" [Piaget 1963, p.127, in Furth 1969].

Piaget's conceptualisation of the role of language in formal operations seems somewhat similar to Vygotsky's characterisation of the role of language in cognitive development in general. Vygotsky [1962] has also studied the development of classificatory ability in children, using a somewhat different task, but essentially arriving at the same stages of development as Inhelder and Piaget. Corresponding to the various behaviours subsumed under Inhelder and Piaget's stage of graphic collections, Vygotsky [1962] describes a phase where the child puts objects in "an unorganised congeries, or heap" [pp.59-61], and a succession of types of behaviour which he calls "thinking in complexes". Vygotsky's "pseudoconcept" seems equivalent to Stage II of Inhelder and

Piaget's system. At this stage the child's initial classifications appear logical, but when the child is asked to carry out additional manipulations, it becomes apparent that he lacks a full understanding of the classes he has constructed. This is shown by asking him inclusion questions [Inhelder and Piaget], or in Vygotsky's task, by watching his behaviour when he is shown that he has based his classification on the wrong properties [Hanfmann and Kasanin, presented in Vygotsky 1962, pp.66-67].

A logical understanding of the relationships involved is the criterion of the final stage of both Vygotsky's and Inhelder and Piaget's analyses of the development of classification.

Vygotsky, like Inhelder and Piaget, argues that concept formation cannot be reduced to association processes but must be regarded as an active, changing part of the intellectual processes. However, he differs from them in the role he assigns to language in the development of classification, and in cognitive development in general. Vygotsky argues that language plays a decisive role in directing concept formation.

"A concept is formed, not through the interplay of associations, but through an intellectual operation in which all the elementary mental functions participate in a specific combination. This operation is guided by the use of words as the means of actively centering attention, of abstracting certain traits, synthesizing them, and symbolizing them by a sign." [Vygotsky 1962, p.81].

Those who have been influenced by Bruner seem to have travelled one step further away from Piaget's theory than Vygotsky, in the emphasis they place on language in the development of classification. Bruner [1964, 1966] argues that cognitive growth is the development of various techniques of representation. For the first two years of life "the child's world is known to him principally by the habitual actions he uses for coping with it." [Bruner 1966, p.1]. This he refers to as Enactive

Representation. The next stage, that of Iconic Representation, is relatively free of action and involves representation through imagery. Finally, there is the translation of action and imagery into language. The remoteness and arbitrariness of language enables abstract logical behaviour that is beyond the scope of concrete imagery. Such logical behaviour will be modelled on the structures provided by language.

Use of this theory to explain the development of classification has led to a primary emphasis on the role of language. Olver and Hornsby [1966] used Vygotsky's analysis as a point of departure for their investigation and they have provided a valuable replication and extension of the categories into which he divided children's classificatory behaviour. Following Bruner, they argue that the development of structures displayed in classifications, such as superordination, are based on the use of such structures in language.

Similarly, Greenfield, Reich and Olver [1966] in their cross-cultural investigation of classification, place great emphasis on the role of linguistic variables in cognitive growth. This emphasis does not seem compatible with the results of investigations such as Furth's [1966] study of the deaf, and Sinclair's [1969] study of the relation between language and the development of concrete operations. These studies indicate that language is not the decisive factor in cognitive growth.

The first experiment reported in this thesis investigated the role of language in the development of classification and concluded that it was not a decisive factor. This experiment emphasised the need for a theory such as Piaget's to explain the development of classification and the remainder of the work for this thesis involved a fuller investigation of classification from this point of view.

Piaget asserts that the development of classificatory ability is dependent on the development of operational thought structures. He also maintains that there is a structural isomorphism between all the concepts subsumed within the stage of concrete operations [Piaget 1956]. This means that the child's ability logically to classify a particular set of materials is but one manifestation of his concrete operational thought structures, while another manifestation might be his ability to seriate [Inhelder and Piaget 1964]. From this point of view, any investigation of classification must concentrate on the structure of concrete operations in general. However, there are problems with this position since the materials on which the internal structures operate seem to affect performance, at least in the development of concrete operations. The best known example of this is that the conservation of quantity occurs before the conservation of weight, which in turn occurs before the conservation of volume [Piaget and Inhelder 1940]. These horizontal décalages are also found in classification. Inhelder and Piaget [1964] report that correct answers to class inclusion questions occur earlier when the materials are flowers than when they are animals. Parker and Day [1971] report that cross-classification develops earlier for perceptual than for functional attributes, which in turn develops earlier than for abstract attributes.

Inhelder and Piaget account for their finding by arguing that children have experience of picking flowers to form a bunch and that they can therefore easily imagine the grouping action necessary for their classification. However, actual animals cannot be collected together in the same manner and the child has to rely more on concepts attained through linguistic information. For instance, the knowledge that ducks are birds and that birds are animals cannot be attained through the child's own actions.

Such findings emphasise the fact that while the general structure of concrete operations may exist, the use of these operations in any particular task is tied to the materials on which they operate. In fact, they have been termed "concrete" by Piaget because they are "operations in which form is inseparably bound up with content" [Inhelder and Piaget 1964, p.149].

Piaget does not provide any detailed model as to how the development of concrete operations relates to the child's experience and understanding of the materials on which he operates. He has been more concerned with describing the logical structure underlying operational thought. However, recently there has been recognition of the importance of investigating the former as well as the latter. Piaget [1972] discusses the possibility that the development of formal operations is specific to the individual's area of specialisation. The idea that formal operations are free from concrete content and yet can only be applied to the area of specialisation of a given individual seems somewhat paradoxical, and emphasises the need for studies of the relationship between operational thought structures and knowledge of the materials to which they are applied.

Greenfield [1973] argues for the importance of such studies, and suggests that cross-cultural research provides a unique opportunity for such work. She discusses some recent cross-cultural studies which have investigated how particular environmental differences affect the development of particular concrete operations. For instance, Durojaye [cited by Greenfield 1973] found that in African cultures, bead stringing hastened the development of the conservation of number.

Dasen [1973] has also investigated the role of the environment in the development of concrete operations. He hypothesised, and found, that

people belonging to a trading culture in which commerce is important (the Ibos) performed relatively better on conservation tasks than on spatial ones. On the other hand, Australian Aborigines and Alaskan Eskimos, for whom hunting is important, performed poorly on the conservation tasks but relatively well on spatial tasks.

Such findings emphasise the need for the development of a model which specifies the nature of the relationship between the general structure of concrete operations and their application to specific materials. This has provided the motivation for the main work of this thesis, which attempts to distinguish experimentally, and to relate theoretically, the following two factors in the development of classification:

- (i) The understanding of the individual items;
- (ii) The development of the classificatory schemes.

CHAPTER 2
TWO ALTERNATIVE THEORIES
OF THE DEVELOPMENT OF CLASSIFICATION

2.1 THE USE OF HIERARCHICAL STRUCTURES
AT DIFFERENT LEVELS OF THOUGHT

It is well documented that children below seven or eight years cannot classify objects into mutually exclusive classes. They fail to use consistently superordinate properties, e.g. "animals", "squares" to generate their collections [Inhelder and Piaget 1964, Vygotsky 1962, Olver and Hornsby 1966].

Two opposing theories, advanced to account for the development of classification, will be discussed. On the one hand, there are those who, with Inhelder and Piaget, believe that mature classificatory behaviour is due to the development of operational thought structures. In contrast, there are those who interpolate from linguistic theories, and believe that classification is dependent on the acquisition of the appropriate semantic markers. This latter category will be discussed first.

The work of Anglin [1970] on the development of meaning in children was based on the assumption that

"the set of features associated with a word represents a large part of its meaning. The extent to which two words share meaning is a function of the intersection of the two corresponding sets of features. Features are roughly similar to what Katz (1966) calls semantic markers." [Anglin 1970, pp.2-3].

These features are hierarchically organised.

Since the word associations [Brown and Berko 1960] and the classifications of young children do not exhibit equivalence judgements

based on common features, Anglin argues that young children do not have the appropriate semantic features.

Bruner [1966] and McNeill [1966] put forward similar points of view. McNeill, strongly influenced by Chomsky's [1965] theory of transformational grammar, has mainly concentrated on the syntactic aspect of language acquisition. This he argues develops very early. By four years of age the child is producing grammatical sentences, and therefore must be using hierarchical structures and transformations. However, because the child cannot utilise hierarchical principles in his classificatory behaviour until seven or eight years, McNeill and Bruner argue that

"the accretion of semantic markers is in contrast with the acquisition of syntactic competence, a slow process that is not completed until well into school age" [McNeill, quoted by Bruner 1966, p.39].

Bruner adds that

"in the linguistic domain the capacities for categorisation and hierarchical organisation are innate" [Bruner 1966, p.43],

and that these abilities are gradually transferred to the semantic function.

It will be argued that these claims of a discrepancy between syntactic and semantic abilities are derived from a false comparison of two different levels of functioning. A distinction must be made between the *use* of hierarchical structures in linguistic productions, and the *understanding* of them that is required for classification tasks. Anglin [1970] showed that no eight or nine year olds, and very few twelve year olds were able to sort words into their grammatical categories. Undoubtedly these children could use such grammatical structures in their comprehension and production of language. Thus when hierarchical structures are used in language it seems to be at a different level of

thought from when they are used in classification tasks. Hence it is incorrect to compare the use of syntactic hierarchies in language, with the understanding of semantic hierarchies that is required for classification.

This use of similar structures at different levels of conceptualisation, which he has called "vertical décalage", is an important concept in Piaget's theory of development [Flavell 1963].

Piaget's [1971] discussion of the correlativity of form and content theoretically clarifies the reason for vertical décalage. Logical structures are concerned with the form of knowledge, not its content. However, the "content" on which a logical form is imposed, when viewed from an earlier stage, is itself a form, which has its own content, etc. Thus

"each element — from sensori-motor acts through operations to theories — is always simultaneously form to the content it subsumes and content for some higher form." [Piaget 1971, p.35].

Therefore a concept achieved at a particular stage can be viewed as form to the content of the preceding stage, and content for some higher form of a subsequent stage. A concrete operational concept is a formalisation of a sensori-motor activity; additionally, it provides the content for formal operational thought.

The above is illustrated by the child's use of hierarchical structures. Complex sensori-motor schemes show the use of hierarchical structures at the level of action [Sinclair 1971]. Restructuring of these schemes enables the use of hierarchies at the new level of representation, as is shown by the linguistic ability of the four year old child. However, as Piaget [1971, p.65] remarks, behaviour at this level is only "semi-logical", "in the quite literal sense of lacking one-half, namely the inverse operations." There is no reversibility of

thought. Further restructuring must occur before the child reaches the stage of concrete operations. At this stage he has reversible hierarchical structures which enable correct performance on the classification tasks.

In contrast, the basic argument of Bruner, McNeill and Anglin is that the inability of young children to use superordinate properties in their classifications is because they do not have the necessary hierarchically related semantic features. Thus these children would not be expected to show any behaviour which involved semantic hierarchies. Unlike Piaget they cannot account for the use of hierarchical structures at different stages of thought.

One way to investigate this difference between the two theories is to see whether semantic hierarchical structures can be used in language before they can be utilised in classificatory behaviour. To investigate the use of semantic hierarchies in language, some experiments involving semantic memory were considered.

2.2 PROACTIVE INHIBITION IN SHORT-TERM-MEMORY

Wickens [1970] summarises a body of research which uses a short-term-memory (STM) technique to reveal some conceptual dimensions along which single words are processed.

Keppel and Underwood [1962] showed that Proactive Inhibition (PI) is involved in the STM task introduced by Peterson and Peterson [1959]. Wickens, Born and Allen [1963] modified this design, and showed that the inhibitory effect could be specific to the class of materials employed.

The S was presented with three to be remembered items; there was a filled retention interval of 20 seconds before recall was required. This constituted one trial. There was a series of such trials. The first

three trials all required memorisation of three consonants (CCC). There was a shift to memorisation of three digits (NNN) on the fourth trial. (Appropriate controls began with NNNs and were switched to CCCs on the fourth trial, or had no shift on the fourth trial.) A marked decrease in recall over the first three trials, reaching an asymptote thereafter, was found with continued use of the same type of materials. However, a shift to new materials on the fourth trial resulted in a marked improvement in recall. Wickens concluded:

"in the STM situation, triads and trigrams, all elements of which are homogeneous with respect to a psychological class, seem to be encoded not only as unique items, but also as members of the same psychological class. If the next item is drawn from a different class, then interference no longer exists - or is minimised - and performance is raised."
[Wickens 1970, p.3].

This paradigm was subsequently extended in the attempt to identify other "psychological classes". A variety of dimensions have been shown to be of importance. These vary from semantic factors such as those of the semantic differential dimensions to the physical characteristics of word presentation, such as shifts between black-on-white displays and white-on-black displays.

Of particular relevance to the present study is an experiment by Loess [1967]. Loess required adult Ss to learn words belonging to a particular taxonomic class, e.g. birds, trees, occupations. After three trials using one class, there was a shift to another. There was a significant decline in recall over trials using the same class, and about 75% recovery from this build-up of PI after shifting class.

This pattern of recall means that subjects must have been using hierarchical structures in the encoding and recall of the words. However, since subjects can be unaware of the categorisations involved in the presented material, but still show appropriate build-up of, and release

from PI [Wickens 1970, p.12], this behaviour seems more closely akin to the use of syntactic hierarchies in language production (as discussed earlier) than to the use of hierarchical structures in classification tasks. The former requires no awareness of the hierarchies involved, the latter does.

2.3 THE RELATIONSHIP BETWEEN CLASSIFICATION AND PI IN STM

If semantic hierarchies are used in language production in a "semi-logical" way, before they can be used to generate classifications, then children at Inhelder and Piaget's [1964] stage of Graphic Collections should show build-up of, and release from, PI when semantic categories are manipulated in a STM task. Alternatively, if Bruner *et al.* are correct, there should be no PI effects until the child's classifications also show the use of hierarchical relationships, since both behaviours would be dependent on the acquisition of the appropriate hierarchically organised semantic features.

The former outcome would indicate that particular semantic hierarchies can be used at two levels of thought. Bruner's theory, unlike Piaget's, does not ascribe to Structuralism, and hence cannot account for the use of a given hierarchy at different levels of thought [Piaget 1971, p.72].

2.4 EXPERIMENT 1: COMPARISON OF THE USE OF SEMANTIC HIERARCHIES IN LANGUAGE AND CLASSIFICATION

2.4.1 Introduction

Five and six year old children were separated into those who classified pictorial items solely on the basis of taxonomic class (animals, food, clothes, etc.), [Stages II or III, Inhelder and Piaget

1964], and those who could not use such rules, but made graphic collections. The children were then given a STM task, modified for use with children of this age, where changes in taxonomic class were manipulated. The build-up of PI, and the amount of release, for both types of children was measured.

It was hypothesised that both children who could, and those who could not, classify items on the basis of taxonomic class, would show the build-up of, and the release from, PI when such classes were manipulated in the STM task.

2.4.2 Classification Task

Materials

Thirty coloured pictures, each drawn on a 4 inch \times 4 inch card, were used. The pictures consisted of 6 animals, 5 items of food, 5 items of clothing, 4 vehicles, 4 parts of the body, 3 people, and 3 pieces of furniture. The individual items are listed in Appendix A1. These were arranged in random order in a 5 \times 6 array.

Procedure

Each child was asked to put together the pictures that were the same as each other in some way. On the basis of the child's sorting behaviour, and the reasons he gave for his classifications, he was assigned to one of three groups:

- (i) Classifiers,
- (ii) Nonclassifiers,
- (iii) Intermediate.

Classifiers formed groups of items solely on the basis of similarities, which contained all, or the majority of all possible

members. These children are at Stage II or III in Inhelder and Piaget's [1964] system.

Nonclassifiers used predominantly "situational" reasons for placing pictures together, e.g. "The bunny eats the carrot". Sometimes they used similarity criteria to generate very small incomplete collections of pictures, e.g. cat and dog together: "Because they are animals"; but the child would then refuse to add any more items. These children are constructing Graphic Collections [Inhelder and Piaget 1964].

Intermediate children, who were not used in the subsequent memory task, were those who showed a fairly good ability to sort with respect to taxonomic class, but who "spoil" some of their collections by using a "situational" criterion as well. For instance, one child put all the clothes together, "because they are things to wear", but also put the man with them, "because he wears them". When asked whether any picture did not go as well as the rest, he removed the dress, "because he doesn't wear that".

2.4.3 Subjects

Kindergarten and First grade children from Garran and Lyons Primary Schools, A.C.T.,¹ were tested until 64 nonclassifiers and 64 classifiers were obtained.

2.4.4 STM Task

Materials

Four categories of 12 items each were used: 12 animals, 12 items of food, 12 items of clothing, 12 parts of the body. The individual items

¹ All the schools visited in the course of work for this thesis were in the newer suburbs of Canberra. Because of the way housing is allocated, these schools all serve a representative cross-section of Canberra's population.

are listed in Appendix A2. A coloured picture of each was drawn on a separate 4 inch × 4 inch card.

