THE DEVELOPMENT OF CLASSIFICATORY BEHAVIOUR IN CHILDREN

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TABLE OF CONTENTS

ABSTRACT

This thesis is concerned with the development of classificatory behaviour in children between five and eleven years. The first experiment investigates the difference between two opposing views on the role of language in classification.

Inhelder and Piaget [1964] argue that language is dependent on cognitive structures, while Bruner [1966] maintains that classificatory ability is dependent on linguistic competence. He argues that children who fail to classify logically do not have the requisite hierarchically ordered semantic features. Experiment 1 showed that children who failed logically to classify pictures of items belonging to various taxonomic classes nevertheless showed a build-up of, and release from, proactive inhibition when items belonging to those classes were manipulated in the short-term-memory task developed by Wickens [1970]. This result indicated that these children had the appropriate semantic features for their classifications, and hence a theory such as Piaget's is required to account for the appreciation of similarity at different levels of thought.

Piaget's theory of knowledge is discussed, and it is concluded that while Piaget has been concerned with elucidating the structural nature of operational thought, he has not concentrated on the exact relationship between the form of operational thought and the content from which it is progressively dissociated. For this reason there is some confusion concerning the role of "horizontal décalages" in a theory which postulates "structures d'ensemble".

This issue motivated the main work for this thesis. It was hypothesised that the development of classification is dependent on

understanding the materials being manipulated as well as on abstracting the classificatory schemes.

To investigate this hypothesis, materials were constructed which enabled measurements to be made of the child's comprehension of the relationships between part and whole of an individual item, as well as his ability to classify a number of such items.

The child's performance when completing 3 × 3 matrices in which the lower right corner was removed, was classified into one of six stages. The child's performance on a series of other tasks presented at the same time showed that his stage of classification was related to his understanding of the relationships within an individual item. The application of scale analysis indicated a unidimensional sequence of development on all these tasks, and hence validated the stages of classification developed and their relationship to the child's understanding of the materials.

The final experiment involved an investigation of the abstraction of the classificatory schemes themselves. It was hypothesised that classifications using similarities and those using differences are generated by the same internal structures, and hence there should be the same sequence of development for both, with simultaneous occurrence of the corresponding stages. The experimental results supported this hypothesis and also threw light on the development of the meaning of "same" and "different".

Thus both understanding the materials and abstraction of the classificatory schemes were found to be important in the development of classification. A theoretical model is presented which relates these two factors and attempts to specify the progressive abstractions responsible for development through the six stages of classification.

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.

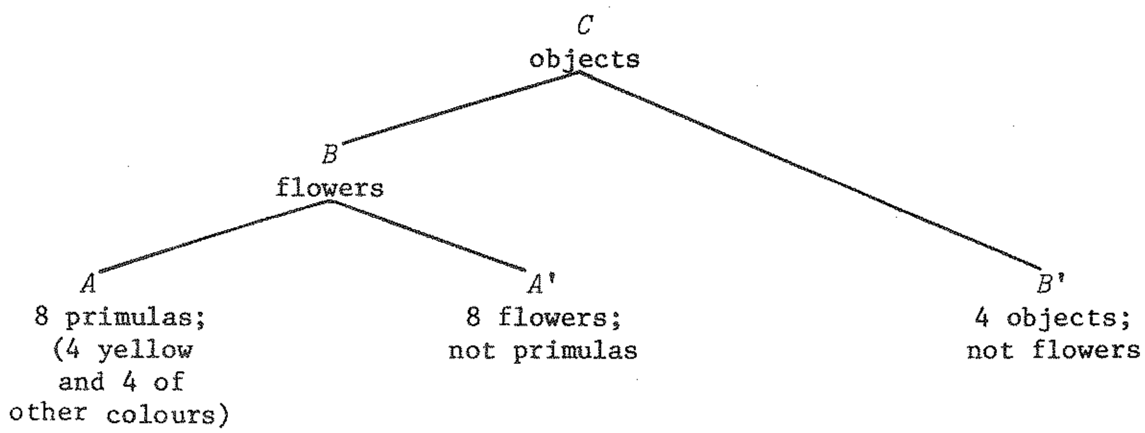
For instance when given a set of toys, CUR (4;2) [Inhelder and Piaget 1964, p.40] comments:

> "*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 8*A*s with the 8*A*'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 basic 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 × 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 × 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 "spoilt" 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

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[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 1	2	3	4		Trials 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, Ex_1, 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, Co_1, requires presentation of the four food triads, omission of the four animal triads. Thus the same food triad appears in the fourth trial of Ex_1 and Co_1.

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 Ex_1, 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
			Nonclassifiers				
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
			Classifiers				
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 Co_1, it must be established that animal and food items are of equivalent difficulty. That is, that the first three (animal) trials of Ex_1 and Co_2 have equivalent performances to the first three (food) trials of Ex_2 and Co_1.

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 "intérioriser". Thus operational intelligence derives from the interiorisation of sensori-motor schemes. The symbolic function derives from the internalisation of overt action.

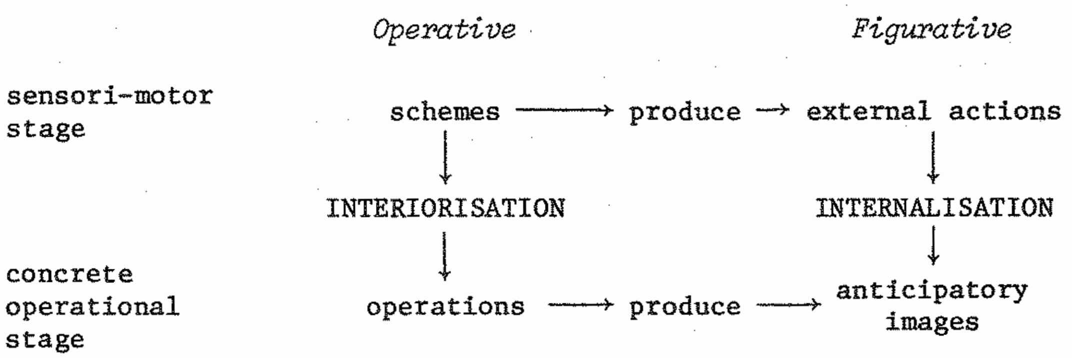
Operational intelligence is internal action in the sense that it is not dependent on external manifestations, as is a sensori-motor scheme. "The object of (operational) thinking is not outside the thinking scheme, as is the case in sensori-motor actions, but remains within and can itself be called a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

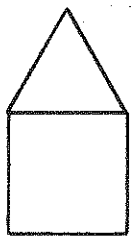
It is plausible to argue that when the preoperational child uses two properties simultaneously, e.g. "red triangle", either in his speech or as a criterion of similarity between two items, the two properties form a "whole" which does not include simultaneous consideration of its parts ("red" and "triangle"). "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 10½ inch × 10½ 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 plasting 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.

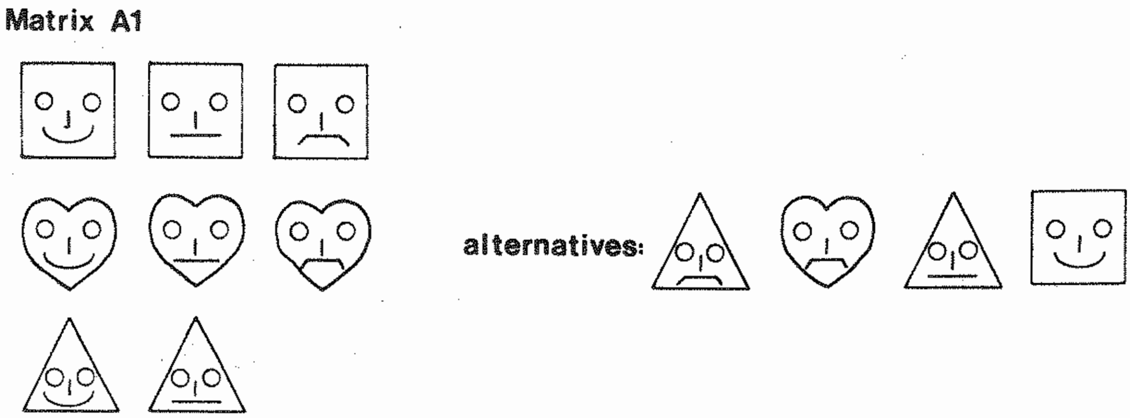
Matrices of two levels of complexity were constructed.

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



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, Y 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 + mouth[1] 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

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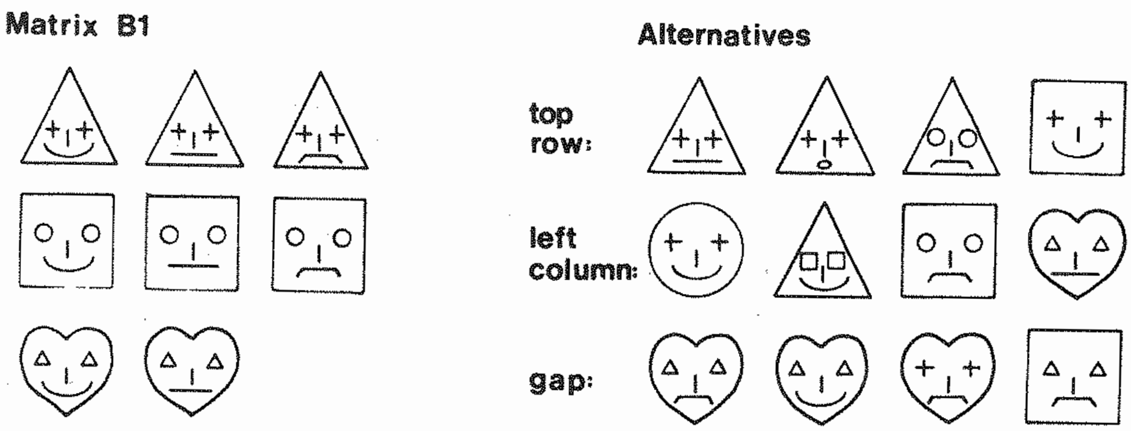
1 "a + b" denotes that the two properties a and b have to be considered together within one collection.

Figure 4.3



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.

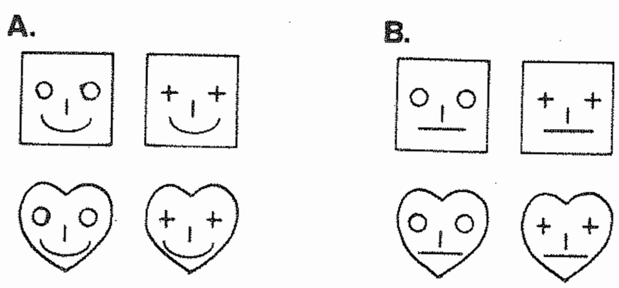
4.4.6 Verbal Switching Ability

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.



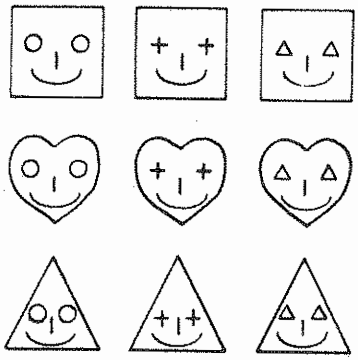


Figure 4.5: The second set of materials used in the verbal switching task.

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.

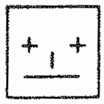
If the child failed to describe the required property, after repeated questioning, two items, the same on all properties except the criterion one (or different on all properties except the criterion one) were chosen, and S was asked for the difference (or similarity) between them. If he still failed, 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 1	2	3	4	5	6	Total
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.

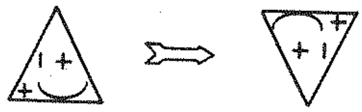
This suggests the following compound hypothesis:

(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], $H = 60.2988$, $p << .001$.)

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.

a  b 

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	Stage 2	Stage 3	Stage 4	Stage 5	Stage 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.

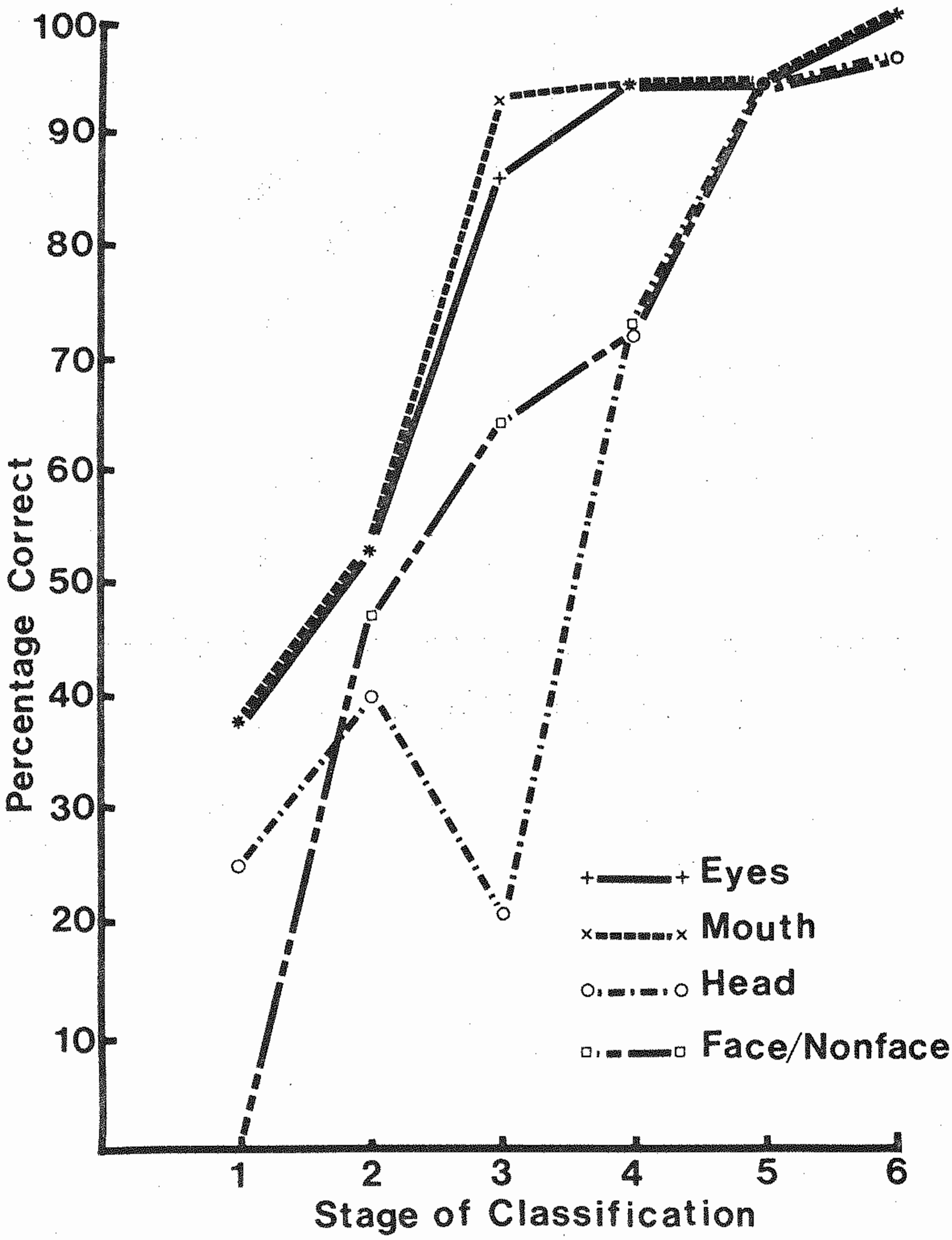


Table 5.4: Scale analysis for the sorting tasks.

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 partialed 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 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).

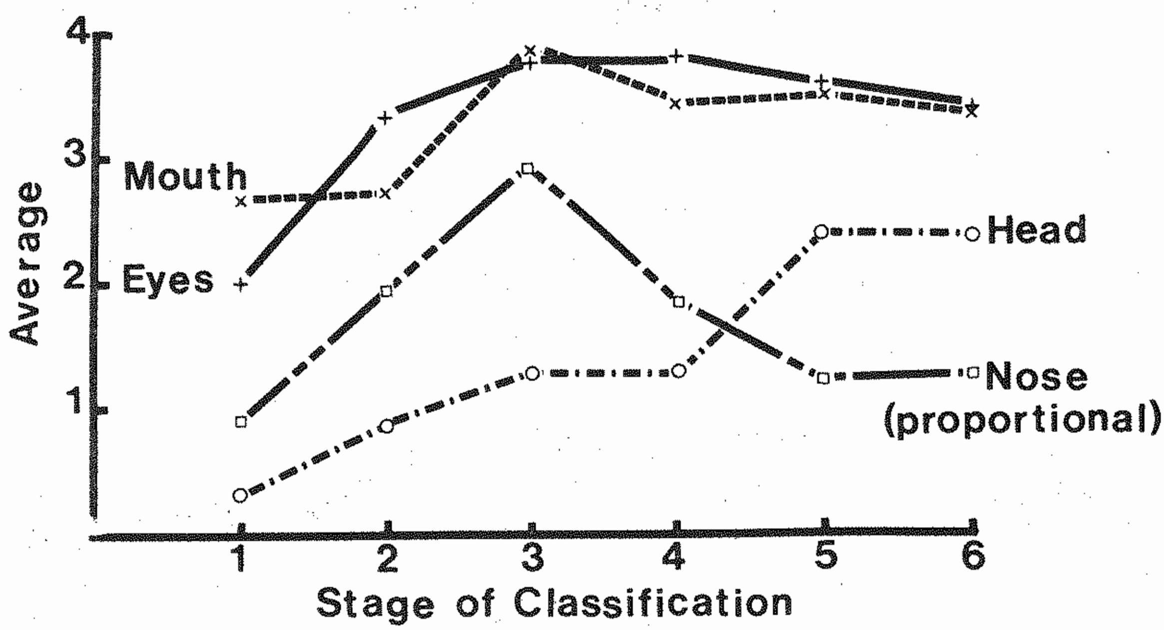
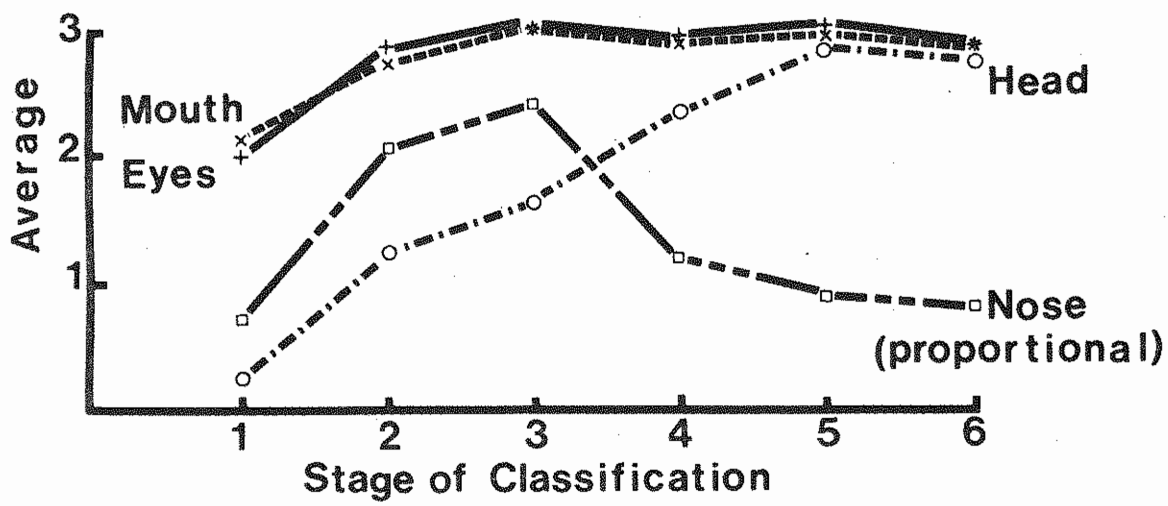


Figure 5.3: The average number of times similarity was described after E's first question: "B" matrices (maximum = 3).



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	$\chi_r^2 = 6.5833$	$p < .05$
Stage 2	$\chi_r^2 = 19.3214$	$p < .001$
Stage 3	$\chi_r^2 = 18.1428$	$p < .001$
Stage 4	$\chi_r^2 = 19.4411$	$p < .001$
Stage 5	$\chi_r^2 = 6.1250$	$p < .05$
Stage 6	$\chi_r^2 = 8.7962$	$p < .02$
All Stages Combined	$\chi_r^2 = 69.7393$	$p < .001$

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).

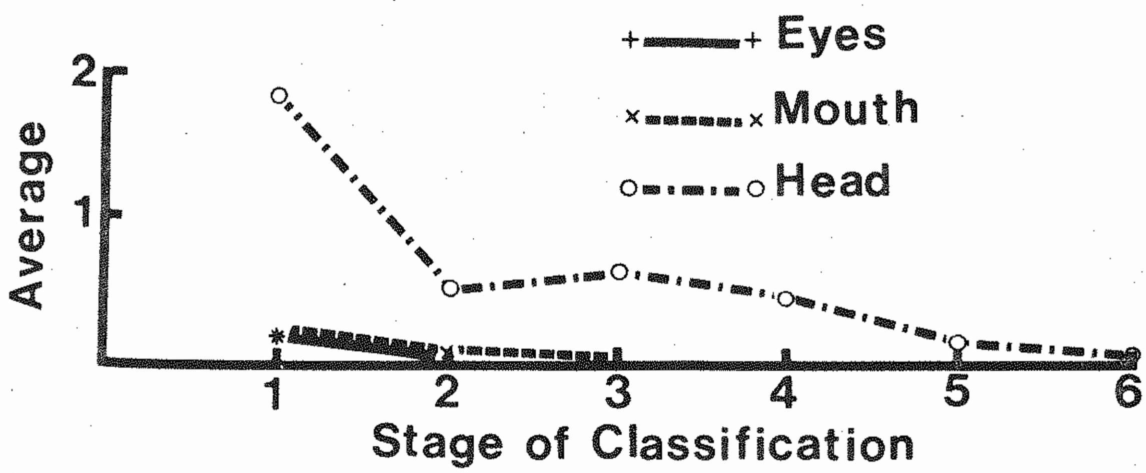


Figure 5.5: The average number of times S failed to describe a property: "B" matrices (maximum = 3).

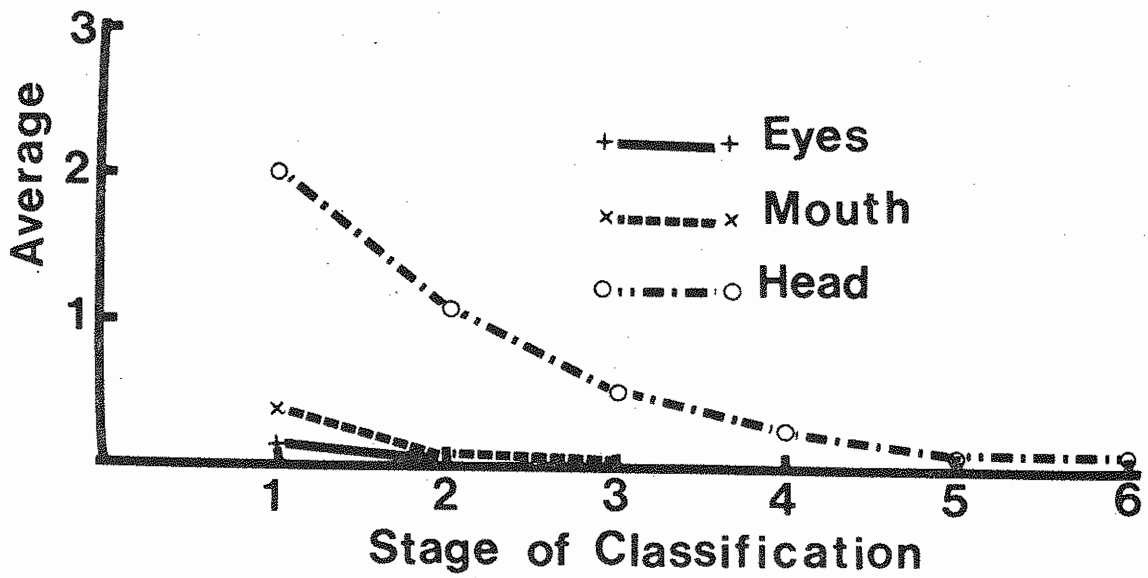


Table 5.7: Friedman Two-way Analysis for Variance by Ranks to test for differences between the failure to describe eyes, mouth and head.

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 characteristation 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.

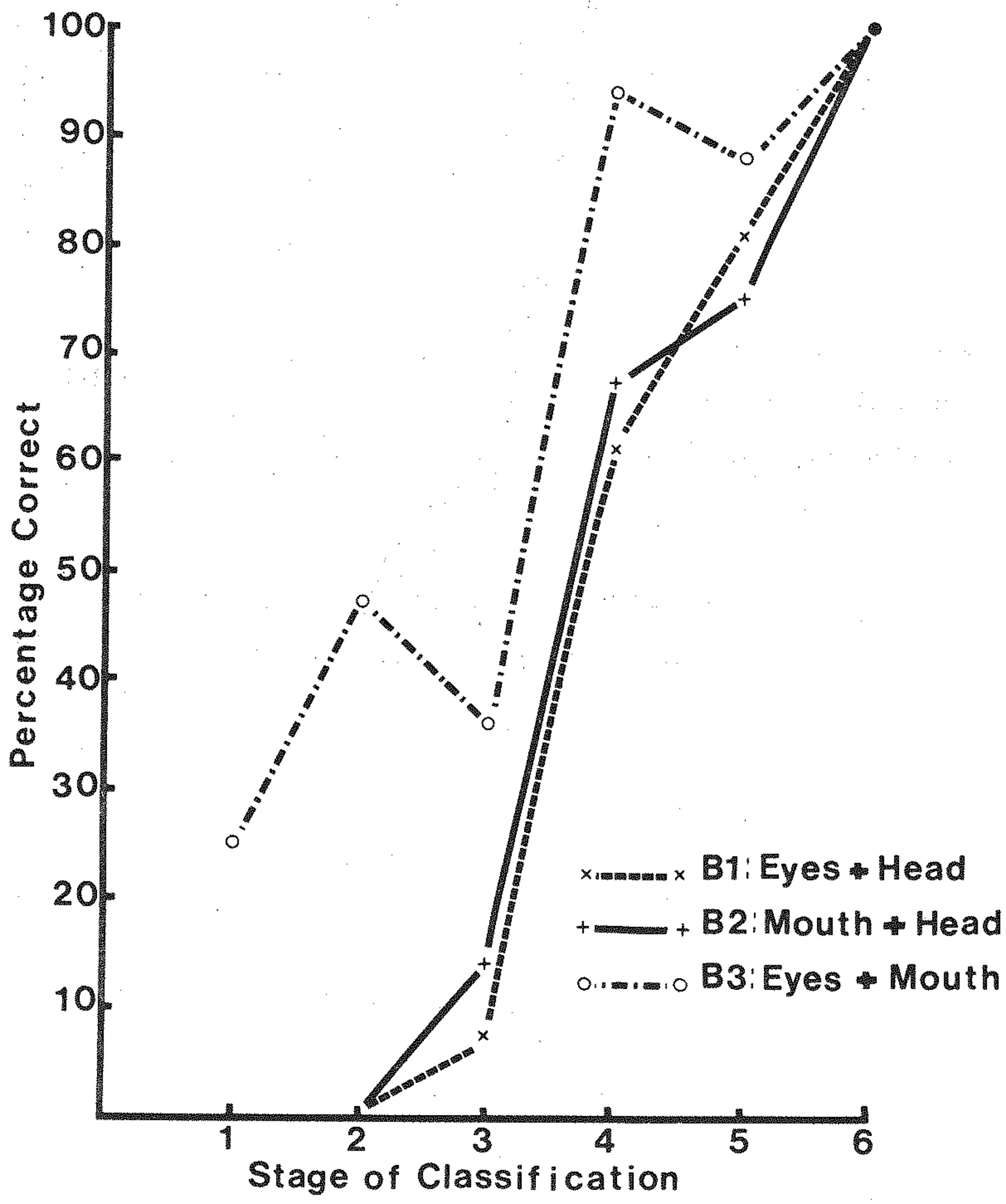
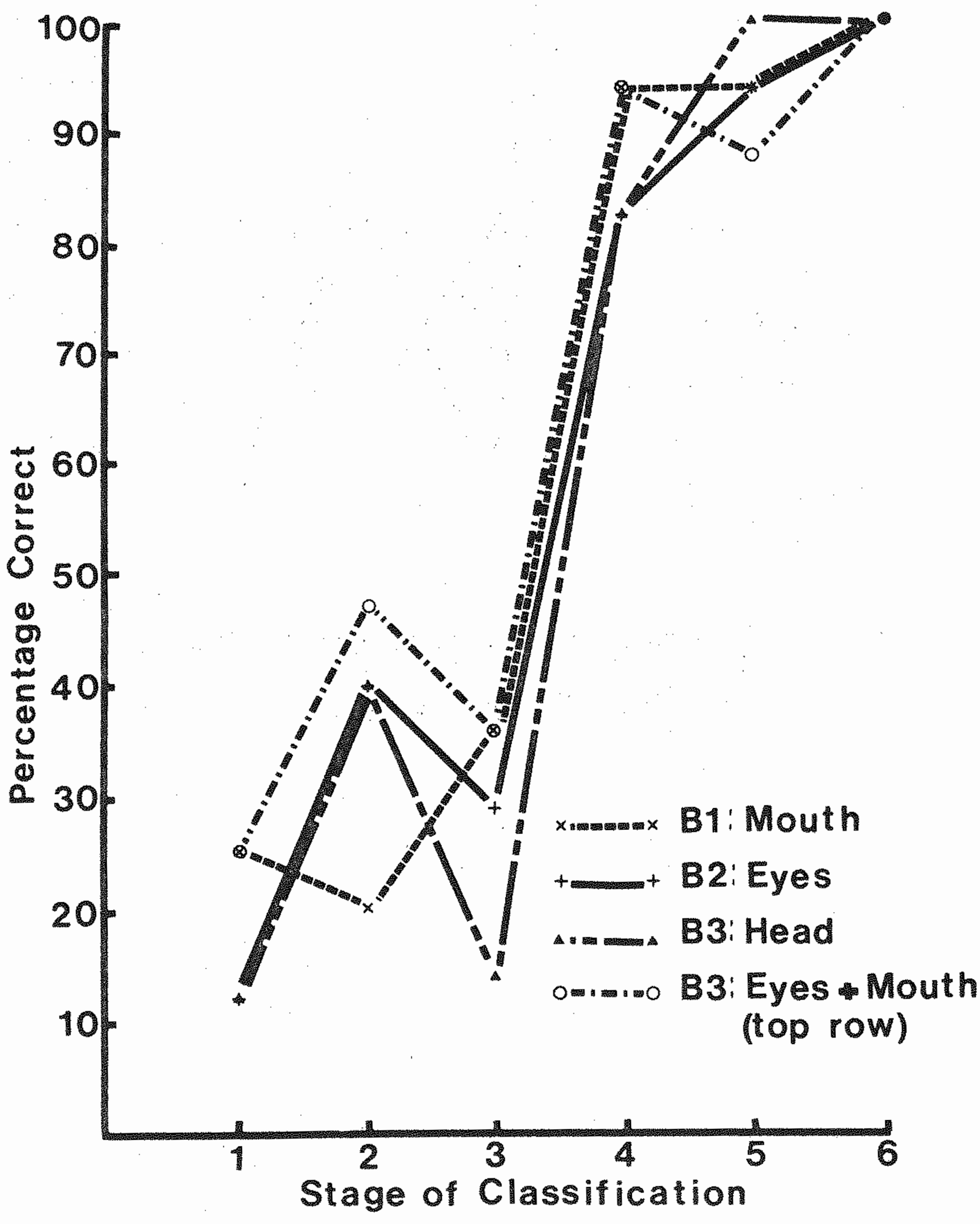


Figure 5.7: The percentage of children at each stage who correctly continue the left column of each "B" matrix; and the top row of B3.



(ii) Co-ordination of eyes + head (e + h), or mouth + head (m + h), (rows of B1 and B2).

Scale analysis was used to test this hypothesised sequence of development. The three measures that were described in section 5.2.3 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 test score out of 6 points, derived by allocating one point to each correct continuation of a collection. The results are reported in Table 5.8.

Table 5.8: Scale analysis for continuing the top row and the left column.

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

$H_t = 0.7690$

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

	e	h	e + m	m + h	e + h
m	0.6472	0.5968	0.5634	0.8088	0.9350
e		0.7170	0.6066	0.8212	0.9392
h			0.6066	0.8212	1.0000
e + m				0.9289	0.9276
m + h					0.7903

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

	m	e	h	e + m	m + h	e + h
ϕ_{it}	0.7551	0.8584	0.8112	0.7382	0.8355	0.9180
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 5.9.

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 partialed 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.