Procedure

Subjects were tested individually about one week after they had taken part in the classification task.

Every child had 8 STM trials, each consisting of 3 to be remembered items. For each trial E laid 3 picture cards face down on the table, telling the child what was on the other side, but not letting him see the picture. E then counted with the child for 10 seconds (filled retention interval) after which the child recalled the pictures on the cards. When the child had given, or failed to give, the 3 items, E turned over the cards to let the child see the pictures. S then had to learn another 3 items. There was a two minute rest period after the fourth trial.

Several modifications were made to the usual paradigm used with adults. A pilot study showed that merely giving the child words to remember was either too difficult or did not motivate the younger children. Introducing the pictures immediately gained their attention.

The child did not see the picture until after he had recalled, or failed to recall, the item. Thus no obvious visual memory was introduced.

The ten second retention interval was shorter than the twenty second interval used with adults. The pilot study indicated that longer times caused the younger children to forget most of the items.

Design

When switching from one category of item to another in the STM task, it is desirable that the two categories are memorised equally well. It

was found in the pilot study that Animal and Food items were easier to recall than Clothing or Body-part items. Consequently during the first four STM trials, a switch between Animal and Food items was investigated. The last four STM trials after the two minute break manipulated a switch between Clothing and Body-part items.

These combinations are additionally appropriate since Nonclassifiers often tended to put an animal and an item of food together in the classification task; e.g. cat-milk; dog-meat; rabbit-carrot. They also put body-parts and clothing together; e.g. foot-shoe. These arrangements therefore are the ones most likely to bring into conflict equivalence and situational associations between items.

For both sets of four STM trials, the first three trials involved items of the same class. For experimental groups the fourth trial involved a switch to another class, while control groups remained on the same class throughout. Each child was in a control group for one set of trials, and in an experimental group for the other.

Sixteen Classifiers and 16 Nonclassifiers were tested in each of the 4 conditions shown in Table 2.1.

Table 2.1: Experimental conditions.

Conditions		Trials					Trials			
		1	2	3	4		5	6	7	8
1	Ex ₁	A	A	A	F	C'o ₁	C	C	C	C
2	Co ₁	F	F	F	F	E'x ₁	B	B	B	C
3	Ex ₂	F	F	F	A	C'o ₂	B	B	B	B
4	Co ₂	A	A	A	A	E'x ₂	C	C	C	B

A = 3 Animal words

F = 3 Food words

C = 3 Clothes words

B = 3 Body-part words

Ex = Experimental Group for A/F words

Co = Control Group for A/F words

E'x = Experimental Group for C/B words

C'o = Control Group for C/B words

Thus the first three trials will give measures of the build-up of PI over repeated memorisation of animal words (Ex_1 and Co_2), or of food words (Ex_2 and Co_1). The amount of release from PI can be calculated by comparing the performance of each experimental group with its corresponding control group on the fourth trial (i.e. Ex_1 compared with Co_1 ; Ex_2 compared with Co_2). The same measures can be made for clothes and body-part items in the last four trials.

Order of Presentation

Within each category the twelve items were divided into four groups of three items. This was done in four different ways so that each item appeared at least once at the beginning, middle and end of a triad, and as far as possible, items did not reappear together in the same triad. The only other restrictions on this grouping were that one of each of the four "wild" animals - lion, tiger, bear, monkey - went into each of the four animal triads; and that the rhyming pair - skirt and shirt - did not appear in the same clothing triad.

For each division of twelve items into four triads a 4×4 balanced latin square was used to vary the order of presentation of the triads. Thus four methods of dividing twelve items into triads, combined with four orders of presentation of the triads gave sixteen different ways of presenting twelve words.

For the four categories of items - Animals, Food, Clothing, Body-parts - one way of presenting each category was always combined with a particular way of presenting every other category. Thus if all 48 words were presented there would be 16 ways of doing so. Each of these 16 ways was used once in each of the four experimental conditions.

If one particular way is considered: for Condition 1, Ex₁, the first three trials would involve the first three animal triads, the fourth trial, the fourth food triad. The fourth animal triad, and the first three food triads would be omitted. The control for this, Co₁, requires presentation of the four food triads, omission of the four animal triads. Thus the same food triad appears in the fourth trial of Ex₁ and Co₁.

Sixteen ways of presenting the words combined with 4 experimental conditions gave a total of 64 cells. Since the total design was carried out on Classifiers and Nonclassifiers, a total of 128 subjects was required. When assigning subjects to cells, age and school class were balanced across experimental conditions as far as possible.

2.4.5 Results

Following the scoring procedure of Wickens *et al.* [1963], one point was given for each item correctly recalled, and an additional point was given if all three items were recalled in the correct order. Each child could therefore score a maximum of four points for a single trial. Table 2.2 gives the total scores for each trial over all subjects in each group. As there were 16 Ss per group, a maximum of 64 points is possible per trial. The scores for individual subjects are given in Appendix B.

Production of PI

Before comparing experimental and control groups on trial 4 performance to test for release from PI, it is necessary to establish that the two classes of material are comparable. For example, before comparing the fourth trial switch from animal to food items in Ex₁, with

Table 2.2: Total scores for each trial for each group.

Condition	Trials 1, 2, 3	Trial 4	Average Age	Trial 1	Trial 2	Trial 3	Trial 4
<u>Nonclassifiers</u>							
Ex ₁	A	F	5.8	39	21	15	31
Co ₁	F	F	5.8	42	23	17	16
Ex ₂	F	A	5.8	42	16	19	38
Co ₂	A	A	5.7	41	27	12	18
C'o ₁	C	C	5.8	31	22	16	17
E'x ₁	B	C	5.8	38	19	13	27
C'o ₂	B	B	5.8	41	16	10	13
E'x ₂	C	B	5.7	45	21	9	27
<u>Classifiers</u>							
Ex ₁	A	F	6.1	45	28	25	44
Co ₁	F	F	6.2	53	32	17	25
Ex ₂	F	A	6.0	50	22	26	41
Co ₂	A	A	6.1	49	32	31	25
C'o ₁	C	C	6.1	43	25	18	16
E'x ₁	B	C	6.2	45	28	25	30
C'o ₂	B	B	6.0	51	19	22	15
E'x ₂	C	B	6.1	48	33	22	40

the continued use of food items in Co₁, it must be established that animal and food items are of equivalent difficulty. That is, that the first three (animal) trials of Ex₁ and Co₂ have equivalent performances to the first three (food) trials of Ex₂ and Co₁.

A separate statistical analysis was done for the first three trials of each of the following:

- (i) Nonclassifiers - animal/food items;
- (ii) Nonclassifiers - clothes/body-part items;

(iii) Classifiers – animal/food items;

(iv) Classifiers – clothes/body-part items.

For each, a Two-Factor Mixed Design Analysis of Variance with experimental conditions as a within subjects variable, was carried out on the scores of the first three trials. Table 2.3 gives the results.

Table 2.3: Analysis of variance on the scores of the first three trials.

	Nonclassifiers		Classifiers	
A/F	(i)		(iii)	
Conditions	F(3, 60) = 0.13	n.s.	F(3, 60) = 0.51	n.s.
Trials	F(2,120) = 54.41	p < .001	F(2,120) = 40.88	p < .001
Trials × Conditions	F(6,120) = 1.12	n.s.	F(6,120) = 1.53	n.s.
C/B	(ii)		(iv)	
Conditions	F(3, 60) = 0.14	n.s.	F(3, 60) = 0.59	n.s.
Trials	F(2,120) = 63.15	p < .001	F(2,120) = 58.55	p < .001
Trials × Conditions	F(6,120) = 1.99	n.s.	F(6,120) = 1.51	n.s.

For each category of words there is a highly significant build-up of PI over the first three trials; there is no significant difference between the experimental conditions, and the interaction effect between experimental conditions and trials does not reach significance. It is therefore legitimate to compare each pair of experimental and control groups on their fourth trial.

Release from PI

t-tests for a difference between two independent means were conducted to test for release from PI. Paired experimental and control

groups had items of the same category on the fourth trial, but differed in their histories up to that trial. The percentage gain resulting from the shift was calculated by the method used by Wickens [1970]. The difference between the experimental and control groups on trial 4 was calculated. This figure was then divided by the decline between trial 1 and trial 4 for the control group. This gave the percentage gain due to the shift. The results are given in Table 2.4.

Table 2.4: Analysis of performances on the fourth trial.

	Nonclassifiers				Classifiers			
	Mean	S.D.	t(30)	% gain	Mean	S.D.	t(30)	% gain
Ex ₁	1.94	1.12	2.33	58	2.75	1.00	2.75	68
Co ₁	1.00	1.15	p < .025		1.56	1.41	p < .01	
Ex ₂	2.38	1.36	2.94	87	2.56	1.21	2.29	67
Co ₂	1.13	1.03	p < .005		1.56	1.26	p < .025	
E'x ₁	1.69	1.30	1.70	71	1.88	1.20	2.21	52
C'o ₁	1.06	0.68	p < .05		1.00	1.03	p < .025	
E'x ₂	1.69	1.30	2.05	50	2.50	0.89	5.29	69
C'o ₂	0.81	1.11	p < .025		0.94	0.77	p < .001	

The results indicate a significant build-up of PI with the use of one taxonomic class, and a significant release from PI with a shift to another class, for all classes used, and for both children who classified correctly (Classifiers), and for those who did not (Nonclassifiers).

2.4.6 Discussion

Nonclassifiers showed build-up of PI with continuous use of one class, and release from it with change of class. This provides clear

evidence that semantic hierarchical structures can be used in language production before they can be used to generate classifications based on taxonomic class.

In the usual STM paradigm, used with adults, S is given no feedback. In this experiment there was a pictorial presentation of the items after recall. This repeated presentation may have increased the PI effect since many items were not learnt well on the first presentation. The second presentation would improve learning, and hence might give greater interference on subsequent items. This would not affect the main concern of this experiment. The experiment indicates that young children use superordinate properties when processing and recalling individual items, but fail to use them in the classification task.

However, the question of the relative memory abilities of the different children should not be ignored. Earlier it was mentioned that a 10 second retention interval was used, instead of the usual 20 second interval, because the youngest children remembered too little with the longer time. Table 2.5 shows that even with the shorter time, nonclassifiers had poorer recall than the classifiers. Table 2.5 gives the average scores (out of a possible 4) for each of the first three trials.

Table 2.5: Memory abilities of Classifiers and Nonclassifiers.

	Trial 1	Trial 2	Trial 3
(i) Nonclassifiers - A/F items	2.56	1.36	0.98
(ii) Nonclassifiers - C/B items	2.42	1.22	0.75
(iii) Classifiers - A/F items	3.08	1.78	1.55
(iv) Classifiers - C/B items	2.92	1.48	1.36

At all points, nonclassifiers have poorer average recall than classifiers; however, there is always the same pattern of recall: build-up of PI with repeated use of one class, release from PI with a switch to another class. The difference in memory ability between classifiers and nonclassifiers will be discussed in greater detail at a later point.

The present experiment indicates that the development of classificatory behaviour can not be accounted for by the acquisition of particular semantic features. Halford [1972, p.178] remarks that Bruner's equation of operational concepts with symbolic thought is certainly not valid for formal operational thinking, since Collis [1971] has shown that children can utilise symbols which are usually associated with formal operations, without having these operations. The present experiment shows that the child can utilise symbols associated with concrete operations without having those operations either.

A similar point is made by Inhelder *et al.* [1966]. Bruner [1964] notes that the children who had the most difficulty transposing a 3×3 matrix which varied on height and width, were those who used "confounded descriptions" when describing the matrix. Confounded descriptions, e.g. "That one is tall and that one is little", have a dimensional term (tall) to describe one end of the continuum, and a global term (little, which could refer to width as well) for the other. Bruner draws his usual conclusion that the language of these children is insufficient for the task requirements, and that improved language would lead to improved performance.

Inhelder *et al.* [1966] and Sinclair [1969] also report similar parallels between language expressions and behaviour on conservation and seriation tasks. However, although preoperational children could be

taught to use the linguistic patterns characteristic of concrete operational children, this did not lead to the achievement of concrete operations.

If it is not legitimate to explain inability on classification tasks by the absence of the required semantic features, either one must admit that the concept of hierarchically ordered semantic features is an inadequate explanation of knowledge; or one must retain a system of semantic features, but posit additional intellectual operations which manipulate them to perform the classification tasks. This latter approach is inadequate for two reasons.

(i) Theories of semantic features are inadequate explanations of knowledge.

(ii) Representation of knowledge by semantic features seems to lead to a mechanical view of the behaviours which use them.

These two arguments will be discussed in turn.

(i) Theories of semantic features are inadequate explanations of knowledge in their own right, and so cannot provide an adequate base for more complex models. In his critique of Katz and Fodor [1963], Bolinger [1965] argues that no word is ever limited to its enumerable senses, but can be used in novel metaphors; also the endless properties of a word can be exposed by anomalous sentences. Anglin [1970] is faced with the same problem. When asked how two words were similar, adult subjects generated "a myriad of equivalence relations" [Anglin 1970, p.94]. They were not restricted at all to the small number of semantic features Anglin had designated as important. The characterisation of semantic knowledge by lists of features would seem to require an infinitely large system. Additionally, these systems have no "origin of meaning". Each

item supposedly obtains its meaning by reference to other terms within the system; but however complex one makes the system, and even if one travels in a complete circle, each term will still be empty of meaning, because it is referred to other empty terms. The system must be given meaning from outside itself; it does not explain meaning.

(ii) Representation of knowledge in this dictionary manner seems to lead to the development of rather mechanical models of the other behaviours which use it; such models cannot account for the use of hierarchical relationships at different levels of thought. This requires a constructivist approach such as is offered by Piaget. The necessity for this type of approach is revealed by examination of Klahr and Wallace's work [Rosenberg 1972].

Klahr and Wallace's Model of Classificatory Processes

Klahr and Wallace [1970] have developed a model of classification in which problem solving processes operate on information about coloured geometric shapes which is stored in lists. They have developed a number of "task specific routines" which utilise the lists of information to perform the classification tasks used by Kofsky [1966]. These give no account of how the child understands what he has to do.

In the Exhaustive Sorting task the child is shown an array of blocks of different shapes and colours. He has to choose a block and put it in a box followed by all the other blocks "like it". He then has to continue with a new box and the remaining blocks. This procedure is repeated until all the blocks have been accounted for. The routine which enables correct performance is [Klahr and Wallace 1970, p.375]:

1. Select a block from the collection and place it in the box.
 - 1.1 Select a value of the block.

2. Find all the blocks remaining in the collection that have the value selected in step 1.1. Place them in the box.
3. Determine the attribute of the value selected in step 1.1.
4. Select a block from the remaining collection and place it in an empty box.
 - 4.1 If none are left exit: output is content of boxes.
 - 4.2 If a block is found, go to step 5.
5. Find the value of the block just selected on the attribute determined in step 3.
6. Find all the blocks remaining in the collection that have the value determined in step 5.
7. Go to step 4.

This presumably represents part of the behaviour of an operational child on this task [Inhelder and Piaget 1964]. The most important factor however is completely lacking: How does the child know he has to do these things, and in this order? How does he construct this routine?

A. In Step 1 the child notices a value of his chosen block and uses it for his subsequent classes. Would he use "square" if all objects in the array were square? Would he use "red" if every object in the array was a different colour? The operational child would have some prior plan of the array that indicated relevant and irrelevant properties. He would not make an arbitrary choice of a value.

B. The child has to find "all" the blocks in the array with the required value (Steps 2 and 6); but what compels the child to go on until he has them "all", if not an understanding of the required organisation of the array. The younger child does not have this understanding, but it is surely not merely because he does not have the mechanical search ability, or does not have the motivational level to continue with the search.

C. Similarly, the child only classifies by values of the same attributes (Steps 3 and 5); but why should he do this? He must have some conceptualisation of the required relationships between the classes he is to construct; i.e. that they be mutually exclusive.

There is nothing difficult in the constructed routine: a young child could mechanically learn and perform it; it is the comprehension of relationships which guide the construction of the routine, which changes with development.

Similarly, questions about hierarchical relationships [Klahr and Wallace 1970, p.379] are solved by a mechanical counting procedure that appropriately adds, subtracts and compares totals, to obtain the right answer. Something the younger child could do — *if he knew he had to do it*. His reason for failure is lack of comprehension of hierarchical relationships which leads him to construct the wrong task specific routine when he is confronted with the task.

In other words, this information processing model misses the crux of the problem of classification. A preoperational child could be taught a task specific routine, but it is task specific; he does not know why it works, or even that it does "work", because he can not understand the end product. He would have to learn a new routine for each task. The operational child, with his comprehension of relationships can create any routine according to task demands.

Klahr and Wallace's recent revision of class inclusion processes [Klahr and Wallace 1972a] does not overcome these problems. The revision is based on the methods of counting the items involved. For the question "more roses or more flowers?" the younger child essentially systematically counts each rose, marking each as he goes. Since he cannot count previously counted (marked) items, when he comes to count the flowers, he

only counts the unmarked flowers. The older child has methods which enable recounting of previously counted items.

This seems far too systematic for the younger child. This author's impression of preoperational children performing class-inclusion problems is that they count very inaccurately. Some items are omitted, others are counted twice, because no really consistent order of counting is imposed. This is in keeping with the young child's inability to understand concepts of number [Piaget 1952].

When commenting on Klahr and Wallace's paper, Hayes [1972] points out that if the young child counts the flowers first, every item will become marked, and the child will find no roses at all. This is not supported empirically.

Klahr and Wallace [1972b] admit this is a problem, and suggest that it may be overcome by adding a verification process to check for consistent results. This seems unlikely. It is much more plausible that before the child starts counting, he works out the referents of "roses" and "flowers". His conclusion will be based on his understanding (or lack of it), of the hierarchical relationships between roses and flowers. This conclusion will guide his construction of a task specific routine; i.e. one that counts particular groups of items and compares totals.

As argued above, the way in which the child understands the task, and hence creates particular task specific routines, is the crux of classificatory ability; but it is omitted in Klahr and Wallace's model.

The remainder of this thesis involves an attempt to develop a model of classification which does indicate how comprehension of the task, and construction of task specific routines could be accounted for. This requires a theory of "thought" as opposed to a mechanical description of

final output behaviour. Piaget's epistemological theory seemed the most appropriate framework for this venture.

CHAPTER 3

A THEORETICAL FRAMEWORK

3.1 PIAGET'S THEORY OF KNOWLEDGE

The following account has been partially derived from Furth [1969], who constructs from the many sources in which aspects of it appear, a clear and seemingly faithful account of Piaget's theory of knowledge. Only those aspects of this theory which are relevant to the subsequent discussion of the development of classification will be discussed.

Piaget makes a distinction between the internal scheme of the sensori-motor stage, and the external actions that are generated by the scheme. Each external action is unique, each internal scheme is general to many external actions. During this stage an internal scheme cannot be used except when processing environmental input to produce a full overt behavioural act. Thus if the child is not acting on an object or event, he cannot "think" about it.

During the preoperational stage, the schemes gradually become dissociated from their external manifestations, i.e. overt action, and there is the progressive development of operational intelligence.

Piaget maintains that operations are reversible internal actions. Furth points out how easily this statement is misinterpreted. It has led to the conclusion that knowledge at the sensori-motor stage is the external actions, and that operational intelligence is these actions carried out internally. This conclusion (which in fact describes Bruner's theory) removes the core of Piaget's theory: the distinction

between the general internal sensori-motor scheme, and its external manifestation in specific overt actions.

Furth has suggested the use of "interiorise" and "internalise" to differentiate between the two ways in which Piaget uses the one word "int erioriser". Thus operational intelligence derives from the interiorisation of sensori-motor schemes. The symbolic function derives from the internalisation of overt action.

Operational intelligence is internal action in the sense that it is not dependent on external manifestations, as is a sensori-motor scheme. "The object of (operational) thinking is not outside the thinking scheme, as is the case in sensori-motor actions, but remains within and can itself be called a product of thinking." [Furth 1969, p.60].

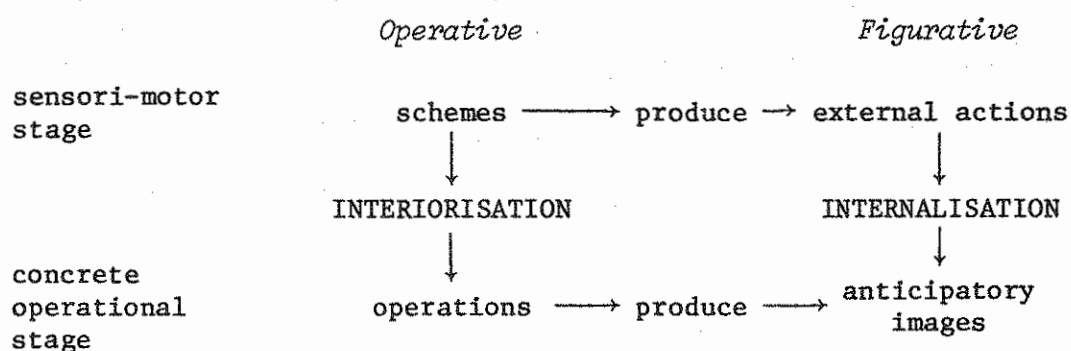
The symbolic function has two aspects: the figurative, which refers to the particular configuration of the symbol, and the operative, which refers to the active internal structures which give the symbol its meaning. The figurative aspect derives from the internalisation of external actions. For example, Piaget [1953, pp.186-187] reports that at 7 months, his daughter on seeing a doll which she has swung many times from her bassinet, gave an abbreviated version of the kicking and grasping actions usually applied. These did not seem intended to produce the usual result; they were rather the half-way stage to complete internalisation.

The symbol as a figurative state does not directly represent the real event. Knowledge of that event is not a direct reading of the environment, but is a transformation of the environment by the internal structures into an object of knowledge. The symbol refers to this object of knowledge, and only through this knowing, to the external event. This

dependence on the internal knowing structures is the operative aspect of the symbolic function.

A distinction has thus been made between the internal structures (operative) and their products (figurative). Progressive interiorisation of the internal structures dissociates the scheme from the specificities of unique external action. At each stage of interiorisation the figurative products of the internal structures become more and more abstract. Thus they progress from full overt actions, to abbreviated actions, to internal symbols, to anticipatory images at the concrete operational stage [Piaget and Inhelder 1969]. This internalisation is always dependent on the interiorisation of the operative component of thought. Figure 3.1 schematises these ideas. This total developmental process will be called "abstraction". (This is not completely equivalent to Piaget's usage.)

Figure 3.1: The development of the operative and the figurative.



In terms of this formulation, it is clear that the "semantic network" theories, discussed earlier, provide merely a figurative characterisation of one aspect of our knowledge. They have no meaning because they do not characterise the operative functions that could produce and interpret such symbols. "To understand a state, one must understand the transformations from which the state results." [Piaget 1966].

The above ideas are summarised by the following definitions.

Definitions

Interiorisation: The progressive dissociation of the internal structures from their particular manifestations, where those manifestations are overt actions at the sensori-motor stage, and internal symbols at the preoperational stage.

Internalisation: The development of the symbolic function through a process whereby external actions become abbreviated and then can be carried out internally. This process is dependent on the interiorisation of the structures which generate overt actions or symbols.

Abstraction: The process of Interiorisation, and its concomitant Internalisation.

3.2 APPLICATION OF THE THEORY TO CLASSIFICATION

The term "intensive concept" will be used to denote the thought of the intension of a class, at any level of development.

At the sensori-motor stage only specific actions are possible. There can be no comparison between objects, because the schemes which they have in common cannot be dissociated from, and used independently of, their various unique external manifestations.

During the preoperational stage, there is a progressive dissociation of the internal schemes from overt action, but their use still remains dependent on internal manifestations — symbols (which are internalised actions). Thus an intensive concept, e.g. "squareness" is dependent on the symbolic support of say, the visual image of several square objects, placed together. Since this intensive concept is so tied to the symbolic

representation of the items already compared, it is not general enough to provide an understanding that future items which are put in the collection must also be exemplars of the same intensive concept. Therefore there is nothing to prevent the child from using a different intensive concept (e.g. colour) for future comparisons.

The advance which the concrete operational child manifests is to be capable of thinking of an intensive concept independently of its use in any individual comparison. This intensive concept will be common to every comparison involved in the classification, but it will be abstracted from the unique aspects of each. Before beginning an overt classification the child can use such an intensive concept as a hypothesis about how the items could be grouped. Individual comparisons will then be guided and constrained by this hypothesis. However, there will be no one-to-one correspondence between this internal plan and the sequence of actions which put it into practice. This single general plan is only possible because the unique aspects of a large number of actions have been omitted.

This use of a general intensive concept as a hypothesis about how to classify the items, explains how the child understands a classification, and constructs the required "task specific routines". This was lacking in Klahr and Wallace's model, because they failed to provide any mechanism for abstracting common components from similar procedures.

Inhelder and Piaget [1964] do not make the above assertions explicitly, but they do seem to imply them. They state that:

"there is a common property between any two elements whenever they are united by a common action. What we want to know is not how common properties arise, but how an assimilatory scheme, being a feature which is common to all behaviour, can begin by functioning in a purely successive manner, and then become an instrument of thinking or representation which is applicable to any number of elements

instead of just two or three (perceived successively and then forgotten). We know that the n elements are then united by a stable interiorized action." [p.286].

The concepts of retroaction and anticipation provide the mechanism for this development. Retroaction and anticipation

"arise as a result of a growing co-ordination between successive actions which eventually overcomes the one-directionality inherent in a succession and takes the form of a shuttling from the present to the past which very soon begins to impinge on the future. Once we are aware that this kind of shuttling is essential to the comparison of elements in a set taken as a whole, we begin to understand why these regulations are likely to end up in the form of operations, since the shuttling is itself a primitive form of reversibility." [p.287].

Inhelder and Piaget provide a wealth of descriptive data concerning this developmental process, but they provide no explicit model of the way in which the abstraction of the internal structures from internal or external manifestations progresses. For instance, they report that correct answers to class inclusion questions occur earlier when the materials are flowers than when they are animals, and they argue that this is due to the child's experience of picking bunches of flowers, together with the impossibility of physically gathering together groups of different animals.

Such findings emphasise the need for investigation of the role of content in concrete operations. This would entail investigation of the two types of knowledge involved:

- (i) Knowledge about the materials;
- (ii) Knowledge about the operations.

Piaget has discussed this distinction. He argues that two different kinds of abstraction are responsible for these two kinds of knowledge.

Physical, or empirical abstraction is involved when the organism reflects on the physical results of its actions. Knowledge of the

physical world, about the properties of objects, such as height, weight, colour and shape, is gained from this form of abstraction. In contrast, formal, or reflective abstraction constitutes a feedback from general co-ordinating activity. This leads to the construction of logico-mathematical concepts such as class, seriation, and number [Furth 1969]. Inhelder [1972, p.105] argues that "the relations between the two abstraction processes and their reciprocal influence have not yet been sufficiently studied".

The main part of this thesis involves an investigation of this relationship. The following hypotheses were generated to describe the progressive abstractions responsible for the transition from preoperational to concrete operational solutions of classificatory tasks.

3.3 ABSTRACTION OF THE SCHEMES INVOLVED IN CLASSIFICATION

Classification requires:

- (i) Schemes which assimilate individual items.
- (ii) Schemes which compare those items, and put them together if similarities are found.

The abstraction of both of these sets of schemes must be considered. Since the latter co-ordinate knowledge obtained from the former, their abstraction must be dependent on the abstraction of the former, and hence the knowledge of individual items will be considered first.

3.3.1 Knowledge of an Item

Elkind and his co-workers [1964, 1969, 1970] have shown that the preoperational child cannot think simultaneously of the "whole" and its "parts" in the perception of individual items. Similarly, Piaget and von Albertini [1954] showed that young children have great difficulty in

recognising dotted outlines of figures familiar to them as wholes; and cannot recognise two familiar figures when they overlap. The child's perception is either global or he responds to very small details, one at a time.

It is plausible to argue that when the preoperational child uses two properties simultaneously, e.g. "red triangle", either in his speech or as a criterion of similarity between two items, the two properties form a "whole" which does not include simultaneous consideration of its parts ("red" and "triangle"). "Red" is unrelated in thought to "triangle", and both are unrelated to "red triangle". If they are unrelated in thought, there can be no way of co-ordinating them in a classification.

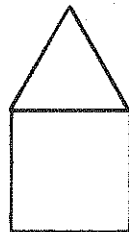
The construction of an item such as a "red triangle" requires the use of a scheme which relates colour and shape. For the preoperational child, this scheme can only be used when relating a particular colour to a particular shape, in order to construct a particular percept or visual image (e.g. a red triangle). Further abstraction enables the concrete operational child to use this scheme dissociated from particular colours or shapes. This abstract scheme, which relates any colour to any shape, is the common component in the construction of any particular colour, shape, or coloured shape. Thus this scheme can unite in thought any of the specific properties of which it is a component. This enables the child to move easily in thought from part to part and from part to whole of an individual item.

This understanding of the relationships between part and whole is a necessary component of the concrete operational child's classificatory ability. The mark of such a child is his mastery of how a classification by one property (e.g. colour), relates to one using a different property (e.g. shape). He can switch flexibly from one criterion to another, and

simultaneously can use several ways of classifying, as is shown by his comprehension of hierarchies, and his ability to cross-multiply classes to form matrix structures. However, the understanding of the relationships between part and whole is not the only requirement for classificatory ability; the classificatory schemes which compare items and put them together, if similarities are found, must be considered in their own right.

3.3.2 Classificatory Schemes

The collection formed by placing a red triangle and a red square together, because both are red, will have a particular spatial arrangement, e.g.



This could be called a "house". This is a particular result of the schemes which compare items, and put them together if similarities are found. The preoperational child can only use these schemes when they are (at least symbolically) processing particular items and producing a specific result. In the above case, the action of putting a red triangle above a red square, and the resulting "house" they make, is not separable in the child's thought from the fact that both are red.

This thought will not be general enough to assimilate a new item. If a new item is added the spatial configuration will change, which means that the child's knowledge of the classificatory schemes is changed. The child has to become able to think of "red items going together" independently of the comparison of particular items, and of the specific

nature of the collection so made. This would enable him to predict the type of item which must be added to an existing collection, and to think of a class, even if its components are not physically united in a particular configuration.

Kofsky [1966] placed a number of squares of different sizes and colours together, and said they were all called "wugs". She then destroyed the spatial arrangement, placing the squares at a distance from each other, and asked if they were still all "wugs". Concrete operational children said that they were still "wugs". Preoperational children said they were no longer "wugs". For the latter, but not the former children, the concept of a class is tied to the physical togetherness of its elements.

3.4 A MODEL OF CLASSIFICATION

Using these ideas one can postulate a series of abstractions which are available to the concrete operational child. The abstractions could provide a plan of a classification which unites in thought a number of different classes, and a number of different items within each class. This would guide and constrain the individual actions used in the actual classification. As mentioned earlier, this is seen as the most important component in classificatory behaviour, but it was missing in Klahr and Wallace's model.

Classifications with respect to colour and shape will be considered. The following abstractions are hypothesised to be necessary for the execution of such classifications.

A. The highest level of abstraction could be:

- (i) Schemes which structure an item as a set of relations between colour and shape.

- (ii) Schemes which compare items — as structured by (i).
- (iii) Schemes which put together items found similar in (ii).

This abstract set of structures would be common to any classification by shape or colour, since (i) is common to the analysis of shape, colour or their interaction, and (ii) and (iii) do not specify the particular classes formed. Therefore this could unite in thought the two dimensions of a matrix, whose rows varied in shape, and whose columns varied in colour. When attention is focused on one of these, e.g. colour, the above abstractions, which are common to both, would be made more specific.

- B. (i) Schemes which structure the colour of items.
 - (ii) Schemes which compare the colour of items — as structured by (i).
 - (iii) Schemes which place together items whose colour was found to be similar by (ii).

This set of abstractions would be common to a classification by any colour, since particular colours are not specified in (i), and the particular classes formed are not specified in (ii) or (iii). This can co-ordinate in thought a set of mutually exclusive classes based on colour. When one of these is considered, this abstraction would be made more specific.

- C. (i) Schemes which structure the colour red.
 - (ii) Schemes which compare the red colour of items — as structured by (i).
 - (iii) Schemes which place together similar red items — as structured by (ii).

This does not specify particular red items (i), or a particular spatial array in which they are organised (iii). Therefore, it can unite in thought all items belonging to the class of red items. It can also

generate the specific actions necessary for classifying any particular red item.

Successful performance on a complex classification task, such as constructing a matrix which varies in two dimensions, would involve an internal trial and error procedure, using the above abstractions, which is rapid and economical because the schemes used are so general, and unite a number of specific actions. This provides a general plan of how an array of items can be organised, which guides the overt placing of each object. When classifying a particular object there must be reference to several levels of abstraction. For instance, when constructing a matrix varying on colour and shape, placing an item for its colour would be generated by abstractions (B) and (C) above. There also must be reference to the abstractions of (A) and the equivalent of (B) and (C) for shape classifications, in order to work out how classifications by shape integrate with those by colour.

3.5 SUMMARY

Some hypotheses concerning the nature of the abstractions necessary for successful performance on classificatory tasks have been advanced.

(i) There is progressive abstraction of the schemes which construct individual items. This enables an understanding of the relationships between the parts and the whole of an item.

(ii) There is progressive abstraction of the classificatory schemes. These co-ordinate knowledge about the items which are to be classified, and hence each stage in their abstraction is dependent on a prior advance in the abstraction of the schemes that construct individual items.