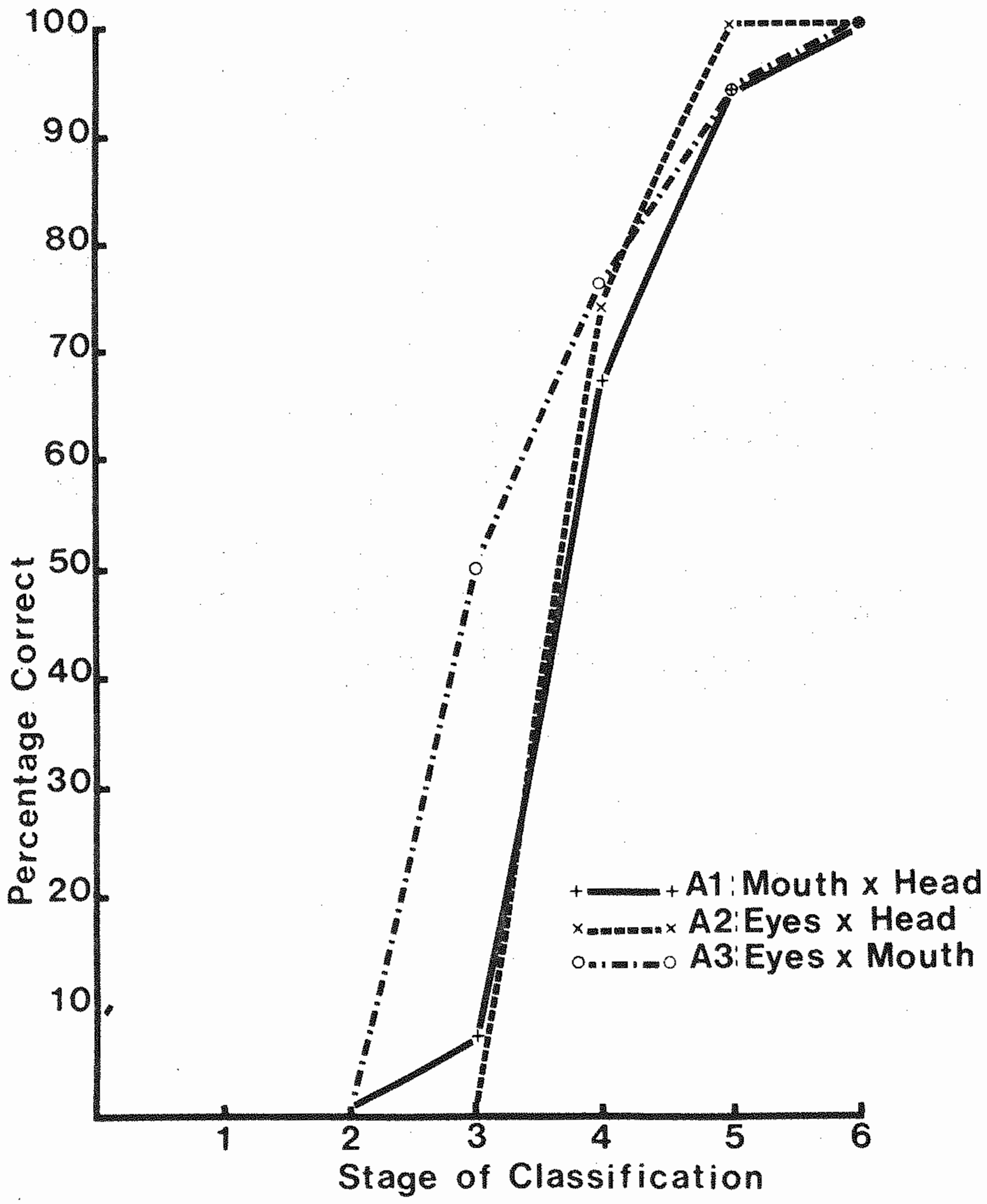
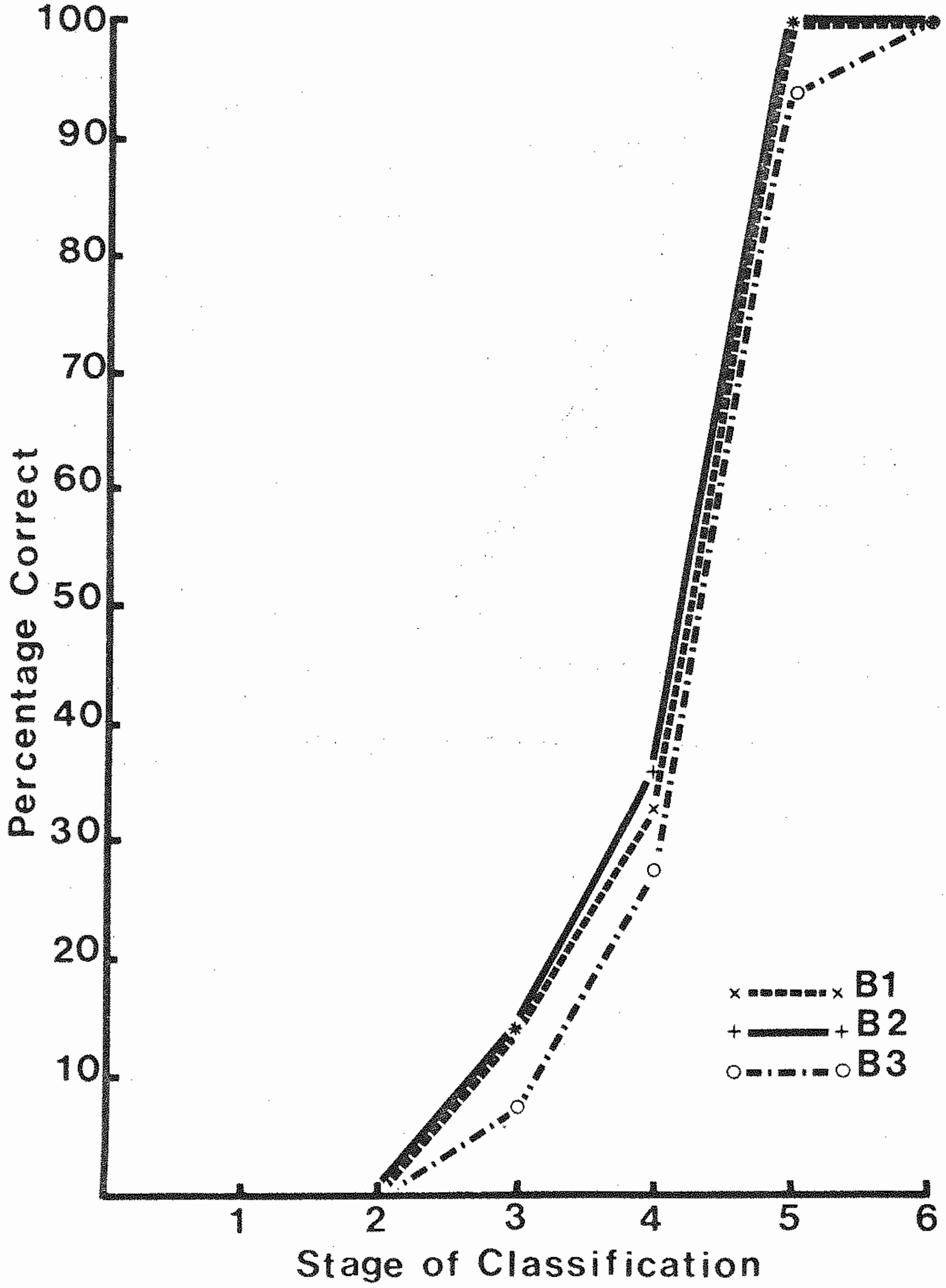


Figure 5.9: The percentage of children at each stage whose eventual choice of "best" alternative to complete each "B" matrix was correct.



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 × 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.

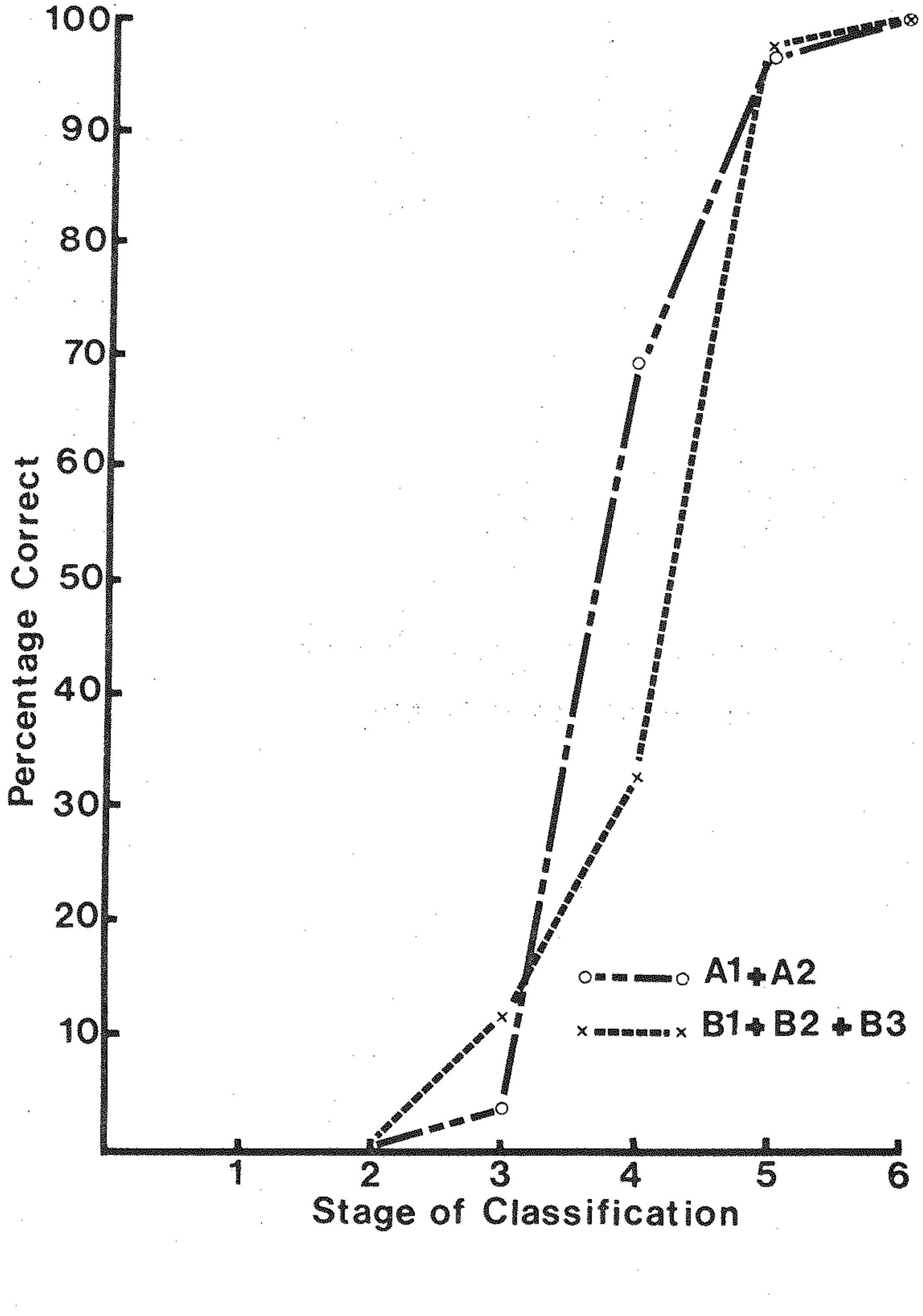


Table 5.10: Scale analysis for the completion of the matrices.

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 partialed 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 simplier, 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.

CHAPTER 6

EXPERIMENT 3: AN INVESTIGATION OF WHETHER THE HEAD IS PERCEPTUALLY LESS SALIENT THAN THE FEATURES

6.1 INTRODUCTION

The results of several tasks in Experiment 2 supported the hypothesis that the relationships between the eyes and the mouth are understood earlier, and hence can be utilised earlier in classifications, than the relationships between the head and the eyes, or the head and the mouth.

However, an alternative hypothesis would suggest that the head shape is perceptually less salient than the features, and thus attracts less attention in the classification tasks. If this is the case, this should be reflected in attempts to memorise individual items. There should be poorer memory of the head than of each feature. However, if, as is hypothesised, the head is remembered as well as the features, this would support the view that the head shape is as perceptually salient as the features, but is difficult to use in the classification tasks because the relationships between the head and a feature are more complex than those between two features.

Children were asked to memorise nine items. Each item was presented for three seconds, and after a retention interval of ten seconds, S had to recognise the previously presented item from a choice of eight items.

6.2 SUBJECTS

Sixty-eight children were tested approximately two months after the testing of the previous experiment. All Stage 1 children were tested, as well as 12 children from each of the other five stages. At each of these latter stages, the six children who appeared to have the least trouble using the head shape in their classifications, and the six children who found the most difficulty using the head shape, were chosen. This was based on E's subjective impression gathered over the total set of data for each child. All Stage 1 children had great difficulty in using the head shape, and no meaningful division could be made between them.

There were thus 10 groups of subjects (Stages 2, 3, 4, 5, 6 × high/low use of head shape); and the Stage 1 children.

6.3 MATERIALS

Memory Items

Nine items were constructed in a similar manner to those used in the matrix tasks of Experiment 2. Pink paper shapes of 3 inch dimensions were glued onto 3½ inch × 3½ inch white cards, and the features were drawn with black felt pen.

The following values for the three properties, head, eyes and mouth, were used:

Head: Square shaped, heart shaped and circular;

Eyes: Circular, cross shaped and triangular;

Mouth: Up-turned, straight and down-turned.

Each value of a property was used three times, and always with a completely different combination of values on the other two properties.

Recognition Sets

Each recognition set consisted of eight items which were arranged in a circle on a 12½ inch × 12½ inch sheet of white card. These items were constructed in an identical manner to the memory items. Each recognition set contained all combinations of two head shapes, two eye shapes and two mouth shapes. Three such sets, to cover all nine memory items, were constructed.

6.4 PROCEDURE

Each memory item was presented for three seconds. After an unfilled retention interval of ten seconds, the recognition set was displayed and S had to point to the correct item. The nine memory items were presented in a standard order. One practice item, with a choice from two alternatives, was presented first. There was a two minute rest period after the fifth memory item.

6.5 RESULTS

Table 6.1 gives the average number of errors made at each stage, on each property, over the nine items. Table 6.2 shows the average number of errors made on each property by Ss with good ability to use head shape (for their stage) (High), and by those with poor ability (Low). This factor will be called "Head Ability".

The raw data are given in Appendix J.

A Three Factor Mixed Design Analysis of Variance, with repeated measures on one factor, was carried out for Stages 2 through to 6. The results are given in Table 6.3. The data for Stage 1 Ss were omitted because these Ss were not divided into high and low ability to use the

Table 6.1: The average number of errors made at each stage.

	Head	Eyes	Mouth
Stage 1	3.13	3.50	3.38
Stage 2	2.08	2.00	2.58
Stage 3	1.67	1.83	1.92
Stage 4	1.17	1.67	1.17
Stage 5	0.50	0.42	0.33
Stage 6	0.75	0.83	0.50

Table 6.2: The average number of errors made by Ss with high and low ability to use the head shape.

		Head	Eyes	Mouth
Head ability				
(Stages 2 - 6	High	0.97	1.07	1.10
combined	Low	1.50	1.63	1.50

Table 6.3: Analysis of variance on the memory experiment data.

Source	Sum of Squares	d.f.	Mean Square	F	p
Total	327.40	179			
Between Ss	170.06	59			
Stage (St)	81.15	4	20.28	14.93	< .001
Head Ability (H)	11.25	1	11.25	8.28	< .01
St × H	9.72	4	2.43	1.79	n.s.
$Error_b$	67.94	50	1.36		
Within Ss	157.34	120			
Properties (P)	0.41	2	0.21	0.15	n.s.
P × St	5.25	8	0.65	0.45	n.s.
P × H	0.24	2	0.12	0.08	n.s.
P × St × H	7.88	8	0.98	0.68	n.s.
$Error_w$	143.56	100	1.44		

head shape, and because only 8, not 12, Ss were tested at this stage. However, inspection of the data reported in Table 6.1 shows that the head was remembered as well as the eyes and the mouth at Stage 1.

These results indicate the following:

(i) The head is equally as salient as the features.

(ii) There is a steady decrease with stage in the number of errors made.

(iii) Ss with good ability to use the head in their classifications (for their stage), have better memories for the figures than those with poor ability to use the head. However, there are still the same relative memory abilities for the different properties. (The interaction between head ability and properties is not significant.)

These results are reminiscent of the results of Experiment 1. In that experiment, nonclassifiers had poorer recall than classifiers, although there was always the same pattern of recall: build-up of proactive inhibition with repeated use of one class, and release from proactive inhibition with a switch to another class (cf. pp.29-30).

Two explanations are possible for this correlation between memory and classificatory abilities. Either an increase with age in central processing space is responsible for cognitive development [McLaughlin 1963, Pascual-Leone 1970]; or the reorganisation of cognitive structures is responsible for changes in memory [Inhelder 1969]. This dilemma concerning which comes first, like the chicken and the egg, does not seem to be soluble empirically. However, theoretically, the latter position must be favoured if one maintains a constructivist approach to cognitive development. Thus increased abstraction of cognitive structures enables a more powerful organisation of input, which in turn facilitates recall of that input.

In the present experiment it is argued that Ss with poor ability to classify by head shape have poor comprehension of the relationships between the parts of the item, and this leads both to a limited memory ability with the items, and to a difficulty in co-ordinating the properties in the classification task.

6.6 DISCUSSION

These results support the hypothesis that the greater difficulty in using the head shape in the classification tasks is due to the differential difficulty in understanding the relationships between the different properties. It is not because the head is merely not noticed. This is also supported by the behaviour of the Stage 1 children who were asked to make items when they could not switch properties in their comparisons. They correctly made the items, and hence showed that they had "attended to" the property they would not use for comparison purposes (cf. pp.63-64).

It is therefore possible to return, in the next chapter, to the theorising which utilises the developing understanding of relationships within an item to explain the development of classification.

CHAPTER 7

VALIDATION OF THE PROPOSED STAGES OF CLASSIFICATORY DEVELOPMENT BY SCALE ANALYSIS

7.1 SUMMARY OF THE STAGES OF DEVELOPMENT

The results of the main experiment reported in Chapters 4 and 5 provide a fairly cohesive picture of the development of classificatory ability.