The experiments reported in Chapters 4, 5, 6 and 7 investigate the relationship between understanding an individual item and the ability to classify a set of such items. Chapter 8 reports an experiment concerned with the abstraction of the classificatory schemes in their own right. while Chapter 9 presents a theoretical model which integrates the abstraction of the schemes which construct individual items with the abstraction of the classificatory schemes.

CHAPTER 4

EXPERIMENT 2: AN INVESTIGATION OF THE DEVELOPMENT OF CLASSIFICATORY BEHAVIOUR

4.1 INTRODUCTION

Central to the previous discussion were speculations concerning how the understanding of a class relates to the understanding of an individual item. One of the main contentions was that if a preoperational child uses two properties in conjunction, e.g. "red triangle", it is as a global unit. There is no understanding of the relations between the parts, or between the parts and the whole. This supposed lack of understanding of the relationships within an individual item would be an important factor in the child's failure to construct logical classes when classifying.

It is necessary to examine the relationship that exists between the child's ability to construct logical classes and his ability to perform in tasks that involve the internal relations described above. This can not be done with the materials usually employed in studies of classification (e.g. geometric shapes of different colours) because of the difficulty in assessing comprehension of the relations between part and part, and between part and whole.

Pilot studies suggested that these aims could be met by the use of variants of the basic materials about to be described. The study also indicated that the set of problems which will be outlined later would provide evidence to support the implied hypotheses.

4.2 THE BASIC MATERIALS

A set of objects was constructed which could be likened to faces, but which could also be manipulated to make nonfaces. For example, "faces" were constructed of pink felt cut-out "heads" shaped as squares, hearts or triangles, as shown in Figure 4.1. Blue felt cut-out features were glued onto these in a facial or nonfacial arrangement. The eyes might be shaped as crosses, circles or triangles, the mouths up-turned, down-turned or straight. The noses were always represented by straight segments.

Figure 4.1: Examples of the basic materials.



A set of individual felt pieces was available from which the child could construct replicas of the items. He could be asked to make an item in its usual orientation, or to make an up-side-down version of it. These materials could be used to examine the child's ability to form classes and also to examine his ability to handle the relations between part and part or part and whole.

The following hypotheses concerning these issues were generated from the results of the pilot study.

4.3 HYPOTHESES

The child's ability to form classes is hypothesised to be dependent on his ability to comprehend the relations between part and part, and

between part and whole of an item. The following tasks were expected to provide measures of this understanding.

1. Up-Side-Down Constructions

A young child who cannot understand the relationships between the parts and the whole of an item, should not be able to construct an up-side-down version of an item seen only in its usual orientation. As his ability to construct items up-side-down improves, so should his classificatory behaviour.

2. Face/Nonface Relations

The group of "nonface" items is defined purely by the nonexistence of the "face" relationships. If the young child cannot conceptualise these relationships, he should not be able to understand the face/non-face distinction. A failure to understand this distinction would be indicated by a failure to use it as a basis on which to compare items. The first understanding of this dichotomy should be accompanied by an improvement in classificatory behaviour.

3. The Different Relationships between Head, Eyes and Mouth

The eyes, nose and mouth of an item, considered together, seem to form a global unit for the young child. No such cohesive relationships seem to link any one of these with the head. It is hypothesised that the relationship between the head and the eyes, for example, is both more complex, and less compelling than that between the eyes and the mouth. Therefore the latter relationship should be understood earlier than the former. It is also hypothesised that the cross-classification of two

properties is dependent on an understanding of the relations between those properties, and hence the eyes and the mouth should be cross-classified before the eyes and the head.

4.4 EXPERIMENT 2

To test these predictions, each subject was given a variety of experimental tasks. These were divided between two testing sessions. Each session lasted approximately 35 minutes with the youngest children, reducing to about 20 minutes with the oldest children. The testing sessions occurred on consecutive days, or with a one-day interval between them. Children of all ages appeared to enjoy the tasks.

Specific details of materials used, procedures followed, and results obtained will be described for each task in turn. Those pertaining to the above hypotheses will mainly be reported in the following chapter. The remainder of this chapter is concerned with the assessment of the child's general classificatory ability and the method of rating this ability for later comparison with performance on other tasks.

A summary of all the tests used, and their order of presentation, can be found in Appendix D.

4.4.1 Subjects

Ninety-eight children were tested at a Canberra suburban public school (Page Primary School). They represented a general cross-section of Canberra's population. Children nearest the average age of each grade were chosen, with equal numbers of boys and girls. Table 4.1 gives the average age and the number tested at each grade. These children constitute the sample for all tasks in this experiment.

Table 4.1: The average age, and the number of Ss tested at each school grade.

Grade	K	1	2	3	4	5	6
Average age	5.5	6.6	7.7	8.10	9.10	11.1	11.11
Number tested	18	14	18	12	12	12	12

4.4.2 General Classificatory Ability

This part of the experiment is concerned with the assessment of the child's general ability to integrate several properties simultaneously in a logical classification. Inhelder and Piaget [1964] emphasise the use of class inclusion questions for this purpose (cf. Chapter 1). However, it is felt, along with Hayes [1972], that these are somewhat unnatural questions. Additionally, this situation does not provide much opportunity for making further, more qualitative analyses of the child's thought processes.

The child's ability successively to resort items according to a number of different criteria provides another measure of logical classifications [Inhelder and Piaget 1964, Nixon 1971]. However, with this task, particular preoperational children may perform correctly by simply forgetting the previous criterion, and using the correct new criterion, oblivious to all others.

In contrast, a task where the child is required to complete a matrix whose rows vary on one property, and whose columns vary on another, provides ample opportunity for assessment, through questioning, of how well he can co-ordinate the various properties. Preoperational solutions [Inhelder and Piaget 1964, Chapter 6] are easily distinguished from operational understanding.

A series of matrix tasks was therefore used in the present experiment because these tasks provided the best measure of operational thought, together with the best opportunity for further analysis of inadequate performance. Additionally, an investigation of the hypotheses concerning the differential relations between the head, the eyes and the mouth could be made by varying the combinations of these properties within the matrices.

4.4.3 Materials

Six 3×3 matrices were constructed. Only "faces" were used. Nine pink paper shapes (heads) with major width and length of 3 inches were glued to a $10\frac{1}{2}$ inch \times $10\frac{1}{2}$ inch sheet of white cardboard to form a 3×3 matrix. Face features were drawn on the "heads" with a black felt pen. The matrix was protected by an adhesive transparent plating sheeting.

The nose was always the same shape, but the other three properties varied:

- (i) The head shape was a square, a heart, or a triangle.
- (ii) The eyes were crosses, circles or triangles.
- (iii) The mouth was up-turned, straight or down-turned.

Matrices of two levels of complexity were constructed.

A. Two properties varied ("A" matrices)

It was hypothesised that cross-classification involving the eyes and the mouth would occur earlier than that involving either feature and the head. To test this, it is necessary to have a matrix for each condition where one of the two pertinent properties varies along the rows, the other along the columns, the third property being held invariant.

Three matrices were constructed on these principles. Each property was held invariant once. An example is given in Figure 4.2.

Figure 4.2

Matrix A1



To assess ability to cross-multiply two properties, the lower right corner item of each matrix was removed, and the child had to complete the matrix from a choice of four alternatives. If the two variable properties are X and Y, the four alternatives provided were:

- (i) X and Y correct.
- (ii) Y correct, X wrong.
- (iii) X wrong, Y correct.
- (iv) X and Y wrong.

The third, invariant property was always correct.

Drawings of the three matrices, and of the four alternatives provided for each, can be found in Appendix E3.

B. Three properties varied ("B" matrices)

It was hypothesised that the relationships co-ordinating all three properties would be more complex than those co-ordinating any two of the

properties. Therefore, cross-multiplications involving any two properties should be achieved before those involving all three properties.

Accordingly, three matrices were constructed in which all three properties varied:

- B1. Head and eyes the same within the rows; mouth the same within the columns.
- B2. Head and mouth the same within the rows; eyes the same within the columns.
- B3. Eyes and mouth the same within the rows; head the same within the columns.

An example is given in Figure 4.3.

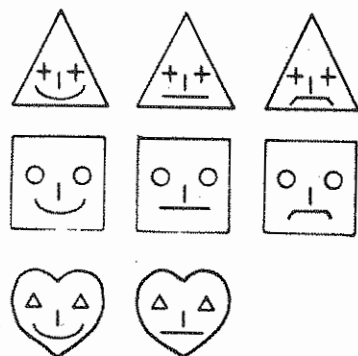
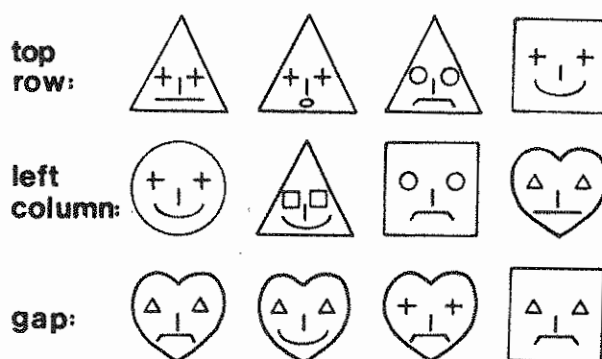
As with the "A" matrices, the ability to cross-multiply was tested by removing the lower right corner item and asking the child to complete the matrix from a choice of four alternatives. One alternative had all three properties correct, the others had two properties correct, and one wrong.

Another two tasks, designed to investigate the differential relationships between the head, eyes and mouth were also carried out on these "B" matrices. The pilot study suggested that young children could use eyes + mouth¹ as a single property when comparing items, but could not combine the head and one of the features (e.g. the eyes) into a single global unit. These had to be treated as independent properties.

Within each row of the "B" matrices two properties are the same, and one is different. To test the child's ability to use two properties simultaneously, within one collection, he was asked to continue the top row of each matrix. He was given four alternatives from which to choose

¹ "a + b" denotes that the two properties a and b have to be considered together within one collection.

Figure 4.3

Matrix B1**Alternatives**

items similar to all those in the top row. These alternatives introduced some new shapes:

- (i) Round head;
- (ii) Square eyes;
- (iii) Round mouth.

If X and Y are the two properties which are the same in the row, and Z the one which differs, the four alternatives provided were:

- (i) X and Y correct; Z the same as one item in the row.
- (ii) X and Y correct; Z different from all other items in the row.
- (iii) X correct; Y wrong; Z the same as one item in the row.
- (iv) X wrong; Y correct; Z the same as one item in the row.

An example is shown in Figure 4.3.

It would be predicted that the child could use the similar eyes + mouth in matrix B3 before he could use the similar eyes + head, or the similar mouth + head, in matrices B1 and B2 respectively. Additionally, if eyes + mouth can be used as a single global property, ability to use this should be similar to ability to use any single property. Within

each column of the "B" matrices one property is the same and two are different. To test the child's ability to use a single property, he was asked to continue the left column of each matrix. Again he was provided with four alternatives. If X and Y are the two properties which differ in the column, and Z the one that is the same, the four alternatives provided were:

- (i) Z correct; X the same as one item in the column; Y different from all items in the column.
- (ii) Z correct; X different from all items in the column; Y the same as one item in the column.
- (iii) and (iv) Z wrong; X and Y the same as one item in the column.

An example is shown in Figure 4.3. Additionally, drawings of all three matrices and their various subsidiary items can be found in Appendix E4.

4.4.4 Procedures

In the first testing session, among the other tasks, the child was asked to complete the three "A" matrices. Their order of presentation was counterbalanced within each age group. In the second testing session, for each "B" matrix in turn, the child was asked to continue the top row, to continue the left column, and to complete the matrix. Order of presentation of these matrices was counterbalanced within each age group.

"A" MATRICES — TWO PROPERTIES VARIED

Description of the Top Row and Left Column

A matrix was placed in front of S who was asked:

- (i) How the three items in the top row were the same.
- (ii) How the three items in the left column were the same.

If in either of these the S failed to name the relevant property he was asked if the items were the same in any other way.

The pilot work suggested that children described the eyes, the nose and the mouth of items more frequently than the head shape. This initial questioning provided a standard situation from which quantitative data could be collected to test these observations. It also provided the child with an initial orientation towards the different dimensions of the matrix.

Matrix Completion

The child was asked to describe the item that would complete the matrix. ("You see there's a picture missing here? If I asked you to make a picture to go there, which was the same as all these (point to right column), and the same as all these (point to bottom row), what would it look like?")

The child then had to complete the matrix from a choice of four alternatives. He was questioned in some detail as to whether alternative items would do, and about the reasons for his choice(s). If the child was not using both dimensions of the matrix simultaneously, it was repeatedly stressed that the item had to be the same as both the row and the column.

"B" MATRICES — THREE PROPERTIES VARIED

Continuation of the Top Row

A matrix was placed in front of S with all but the top row concealed. S was asked how the three items were the same, and if necessary, whether they were the same in any other way. Four more items were presented, and S was told:

"I want you to see if any of these pictures are the same as all these (point to top row), in *all* the ways that they are the same. If there are any pictures the same, can you put them with these (top row), so that you have a long line of pictures all the same as each other."

He was asked about the reasons for his choice, and why the items not chosen could not go.

Continuation of the Left Column

After the above task, all but the left column of the matrix was concealed, and the same procedure was carried out.

Matrix Completion

The total matrix was uncovered, and the same questions about the item that would complete the matrix were put to the child as with the "A" matrices.

4.4.5 Summary of Findings

These procedures produced much specific data concerning the differential relationships between the head, the eyes and the mouth properties. These will be discussed fully in the next chapter. The present concern is with the general approach of the child towards the tasks.

On the bases of performances on these tasks, the development of classificatory ability can be divided into six stages, based on behaviour which was common to the child's handling of each matrix, irrespective of the different combinations of properties used in each. The first obvious difference between children was that some showed no tendency to co-ordinate properties in both the row and the column when

completing the matrix, while others achieved some sort of co-ordination. The former children would only compare an item with the row or the column items, but never with both simultaneously. If they were attending to, say, the row, and E diverted their attention to the column items, they forgot about the row items. A finer distinction was made between these children on the basis of their performance on an additional task which had proved useful in the pilot study.

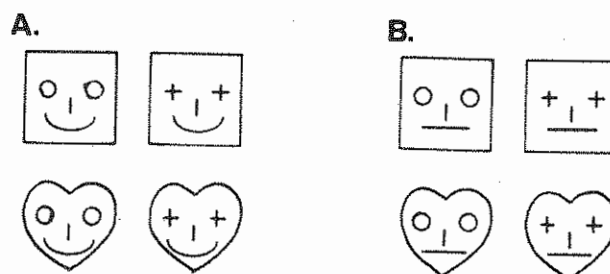
4.4.6 Verbal Switching Ability

The pilot study indicated that some children found it much more difficult than others to switch from comparisons on one property to comparisons on another, within one collection. This difficulty, which hindered their classifications in all tasks, was most readily observable in a task where E asked S to describe one property after another of a matrix (i.e. to switch between properties in their verbal descriptions).

Method

E constructed the two 2×2 matrices shown in Figure 4.4 from individual felt items. S was asked for the difference between the two matrices. Matrix B was removed, and a third row and column were added to matrix A to construct the 3×3 matrix shown in Figure 4.5.

Figure 4.4: The first set of materials used in the verbal switching task.



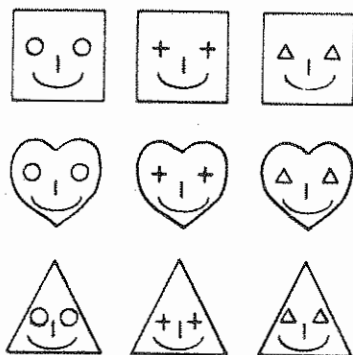


Figure 4.5: The second set of materials used in the verbal switching task.

S was asked for the difference: (i) between the rows, (ii) between the columns (or vice versa, so that the order of eye and head comparisons was balanced across Ss). When asking for the difference between the rows, E placed the items within a row close together, and made a large space between the rows; and vice versa for the column comparisons.

If the child failed to describe the required property, after repeated questioning, two items, the same on all properties except the criterion one (or different on all properties except the criterion one) were chosen, and S was asked for the difference (or similarity) between them. If he still failed, he was asked to construct a copy of both items (from a set of individual felt pieces).

Results

Children were placed in the lowest stage of classificatory ability if this task proved difficult for them. These children showed a certain confusion between "same" and "different". For instance, if a child who had just made comparisons on the basis of eye shape, was asked how



and



were different, he would say: "This has round eyes, and this has round eyes." If asked how



and



were the same, he would say: "This has round eyes and this has cross eyes."

In both cases the child could make the items correctly from individual felt pieces, and hence had perceived the head shape. The question "How are they different (the same)." appeared to mean "Compare the eyes." It seemed that the child's understanding of "same" or "different", at that point, was tied to a particular property, the eyes. The child could not understand that "same" or "different" could also apply to another property. Two protocols of this behaviour can be found in Appendix F.

4.4.7 Stages of Classificatory Ability

It is now possible to describe the stages through which children in this sample passed in their development of classificatory ability. (Protocols of the stages 2 to 6 can be found in Appendix G.)

Stage 1

Children who were so inflexible in the verbal switching task that it became necessary for E to ask the child to make two items, were assigned to Stage 1. There were 8 children at this stage; of these, 6 could not switch to considering head shape, one could not consider eye shape, and one could not compare mouth shape or head shape. They all made the two items correctly.

Stage 2

Similarly to Stage 1, these children did not use both the row and the column when completing the matrix. However, they always changed criteria in the verbal switching task before it was necessary for E to ask them to make two items.

Stage 3

When completing the matrix, these children compared items to both the row and the column simultaneously. However, they showed no comprehension that a new item should be similar to *both* the items in the row, and to *both* the items in the column. For instance, if eye shape was different across the row, and similar within the column, these children would be quite happy to complete the matrix with an item that had similar eyes to one item in the row. They would not be concerned that the eyes were different from the other item in the row and from the column items. (A protocol is given in Appendix G.)

Similarly, when continuing the top row or the left column of the "B" matrices these children did not consider the structure of the whole collection. Instead they made "two item comparisons" involving the wrong properties. For instance, to a column of items with similar eyes, but different mouth and head shapes, a child might add an item with the wrong eyes, because its mouth was similar to another item in the collection.

Children at this stage did not seem to understand the structure of a collection. Consequently, they accepted a number of alternatives for completing a matrix, or for continuing a row/column, and maintained that they were all equally good.

Stage 4

This stage comprised children who used the structure of the whole collection when making comparisons, and who either never, or only very occasionally, used "two item comparisons". However, these children still made many mistakes. They thought that most, or all, of the alternatives provided for completing a matrix were equally good. In these cases, they made no reference in their explanations to properties which were wrong. Similarly, legitimate properties were often omitted from consideration.

It seemed that the child understood the structure of a collection with respect to one property at a time, but had difficulty in simultaneously integrating all properties together, to complete the matrix. One property at least would be omitted from consideration.

Stage 5

These were children who based their comparisons on all items in a collection, and never used "two item comparisons". However, they still thought the matrix could be completed with several items, although they usually worked out the "best" one. They knew why the other alternatives were not as good, but they still argued that they could be used. There was no final understanding that only one item could legitimately complete the matrix.

Stage 6

The child at this stage denied from the beginning that any alternative, other than the correct one, could complete the matrix. His internal criterion of the requirements of the matrix allowed no deviations.

These six stages of classification are summarised in the following section.

4.4.8 Summary of the Stages of Classificatory Ability

Stage 1: Very inflexible switching, no multiplication.

Stage 2: Moderate to flexible switching, no multiplication.

Stage 3: Multiplication but only between successive two item comparisons, rather than between *all* items.

Stage 4: Occasional, or no, two item comparisons, but still unable to work out the best alternative.

Stage 5: No two item comparisons. Still thinks incorrect alternatives can complete the matrix, but can usually work out the "best" one. *Stage 6:* Completely correct, no consideration of incorrect alternatives.

The members of the sample were allocated to stages on the basis of the above criteria. The distribution by age and school grade within the stages is shown in Table 4.2.

Table 4.2: The distribution of stages of classification within each school grade.

Average Age	Grade	Stage						Total
		1	2	3	4	5	6	
5.5 years	K	8	9		1			18
6.6 "	1		5	2	7			14
7.7 "	2		1	8	4	1	4	18
8.10 "	3			2	1	5	4	12
9.10 "	4			1	3	4	4	12
11.1 "	5			1	2	2	7	12
11.11 "	6					4	8	12
Total		8	15	14	18	16	27	98

It is now possible to examine the relation between the child's stage of classification and his ability to handle the relations between part and part, and between part and whole of an item. This is investigated in the next chapter.

CHAPTER 5

THE RELATION BETWEEN UNDERSTANDING THE CONSTRUCTION
OF AN INDIVIDUAL ITEM AND CLASSIFICATORY ABILITY

Three different ways of investigating the relation between the child's stage of classification and his ability to handle the relations between the parts and the whole of an item were used.

- (i) Up-Side-Down Constructions.
- (ii) Face/Nonface Relations.
- (iii) The Different Relations between Head, Eyes and Mouth.

These will be described in turn.

5.1 UP-SIDE-DOWN CONSTRUCTIONS

Furth [1970] reports that while young children can draw an up-side-down version of a simple shape, e.g. a triangle, they are unable to do so if a schematic face is drawn inside the shape.

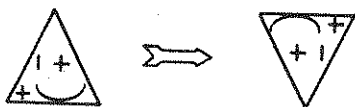
This suggests the following compound hypothesis:

(i) To construct an item up-side-down (hence USD), the child must be able to think of each part as a separate entity, and of how it relates to the other parts, to construct the whole.

(ii) Classification is dependent on understanding such part-whole relationships. Consequently, the ability to construct the items USD should be related to the ability to classify them.

5.1.1 Materials

Eight felt figures, 4 faces and 4 nonfaces, were used. In each, the rotation USD produced a visually different orientation of the head shape, and of either the eye shape or the mouth shape. The USD rotation also caused a left-right reversal of the parts of the asymmetrical nonfaces, e.g.



Drawings of the 8 items can be found in Appendix E1.

5.1.2 Procedure

S was asked to draw four of the items and to reconstruct the other four, first in their normal orientation, and then USD. Except for the first two items, S never saw the items USD. The first two items were turned USD to establish that S understood the task. However, they were again returned to their normal orientation while S constructed his USD version.

5.1.3 Scoring

USD constructions were scored as follows:

- (i) One point for turning the head USD.
- (ii) One point for turning the eyes/mouth USD.
- (iii) One point for changing the relative positions of the eyes, nose and mouth; i.e. putting the mouth above the eyes, etc.
- (iv) One point for a left-right reversal in the nonfaces.

Therefore a face correctly made/drawn USD received 3 points; a non-face correctly made/drawn USD received 4 points. A maximum of 28 points could be achieved for the 8 items.

5.1.4 Results

No children had any difficulty in constructing the items in their normal orientation, although some children drew the features without the enclosing head shape. In these cases, E instructed them to draw the head. The majority of children drew the head before the features.

The mean and standard deviation of the USD score for children at each stage of classification (as derived in the previous chapter) are given in Table 5.1.

Table 5.1: The mean and standard deviation of the USD score at each stage of classification.

	Stage					
	1	2	3	4	5	6
Number of children	8	15	14	18	16	27
Mean	7.00	16.13	18.50	21.83	22.87	26.48
S.D.	2.56	3.85	5.39	4.70	3.80	1.28

There is a highly significant difference between the stages (Kruskal-Wallis One-Way Analysis of Variance [Siegel 1956], $H = 60.2988$, $p \ll .001$.)

The Mann-Whitney U Test was used to test for differences between adjacent stages. These results are shown in Table 5.2.

Table 5.2: Mann-Whitney U Test for differences in USD Scores between adjacent classification stages.

Stages				
1 and 2	2 and 3	3 and 4	4 and 5	5 and 6
U = 0	U = 74	U = 77	U = 130.5	z = -3.1156
p < .001	n.s.	p < .05	n.s.	p < .001

At Stage 1 there is almost no ability to construct an item USD. Progression to Stage 2 is accompanied by a big improvement in this ability. Thereafter, improvements in USD constructions accompany improvements in classification.

This supports the hypothesis that the inability of the Stage 1 child to switch between comparing different properties is due to his lack of understanding of the relations between them. Each improvement in classificatory ability is accompanied by an improved performance in the USD task.

5.2 FACE/NONFACE RELATIONS

Ability to differentiate between the faces and the nonfaces, both of which have the same individual parts, must be based on the ability to conceptualise the presence or the absence of the "face relationships". If the child cannot understand these relationships, he should not be able to conceptualise the face/nonface distinction. A failure to understand this distinction would be indicated by a failure to use it as a criterion for comparing items, in situations where other criteria (e.g. differences in mouth shape), can be used.

This leads to the following dual hypothesis:

(i) Comprehension of the face/nonface dichotomy is dependent on understanding the relationships between the features.

(ii) The failure of the Stage 1 child to switch from comparing one property to comparing another, is due to a failure to understand the relationships between those properties. Therefore he should also fail to conceptualise the face/nonface dichotomy.

5.2.1 Method

Subjects were required to sort eight items into two groups on the basis of each of the following four criteria:

- (i) Face/nonface dichotomy;
- (ii) Head shape;
- (iii) Eye shape;
- (iv) Mouth shape.

A variation of a paradigm developed by Nixon [1971, Cross-classification Task] was used for all four criteria. E extracted, from the eight items, two exemplars, of the required classes, which were the same on all dimensions except for the one selected. S was required to continue the classification suggested by these exemplars.

The same materials were used for the head shape, eye shape and mouth shape criteria, while different items were used for the face/nonface sort. The procedures for the first three criteria will be described first, since they provide the base-line against which to compare the procedures and the results of the face/nonface sort. (In fact, the face/nonface sort was always presented before the other three.)

HEAD, EYES AND MOUTH

Materials

Eight felt faces were used which provided all combinations of:

heart or square head;

circle or cross eyes;

smiling or straight mouth.

Procedure

Subjects were required to sort with respect to head shape, eye shape and mouth shape, the order of presentation being counterbalanced within each age group. For each sort, the 8 items were placed randomly on the table in front of S. E indicated the two exemplars of the required classification, and asked S to continue sorting the items into the two groups. The exemplars were similar on all but the criterion property. If S failed he was given additional opportunities, and help from E, such as being asked how the two exemplars differed. After each test, the items were rearranged randomly, and exemplars for a new classification were chosen.

FACE/NONFACE

The face/nonface sort, which was presented prior to the presentation of the head, eyes and mouth classifications, differed from these classifications in two respects.

(i) Different materials, which incorporated the face/nonface dichotomy, were used.

(ii) As this classification had proved much harder than the others for the younger children in the pilot study, Ss were given additional

help to make sure failures to conceptualise the face/nonface dichotomy were genuine.

Materials

Eight felt items were used: 4 faces and 4 nonfaces. These were composed of:

- 4 square and 4 heart heads;
- 4 cross and 4 round eyes;
- 4 straight and 4 smiling mouths.

The features of each nonface were organised in a different spatial arrangement.

Six additional items, 3 faces and 3 nonfaces, were used later in the task. These introduced some new properties:

- circular and triangular heads;
- square and triangular eyes;
- down-turned mouths.

(The items used are illustrated in Appendix E2.)

Procedure

The first 8 items were randomly positioned on the table before S. The following items were used to exemplify the required classes, and E questioned S about their differences.



If S did not spontaneously say so, E told him, that "a" was a face, while "b" was not. S was then asked to put all the other items with "a"

or "b". If S grouped the items incorrectly, he was given additional opportunities, and if he continued to make mistakes, E told him to put the faces with "a", and the ones that were not faces with "b". If he still failed, E pointed to particular wrongly placed items, and asked "Is this a face? Can it go here?" etc. If there was eventual success, E produced the 6 additional items, and asked S to place each one in one of the two collections he had made.

5.2.2 Scoring

For each of the above four classifications (face/nonface, head, eyes and mouth), Ss were assigned to one of three categories on the basis of their performance.

Category 1: Children who correctly sorted the eight items on their first attempt.

Category 2: Children who were incorrect on their first attempt, but who achieved a correct classification on a subsequent attempt.

Category 3: Children who failed to achieve a correct classification.

The criteria for categories 2 and 3 were modified for the face/nonface classification. In this task, E sometimes gave so much help with the first eight items, that the eventual correct classification was not so much a proof of S's comprehension of the face/nonface dichotomy, as of E's comprehension. Presentation of the additional 6 items tested S's comprehension. If he used the face/nonface distinction as a criterion for grouping these items, he was placed in category 2. If he could not use this criterion, he was placed in category 3. (A protocol of a child in this category can be found in Appendix H.)

5.2.3 Results

The percentage of children at each stage of classification who were assigned to category 3 (complete failure) is shown in Table 5.3.

Table 5.3: The percentage of children at each stage of classification who failed to achieve a correct sort.

	Stage					
	1	2	3	4	5	6
Number of Ss	8	15	14	18	16	27
Face/Nonface	75	6.6	0	0	0	0
Head	12.5	0	0	0	0	0
Eyes	0	0	0	0	0	0
Mouth	0	0	0	0	0	0

Within Stage 1 the difference between the four properties was significant (Cochran Q Test [Siegel 1956], $Q = 15.6315$, $p < .01$.)

This objective result confirmed a subjective feeling. The failure with the face/nonface sort of children at Stage 1 seemed to be due to a lack of any understanding of the concept, while difficulties with other properties seemed to be due to a fixation on the wrong property, rather than to a lack of comprehension of the required property.

The failure on this face/nonface sort cannot be attributed to interference from previous sorts, since it was always administered first. It cannot be attributed to a lack of familiarity with the materials, since the same effect was also observed in the pilot study, where this classification was always administered after the other three. The failure is all the more significant, because the child, in view of his difficulties, was given much more assistance by E, than he was with the other criteria.

The percentage of children in category 1 (successful first attempt), for each stage of classification, and for each criterion, is shown in Figure 5.1. At Stage 1, no child correctly sorted items into faces and nonfaces on his first attempt. This was not true for any of the other three criteria. After Stage 1, the face/nonface criterion provided no special difficulty, compared to the other criteria.

This supports the dual hypothesis:

(i) Since the Stage 1 child has some classificatory ability with the head, eyes and mouth criteria, his failure with the face/nonface criterion can be argued to be due to a lack of comprehension of the "face relationships".

(ii) Since failure with the face/nonface sort is closely correlated with the lowest stage of classification (the two Stage 1 children who eventually achieved a correct face/nonface sort, required much assistance from E), it may be argued that the inability of the Stage 1 child to switch between comparing different properties is due to a lack of understanding of the relationship between them.

Additional analyses of the data were made. Over all stages, classification was easier with respect to the eyes or the mouth than it was for the head shape. (Cochran Q Test, $Q = 18.7894$, $p < .001$.)

Scale analysis was used to test whether there was a constant order of acquisition of these abilities. (Eyes and mouth first, followed by head shape and face/nonface sorts.) A description of Scale Analysis and the rationale for the particular techniques employed here are given in Appendix C. The outcome of this analysis is summarised in Table 5.4.

For each criterion, children were given one point for sorting items correctly on their first attempt (category 1), and no points if they

Figure 5.1: The percentage of children at each stage achieving a correct sort on their first attempt.

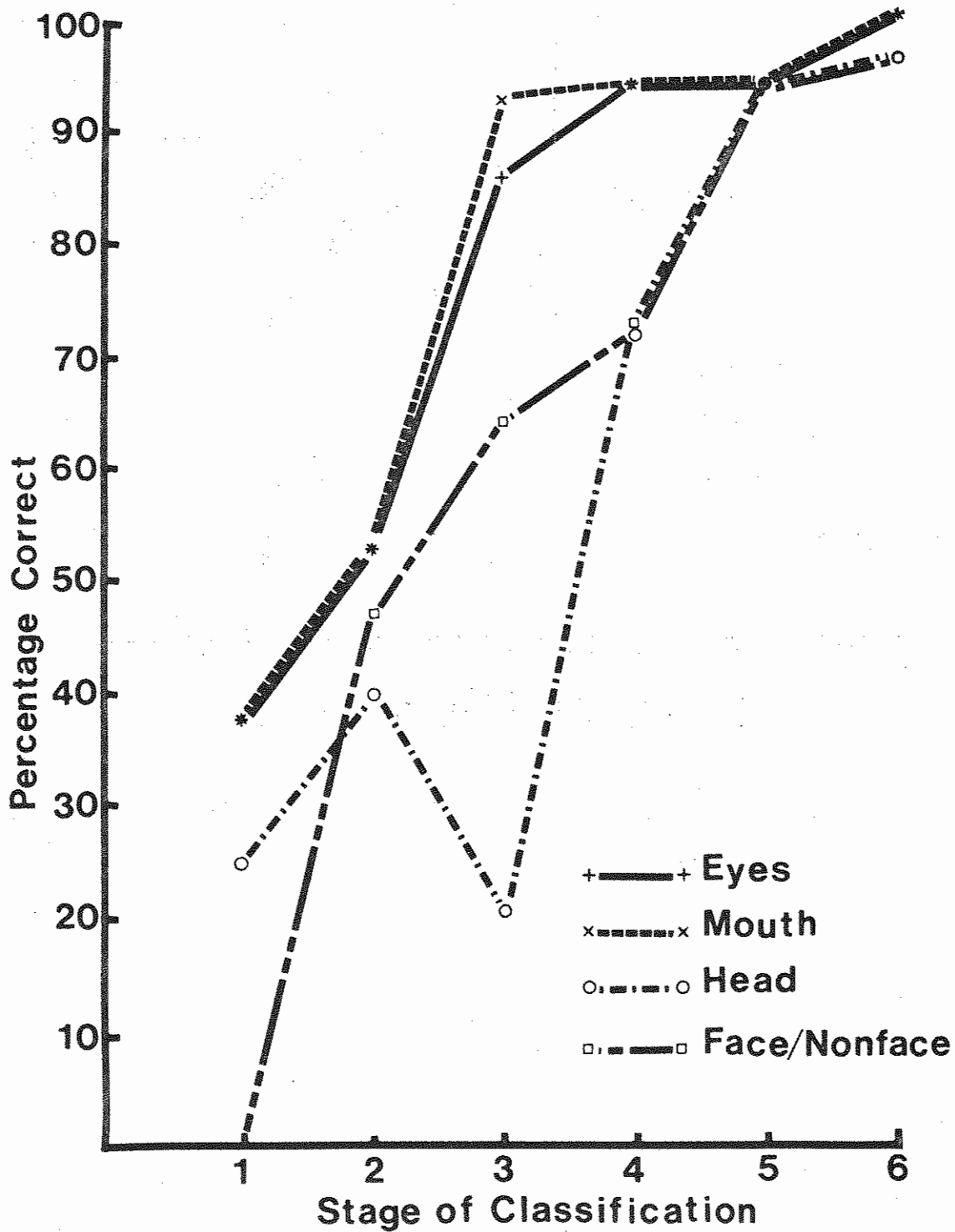


Table 5.4: Scale analysis for the sorting tasks.