Stage 1

There is no understanding of the relationships between the properties. This leads to an inability to switch between the properties in the classification task, as well as to a failure to conceptualise the face/nonface dichotomy, and to construct items USD.

Stage 2

There is the first conceptualisation of the structure of an individual item. This enables moderate to flexible switching between properties in the classification task, as well as to some understanding of the face/nonface dichotomy. There is also a big advance in the ability to construct items USD. There is no cross-multiplication.

Stage 3

The classification schemes become abstract enough to allow understanding that the gap item has to be the same as the row and the column of the matrix. However, this cross-multiplication is only between successive two item comparisons; there is no real understanding of the structure of the whole collection. The top row and the left column of the "B" matrices also are continued through the use of two item comparisons. The first real ability to integrate two properties occurs in the cross-multiplication of eyes and mouth in matrix A3.

Stage 4

The child now has some understanding of the structure of a collection, because his classification schemes are more abstract, and so whole collection comparisons replace the two item comparisons used up till now. However, the child still can not integrate adequately the classification schemes for each property; so there is a high rate of success with the "A" (two property) matrices, but not with the "B" (three property) ones. There is only limited ability with any task where three properties are involved; e.g. continuing the top row of a "B" matrix, where the co-ordination of two similar properties, and one variable property is required.

Stage 5

By this stage there is a reasonable integration of the classificatory schemes for each property, and so there is reliably correct performance on all tasks. However, the child's belief that alternative items can complete the matrix, as "second best", indicates there is no final comprehension of the structure of the total matrix.

Stage 6

There is full understanding of all relationships involved in a classification task.

To test the validity of this hypothesised sequence of development, scale analysis was carried out on the total set of data.

7.2 SCALE ANALYSIS

The proposed sequence of development, summarised above, was based on an amalgamation of the results from a number of different tasks. If these separate measures are all tapping the development of the same cognitive structures, the application of scale analysis to the total set of results should show evidence of a unidimensional sequence of development. Only the tasks which seemed to provide a good measure of the development of classificatory ability were used in the analysis.

The data from the task where items were sorted into two groups on the basis of one property — head, eyes or mouth — were not used. It was pointed out in the analysis of these data (p. 81) that correct performance could be achieved by preoperational methods. The young child may be correct, but not because he has understood the structure of the set of items and chosen the correct property for logical reasons.

Similarly, continuing the left column of the "B" matrices and the top row of matrix B3 (eyes + mouth) are not reliable indices of classificatory ability (cf. pp. 95-96), so these data also were omitted.

The following data, and method of scoring, were used:

(i) *Face/Nonface dichotomy* (F/NF): Two categories of response were used:

0: never achieving a correct classification;

1: immediately, or eventually achieving a correct classificiation.

(ii) *Up-Side-Down Constructions* (USD): Three categories were used:

0: 0 to 10 points;

1: 11 to 24 points;

2: 25 to 28 points.

(iii) *Matrix "A3"* (e × m): Two categories were used:

0: wrong;

1: immediately or eventually correct.

(iv) *Matrices "A1" and "A2"* (e × h; m × h): Three categories were used:

0: both wrong;

1: one eventually correct;

2: both eventually correct.

(v) *"B" Matrices* ("B"): Three categories were used:

0: all wrong;

1: one or two eventually correct;

2: all eventually correct.

(vi) *Top row continuation of Matrices "B1" and "B2"* (e + h; m + h): Three categories were used:

0: both wrong;

1: one correct;

2: both correct.

(vii) *Stage*: Six categories were used, one for each stage.

7.2.1 Predictions

If the theoretically predicted sequence of development is correct, there should be a linear sequence of development for the above tasks, corresponding to that shown in Table 7.1.

Table 7.2 gives the number of Ss producing each category of response.

Each S had a total score composed of the summation of his scores on each individual task. The score of each S on the individual tasks is given in Appendix I. If there is a unidimensional scale a Ss total score should predict his score on each individual task.

Table 7.1: The theoretically predicted category of response on each task at each stage.

	Tasks					
Stage	F/NF	USD	e × m	e × h; m × h	"B"	e + h; m + h
1	0	0	0	0	0	0
2	1	1	0	0	0	0
3	1	1	1	0	0	0
4	1	1	1	2	1	1
5	1	2	1	2	2	2
6	1	2	1	2	2	2

Table 7.2: The number of Ss producing each category of response.

	F/NF		USD			e × m		e × h; m × h			"B"			e + h; m + h		
Category of response	1	0	2	1	0	1	0	2	1	0	2	1	0	2	1	0
Number of Ss	91	7	45	43	10	63	35	52	7	39	46	9	43	47	11	40

Stage					
6	5	4	3	2	1
27	16	18	14	15	8

The predicted response pattern for each total score, derived from applying Goodenough's method of scalogram analysis to the data, is shown in Table 7.3.

For Stages 6, 5, 3, 2, 1, there is the same median and mode, and these have the same response pattern as that predicted theoretically (Table 7.1). At Stage 4 the median falls between two types of response pattern, one of which is the mode, and the theoretically predicted response pattern (total score 11). Thus if a scalogram analysis of this

Table 7.3: Prediction of the response pattern for each total score based on Goodenough's method of scalogram analysis.

Stage	F/NF	USD	e × m	e × h; m × h	"B"	e + h; m + h	Total Score	Predicted Number of Ss
6	1	2	1	2	2	2	16	27 ← *
5	1	2	1	2	2	2	15	16 ← *
4	1	2	1	2	2	2	14	2
4	1	1	1	2	2	2	13	1
4	1	1	1	2	1	2	12	1
4	1	1	1	2	1	1	11	5 *
								←
4	1	1	1	1	1	1	10	3
4	1	1	1	1	0	1	9	3
4	1	1	1	1	0	0	8	1
4	1	1	1	0	0	0	7	2
3	1	1	1	0	0	0	6	2
3	1	1	0	0	0	0	5	12 ← *
2	1	1	0	0	0	0	4	13 ← *
2	1	0	0	0	0	0	3	2
1	1	0	0	0	0	0	2	1
1	0	0	0	0	0	0	1	7 ← *

← marks the median for each stage.

* marks the mode for each stage.

data indicates a unidimensional scale, there will be support for the theoretically predicted sequence of development.

7.2.2 Results

Table 7.4 gives the results of this analysis, using Goodenough's [1944] method of scalogram analysis. The Plus Percentage Ratio (PPR) for the whole test was calculated with both stage of classification included as an item, and with it omitted.

Table 7.4: Scale analysis for all tasks.

	Stage Scores Included	Stage Scores not Included
Coefficient of Reproducibility for the whole test, (R_t):	0.8543	0.8640
Minimal Marginal Reproducibility for the whole test, (MMR_t):	0.5408	0.5850
Plus Percentage Ratio for the whole test, $\left(PPR_t = \frac{R_t - MMR_t}{1 - MMR_t}\right)$:	0.6827	0.6722

Plus Percentage Ratio for each pair of items (PPR_{ij}):

	F/NF	USD	e × m	e × h; m × h	"B"	e + h; m + h
Stage	0.9741	0.7580	0.9055	0.9656	0.9185	0.8687
F/NF		0.9663	1.0	1.0	1.0	1.0
USD			0.8861	0.8584	0.8475	0.8268
e × m				0.9010	0.8848	0.8603
e × h; m × h					0.7958	0.7112
"B"						0.6310

Plus Percentage Ratio relating each item to the total score (PPR_i):

Stage	0.7042
F/NF	0.8559
USD	0.5849
e × m	0.7712
e × h; m × h	0.8259
"B"	0.6538
e + h; m + h	0.6274

Additionally, correlations between the child's total test score (not including his stage of classification), his stage of classification, and his school grade, were carried out. The results are given in Table 7.5.

Table 7.5: Correlations between total test score, stage of classification and school grade.

	Stage	Test Score	
School Grade	0.7724	0.7667	
Classification Stage		0.9645	(0.9134 with Grade partialed out)

These correlations are all significant at $p < .001$ level.

7.2.3 Discussion

There is no universally accepted level of significance for these results. Peel [1959] suggests that a coefficient of reproducibility of 0.75 or higher is sufficient to give strong support for a sequence of developmental stages. Those found here, both with and without the stage of classification included, are above 0.85. The Plus Percentage Ratio used here, which removes the effect of the difficulty level of the items, will inevitably be lower than the coefficient of reproducibility.
De Lemos [1966] suggests that 0.60 may be an indication of scaleability for this measure. The PPRs obtained here are above this value. Thus there is strong support for the hypothesised sequence of developmental stages. There is also validation of the division of Ss into 6 Stages of development. This division was only once based on the test results used in the above analysis:

Stage 1 versus Stage 2: This was based on whether S could switch between properties. A factor not included in the above task results.

Stage 2 versus Stage 3: This was based on whether S could use the row and the column simultaneously when completing the matrix. This was not directly included in the above task results.

Stage 3 versus Stage 4: This was based on whether S used the structure of the whole collection when extending an existing collection, or whether he used two item comparisons. This was not directly included in the above task results.

Stage 4 versus Stage 5: This was based on the number of matrices whose missing items eventually were chosen correctly. This is a factor involved in the above task results.

Stage 5 versus Stage 6: This was based on whether S thought that alternative items could still complete the matrix, even though as "second best". This was not included in the above task results.

Thus the distinction between Stages 4 and 5 was the only one which was based on the results of the tasks used in the above scalogram analysis. The other differentiations between stages were not based on those results. The high Plus Percentage Ratios (PPR_{ij}) between Stage and each other task; together with the high correlation between Stage and the Total Test score (not including Stage), after partialing out school grade, validates the use of these stages when describing the development of classificatory ability.

The coefficients obtained here are much higher than those obtained by Kofsky [1966] in her scalogram analysis of a number of classificatory tasks which had been hypothesised to occur in a fixed sequence of development. Two reasons could account for this. Firstly, Kofsky's tasks seem to cover a much wider range of behaviours than do the ones included here.

Secondly, in the present analysis, only results which provided good measures of the difference between various levels of thought were used. The results of tasks which could be solved correctly by preoperational and concrete operational children, but for different reasons, were not included in the scalogram analysis. For instance, it was argued that the left column of the "B" matrices and the top row of matrix B3 (eyes + mouth) could be continued correctly by children at Stages 1, 2 and 3 if they happened to fixate on the correct property, at the expense of the other properties. Children at Stage 4 and above were correct on these tasks because they worked out how each property related to the others in a particular collection. Thus it is argued that correct performance on these tasks does not provide a reliable index of classificatory ability. In contrast, correctly continuing the top row of matrices B1 and B2 (e + h and m + h, respectively) can only be achieved if the child can logically integrate the two requisite properties. Therefore correct performance on these tasks is a reliable index of classificatory ability, and as such was used in the scalogram analysis. Kofsky did not exclude task results which did not seem to provide reliable indices of classificatory behaviour.

In the present analysis, while the high coefficients indicate that for most children the relationship between performance on different tasks was as predicted, there were the occasional exceptions. For instance,

L.S. (7;8), Classificatory Stage 3, had an up-side-down score of 9;

K.F. (6;7), Classificatory Stage 4, had an up-side-down score of 12;

these scores are much lower than those which would have been predicted from their stage of classification. Such exceptions do not necessarily disprove the hypothesis that the development of classification is dependent on understanding the relationships within an individual item. There is no way to measure directly the understanding of the relations between part and whole of an individual item, and so this understanding was inferred from the ability to draw an up-side-down version of an item. However, as well as the comprehension of the relations between part and whole, this task will involve other factors such as the drawing skills investigated by Goodnow [1972]. A child could be deficient in these additional factors relative to his understanding of the part-whole relations, and this would lead to discrepancies between performance on this task and classificatory ability.

In experiments such as these, it may be worth subsequently studying those exceptional children who have dissimilar abilities on two tasks which are hypothesised to involve similar structures, rather than to concentrate on children who perform similarly on both tasks. The following of such a policy might well throw light on the factors involved in the two tasks. There is also a need for more longitudinal studies. The conclusions of the present experiment, for instance, would be strengthened if a parallel development on several of the tasks reported here, was discovered in children tested over long periods of time.

CHAPTER 8

"SAME" AND "DIFFERENT"

The results of the work reported in the previous chapters indicate that the development of classification is dependent on the development of the understanding of the relationships between part and whole of an individual item. In Chapter 3, it was argued that another factor was also important in the development of classification. The classificatory schemes which compare items and put them together if similarities are found must also be abstracted. This abstraction is necessary if the child is to think of a class independently of the specific comparisons he has made, and of the specific spatial configuration into which he has organised the items. The aspect of the abstraction of these classificatory schemes which concerns the comparison of items will be considered in this chapter.

8.1 COMPARISON SCHEMES

A child at Stage 1 found it impossible to hold in mind comparisons with respect to two different properties. Thus if he made a comparison on eye shape he could not switch to one on head shape, without forgetting the former. This is a very good example of the young child's inability to use a scheme except when it is processing specific input. In this case the young child cannot think of comparing items except in the context of comparing eye shape.

To be able to switch between comparing eye shape and comparing head shape, it was hypothesised that the child has to be able to understand the relationships between the eyes and the head. This was supported by the results of Experiment 2. Thus in the development of classificatory ability, the comparison schemes process more and more abstract relationships.

However, another aspect of the development of the comparison schemes must also be considered. If the child is comparing, for example, eye shape, he will arrive at one of two different results, depending on the input he is processing:

(i) Eye shape the same;

(ii) Eye shape different.

It is hypothesised that the same general comparison schemes are used in both cases, and that these comparison schemes produce the result "same" or "different" depending on the items processed.

If "same" and "different" are two specific results of the same general comparison schemes, then abstraction of these schemes from specific input and results would enable the child to think of comparisons independently of either of the specific results "same" or "different". He would also be able to understand a general equivalence between "same" and "different". Some results from Experiment 2 suggest that is is so.

8.1.1 Use of Difference Criteria

When continuing the top row or the left column of the "B" matrices, or completing any matrix, some children were concerned with differences as well as with similarities (cf. p.90).

Continuing the top row of matrix B2 will be considered as an example.

The row has the head and the mouth shapes the same, while the eye shapes are different. Although E only talked in terms of similarities, some children were as concerned that a new item had different eyes from the previous ones, as that it had the same head and mouth. These children would argue that only alternative 1 would do, "*Because there are no square eyes.*" Alternative 2 would not do, "*Because there's one with cross eyes.*" The eyes have to be different.

In contrast, other children would only select eye shapes that had already appeared in the collection. They argued that alternative 2 would do, "*Because there's one with cross eyes.*" Alternative 1 would not do, "*Because there are no square eyes.*"

Many other children considered the eyes to be irrelevant, and selected alternatives 1 and 2.

It is of interest that some children used identical sentences to express completely opposite thoughts; cf. the italicised sentences. The first child says that alternative 1 will do, the other says that it will not do, "Because there are no square eyes." The meaning of a sentence will not be found in its linguistic structure; it resides in the schemes which it represents.

A similar use of differences was found when some children completed a matrix (cf. Appendix F, Stage 6, E.P.).

This use of difference to continue a collection will be called a "*difference criterion*".

Table 8.1 shows the percentage of children at each stage who somewhere in their reasoning used difference criteria.

Table 8.1: The percentage of children at each stage who used difference criteria.

	Stage					
	1	2	3	4	5	6
% children	0	0	0	33	38	63

This is very different from merely describing differences in an existing collection. A Stage 1 child can say that "This has cross eyes, this has triangle eyes, this has circle eyes", but he will not use the difference as a *criterion* for adding to that collection.

It was hypothesised that Stage 3 children could not understand the structure of a whole collection because they could not integrate successive comparisons of two items at a general enough level to predict the nature of additional items. By Stage 4 this generality is achieved for each property considered separately, but the integration of the different properties is poor. Use of difference criteria must require an understanding of the structure of the whole collection, with respect to the considered property. Therefore it is logically necessary for this theory that difference criteria are used only at Stage 4 and above.

A new meaning of "same" appears at Stage 4. This meaning illustrates the reason why children use difference criteria as well as similarity ones. In response to the question "How are these (top row, say), all the same?" some children at Stage 4 and above answered along the lines:

"They're all the *same* because they have *different* eyes, the *same* mouth and the *same* head."

The second and third uses of "same" have the standard meaning of equivalence on a property. The first meaning is new. It refers both to properties being the same across all items and to a property being *different* across all items. In other words, it means that there is a consistent relationship between all the items on a given property. This consistent relationship can either be one of all items being the same on the property, or of all items being different on the property.

This more general meaning of "same" is consistent with the hypothesis that "same" (narrow sense) and "different" are two different results of the same comparison schemes, and that these comparison schemes have now been abstracted from those two specific results. Thus the child can understand an equivalence between "same" and "different".

It is possible to postulate the course of development of the meaning of "same" and "different" based on the results of Experiment 2, and using the hypothesis that they are both different results of the same comparison schemes.

8.1.2 The Development of the Meaning of "Same" and "Different"

The meaning of both "same" and "different" will be postulated to follow the same course of development, since the development of the meaning of both is hypothesised to depend on the progressive abstractions of the same comparison schemes.