Loevinger's coefficient of homogeneity for the set of items,

$$H_t = 0.4315$$

Loevinger's coefficient of homogeneity between each pair of items, H_{ij} :

	Eyes	Head	Face/Nonface
Mouth	0.2825	0.4980	0.4405
Eyes		0.6236	0.5629
Head			0.3006

White and Saltz's coefficient of homogeneity between each item and the total test score, ϕ_{it} :

	Mouth	Eyes	Head	Face/Nonface
ϕ_{it}	0.5276	0.7012	0.6344	0.6000
Significance level	$p < .001$	$p < .001$	$p < .001$	$p < .001$

required E's assistance (categories 2 and 3). This gave each child a total test score of 4 points. The following measures were computed:

(i) Loevinger's coefficient of homogeneity for the set of items (H_t) ("item" here refers to a classification on the basis of one of the criteria). This measures the degree to which the order of acquisition of the items is constant.

(ii) Loevinger's coefficient of homogeneity between each pair of items (H_{ij}). This measures the degree to which the order of acquisition of a pair of items i and j , is constant.

While there is no standard level of significance for these two measures, coefficients greater than .60 will be taken to indicate scaleability (cf. Appendix C for the rationale).

(iii) White and Saltz's coefficient of homogeneity between each item and the total test score (ϕ_{it}). This measures the degree to which the total test score determines the score for item i . The significance of this measure is derived from the χ^2 distribution.

Additionally, correlations between the child's total test score, his stage of classification, and his school grade were carried out. The results are given in Table 5.5.

Table 5.5: Correlations concerning the sorting tasks.

	Stage	Total Test Score	
School Grade	0.7724	0.6238	
Classification Stage		0.7851	(0.6107 with Grade partialled out)
(p < .001 for all correlations)			

The significant correlation between the total test score and stage of classification, indicates that ability on these sorting tasks is related to classificatory ability, as measured by different classification tasks. However, the low coefficients of homogeneity indicate that there is no constant order of acquisition of sorting by the four criteria.

It is argued that when a young child correctly classifies items into two groups, he succeeds because he has, by chance, fixated on the relevant criterion and become oblivious to the other criteria. This means that, for these young children, success with one property is not a predictor of performance with another. Successful performance is determined by the probability of fixation on the relevant property, at any given point in time (and there is a greater probability that the eye

shape or the mouth shape will be fixated than the head shape). Hence no orderly sequence of development is revealed by the scale analysis.

The overall ease of the eyes and the mouth classifications, compared with the classification of the head shape, introduces a third way of investigating the relation between understanding an item and classificatory ability.

5.3 THE DIFFERENT RELATIONS BETWEEN HEAD, EYES AND MOUTH

Some observations made in the pilot study indicated that the eyes, the nose and the mouth were linked by a more cohesive set of relations than were the eyes and the head, or the mouth and the head. These impressions were based on the following observations:

(i) When extending a collection of items which E had started, the young child who could not yet integrate two independent properties was able to classify on the basis of eyes, nose and mouth simultaneously, but could not apply a multiple criterion when the properties involved were the eyes and the head, or the mouth and the head. In other words, he could use the eyes + nose + mouth as a single global property, but the head and any one of the features, e.g. the eyes, had to be considered as two properties.

(ii) When describing similarities with respect to one of the features, e.g. the eyes, the other features, e.g. the nose and the mouth, which might be logically irrelevant for comparison purposes, were often also described. There seemed to be no such compulsion to describe the head shape.

These impressions formed the basis of the following compound hypothesis:

(i) The relationships between the eyes and the mouth are simpler, and will therefore be understood earlier, than those between the eyes and the head, or the mouth and the head.

(ii) The child's ability to cross-classify two properties is dependent on his understanding of the relations between those two properties. Therefore the eyes and the mouth should be cross-classified before the eyes and the head, or the mouth and the head.

Investigation of this compound hypothesis involved three tasks which were described in section 4.4.4. Two tasks were used to confirm the pilot study observations, and hence to support part (i) of the hypothesis:

(a) S was asked to give a verbal description of the top row and the left column of all matrices;

(b) S was asked to continue the top row and the left column of the "B" matrices.

Part (ii) of the hypothesis was investigated through an analysis of the results of completing the "A" matrices, where different pairs of properties had to be cross-classified.

The three tasks will be reported in the above order.

5.3.1 Description of the Top Row and Left Column

When first presented with each matrix, S was asked the following questions:

(i) How the items in the top row were the same.

(ii) How the items in the left column were the same.

If he failed to name a relevant property, the question was repeated (cf. section 4.4.4). Throughout the questioning for the "A" matrices,

the property being held invariant was considered by E to be irrelevant and therefore S was not prompted if he failed to describe it. Similarly, S was not prompted if he failed to describe the nose.

Results

The average number of times similarity on each property was described after E's first question, is shown in Figure 5.2 ("A" matrices) and Figure 5.3 ("B" matrices).

In the "A" matrices there could be a maximum score of 4 since each property was similar in the following four conditions:

- (i) In the top row of the matrix in which the property varied in the left column;
- (ii) In the left column of the matrix in which the property varied in the top row;
- (iii) and (iv) In both the top row and the left column of the matrix in which the property was held invariant.

In the "B" matrices there could be a maximum score of 3, since each property was similar in either the top row or in the left column of each matrix, but never in both.

For each set of three matrices (3 "A" matrices and 3 "B" matrices), the nose could be described a maximum of 6 times, since it remained invariant in all conditions. The score for the nose, reported in Figures 5.2 and 5.3, has been made proportional to a maximum score of 4 for the "A" matrices (Figure 5.2), and to a maximum score of 3 for the "B" matrices (Figure 5.3).

Table 5.6 shows the results of a Friedman Two-Way Analysis of Variance by Ranks [Siegel 1956], conducted to test for differences

Figure 5.2: The average number of times similarity was described after E's first question: "A" matrices (maximum = 4).

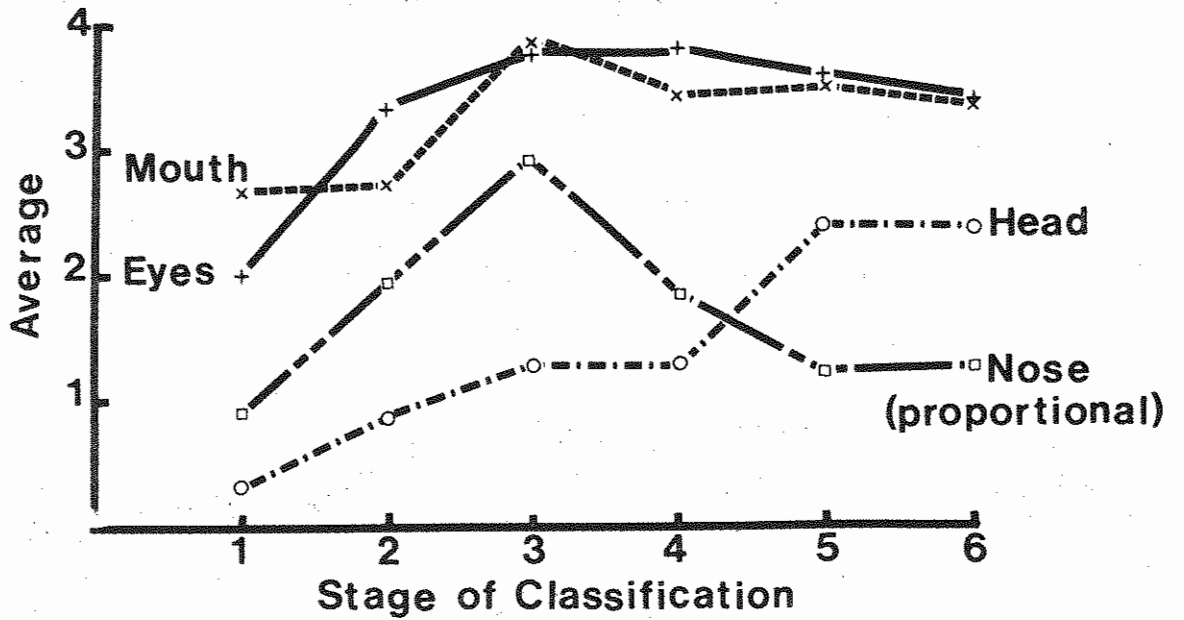
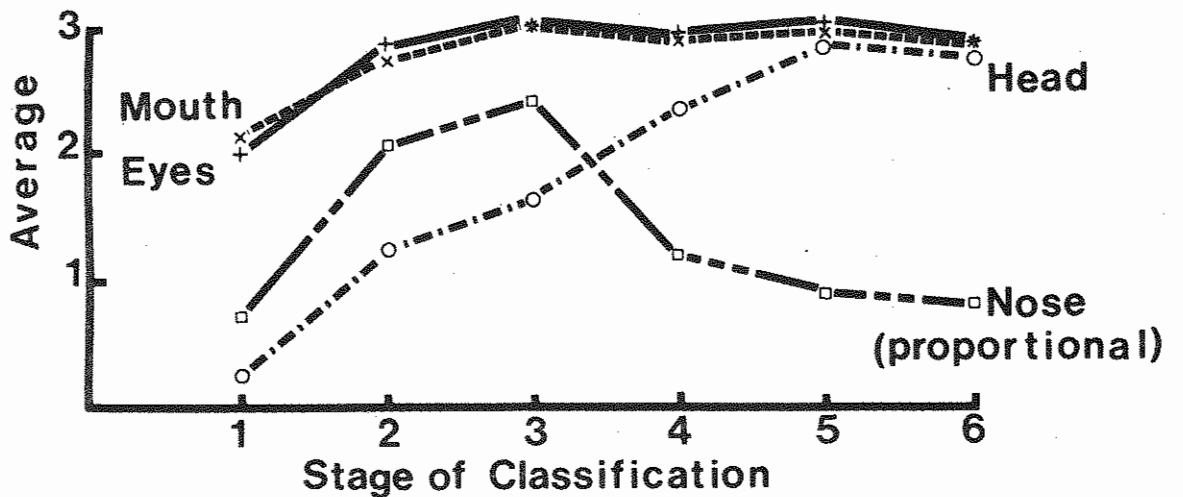


Figure 5.3: The average number of times similarity was described after E's first question: "B" matrices (maximum = 3).



between the spontaneous descriptions of the eyes, the mouth and the head, over all 6 matrices combined.

Table 5.6: Friedman Two-Way Analysis of Variance by Ranks to test for differences between spontaneous descriptions of eyes, mouth and head.

Stage 1	$\chi^2_{\text{R}} = 6.5833$	$p < .05$
Stage 2	$\chi^2_{\text{R}} = 19.3214$	$p < .001$
Stage 3	$\chi^2_{\text{R}} = 18.1428$	$p < .001$
Stage 4	$\chi^2_{\text{R}} = 19.4411$	$p < .001$
Stage 5	$\chi^2_{\text{R}} = 6.1250$	$p < .05$
Stage 6	$\chi^2_{\text{R}} = 8.7962$	$p < .02$
All Stages Combined	$\chi^2_{\text{R}} = 69.7393$	$p < .001$

Figures 5.4 and 5.5 report the average number of times Ss at each stage of classification failed to describe a property which was relevant, even after E's prompting.

For the "A" matrices (Figure 5.4), E considered each property to be relevant twice, once in each of the two matrices where the property varied. For the matrix in which the property was held invariant, E did not prompt S to describe the invariant property. For the "B" matrices (Figure 5.5) similarity on each property was relevant three times.

Table 5.7 shows the results of a Friedman Two-Way Analysis of Variance by Ranks conducted to test for differences, over all 6 matrices, between the failure to describe the eyes, the mouth and the head.

Figure 5.4: The average number of times S failed to describe a property: "A" matrices (maximum = 2).

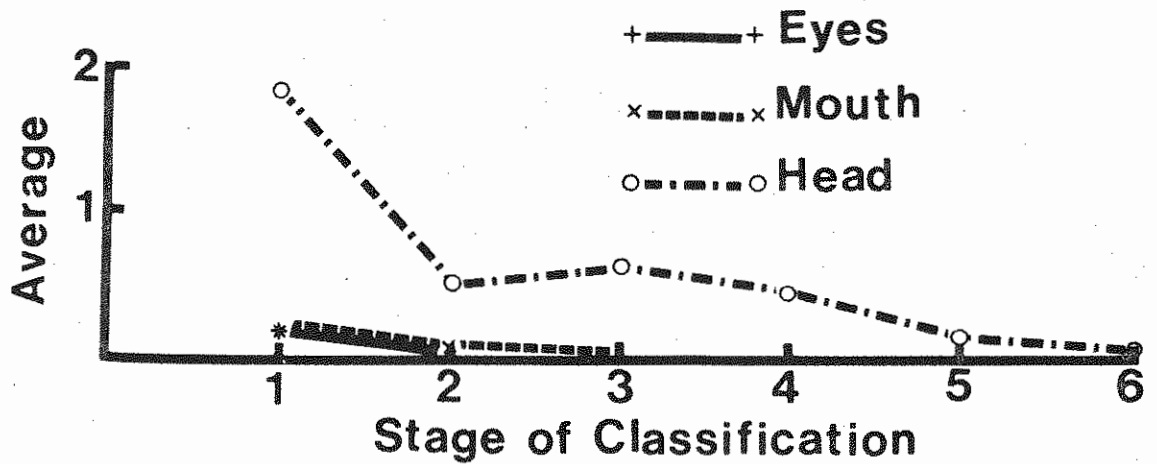


Figure 5.5: The average number of times S failed to describe a property: "B" matrices (maximum = 3).

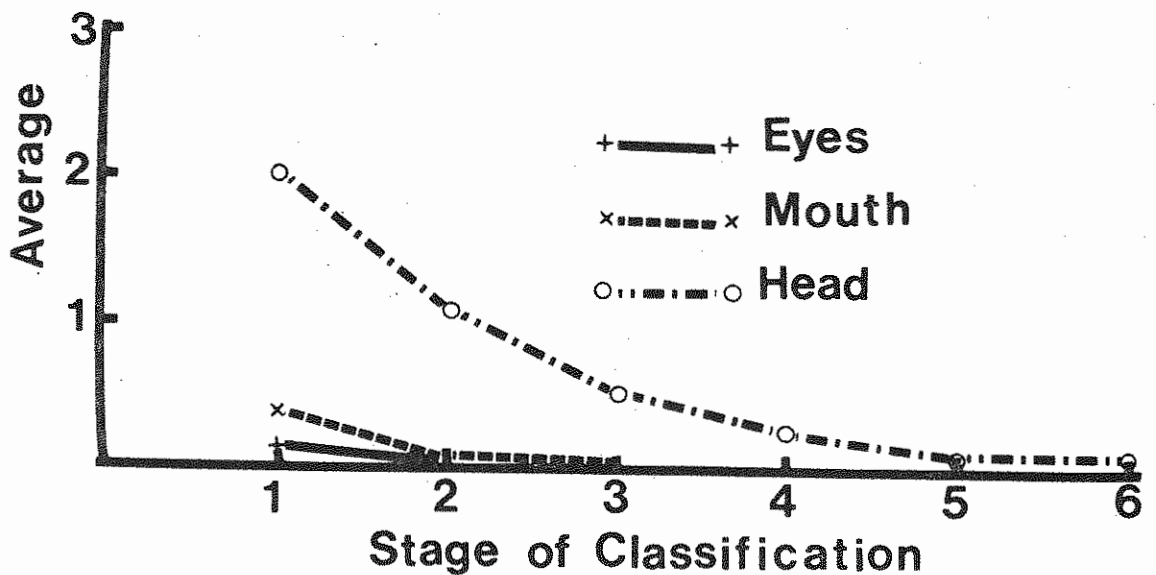


Table 5.7: Friedman Two-way Analysis for Variance by Ranks to test for differences between the failure to describe eyes, mouth and head.