Stage 1

At Stage 1 (age 5), the lowest age investigated here, there is a certain confusion between "same" and "different". For instance if a child who has just compared the eye shape of some items is asked how two items with similar eyes but different head-shapes are *different*, he is likely to say "This has round eyes, and this has round eyes". If asked how two items with different eyes but similar heads are the same, he might say "This has round eyes, and this has cross eyes" (cf. Appendix G). In both cases he can make the items correctly, and hence has perceived the head-shape (cf. pp.63-64).

"Same" and "different" seem to mean the result of a comparison of, in this case, the eyes, without real differentiation of the type of result (same or different). The child cannot understand that "same" or "different" can also apply to other properties, e.g. the head. The meaning of "same" and "different" is given by the state of the comparison schemes. These can only be used in the context of comparing a particular property, in this case the eyes.

Stages 2 and 3

There is increased abstraction of the properties compared, so the comparison schemes can be used in the context of comparing a more general set of relations between several properties. This can generate the specificities of comparing particular properties. Thus the results of the comparison schemes — same/different — are more abstract; it is understood that they can extend over more than one property. However, they can not co-ordinate successive comparisons of two items at a general enough level to predict the nature of additional items when extending a collection. There is no understanding of the structure of a total collection.

Stages 4 and 5

The comparison schemes have been abstracted from specific items and specific results — same/different. This enables the first appearance of "difference criteria", because the child understands that "all the same on property x", and "all different on property x" are both consistent comparison relations between items. This abstraction is also called "same (cf. pp.126-127).

However, this level of abstraction does not integrate successfully all the properties. For instance, there can be successive switching from thought of "consistent relations between items on eye-shape", and "consistent relations between items on head-shape", because the relations between them are partly understood; but that understanding is not general enough to enable simultaneous thought of both.

Stage 6

By this stage there is a single abstraction that can generate the specifics of any comparison on any property, and hence can unite, in thought, comparisons on all properties. Thus the general thought "consistent relations (either of similarity or difference) between items for any property" can generate the structure of the whole matrix: any property of any item must be consistently related (either all same, or all different) to all the items in a collection (row or column). From this the specificities of particular rows/columns, particular properties, particular values of the properties, and the particular results same/different can be worked out.

Thus the understanding of "same" and "different" at each stage has been hypothesised to be dependent on the level of abstraction of the comparison schemes. The following experiment investigates this hypothesis.

8.2 EXPERIMENT 4: THE DEVELOPMENT OF "SAME" AND "DIFFERENT"

8.2.1 Introduction

The above characterisation of the abstraction of the comparison schemes and the accompanying development of the understanding of "same" and "different" was based on tasks where similarity relationships were stressed. Difference criteria did not have to be used to solve the tasks, and many children at Stages 4, 5 and 6 never used them.

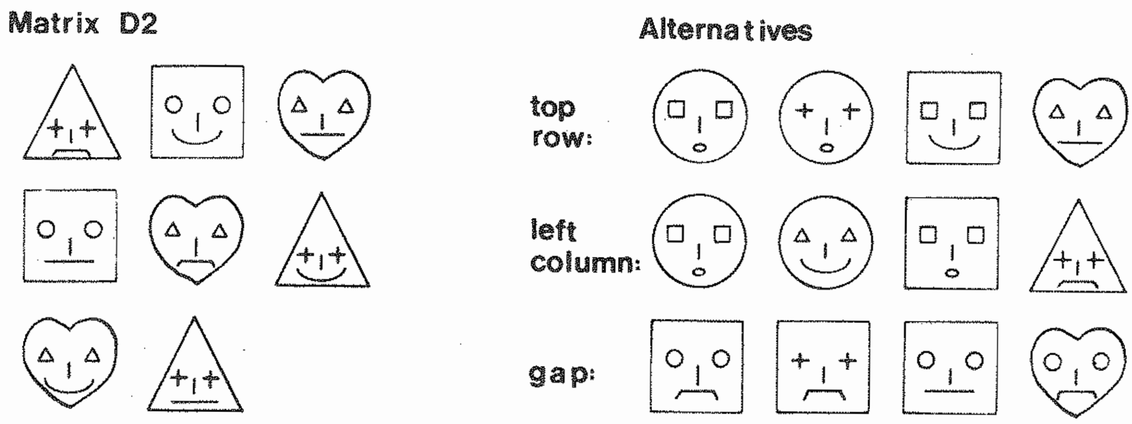
If "same" and "different" are dependent on the abstraction of the same internal schemes, then tasks where differences have to be used should produce the same developmental stages as those for similarity tasks. Each child should be at the same stage with similarity and difference tasks.

Accordingly, two matrices whose structures were derived from differences between properties (latin square structures), were constructed.

8.2.2 Materials

Two "latin square" matrices such as the one shown in Figure 8.1, were constructed out of the same materials as the "similarity" matrices used in Experiment 2. All three properties — head, eyes and mouth — were varied. These two "difference" matrices will be called D1 and D2. For both matrices, four alternatives were available from which to choose an item with which to complete the matrix. One alternative had all three properties correct; while each of the other three had two properties correct, one wrong. For D2, but not D1, four alternatives were available from which to continue the top row, and another four for continuing the left column. Drawings of these matrices, and of the alternative items, are given in Appendix K.

Figure 8.1: A "difference" matrix.



Additionally the three "B" matrices (three variable properties) used in Experiment 2 were used. These "similarity" matrices will be called here S1, S2 and S3, corresponding to B1, B2 and B3 respectively. One change was made. One of the alternatives for continuing the left column was replaced by an item which was different from all items in the left column on both the variable properties.

8.2.3 Subjects

Forty children tested in Experiment 2 were retested approximately two months later. These comprised:

5 of the more flexible Stage 2 children
5 Stage 3 children
10 Stage 4 children
10 Stage 5 children
10 Stage 6 children.

At Stages 4, 5 and 6 five children who had used "difference criteria" and five who had not, were chosen.

8.2.4 Procedure

Each S was tested once. The five matrices were always given in the same order:

S3, S1, D1, D2, S2.

(i) Similarity Matrices

The testing procedure for all three similarity matrices was the same, and consisted of:

(A) Continuation of the top row;

(B) Continuation of the left column;

(C) Completion of the matrix.

For these matrices E never used the words "same" or "different", but always talked about items "going together". This was perfectly acceptable to the children.

(ii) Difference Matrices

D1

Completion of the matrix: S was shown the four alternatives, and asked to find the best one to complete the matrix. The same phrasing was used as for S3 and S1 (a picture "to go with both of these, and both of those"). No indication was given that D1 had a different type of structure from the similarity matrices. E questioned S about his choice. If S was using differences, E continued questioning to establish S's ability to complete the matrix. If S was confused, or only used similarities, E explained the structure of the matrix: how all the items in any row or column had to be different from each other. S was then invited to find an item "different from both of these (bottom row), in all the ways they are different, and different from both of these (right column), in all the ways they are different". Questioning proceeded to establish S's ability to use differences to complete the matrix, after this help from E.

D2

Continuation of the top row: E asked the child how the top row items "go together". The child was then asked to choose any items (from four alternatives) which could go with all the other items in the row. E questioned S about his choice(s), and if the child had used similarities, E explained how the items in the row all had different eyes, mouth and head, so that any new item had to be different in all these ways. S then made another choice, in accordance with these instructions, and E questioned S again.

Continuation of the left column: The procedure was the same as for the continuation of the top row task.

Completion of the matrix: The procedure was the same as for D1.

8.2.5 Results

S3 and S1 were used to re-establish both S's stage of classification, and whether he used "difference criteria". Ten of the 40 children were re-classified.

Table 8.2 gives the new numbers in each group.

Table 8.2: The number of children in each group.

Stage 2	Stage 3	Stage 4		Stage 5		Stage 6	
		ND	D	ND	D	ND	D
5	6	3	3	4	5	4	10

ND: no use of difference criteria
D: use of difference criteria.

Spontaneous Use of Differences in D1 and D2

Table 8.3 gives the average number of times an S had to be told by E to use differences. For each S there was a possible total of 4 occasions: Completion of matrices D1 and D2, and continuing the top row and the left column of D2.

Table 8.3: The average number of times E told S to use differences.

Stage 2	Stage 3	Stage 4		Stage 5		Stage 6	
		ND	D	ND	D	ND	D
4.00	3.50	1.33	0.00	2.50	0.80	0.25	0.60

(Maximum: 4)

There was no difference between "D" and "ND" Ss (Stages 4, 5 and 6) (Mann-Whitney U Test, $U = 64$, n.s.).

The Kruskal-Wallis One-Way Analysis of Variance [Siegel 1956] gave a significant difference ($H = 23.29$, $p < .001$) between the five stages. The Mann-Whitney U Test was used to test for differences between adjacent stages. The results are given in Table 8.4.

Table 8.4: The difference between adjacent stages in the number of times E told S to use differences.

Stage 6 versus Stage 5	$U = 38$	n.s.
Stage 5 versus Stage 4	$U = 18.5$	n.s.
Stage 4 versus Stage 3	$U = 0.5$	$p < .002$
Stage 3 versus Stage 2	$U = 10$	n.s.

Thus at Stages 4, 5 and 6 there was a good ability to work out, without help from E, that differences had to be used in D1 and D2. There were no significant differences between these stages. When E's help was required by Ss at these stages, it was mainly during the first experiences with the difference tasks (i.e. the completion of matrix D1 and the continuation of the top row of D2), not on the later ones (Sign Test, $p < .001$). Thus Ss at these stages could benefit from E's help.

In contrast, children at Stages 2 and 3 needed E's help on significantly more occasions than did children at the later stages. For the majority of these children at Stages 2 and 3, E had to tell S on each of the four tasks to use differences. There was no significant difference between the number of times E gave help on the first two and on the last two tasks. This showed that these children did not benefit from E's help. In 55% of their responses, children at Stage 2 either completely ignored E's instructions to use differences, or initially tried to use differences, but then fell back to making two item similarity comparisons. 25% of the responses of children at Stage 3 were also of this type. There was no ignoring or forgetting of E's instructions at Stage 4 and above.

These results shed light on the hypothesis that children at Stage 4 and above have the necessary abstract schemes to enable them to understand a set of difference relationships within a whole collection; while children at Stages 2 and 3 do not. The sharp dichotomy found between Stages 4 and above, compared to Stages 2 and 3, supports this hypothesis. This hypothesis is further verified by looking at the way in which Ss used differences.

Ability to Use Differences

It was predicted that when children tried to use differences, either spontaneously, or under E's instructions, they would make the same types of error as when using similarities. Their attempts to use differences, whether spontaneously, or under E's instructions, were classified as follows:

A. Difference instructions were ignored, and there was a continued use of similarities.

B. Difference was used for one or two properties, while two item similarity comparisons were used for the others. Or difference was used within a two item comparison, with no attempt to make the item different from all items in the row and column.

C. Difference was used correctly on some properties, but not on others. The other properties were omitted from consideration, and alternatives were accepted as equivalent.

D. The child either eventually worked out what was correct, after an initial wrong attempt, or he knew the best item, but he also said that other alternatives would do, although they were not as good.

E. All properties were correct.

These classifications obviously correspond to those of the similarity matrices.

Stages 2 and 3, Similarity Matrices:
"A" and "B", Difference Matrices

The structure of a whole collection, even with respect to one property, is not understood. Thus if differences are used following E's instructions, it is not understood why, and mistakes are made (e.g. also using similarities).

Stage 4, Similarity Matrices:
"C", Difference Matrices

Simultaneous co-ordination of all three properties is not possible. This leads to a property being omitted from consideration, and hence to the acceptance of several alternatives. However, those properties that are considered, are considered correctly; there are no "two item comparisons".

Stage 5, Similarity Matrices:
"D", Difference Matrices

All properties can eventually be co-ordinated correctly, but either this is not done on the first occasion, or the child still thinks other alternatives will also do.

Stage 6, Similarity Matrices:
"E", Difference Matrices

All properties correctly co-ordinated, no alternatives allowed.

Table 8.5 shows the distribution of children with each stage on the similarity matrices, the majority of whose responses on the difference matrices fall in each of the above categories.

Table 8.5: The distribution of stages on the difference matrices within each stage on the similarity matrices.

Difference Matrices	Similarity Matrices				
	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
A.	3	1			
B.	2	3			
C.		2	4		
D.			2	6	
E.				3	14

The correlations between stage on the similarity matrices, stage on the difference matrices and school grade are shown in Table 8.6.

Table 8.6: Correlations for stages of classification on the similarity and difference matrices.

	Similarity Matrices	Difference Matrices	
School Grade	0.62	0.60	
Similarity Matrices		0.94	(0.90 with Grade partialed out)

These correlations are all significant at $p < .001$.

There is a very high correlation between ability on the two types of matrices. The errors made on the difference matrices are of the same kind as those made on the similarity matrices. The tendency towards a higher ability on the difference matrices is probably due to the specific help given by E on these matrices. No such help was given when errors were made on the similarity matrices.

8.2.6 Discussion

An attempt has been made to indicate how language could be dependent on cognitive structures, rather than the reverse (as postulated by Bruner *et al.* [1966]). "Same" and "different" were hypothesised to be two different results of the same comparison schemes, the abstraction of these schemes being responsible for the developing understanding of both. The correlation between ability to use similarities and differences in classifications, together with the correspondence between classificatory ability and the verbal use of "same" and "different" suggests that this is so.

These results tie in well with those of Donaldson on the use of relational terms in younger children [Donaldson and Balfour 1968, Donaldson and Wales 1970]. Donaldson also argues that language acquisition should be related to other aspects of cognitive development. She showed that young children (three-and-a-half to five years) regard "less" as equivalent in meaning to "more", and, more importantly for the present discussion, that they appear to make no distinction between the instructions "Give me one that is the same in some way", and "Give me one that is different in some way" [Donaldson and Wales 1970, p.224]. "Different" is usually taken to mean a different item with the same attributes.

The youngest children tested in the present experiment (five year olds), seemed to have differentiated between "same" and "different" in their application to one property at a time. Thus the description of two items as having "different eyes" would be comprehended in the adult manner, rather than as a denial of the identity of the two sets of eyes along with the presence of their similar shape. However, if a second property had to be considered, e.g. head-shape, confusion arose. The comparison schemes could only process one property at a time. Thus "How are these different?" means, for example, "Compare the eyes"; if the eyes are similar, anomalous answers are produced.

Donaldson's children, who were younger than the present children, did not seem able to differentiate between "same" and "different" even in their application to one property at a time. Thus a description of two items as having "different eyes" would most likely be comprehended by Donaldson's children as two different sets of eyes with the same shape.

Another study has also indicated the dependence on cognitive structures of the understanding of "same" and "different". Harasym, Boersma and Maguire [1971] compared the semantic differential judgements of conservers and non-conservers for the words "more", "less", "same" and "different". For conservers "more" and "less" were judged to be opposite to each other, while "same" and "different" were judged to be very similar. The opposite was true of the non-conservers: they did not appear to differentiate between "more" and "less", but did between "same" and "different".

Harasym *et al.*'s children were of similar ages to the ones used in the present experiment, and the results again fit the proposed theory. By five years children have differentiated between "same" and "different" with respect to one property at a time, and therefore treat them differently in semantic differential judgements. However, they cannot apply these relationships consistently in structuring a whole collection. At Stage 4 in the present experiment a new meaning of "same" seemed to emerge: a consistent relationship between items, whether of equivalence (all the same), or nonequivalence (all different), (cf. p.127). Thus there is a new appreciation of the similarity of "same" and "different" relationships as a result of which the words are treated alike in semantic differential judgements.

Amalgamating these various results we may postulate the development of "same" and "different" to be:

(i) 3½ years: "Same" and "different" are not differentiated, even when applied to one property [Donaldson].

(ii) 5 years: "Same" and "different" are differentiated only when used for one property. Confusions arise when the co-ordination of several properties is required [present experiment]. "Same" and "different" are judged to be different in meaning [Harasym *et al.*].

(iii) 8 years: At an abstract level both "same" and "different" are understood to represent consistent relationships between items [present experiment]; and hence are given similar semantic differential ratings [Harasym *et al.*].

The position argued for here is similar to that of Sinclair [1969, p.325] that "language is not the source of logic, but is on the contrary structured by logic". To argue, like Griffiths, Shantz and Sigel [1967] and Braine [1959] that nonverbal methods of testing should be used because the child may not have the linguistic concepts of "same", "different", "more" and "less", seems to beg the question. Beilin [1965] showed that not understanding "same" does not prevent the acquisition of conservation, and training in conservation removes all pretest differences in such comprehension. Additionally, the work of Sinclair [1969] indicates that the same cognitive structures are responsible for the mature understanding of relational linguistic terms, and for correct performance on concrete operational tasks.

A further aspect of the results of Experiment 4 also requires discussion. It was hypothesised that children at Stage 4 and above had the necessary abstract structures to understand the relationships of "all the same" or "all different" for a whole collection of items, even if they did not spontaneously use difference criteria. If they did not spontaneously use differences for the difference matrices, E's instructions were sufficient to enable them to do so, although the manner in which they used difference criteria was dependent on the level of abstraction of their schemes; that is, children at Stage 4 and above on the similarity matrices always performed at level C or above on the difference matrices, but there was a correlation between being at Stage 4, 5 or 6 and the level of performance (C, D or E) on the difference matrices (cf. p.137).

In contrast, it was hypothesised that children at Stages 2 and 3 lacked the abstractions necessary for the concept "all different" and E's instructions did not lead them to any success with the difference matrices.

There have been many attempts to teach concrete operational concepts most of them concerned with conservation [Brainerd and Allen 1971]. Since success is relatively independent of the methods used, Halford [1970, 1972] concludes that development of Piagetian concepts is dependent on S's internal constructions which are only indirectly affected by external events: there can be no direct absorption of information if the appropriate structures do not exist. This was confirmed in the present experiment. Although no expanded training procedure was employed, E gave very explicit instructions about how the items had to be different from one another. This only led to appropriate behaviour in Ss who were thought to have adequate structures to which to assimilate these instructions.

Dasen [in prep.] working with Canadian Eskimos, hypothesised that 12 to 14 year-olds, but not 10 to 11 year-olds, had the "competence" (internal structures) necessary for the conservation of quantity, but not the necessary experience to produce the correct performance. Training easily induced conservation in the 12 to 14 year-olds, but not in the 10 to 11 year-olds. This provides further evidence that the self-regulating activity responsible for the development of cognitive structures cannot be directly affected by external events. Instruction can only directly influence the manner in which existing structures are put into practice.

Inhelder [1971] also argues that the success of training is related to the child's original level of development, and that children who have been trained on a concept often show distorted reasoning. These distortions indicate that a true logical structure has not been acquired. Such "pseudo-acquisitions" are the most probable explanation for the more spectacular claims of the acquisition of new structures through training. For instance, Engelmann [1971] claimed he had taught kindergarten children the concept of specific gravity as well as the conservation of volume, weight and substance. However, when Kamii and Derman [1971] retested the children trained by Engelmann they found many instances of preoperational reasoning. Their questioning made it very apparent that while the children had rote learnt verbal rules, they had failed to acquire any logical concepts. This type of evaluation of the concepts acquired through training is extremely valuable and one wishes it was applied more often.

8.2.7 Conclusion

This experiment supports the hypothesis that "same" and "different" are two different results of the same comparison schemes; and that the development of classificatory ability is dependent on the progressive abstraction of these comparison schemes. This result, together with the results of Experiment 2, support the hypothesis developed in Chapter 3, that the development of classificatory behaviour is dependent on the following two factors:

(i) Abstraction of the schemes which construct individual items;

(ii) Abstraction of the classificatory schemes.

Since the latter co-ordinate knowledge obtained from the former, each advance in the latter's abstraction may be hypothesised to be dependent on a prior advance in the abstraction of the schemes that construct individual items.

The following chapter presents a theoretical model which outlines the level of abstraction at each stage of development, for each of these two sets of schemes. It also indicates how the abstraction of the classificatory schemes is dependent on the abstraction of the schemes that construct individual items.

CHAPTER 9

A THEORETICAL MODEL

Two processes in the development of classification have been investigated experimentally:

(i) The abstraction of the relations involved in the construction of individual items;

(ii) The abstraction of comparison schemes.

These are not separate. Each level of abstraction of the comparison schemes has been hypothesised to be dependent on a prior abstraction of the relationships involved in the construction of individual items.

Since the comparison schemes are not originally differentiated from the materials they process, and since the relationships involved in different sets of materials are abstracted at different rates, there will be horizontal décalages in the development of classificatory ability. That is, the abstraction of the comparison schemes will be at different stages, depending on the level of abstraction of the properties processed (cf. the eyes × mouth versus the eyes × head differences).

To indicate how the progressive abstractions of the comparison schemes could be co-ordinated with those involving the relationships within individual items, a theoretical model has been constructed.

This model has also been developed as a counter to the type of model proposed by Klahr and Wallace [1970]. They provided no mechanism for showing how the child understood what he had to do, and hence how he constructed the required task specific routine. It was argued that this understanding would be provided by schemes which had been abstracted from specific content and specific results. These abstractions would be common to many specific actions. For instance, there could be an abstraction common to all the specific actions involved in grouping square items together. This abstraction would unite in thought all those specific actions, and provide the child with an understanding of their overall result, i.e. a class of square items. It would also provide a guide for carrying out the specific actions for forming that class.

No detailed models of such abstraction processes have been developed, and the one presented here is a first attempt to do so. As such, this model must be regarded as an indication of how this author feels such models should be developed, rather than as a final product. It is considered that the significance of this approach lies in its overall methodology, rather than in its specific details.

9.1 A THEORETICAL FRAMEWORK

Studies of perception [e.g. Neisser 1967] indicate that all our perceptions are constructed by computing sets of relations. There are no actual "things" that are seen but rather we ascribe a constancy, an objectivity, to certain sets of relationships whose basic form recurs in many different perceptions. For instance, the perception of colour is, in its simplest form, the relation between the excitation/inhibition of the red-green receptors and that of the yellow-blue ones. This is made more complex by additional relationships to do with constancy.

There is no thing, no property, "red". It is a set of relations constructed by the organism. Its "property" quality is similarly constructed by the organism. This is Piaget's point: knowledge is an action; for the organism the environment has no existence, except through its assimilation to the internal structures.

The development of this constructive ability is slow.

> "Thus a trained animal gives a color response as a function of an unstable exterior schedule of physiological rewards. A preoperational child, in a so called concept formation experiment, succeeds in responding to the relevant attributes as a function of a more stable internal knowledge of color. Yet compared to the operational period the younger child is still centered on his own action towards the color and does not regard the color attribute in an objective fashion which permits him to see it as a reversible attribute within the classes of other possible attributes." [Furth 1966, pp.215-216].

Similarly, with reversible figures (e.g. the Peter-Paul Goblet], in which there are no constant "things". What is seen is very dependent on the relations computed, what is made into figure, what into ground. There is a balanced set of relationships within the total perception whereby, if one aspect is changed, the structure of the total set of relationships is altered to relate to that changed aspect.

Again, the ability to conceptualise this perceptual dichotomy is not achieved until the concrete operational period [Elkind 1969].

An attempt will be made to describe the development of classification from a "computational" view point, to indicate the relational nature of what is occurring, and to indicate that the internal structures must be constantly restructured to allow development of new levels of behaviour to occur.

The internal structures, or schemes, are considered to be similar to procedures encoded by computer programs. A procedure is a set of instructions that can operate on a variety of input data, to produce a variety of results. For instance, there can be instructions to add two numbers. Any two numbers can be input data, and depending on the input, any number can be the result. However, the computer has no knowledge of what "adding" is. All it can do is to enact the procedure on specific data. There can be no understanding of that which is common to adding 2 + 3, and adding 105 + 928. This is akin to the sensori-motor child. He can only use his schemes/procedures when processing particular environmental data and producing a particular result (overt action). Unlike the computer program, however, the child can develop beyond this stage.

For instance, an adult can understand about adding two numbers together independently of any particular numbers.

It is argued that the child becomes able to do this with his own procedures. He becomes able to use his procedures independently of processing specific input and producing specific results (Piaget's process of "interiorisation", cf. section 3.1). This process is here called the abstraction of the procedures from specific content (input and results).

The development of classificatory behaviour has been characterised as being dependent on the following:

(i) A growing understanding of the relations that construct an individual item;

(ii) An abstraction of the classificatory schemes. This allows thought of a class independently of its specific items and spatial configuration.

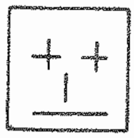
The abstraction of the classificatory schemes has been hypothesised to be dependent on the prior abstraction of the relations between the parts and whole of an individual item. Thus the first step in the development of the theory is to characterise the perception of an item, and the development of the ability to understand the relationships involved. The procedures responsible for the construction of individual items will be called PERCEIVE. A series of Developmental Periods will be postulated. These are to be distinguished from the Classificatory Stages derived from the experimental work.

9.2 PERCEIVE

9.2.1 Developmental Period A

At some point during early development the child can co-ordinate the successive perceptual inputs produced by each eye-movement sufficiently well to construct some sort of perception of the whole event. However, no part of the event can be separately considered, it is constructed as a global whole.

If the child perceives:

A.  and B. 

the square head in each case is involved in a totally different set of relationships. In A, each part of the square is related to each part of:

In B, each part of the square is related to each part of:

There is no "square" existing by itself, in either set of relationships. The procedures which compute the different parts of it relate one part to e.g.  , another part to e.g.  , etc., in constructing the whole event.

The child is computing the relationships between the perceptual inputs which have as their result the total event. There is no construction of "properties" and their relationships, such as may be described by the sentence: a "pink square" with a "blue cross" in each top corner, a "blue line" in the middle, and a "blue curve" below the line. These are later abstractions from the total construction.

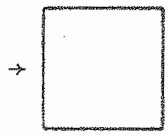
9.2.2 Developmental Period B

There are no viable computer theories as to how programs can restructure or modify themselves. The computer scientist has to do the restructuring. The developing child, it is postulated, restructures his procedures. It cannot be said how, it can merely be indicated that it occurs. An illustration will be given of the sort of reconstructions that might be possible at an early stage.

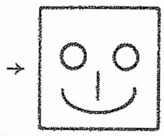
The procedures which construct the total global event can be restructured to enable a part of the whole event to be constructed independently. The first procedure would compute the relationships involved in one part of the total event, the second would utilise this result in computing the total event. That is, part of the total construction process becomes differentiated from the rest, and can be used by itself. Its results may be available for subsequent analyses. This can be achieved in different ways, just as the Peter/Paul Goblet can be constructed in different ways. Two methods will be considered.

Method 1

Procedure i: Find the background of the item, and compute shape



Procedure ii: Find the foreground of the item, and relate it to the results of procedure i



(The term "background" refers to the head which contains the other parts of the item. "Foreground" refers to the inside of the item. Each sentence describes the type of instructions a procedure carries out. The subsequent arrow and symbolisation give a particular result of the procedure for a particular analysis.)

Other differentiations of the parts involved in the construction of the total item could be avilable to the individual at this period; however, the alternative ways will not be simultaneously possible, just as the alternative ways of constructing the Peter/Paul Goblet cannot be achieved simultaneously. If "Peter and Paul" are seen, the other area of the picture does not emerge as a separate entity. Similarly, if the "goblet" is constructed, the remainder of the picture has no separate individuality. An alternative method of constructing the items used in the present experiment could be:

Method 2

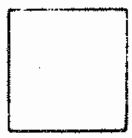
Procedure i': Find the foreground of the item, and compute shape

→ 

Procedure ii': Find the background of the item, and relate it to the results of procedure i'

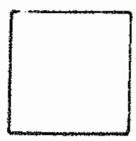
→ 

In method 1, procedure (i) allows a separate consideration to be made of its result:



In method 2, procedure (i') allows a separate consideration to be made of its result:

In method 1 there is no separate computation of: 

In method 2 there is no separate computation of: 

Therefore computing the event by method 1 is not the same as computing it by method 2. Neither is the same as computing the event when none of the parts are differentiated, as in developmental period A.

9.2.3 Developmental Period C

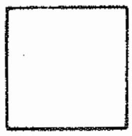
In developmental period B, method 1, procedure (i) computes all the relations for the background (hence abbreviated to Bgr), ignoring what must have been incidentally computed about the foreground (hence abbreviated to Fgr). The Fgr was analysed in relation to the Bgr in the following procedure. Similarly, method 2, procedure (i') computes information about the Fgr, ignoring that computed for the Bgr, which must be computed in a subsequent procedure. There is greater efficiency if the Bgr-Fgr information is computed in a separate procedure. This would be differentiated from the total construction, and its results could be referred to by subsequent analyses, when required.

To analyse the Fgr and Bgr of an item, the input must be clustered into regions, and then these clusters separated into Bgr and Fgr. The necessary restructuring will be described as occurring at this and the following period. Again, two alternative methods of constructing the item, which cannot be computed simultaneously, will be considered.

(Procedure is abbreviated to pr.)

Method 1

pr i: Register input, and cluster → description of clusters

pr ii: Find Bgr clusters and compute shape → 

pr iii: Find Fgr clusters and relate them to the results of pr ii

→ 

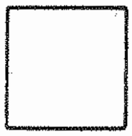
Method 2

pr i: Register input, and cluster → description of clusters

pr ii': Find Fgr clusters and compute shape → 

pr iii': Find Bgr clusters and relate them to the results of pr ii'

→ 

Both of these alternative methods of constructing the item use the same initial procedure (i) which registers input, and clusters it. However, method 1 still does not separately compute:  , and method 2 does not separately compute: 

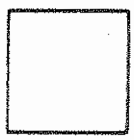
9.2.4 Developmental Period D

It is postulated that the restructuring which enables a separate analysis to be made of all the Bgr/Fgr information, also enables a separate analysis to be made of the shape of both the Fgr and Bgr, within one perceptual construction of the item. Two alternative methods of constructing an item on these principles are considered, and again, while they are both hypothesised to be available to an individual, they cannot be used simultaneously.

Method 1

pr i: Register input and cluster → description of clusters

pr ii: Analyse into Fgr and Bgr clusters → description of Fgr clusters, and of Bgr clusters

pr iii: Compute the shape of the Bgr clusters → 

pr iv: Compute the shape of the Fgr clusters → 

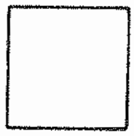
pr v: Relate the results of pr iii to pr iv → 

Method 2

pr i: Register input and cluster → description of clusters

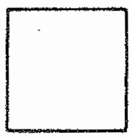
pr ii: Analyse into Fgr and Bgr clusters → description of Fgr clusters, and of Bgr clusters

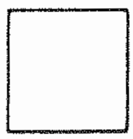
pr iv: Compute the shape of the Fgr clusters → 

pr iii: Compute the shape of the Bgr clusters → 

pr v': Relate the results of pr iv to pr iii → 

The final procedures (v and v') of these two methods are dissimilar. The difference between the constructions of these two procedures could be indicated by the following two representations:

Method 1:  contains 

Method 2:  inside 

9.2.5 Foreground Relationships

A similar process of differentiation is postulated for the relationships within the Fgr. After the Fgr can be separately differentiated (Developmental Period B, method 2), there can be a reconstruction of the procedures involved to allow a separate consideration of its parts.

(Just the procedures for Fgr will be considered here.)

Developmental Period C

Two alternative methods of constructing the Fgr will be described. Again, these are both considered to be available to the individual, although they cannot be used simultaneously.

Method 1

pr i: Find the top Fgr clusters and compute shape → 

pr ii: Relate the other Fgr clusters to the results of pr i

→ 

Method 2

pr i': Find the bottom Fgr clusters and compute shape → 

pr ii': Relate the other Fgr clusters to the results of pr i'

→ 

In method 1  is not separately computed.

In method 2  is not separately computed.

Therefore constructing  by method 1 is not the same as constructing it by method 2. Neither is the same as its construction with no separate differentiation of any of its parts, as in Developmental Period B.

Developmental Period D

When finding the clusters for the "eyes" in method 1, procedure (i) of Developmental Period C, the procedure finds the topmost clusters, but does not order the remaining ones at this point. There is merely a division between the top clusters and lower ones. Ordering of the lower clusters is done in a later procedure, in conjunction with analysing their shape. Similarly, in method 2, procedure (i'), the lowest cluster is found, but the ones above are not ordered with respect to each other at this point.

(Obviously eyes = top clusters, nose = middle cluster, mouth = bottom cluster, is a gross simplification. It is merely an indication of what might be occurring.)

A restructuring will enable computation of all the spatial relations between the Fgr clusters at once, and independently of the analysis of their shape. This example should indicate that the restructuring is not just a change within a set of procedures, a rearrangement of their instructions. It is the creation of something new. Before this, a procedure to order every item did not exist. Finding the top item was different from finding the bottom item.

This restructuring which analyses the spatial relations between the Fgr clusters, will enable the shape of each Fgr cluster to be computed independently. The shapes can then be integrated to construct the total Fgr. Again, two alternative methods of constructing the Fgr are considered.

Method 1

pr i: Compute the spatial relations of the Fgr clusters →
((clusters 1 and 2) above (cluster 3) above (cluster 4))

pr ii: Compute the shape of the top Fgr clusters → 

pr iii: Compute the shape of the middle Fgr cluster →

pr iv: Compute the shape of the bottom Fgr cluster → 

pr v: Relate the results of pr ii, pr iii and pr iv → 

Method 2

pr i: Compute the spatial relations of the Fgr clusters →
((cluster 4) below (cluster 3) below (clusters 1 and 2))

pr iv: Compute the shape of the bottom Fgr cluster → 

pr iii: Compute the shape of the middle Fgr cluster →

pr ii: Compute the shape of the top Fgr cluster → 

pr v': Relate the results of pr iv, pr iii and pr ii → 

In these two alternative methods, procedures v and v' construct  by different nonreversible sets of relations which may be described by the following representations:

Method 1:  above above 

Method 2:  below below 

9.2.6 Analysis of the Total Item in Developmental Period D

The perception of the total event at Developmental Period D can now be characterised by the following set of procedures.

pr i: Register input and cluster

pr ii: Analyse into Fgr and Bgr clusters (uses the results of pr i)

pr iii: Compute the spatial relations of the Fgr clusters (uses the results of pr ii)

pr iv: Compute the shape of the top Fgr clusters (uses the results of pr iii)

pr v: Compute the shape of the middle Fgr cluster (uses the results of pr iii)

pr vi: Compute the shape of the bottom Fgr cluster (uses the results of pr iii)

pr vii: Compute the shape of the total Fgr (uses the results of pr iii, pr iv, pr v and pr vi)

pr viii: Compute the shape of the Bgr cluster (uses the results of pr ii)

pr ix: Compute the shape of the total item (uses the results of pr ii, pr vii and pr viii).