Stage 1	$\chi_r^2 = 6.3333$	$p < .05$
Stage 2	$\chi_r^2 = 6.2500$	$p < .05$
Stage 3	$\chi_r^2 = 8.6785$	$p < .02$
Stage 4	$\chi_r^2 = 3.7941$	n.s.
Stage 5	$\chi_r^2 = 0.2812$	n.s.
Stage 6	$\chi_r^2 = 0.8888$	n.s.
All Stages Combined	$\chi_r^2 = 17.9734$	$p < .001$

Points of interest are:

(i) The eyes were compared as often as the mouth at all stages, with near maximum performance by Stages 2 or 3 (Figures 5.2 and 5.3). Both seldom go completely unmentioned (Figures 5.4 and 5.5).

(ii) At Stage 1 the head shape is seldom mentioned, even after E's prompting. There is a steady increase in its use, until by Stage 5 (on the second set of matrices, Figure 5.3), there is near maximum performance, equal to that with the eyes and the mouth. This coincides with the data discussed in other sections: only at Stage 5 are the relationships between the properties reasonably well integrated into classificatory schemes.

(iii) A curious result, which fits well into the theory being developed, is the U-shaped curve for the number of times the nose is described spontaneously (Figures 5.2 and 5.3). There is a significant difference in the number of times it is described at the various stages (Kruskal-Wallis One-Way Analysis of Variance by Ranks [Siegel 1956], $H = 11.9592$, $p < .05$).

It is argued that at Stage 1, where there is an inability to switch between properties, the nose is not easily considered: because it never varies, it would not attract attention as much as a property that did.

In Stages 2 and 3 there is a progressive ability to structure the relationships between the properties, especially between the features. The nose plays an important role in these relations. However, while there is mobility in considering one property after another, there is no understanding of the structure of the matrix, because the classificatory schemes can only cope adequately with "two item comparisons". Hence there can be no understanding that because the nose never varies, it is irrelevant to the structure of the classes. Because the nose is important in the relationships that mediate switching between the eyes and the mouth, it will be mentioned.

In Stages 4 to 6, as understanding of the structure of the matrix improves, the tendency to mention the nose (which is still utilised in the relationships between the features), is reduced, due to a comprehension of its irrelevancy. Again Stage 5 marks the apparent completion of this process.

The above results confirm the difficulty, observed in the pilot study, which the younger children have in considering the head shape at the same time as the eyes and the mouth. The following task indicates why there should be this difficulty. The results of this task suggest that the child can consider the eyes, the nose and the mouth as a single global unit, while he must consider the head and any one of the features as two separate properties.

5.3.2 Continuation of the Top Row and Left Column

For each "B" matrix, S was asked to do the following tasks:

- (i) Describe the similarities within the top row;
- (ii) Continue the top row;
- (iii) Describe the similarities within the left column;
- (iv) Continue the left column;
- (v) Complete the matrix.

The continuations of the top row and of the left column will be considered here. In both these tasks, S was provided with four alternative items from which to select any items which were the same as the top row (left column), in all the ways that the items of that collection were the same (cf. section 4.4.4).

The alternatives included not only items whose relevant properties were similar to those of the existing collection, but items which had new values of the variable properties. These latter items were included to test whether the child could think of the "relevant" properties independently of the "irrelevant" values of the variable properties. However, behaviour towards these "irrelevant" properties was in itself, of interest. Many children in Stages 4, 5 and 6 would continue the row (column) only with items whose "irrelevant" properties were different from all those that had already occurred. They would not allow a value of the variable property to be repeated. Thus their characterisation of the top row of matrix B3, say, would be, not only that the eyes and the mouth had to be the same, but that all the heads had to be different from one another.

The present analysis will only be concerned with behaviour towards the similar properties, and will not incorporate attitudes towards the variable properties which will be discussed in section 8.1.2.

Results

The percentage of children at each stage who correctly used both of the similar properties when continuing the top row of each matrix, is shown in Figure 5.6. The increase with stage is to be expected. More interestingly, eyes + mouth are easier to consider together than are eyes + head or mouth + head. There is some ability with the first at Stage 1, while there is none with the latter two until Stages 3 or 4. The difference between these three sets of properties was significant (Cochran Q Test, $Q = 28.222$, $p < .001$).

This lends support to the hypothesis that eyes + mouth can be used "globally" as a singly property, whereas eyes + head and mouth + head cannot be. This is further supported by the results from the task requiring a continuation of the left column.

If eyes + mouth can be used as a single global property, this combination should be as easy to use as any one property. Continuing the left column of a matrix requires the use of a single property. The percentage of children at each stage who correctly continue the left column of each matrix is shown in Figure 5.7. The success rate for using eyes + mouth together in the top row of matrix B3 (which is also depicted on the same graph), is identical to the success of using any single property when continuing the left columns of B1, B2 or B3 (Cochran Q Test, $Q = 1.99$, n.s.). However, there is a significant difference between the six conditions involved in continuing the rows and the columns of B1, B2 and B3 (Cochran Q Test, $Q = 41.3432$, $p < .001$).

Thus the order of development seems to be:

(i) Use of any property, mouth (m), eyes (e), or head (h), by itself (columns of B1, B2 and B3), or use the eyes + mouth (e+m) together (row of B3).

Figure 5.6: The percentage of children at each stage who correctly continue the top row of each "B" matrix.

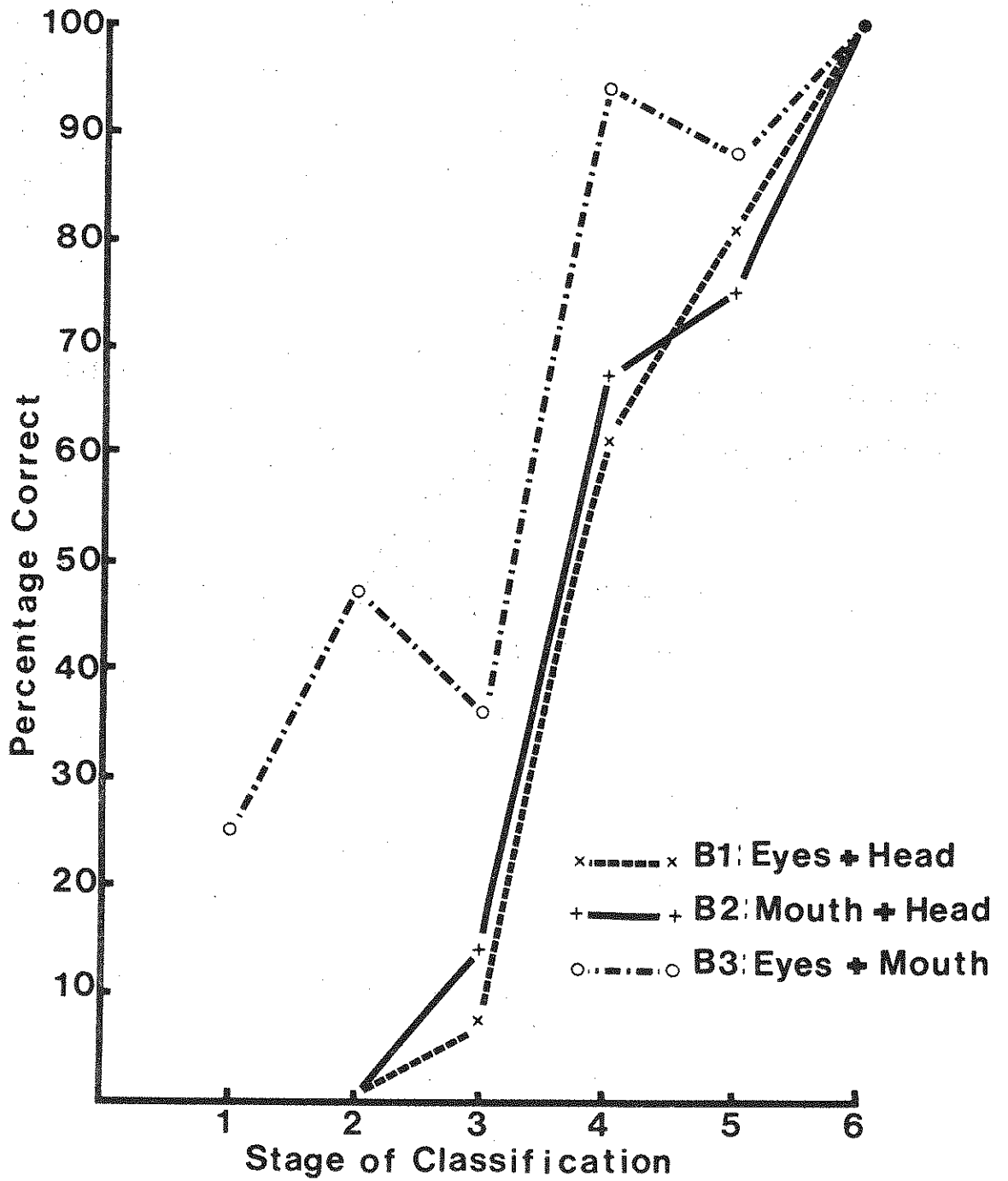
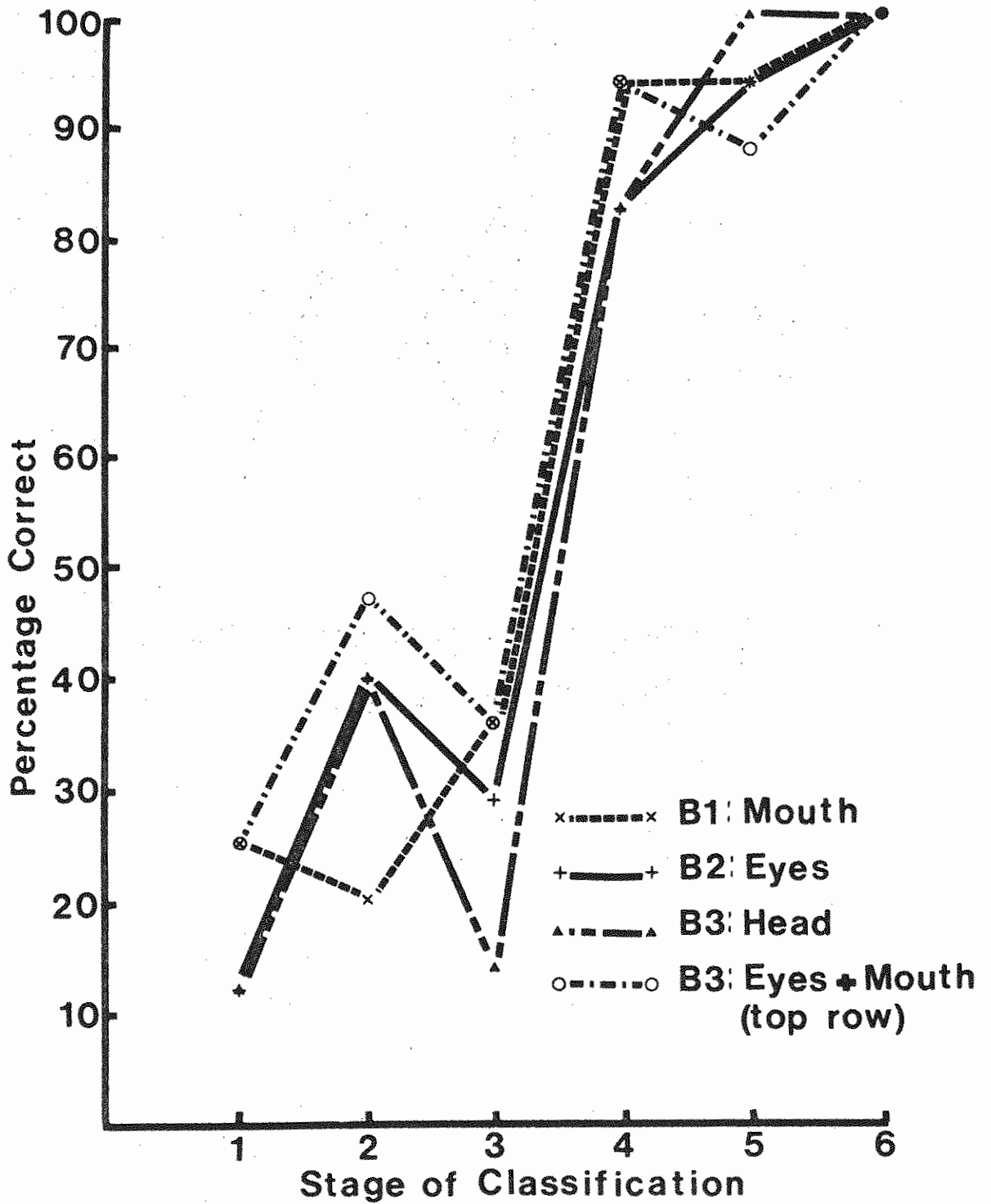


Figure 5.7: The percentage of children at each stage who correctly continue the left column of each "B" matrix; and the top row of B3.



Additionally, correlations between the child's total test score, his stage of classification, and his school grade were carried out. The results are given in Table 5.9.

Table 5.9: Correlations concerning the continuation of the top row and the left column.

	Stage	Total Test Score	
School Grade	0.7724	0.6616	
Classification Grade		0.8451	(0.7015 with Grade partialled out)

($p < .001$ for all correlations)

The high coefficient of homogeneity for the set of items ($H_t = 0.7690$) supports the claim that any single property and eyes + mouth together, can be used in classifications before eyes + head and mouth + head can be co-ordinated within a single collection. This receives additional support from the high H_{ij} s between pairs of items where mouth + head or eyes + head are one member of the pair, and a single property or eyes + mouth, are the other member. This validates the hypothesis that the eyes + mouth can be used as a single global unit, whereas the head and any one of the features have to be considered as two independent properties.

The H_{ij} s are lower for pairs of items where both items are single properties or eyes + mouth. It is argued that correct use of a single property (or eyes + mouth) may occur (at Stages 1, 2 and 3) because of a fixation on that property, but that this may occur without an adequate understanding of the structure of the whole collection and of the role of other properties. Thus correct performance with a single property will result from a chance fixation, and will not be a predictor of success

with any other one property. That, also, will be due to chance. An equivalent case was made for the even lower H_{ij} s, and lower H_t , found for the task of sorting items into two groups with respect to each property individually (section 5.2.3).

In contrast, it is argued that the co-ordination of the eyes and the head, or the mouth and the head, which is necessary for correctly continuing the top row of matrices B1 and B2 respectively, requires an abstract understanding of the relationships involved. If the child has this understanding he will also be able to handle a single property (or eyes + mouth) successfully. This leads to the high H_{ij} s between a single property and eyes + head, or mouth + head.

5.3.3 Initial Conclusions

The results from the last two studies (description of the top row and left column, and continuation of the top row and left column) support the hypothesis that the eyes, the nose and the mouth can form a global unit, and hence young children are able to consider all of them simultaneously. In contrast, the relationships between the head and any one of the features are more complex, and hence more difficult to handle.

This hypothesis formed one part of a more complex "compound" hypothesis, which extends the above formulation as follows.

The child's ability to cross-classify two properties is dependent on his understanding of the relations between those two properties. The less complex relations between the eyes and the mouth should be understood before those between the eyes and the head (or the mouth and the head), and hence the eyes and the mouth should be cross-classified before the eyes and the head (or the mouth and the head). (The cross-classification of the eyes and the mouth entails an abstract

co-ordination of those two properties, rather than their combination in a global whole.)

This latter hypothesis was investigated through completion of the "A" matrices, where different pairs of properties have to be cross-classified, while the third property is held invariant.

5.3.4 Matrix Completion

The three "A" matrices had one property held invariant, while a second varied across the rows, and a third across the columns. Each property – head, eyes and mouth – fulfilled each role once. The lower right hand corner item of each matrix was removed, and S was asked to complete the matrix with one of four alternative items.

Correct completion of each of these matrices required the following:

Matrix A1: Cross-classification of the mouth and head properties, while the eyes were held invariant.

Matrix A2: Cross-classification of the eyes and head properties, while the mouth was held invariant.

Matrix A3: Cross-classification of the eyes and mouth properties, while the head was held invariant.

It was hypothesised that matrix A3 would be correctly completed at an earlier stage than matrices A1 and A2.

It was also hypothesised that the relationships between any two properties would be understood before those between all three properties. Hence any two properties should be cross-classified before all three properties. In the three "B" matrices all three properties were varied. Therefore it was hypothesised that all the "A" matrices would be correctly completed at an earlier stage than all the "B" matrices.

The hypothesised developmental sequence was:

- (i) Correct completion of matrix A3 (eyes × mouth);
- (ii) Correct completion of matrices A1 and A2;
- (iii) Correct completion of matrices B1, B2 and B3.

Results

The percentage of Ss at each stage whose eventual choice of the "best" item to complete each "A" matrix was correct, is shown in Figure 5.8.