9.2.7 Developmental Period E

By Developmental Period D there has been differentiation of the procedure which separates Fgr and Bgr clusters (procedure ii), and also of the procedure which computes the spatial relationships between the Fgr clusters (procedure iii). At this next period (E) these can be co-ordinated so that a separate analysis of the spatial relationships between all the Fgr clusters and the Bgr cluster can be made. This result would be used in the final construction of the whole item, when the shapes of these various clusters are related.

Thus at Developmental Period E the perception of the total event could be characterised by the following set of procedures, which are similar to those of the previous period, with one addition.

pr 1: Register input and cluster

pr 2: Analyse into Fgr and Bgr clusters (uses the results of pr 1)

pr 3: Compute the spatial relations of the Fgr clusters (uses the results of pr 2)

pr 4: Compute the spatial relations of the Fgr and Bgr clusters (uses the results of pr 2 and pr 3)

pr 5: Compute the shape of the top Fgr clusters (uses the results of pr 3)

pr 6: Compute the shape of the middle Fgr cluster (uses the results of pr 3)

pr 7: Compute the shape of the bottom Fgr cluster (uses the results of pr 3)

pr 8 Compute the shape of the total Fgr (uses the results of pr 3, pr 5, pr 6 and pr 7)

pr 9: Compute the shape of the Bgr cluster (uses the results of pr 2)

pr 10: Compute the shape of the total item (uses the results of pr 4, pr 8 and pr 9).

The numbers given to the procedures in the above characterisation will be used in all future discussion.

A continual restructuring of the perceptual procedures has been postulated. Only certain aspects have been concentrated on. Aspects such as colour, texture, size, position on the table, etc., have been ignored, although they are obviously included in, and become differentiated from, the analysis of the total event. This model indicates that there is a restructuring process; that the perceptual structuring at different stages of development is different; and that the form of this development is from a global, undifferentiated whole, towards the ability to construct any of the parts, and their relation to the total event. Attention should be focused on these features of the model, rather than on its specific details.

9.2.8 Dissociation of the Procedures from Particular Content

Another process is also considered to exist in the development of the perception of the total event. The procedures, e.g. analyse shape, count, compute colour, can operate on many different sets of input. Each will produce a different result. For instance, "analyse shape" can have the results: square/heart/triangle, but the actual procedure used is the same in each case. It has been postulated that the young child cannot think about a procedure except in conjunction with a particular result. This is all a computer can do. However, the computer scientist can look at a program when it is not processing data, and study the relationships it computes. It is argued that the child becomes able to do this with his own procedures, although the process whereby this occurs is not explained, just as there is no idea of how to achieve this by a computer.

The perception of an item (I) is structured by a series of differentiated procedures. Each procedure, and its result, will be represented:

$$\text{pr } n \rightarrow P_n(I,i)$$

where pr n means procedure, number n, and

$$\rightarrow P_n(I,i)$$

is read as the result of pr n when item (I) is analysed to have value i.

For instance, if procedure 5 computes the shape of the eyes of item A, this would be characterised:

$$\text{pr } 5 \rightarrow P_5(A,a)$$

where, for instance, a = round eyes.

The young child can only think of a procedure when it is processing specific input to produce a particular result. Abstraction enables thought of the procedure when it is not processing data. The thought of procedure n when dissociated from specific content will be called P_n.

Thus P_5 represents thought of the procedure which computes eye shape independently of any particular item (e.g. A), or any eye shape (e.g. a = round eyes).

An ordered sequence for the abstraction of the various procedures which structure an item is hypothesised. The abstraction of some procedures must be dependent on the prior abstraction of others. A summary of the total set of abstractions is given on Table 9.1 (p.168).

9.2.9 Procedure 1: Clustering of Input

The simplest procedure considered here is that which registers the input and clusters it (pr 1). The ability to think of this dissociated from specific input or results (P_1), is the first postulated to develop.

This means that:

(A) Any item can be thought of as a procedure which organises input into clusters, without specification of those clusters.

(B) Any cluster of any item can be thought of at an abstract level as this procedure dissociated from content.

Once there is the ability to conceptualise a cluster independently of specific input, i.e. as a set of relations that separates one cluster from another, new abstractions, involving procedures that compute additional relationships for the clusters, become possible.

9.2.10 Procedure 2: Analysis into Fgr and Bgr Clusters

Procedure 2 analyses the clusters found by procedure 1 into Fgr and Bgr. After a cluster can be considered independently of specific content (P_1), the Fgr/Bgr relations computed on clusters can be dissociated from specific input and results (called P_2).

This means that:

(A) Any item can be thought of as a set of relations between Fgr and Bgr clusters, no content being specified.

(B) The procedure that computes Bgr and Fgr has the Bgr clusters as one result, the Fgr clusters as another. Therefore this procedure, dissociated from content, unites in thought these two properties of the item: (a) Bgr clusters; (b) Fgr clusters.

(C) The two ways of conceptualising the relation between the Fgr and Bgr:

(a) cluster x contains cluster y;

(b) cluster y inside cluster x;

can now be united in thought by the abstracted procedure. It does not specify the content of either, but rather, the abstracted procedure can generate either. The procedure is "reversible".

9.2.11 Procedure 3: Analysis of the Spatial Relationships between the Fgr Clusters

Dissociation of procedure 1 from content also enables the subsequent dissociation of procedure 3 to be made. Procedure 3 analyses the spatial relations between the Fgr clusters. The first stage of abstraction is postulated to involve the dissociation of the procedure from the specific spatial arrangement of the clusters. However, it is still tied to the fact that the clusters analysed are the Fgr of the item (P_3).

This means that:

(A) The Fgr of any item, whether it is a "face" or a "nonface", can be conceptualised as this set of abstracted relations.

(B) Since this procedure can produce any of the individual relations:

(a) top clusters (= eyes);
(b) middle cluster (= nose);
(c) bottom cluster (= mouth);

when dissociated from content it can allow thought of any of these. Hence it can unite in thought these different properties.

(C) Since this procedure can have a variety of relations as a particular result, it allows understanding of the equivalence of results such as:

(a) cluster x above cluster y above cluster z;
(b) cluster z below cluster y below cluster x.

The procedure is "reversible".

9.2.12 Procedures 5, 6, 7, 9: Analysis of the Shape of a Cluster

The procedure which analyses the shape of a cluster, e.g. the eyes, can also be dissociated from content, once a cluster can be considered as a set of relations dissociated from content (P_1, section 9.2.9).

Dissociated from the analysis of a particular shape, the procedure can enable thought of a cluster of any shape. Hence it can unite in thought clusters of different shapes.

However, a co-ordination of this abstraction with the abstractions detailed in sections 9.2.10 and 9.2.11 (P_2, and P_3) has not yet been achieved. Thus if the shape of the top inside clusters (= eyes), is being analysed, although these clusters can be conceptualised as being of any shape, the thought is still tied to the fact that the clusters are the top inside ones. The two separate properties, "eyes of any shape" and "mouth of any shape" can not yet be united in thought. The necessary higher order abstraction for this has not been achieved (cf. section 9.2.14).

Thus there can be the following thoughts:

Top inside clusters (= eyes) — any shape (P_5)

Middle inside cluster (= nose) — any shape (P_6)

Bottom inside cluster (= mouth) — any shape (P_7)

Outside (= head) — any shape (P_9).

The following abstractions have now been achieved:

(i) P_1: Clustering of input;

(ii) P_2: Analysis into Fgr and Bgr clusters;

(iii) P_3: Analysis of the spatial relationships between the Fgr clusters;

(iv) P_5, P_6, P_7, P_9: Analysis of the shape of particular clusters (eyes, nose, mouth and head, respectively).

The P_1 abstraction is postulated to occur first, followed by all the other abstractions, which are postulated to occur at about the same time as each other. This order of development is necessary because the P_1 abstraction is a prerequisite for the other abstractions. After these other abstractions have been achieved, higher order abstractions which integrate them can occur.

9.2.13 Procedure 4: Analysis of the Spatial Relationships between All the Fgr and the Bgr Clusters

The abstraction described in section 9.2.10 concerning the Fgr/Bgr relations (P_2), allows an understanding to be achieved of how the Fgr as a whole relates to the Bgr. The abstraction described in section 9.2.11

concerning the spatial relations between the Fgr clusters (P_3), gives an understanding of these relations. Co-ordination of these two abstractions allows a consideration to be made of how the spatially organised Fgr clusters relate to the Bgr (P_4).

This means that:

(A) This abstracted set of procedures can generate the relationships between all the Fgr and Bgr clusters for any item (it does not include an analysis of their shapes). Hence any item can be thought of as a set of relations between the Bgr and the spatially related Fgr clusters; the precise nature of the relations (the content of the procedure) would not be specified. This abstract set of procedures can generate these relations for any particular item, and therefore can unite all items in thought at this level.

(B) The different properties, e.g. top inside clusters (= eyes), outside cluster (= head) etc. are all results of these procedures. Hence this abstraction can unite all of them in thought.

(C) There is reversibility of thought for these relationships. Because the abstraction is common to both of the following, it gives an understanding of their equivalence.

(a) Head contains (eyes above nose above mouth);
(b) (Mouth below nose below eyes) inside head.

9.2.14 Procedure 8: Analysis of the Spatial Relationships between the Shapes of the Fgr Clusters

The abstraction of the spatial relations between the Fgr clusters (section 9.2.11, P_3) can be integrated with the abstract shape procedure, as it appears in section 9.2.10:

Top inside clusters (= eyes) – any shape (P_5);
Middle inside cluster (= nose) – any shape (P_6);
Bottom inside cluster (= mouth) – any shape (P_7).

This integration (P_8) will give an understanding of the relation between the individual shapes of the Fgr clusters and the spatial arrangement they make with one another.

Whereas before, the child could think of either "eyes of any shape" (P_5), or "any spatial arrangement between the Fgr clusters" (P_3), but he could not think of the co-ordination of both; he now can think of "any spatial relationship between the Fgr clusters of any shape" (P_8). (These sentences are descriptions of the relationships available to the child and it is not implied that the child's thought is these sentences.)

This means that:

(A) The Fgr of any item can be conceptualised by this abstract set of procedures.

(B) These abstracted procedures can generate any of the parts of the Fgr of any item. Hence they can unite in thought any of the parts; e.g. they can unite in thought the two properties: "eyes of any shape" and "mouth of any shape".

9.2.15 Procedure 10: The Abstract Co-ordination of All Relationships

The previous two sections have described the following abstractions:

(i) P_4: Analysis of the spatial relationships between all the Fgr and the Bgr clusters (no shape analysis);

(ii) P_8: Analysis of the spatial relationships between the shapes of the Fgr clusters.

After these abstractions have been achieved, they can be co-ordinated to give comprehension of the total set of relations involved in the perception of an item. This final abstraction (P_{10}) co-ordinates the spatial relationships between the shapes of the Bgr and Fgr clusters.

This means that:

(A) This abstracted set of procedures can generate the total perception of any item. Hence it gives a conceptualisation of the structure of any item, independently of content.

(B) It can generate any of the properties of an item concerning the Bgr/Fgr clusters, their spatial relations, and their shapes. Hence it can unite in thought any, or all of them.

9.2.16 Summary

The developmental process described above progresses from the differentiation of the parts of a total perception, to the dissociation of the procedures from particular content. Finally, the structure of the total event can be conceptualised by an abstract set of co-ordinated procedures.

For convenience, this process has been divided into a succession of stages. Certain differentiations and abstractions must occur before others. The term "Developmental *Period*" has been used to avoid confusion with the developmental *stages* that were derived from the data of experiment 2. However, the correspondence between the two will be detailed later.

The hypothetical sequence of development is summarised in Table 9.1. When a procedure is termed "differentiated" this means that it can be used by itself, apart from the total construction of the event. Its results are available for use by other procedures. When a procedure is termed as "abstracted" this means that it is dissociated from particular content. The first column on the left lists the procedures into which the total perception eventually can be differentiated by Developmental Period E. The course of development of each one is mapped across the page, the subsequent columns indicating successive developmental periods.

Table 9.1: The development of PERCEIVE.

Procedures	A	B	C	D	E	F	G
	Theoretical Development Periods						
1. Cluster input	UNDIFFERENTIATED (rows 1–9)	UNDIFFERENTIATED (rows 1–7)	Differentiated → $P_1(I,i)$	Abstracted → P_1		Abstracted spatial relationships between the Fgr and Bgr clusters → P_4 (rows 1–4)	All relationships abstracted → P_{10} (rows 1–10)
2. Fgr and Bgr clusters			UNDIFFERENTIATED (rows 2–4)	Differentiated (uses pr 1) → $P_2(I,i)$	Abstracted → P_2		
3. Spatial relations of Fgr clusters				Differentiated (uses pr 2) → $P_3(I,i)$	Spatial relations abstract, tied to Fgr → P_3		
4. Spatial relations of Fgr and Bgr clusters				UNDIFFERENTIATED	Differentiated (uses pr 2 and 3) → $P_4(I,i)$		
5. Shape of the top Fgr cluster			Differentiated (uses pr 1) → $P_5(I,i)$	Restructured to use pr 3 → $P_5(I,i)$	Shape abstracted, tied to "top Fgr clusters" → P_5	Abstracted spatial relationships between the shapes of the Fgr clusters → P_8 (rows 5–8)	
6. Shape of the middle Fgr cluster			Differentiated (uses pr 1) → $P_6(I,i)$	Restructured to use pr 3 → $P_6(I,i)$	Shape abstracted, tied to "middle Fgr cluster" → P_6		
7. Shape of the bottom Fgr cluster			Differentiated (uses pr 1) → $P_7(I,i)$	Restructured to use pr 3 → $P_7(I,i)$	Shape abstracted, tied to "bottom Fgr cluster" → P_7		
8. Shape of the total Fgr		Differentiated → $P_8(I,i)$	Restructured to use pr 5, *or* pr 6 *or* pr 7 → $P_8(I,i)$	Restructured to use prs 5, 6, 7 together → $P_8(I,i)$	→ $P_8(I,i)$		
9. Shape of the Bgr cluster		Differentiated → $P_9(I,i)$	Restructured to use pr 1 → $P_9(I,i)$	Restructured to use pr 2 → $P_9(I,i)$	Shape abstracted, tied to "Bgr cluster" → P_9	→ P_9	
10. Shape of the total item	Global construction → $P_{10}(I,i)$	Restructured for use of pr 8 *or* pr 9 → $P_{10}(I,i)$	Restructured to use prs 1 and 8, *or* prs 1 and 9 → $P_{10}(I,i)$	Restructured to use prs 2, 8, 9 together → $P_{10}(I,i)$	Restructured to use prs 4, 8, 9 together → $P_{10}(I,i)$	→ $P_{10}(I,i)$	
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
			Experimental Developmental Stages				

Acquisitions in a left hand column must occur before those in a right hand column. Two additional developmental periods, F and G, have been hypothesised to occur after Developmental Period E to cover the course of abstraction of all the procedures.

9.3 CLASSIFICATORY BEHAVIOUR

The development of the perception of an item proposed above now has to be related to the development of classificatory behaviour. Classificatory behaviour will be characterised by three sets of procedures:

PERCEIVE
COMPARE
PUT TOGETHER

PERCEIVE has just been discussed. COMPARE and PUT TOGETHER are hypothesised to operate on the results of PERCEIVE. This means that the procedures of PERCEIVE have to be differentiated from the total construction process before their results can be used by COMPARE and PUT TOGETHER. The general nature of the classificatory procedures will be discussed first, before their relation to the experimental results is outlined.

The perception of an item (I) is structured by a series of differentiated procedures. Each procedure (n) and its result has been represented:

$$\text{pr } n \rightarrow P_n(I,i)$$

where pr n means procedure number n, and

$$\rightarrow P_n(I,i)$$

is read as the result of pr n when item (I) is analysed to have value i.

To exemplify the proposed relationship between PERCEIVE, COMPARE and PUT TOGETHER the classification of two items (A) and (B) will be considered with respect to a single property which is analysed by PERCEIVE procedure n.

($\doteqdot$ means either = (same) or $\neq$ (different).)

PERCEIVE (A) PERCEIVE (B)

pr n $\rightarrow P_n(A,a)$ pr n $\rightarrow P_n(B,b)$

COMPARE $(P_n(A,a),\ P_n(B,b)) \rightarrow P_n(A,a) \doteqdot P_n(B,b)$

If $P_n(A,a) = P_n(B,b)$

PUT TOGETHER $(P_n(A,a),\ P_n(B,b)) \rightarrow$ Spatial arrangement of $(P_n(A,a),\ P_n(B,b))$ together.

This characterisation indicates that both COMPARE and PUT TOGETHER process the products of PERCEIVE. In this case the products of PERCEIVE, procedure n, are $P_n(A,a)$ and $P_n(B,b)$. For instance, if procedure n analyses eye shape, and items A and B both have cross eyes, then COMPARE $(P_n(A,a),\ P_n(B,b))$ means "Compare the cross eyes of item (A) with the cross eyes of item (B)".