The answers included in this category were those of children who had a logical reason for why the item was best. Thus any children at Stages 1 or 2 who chose the correct alternative because it was similar to the adjacent item in the row, for instance, but who did not compare it to both the row and column items, were not included in this category.

At Stage 3, where the ability to consider both the row and the column simultaneously first appears, there is a clear superiority in the ability to cross-multiply the eyes and the mouth. There is practically no success in cross-multiplying the eyes and the head, or the mouth and the head. The differences between these three matrices are significant (Cochran Q Test, $Q = 6.3333$, $p < .05$).

These results support the hypothesis that cross-classification of the eyes and the mouth occurs before cross-classification of the eyes and the head, or the mouth and the head.

The percentage of Ss at each stage, whose eventual choice of the "best" item with which to complete each "B" matrix was correct, is shown in Figure 5.9. These three matrices were of equivalent difficulty (Cochran Q Test, $Q = 2.8888$, n.s.). Analysis (Cochran Q Test) of the

Figure 5.8: The percentage of children at each stage whose eventual choice of "best" alternative to complete each "A" matrix was correct.

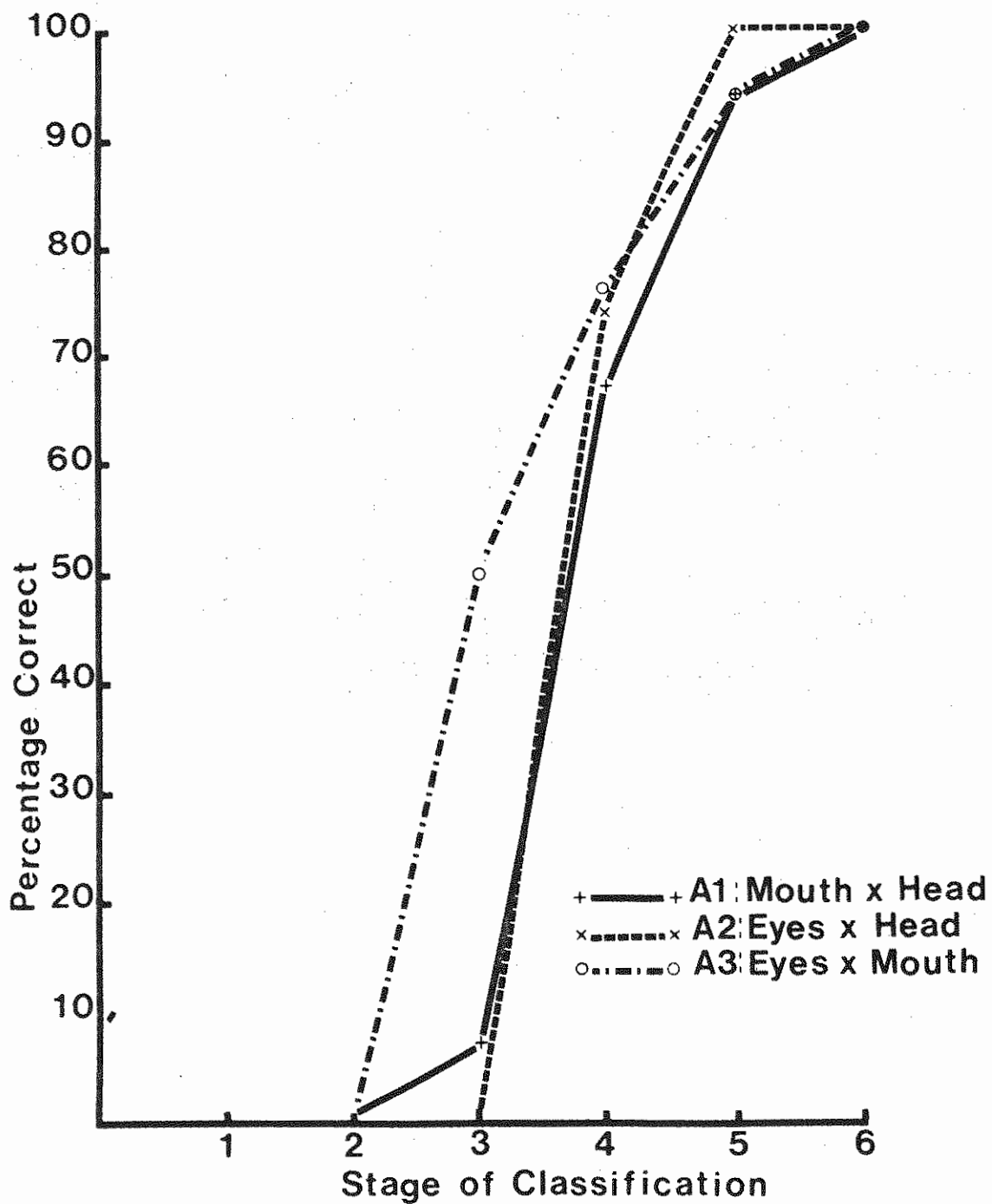
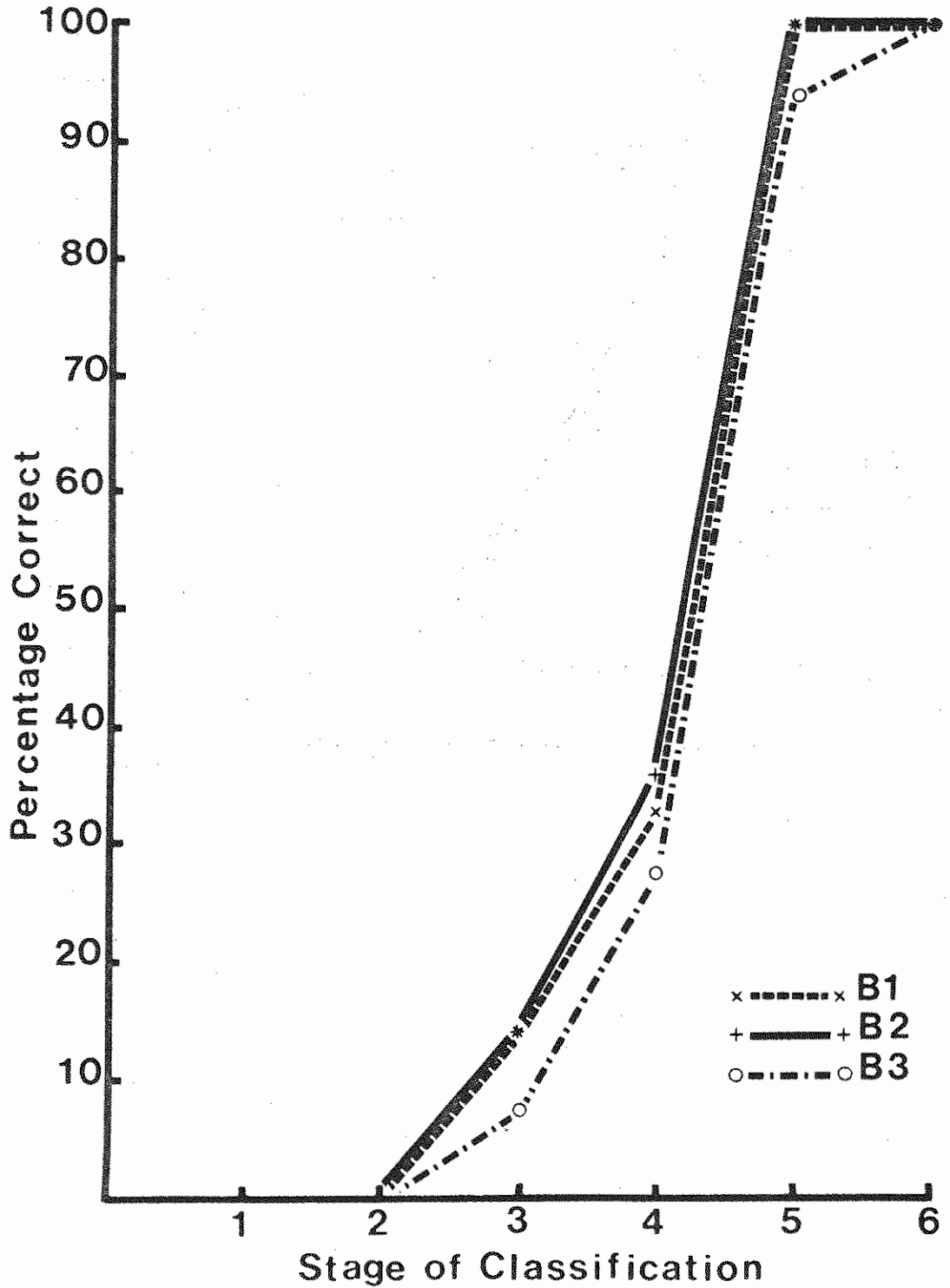


Figure 5.9: The percentage of children at each stage whose eventual choice of "best" alternative to complete each "B" matrix was correct.



differences between performances on matrices A1, A2, B1, B2, and B3 (A3 was omitted) at each stage, showed they were of equivalent difficulty at Stages 3 ($Q = 0.3255$, n.s.), 5 ($Q = 0.1875$, n.s.) and 6 ($Q = 0.0$, n.s.); but at Stage 4 the two property matrices (A1 and A2) were easier than the three property ("B") ones ($Q = 17.1612$, $p < .01$).

These results are illustrated in Figure 5.10, which shows the percentage of correct responses at each stage for matrices A1 and A2 combined, and for all the "B" matrices combined.

This supports the hypothesised developmental sequence:

- (i) Some ability with eyes \times mouth cross-multiplication only (Stage 3).
- (ii) Equal ability to cross-multiply any two properties; poor ability with three properties (Stage 4).
- (iii) Equal ability with two and three property cross-multiplications (Stage 5).

Scale analysis was used to test this hypothesised sequence of development. The same three measures used in sections 5.2.3 and 5.3.2 were computed here.

- (i) Loevinger's coefficient of homogeneity for the set of items (H_t).
- (ii) Loevinger's coefficient of homogeneity between each pair of items (H_{ij}).
- (iii) White and Saltz's coefficient of homogeneity between each item and the total test score (ϕ_{it}).

Each child had a total score of 6 points, derived by allocating one point to each correct completion of a matrix.

The results are reported in Table 5.10.

Figure 5.10: The percentage correct for matrices A1 and A2 combined, and for all the "B" matrices combined.

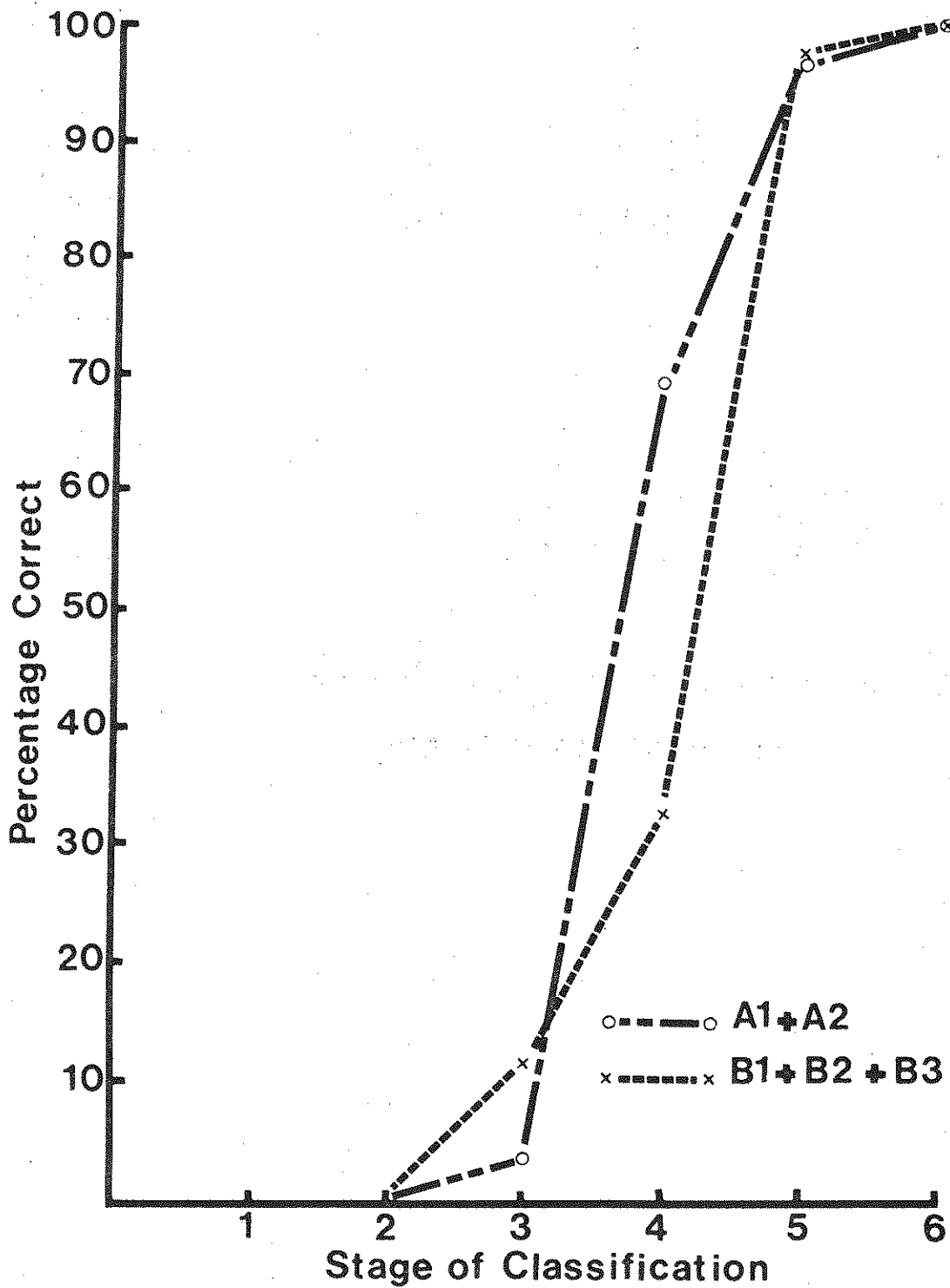


Table 5.10: Scale analysis for the completion of the matrices.

Loevinger's coefficient of homogeneity for the set of items,
 $H_t = 0.8628$

Loevinger's coefficient of homogeneity between each pair of items, H_{ij} :

	A2	A3	B1	B2	B3
A1	0.8728	0.8473	0.8209	0.8243	0.8576
A2		0.7755	0.8623	0.8654	0.9514
A3			0.7799	0.8924	0.7668
B1				0.9164	0.9565
B2					0.9112

White and Saltz's coefficient of homogeneity between each item and the total test score, ϕ_{it} :

	A1	A2	A3	B1	B2	B3
ϕ_{it}	0.9033	0.9166	0.7777	0.9182	0.9180	0.9183
Significance level	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p < .001$

Additionally, correlations between the child's total test score, his stage of classification, and his school grade were carried out. The results are given in Table 5.11.

Table 5.11: Correlations concerning the completion of the matrices.

	Stage	Total Test Score
School Grade	0.7724	0.7211
Classification Score		0.9185 (0.8220 with Grade partialled out)

($p < .001$ for all correlations)

The high coefficient of homogeneity ($H_t = 0.8628$) and the high H_{ij} s between all pairs of items support the developmental sequence proposed above.

5.4 SUMMARY

The results of these several types of task support the hypothesis that the development of classificatory behaviour is dependent on the developing comprehension of the relationships between the parts and the whole of an individual item. The following hypotheses were investigated and confirmed.

1. Up-Side-Down Constructions

Both classificatory ability and the ability to construct an USD version of an item require an understanding of the relations between the parts and the whole of an item.

The two abilities were found to be correlated, especially at the transition between Stages 1 and 2.

2. Face/Nonface Relations

Comprehension of the face/nonface dichotomy requires a comprehension of the "face relationships"; so does classification.

The classification deficiencies of the Stage 1 child were accompanied by a failure to comprehend the face/nonface distinction. This failure was overcome at Stage 2.

3. Head/Eyes/Mouth Relations

(i) The relationships between the eyes and the mouth are simpler, and hence will be understood earlier than those between the head and any one feature.

(a) Descriptions of the head-shape were often omitted, whereas the eyes and the mouth were frequently described.

(b) It was found that eyes + mouth could be used as a global unit, but eyes + head and mouth + head could not be.

(ii) Cross-classification of two properties requires an understanding of the relations between those two properties. The relations between the eyes and the mouth should be understood earlier than those between the head and any one feature. Therefore, the eyes and the mouth should be cross-classified before the head and the eyes, or the head and the mouth.

This was found to be the case.

5.5 AN ALTERNATIVE EXPLANATION FOR THE DIFFERENT RELATIONSHIPS BETWEEN HEAD, EYES AND MOUTH

The above findings lend themselves to an alternative explanation which needs to be examined before they can be integrated into a more general conclusion.

The alternative explanation would suggest that, for some reason, the head-shape was perceptually less salient than the features and thus attracted less attention. This possibility will now be examined.