It is postulated that the young child can only think of COMPARE and PUT TOGETHER when they are processing specific products of PERCEIVE (e.g. $P_n(A,a)$ and $P_n(B,b)$) in order to produce specific results (e.g. $P_n(A,a) = P_n(B,b)$).

Since the collection so formed (PUT TOGETHER) and the reasons for its formation (COMPARE) are fully tied to the specificities of items (A) and (B), the child lacks any general characterisation of the (A,B) collection which could specify how this collection should be extended to include new items.

For instance, if "COMPARE (P_n(A,a), P_n(B,b)) → P_n(A,a) = P_n(B,b)" represents "Compare the cross eyes of item (A) and the cross eyes of item (B); this shows that the cross eyes of item (A) are the same as the cross eyes of item (B)", this representation does not specify how a new item (I) should compare with item (A) or item (B) if it is legitimately to join the (A,B) collection. A more general thought such as "Compare the eyes of any items; this shows they have the same cross eyes" is required. This general thought would be common to the comparison of items (A) and (B) as well as to the comparison of item (A) or item (B) with any other new item which could legitimately join the collection. The ability to form such a general characterisation will be discussed later. It is hypothesised that young children do not have this ability.

Similarly their thoughts of PUT TOGETHER are tied to the specificities of the items which are placed together. Hence these children can have no general characterisation of the extension of a class. This lack of generality also means that the child cannot cross-multiply. For instance, the following characterisations of two collections which must be cross-multiplied are too specific to be co-ordinated in thought.

PUT TOGETHER (P_n(A,a), P_n(B,b)) → (P_n(A,a), P_n(B,b)) in a horizontal row;

PUT TOGETHER (P_n(C,c), P_n(D,d)) → (P_n(C,c), P_n(D,d)) in a vertical column.

These are the two different results of the PUT TOGETHER procedure for the two collections which must be cross-multiplied. They cannot both be considered simultaneously because they are incompatible, unrelated thoughts. To cross-multiply, both collections must be characterised by the same abstract procedure which is independent of specific items and the specific spatially arranged collections they make together. This abstraction would allow understanding of the relationship between the two collections, and could generate the specificities of either.

The ability to think of a procedure dissociated from particular content has already been discussed in the context of PERCEIVE.

COMPARE and PUT TOGETHER operate on the results of PERCEIVE, therefore each stage in their abstraction cannot occur until after a corresponding abstraction of PERCEIVE. The following development of the abstraction of COMPARE and PUT TOGETHER when processing the results of procedure n of PERCEIVE is hypothesised.

1. No abstraction of PERCEIVE, COMPARE or PUT TOGETHER.
2. For the first time procedure n is dissociated from particular content. Thus $P_n(A,a)$ can be understood as the set of relations computed by procedure n independently of the specific (A,a) content. So can $P_n(B,b)$. This abstraction has been called P_n.
3. A further set of abstractions concerning how COMPARE and PUT TOGETHER operate on P_n has to be achieved before COMPARE and PUT TOGETHER can be considered independently of specific content. These are discussed below.

9.3.1 Abstraction of COMPARE

$$P_n(A,a) = P_n(B,b): \quad \text{(same), and}$$

$$P_n(A,a) \neq P_n(B,b): \quad \text{(different)}$$

are two different results of the same COMPARE procedure. If the COMPARE relationships can be considered independently of specific items (A) and (B), and specific results "same" and "different", then there can be thought of any comparison between any items with respect to the results of procedure n (P_n). This abstracted COMPARE procedure will be called

COMPARE (P_n). COMPARE (P_n) does not specify what items are compared, what values of P_n they take, or whether the result is "same" or "different".

When generating a particular comparison COMPARE (P_n) will undergo progressive specification. For instance:

1. COMPARE (P_n)

   (This does not specify the items compared, their values on P_n, or whether the result is "same" or "different".)

2. COMPARE (P_n) $\rightarrow P_n = P_n$

   (This does not specify the items compared, nor their values on P_n. It does specify the result "same".) Similarly,

   COMPARE (P_n) $\rightarrow P_n \neq P_n$ specifies the result "different".

3. COMPARE (P_n) $\rightarrow P_n(A,a) = P_n(B,b)$

   (This specifies the items compared, their values, and the result "same".)

Thus COMPARE (P_n) allows thought of COMPARE independently of any specific items or values, but it specifies that the comparison is with respect to P_n. It can unite in thought all the more specific comparisons which it can generate. For instance, if P_n was the analysis of eye shape, COMPARE (P_n) could unite in thought a set of mutually exclusive classes based on eye shape, because it is common to the comparisons involved in the construction of each individual class.

9.3.2 Abstraction of PUT TOGETHER

$(P_n(A,a), P_n(B,b))$ in a horizontal row, and

$(P_n(C,c), P_n(D,d))$ in a vertical column

are two different results of the PUT TOGETHER procedure. If PUT TOGETHER can be conceptualised independently of the specific values of procedure n, of the specific items, and of the specific spatial configurations so made, then there can be a general characterisation of any collection formed, and there can also be a co-ordination in thought of a number of different collections.

This abstracted PUT TOGETHER procedure will be called PUT TOGETHER (P_n). This does not specify specific values of P_n, specific items, or their specific spatial configurations, however it does specify that P_n is processed.

When generating a particular collection, PUT TOGETHER (P_n) will undergo progressive specification. For instance:

1. PUT TOGETHER (P_n)

   (This does not specify the items put together, nor their values on P_n, nor their spatial arrangement.)

2. PUT TOGETHER (P_n) $\rightarrow$ P_n in a horizontal row; or

   PUT TOGETHER (P_n) $\rightarrow$ P_n in a vertical column.

   (These specify the type of collection (row or column), without specifying the particular items and their values on P_n.)

3. PUT TOGETHER (P_n) $\rightarrow$ (P_n(A,a), P_n(B,b)) in a horizontal row.

   (This specifies the items put together, their values on P_n, and the resulting configuration of the collection.)

The above COMPARE and PUT TOGETHER abstractions enable:

(i) The achievement of a consistent continuation of an existing collection (with respect to P_n);

(ii) The achievement of the cross-multiplication of two collections (with respect to P_n).

These will be discussed in turn.

9.3.3 Consistent Continuation of a Collection

If items (A) and (B) are classified together with respect to property n, the procedures used, both dissociated from content, and with progressive specification, are:

	Abstract	1st Specification	Total Specification
PERCEIVE	pr n → P_n		P_n(A,a); P_n(B,b)
COMPARE	→ COMPARE (P_n)	$P_n = P_n$	P_n(A,a) = P_n(B,b)
PUT TOGETHER	→ PUT TOGETHER (P_n)	P_n in horizontal row	(P_n(A,a), P_n(B,b)) in horizontal row

For any new item (I) to join the (A,B) collection its classification with (A) or (B) must obey the "abstract" and the "1st specification" of the classificatory procedures for (A) and (B). The final "total specification" will of course be different from that for (A) and (B).

For instance, classifying (A) and (I):

	Abstract	1st Specification	Total Specification
PERCEIVE	pr n → P_n		P_n(A,a); P_n(I,i)
COMPARE	→ COMPARE (P_n)	$P_n = P_n$	P_n(A,a) = P_n(I,i)
PUT TOGETHER	→ PUT TOGETHER (P_n)	P_n in horizontal row	(P_n(A,a), P_n(I,i)) in horizontal row

The "abstract" and "1st specification" of the classificatory procedures is identical for both the (A,B) and the (A,I) classifications. Hence the two can be united in thought. These abstractions provide an understanding of how all the items within a collection must be similar. If "$P_n \neq P_n$" is obtained as the "1st specification" when (A,I) are compared, then (I) cannot go in the (A,B) collection.

9.3.4 Cross-Multiplication

The characterisation of the (A,B) collection above will be considered as one of the collections which must be cross-multiplied. The other one will be:

	Abstract	1st Specification	Total Specification
PERCEIVE	pr n → P_n		$P_n(C,c)$; $P_n(D,d)$
COMPARE	→ COMPARE (P_n)	$P_n \neq P_n$	$P_n(C,c) \neq P_n(D,d)$
PUT TOGETHER	→ PUT TOGETHER (P_n)	P_n in vertical column	($P_n(C,c)$, $P_n(D,d)$) in vertical column

The two collections (A,B) and (C,D) can represent the intersecting row and column of a matrix, where the intersecting item has to be found. Usually (C,D) would be similar to each other on a second property, while (A,B) would be different on that property. Integration of the two properties is postulated to involve a higher order abstraction, and will be considered later, in the context of the particular materials used in the previous experiments. At the moment attention is focused on the ability to consider the row and the column simultaneously.

The abstract procedures:

PERCEIVE	pr n → P_n
COMPARE	→ COMPARE (P_n)
PUT TOGETHER	→ PUT TOGETHER (P_n)

are common to the analysis of the row collection and the column collection, and hence can unite both in thought. Subsequently different specificities are generated for the two collections from this common characterisation.

9.4 THE RELATION BETWEEN THE EXPERIMENTAL AND THEORETICAL STAGES

The theoretical analysis of PERCEIVE was divided into Developmental Periods A to G (summarised in Table 9.1). The analysis of the experimental results divided the children's behaviour into classificatory stages 1 to 6. The correspondence between these will now be made.

The abstraction of COMPARE and PUT TOGETHER when processing a particular PERCEIVE procedure is hypothesised to develop after the abstraction of that PERCEIVE procedure. For convenience, it is argued that the COMPARE and PUT TOGETHER abstractions occur one developmental period after the PERCEIVE abstraction.

9.4.1 Developmental Period A

At Developmental Period A only a global perception of an item can be computed. This will include specificities of time and place which give each item a uniqueness which does not enable a comparison to be made between two items; they are always different.

9.4.2 Developmental Period B

Developmental Period B was given as an illustration of a step in the process of differentiation. It was hypothesised that some aspects of the perception can be differentiated from the globality of the total event. Hence some comparisons between different events are possible. For current theoretical requirements the exact nature of this developmental period is not important.

9.4.3 Developmental Period C: Stage 1

This period is thought to characterise the behaviour of the children in the lowest stage of development investigated in the present experiments (Stage 1). Stage 1 was characterised experimentally by the following behaviours:

(i) An ability to make comparisons on any of the properties: head, eyes, nose, mouth, features as a whole, item as a whole; together with an inability to switch flexibly from comparisons on one of these properties to comparisons on another;

(ii) An inability to construct items up-side-down;

(iii) An inability to understand the face/nonface dichotomy.

These behaviours are generated by the procedures available at Developmental Period C. Each will be discussed in turn.

At Developmental Period C each of the following parts are available as products of differentiated procedures: head, eyes, nose, mouth, features as a whole, item as a whole. However, at this period the perception of an item which differentiates the head does not also differentiate the features, and vice versa. Hence there can be no switching between, for instance, comparing the eyes and comparing the head. To do so the mode of perception has to be changed from the mode that differentiates the eyes, to the one that differentiates the head. COMPARE and PUT TOGETHER have to be changed from processing the results of the former to processing the results of the latter. These two ways of operating are incompatible at this level of specificity. There can only be thought of one or the other, but not of both.

This lack of differentiation of all the parts within a single perception of an item also means that there can be no ability to construct an item up-side-down. To construct an item up-side-down, it is hypothesised that each part must be considered both as a separate entity, and in its relation to the whole.

Additionally, there can be no understanding of the face/nonface dichotomy, since procedure 3, which computes the relationships between the features independently of their shapes, is not available as a differentiated procedure at this period. At this period the relationships between the features can only be considered in the context of the features as a whole, where particular shapes are also computed (pr 8).

9.4.4 Developmental Period D: Stage 2

Stage 2 was characterised by the following behaviours:

(i) A moderate to flexible ability to switch between comparisons on different properties;

(ii) The first ability to construct an item up-side-down;

(iii) Relative success with the face/nonface sort;

(iv) The use of two item comparisons when continuing a collection (rather than the use of the structure of the whole collection);

(v) A lack of cross-multiplication.

These behaviours are generated by the procedures which were postulated to characterise Developmental Period D. Each of these behaviours will be accounted for in turn. At Developmental Period D a single perception of an item can be differentiated into the following procedures:

PERCEIVE

pr 1: Register input and cluster
pr 2: Analyse into Fgr and Bgr clusters
pr 3: Compute the spatial relations between the Fgr clusters
pr 5: Compute the shape of the top Fgr clusters
pr 6: Compute the shape of the middle Fgr clusters

pr 7: Compute the shape of the bottom Fgr cluster
pr 8: Compute the shape of the total Fgr
pr 9: Compute the shape of the Bgr cluster
pr 10: Compute the shape of the whole item.

Differentiation of all these properties within one method of constructing the item enables the achievement of the first ability to switch between comparing the various properties. When the child compares two items on eye shape (procedure 5) he must use procedure 3 to find the eye clusters, before he can analyse their shape. Similarly, when comparing mouth shape, he must use procedure 3 to find the mouth cluster, before he can analyse its shape. Thus comparison of both eye shape and mouth shape have in common the use of procedure 3. This can mediate the switch from comparing eye shape to comparing mouth shape. A switch between comparing the head shape and comparing one of the features, for instance the eyes, will be more difficult, because they have less in common, and the relationships between them are more complex. They have procedure 2 in common, but after procedure 2, procedure 3 has to be used for analysing the eyes, but not for analysing the head. The relationships between the two is thus much less direct than that between the eyes and the mouth.

Differentiation of all the parts of an item within a single method of constructing the whole item also enables the achievement of the first ability to construct items up-side-down, since all the parts are separately analysed and then co-ordinated to form the whole.

The new differentiation at this period of procedure 3, which analyses the spatial relations between the Fgr clusters before their shapes are analysed, enables the first understanding of the face/nonface dichotomy to be achieved.

At Developmental Period D all the PERCEIVE procedures (except procedure 1) are fully dependent on specific content (cf. Table 9.1). The abstraction of procedure 1 is occurring for the first time. Hence COMPARE and PUT TOGETHER are also dependent on specific content, and there can be no consistent continuation of an existing collection which obeys the structure of the whole collection, and no cross-multiplication. The reasons for this were discussed earlier (sections 9.3.3 and 9.3.4).

9.4.5 Developmental Period E: Stage 3

Stage 3 was characterised by the ability to consider both the row and the column when completing a matrix, together with a predominance of two item comparisons for each of the criterion properties (instead of using the structure of the whole collection). This behaviour is generated by the state of the procedures at Developmental Period E.

In Developmental Period D (Stage 2) the first ability to use PERCEIVE procedure 1 dissociated from specific results (P_1) was postulated. This means that at the next Developmental Period (E, Stage 3) the processing of this procedure by COMPARE and PUT TOGETHER can be dissociated from specific results. PERCEIVE procedure 1 analyses the input into clusters. Abstracted it gives an understanding of any item as a set of relations for analysing clusters. Abstraction of COMPARE and PUT TOGETHER (while processing procedure 1) from any specific results (same/different; horizontal row/vertical column) enables the achievement of the first ability to cross-multiply. This is possible because both of the collections (row and column) which must be cross-multiplied have in common the following abstractions:

PERCEIVE pr n $\rightarrow$ P_1
COMPARE $\rightarrow$ COMPARE (P_1)
PUT TOGETHER $\rightarrow$ PUT TOGETHER (P_1)

(cf. section 9.3.4).

These abstractions allow simultaneous thought of both collections at this abstract level. This mediates the switching from consideration of the specificities of one collection to consideration of the specificities of the other collection. However, the critical properties in both collections are the head, the eyes and the mouth shapes. COMPARE and PUT TOGETHER are not yet abstracted for these properties, therefore when there is an attempt to use these properties as criteria for continuing the row or the column, in order to complete the matrix, two item comparisons will be used. The general structure of the whole collection for these properties cannot be conceptualised.

Additionally, switching between comparing head shape and comparing one of the features (e.g. the eyes) becomes easier because procedure 4, which co-ordinates the spatial relationships between all the Fgr and Bgr clusters, has been differentiated for the first time. This procedure would be common to the analysis of head shape and to the analysis of eye shape. Hence it can mediate the switch between comparing eye shape and comparing head shape. However, this is still a more complex set of relationships than that between the eyes and the mouth.

9.4.6 Developmental Period F: Stage 4

Experimental Stage 4 was characterised by the ability to use the structure of the total collection with respect to any one property when continuing a collection, together with an inability to integrate simultaneously all the relevant properties when completing a matrix. It was as if each property was considered in turn, rather than there being any single structure which specified the relationships between all the properties. This behaviour is generated by the procedures at Developmental Period F.

In Developmental Period E (Experimental Stage 3) there is the new ability to think of a procedure which analyses the shape of a cluster independently of specific shapes. However, there is still a dependence on the relationships which specify which cluster in the item is being analysed, e.g. the eyes, the head, etc. Therefore the child can think of:

pr 5: Fgr, top clusters (eyes) – any shape (P_5)
pr 6: Fgr, middle cluster (nose) – any shape (P_6)
pr 7: Fgr, bottom cluster (mouth) – any shape (P_7)
pr 9: Bgr cluster (head) – any shape (P_9)

At the next Developmental Period (F, Stage 4) COMPARE and PUT TOGETHER can be considered as abstracted sets of relations while processing any of the above properties. This means that COMPARE and PUT TOGETHER when processing, say, eye shape, can be thought about independently of specific items, specific eye shapes, or specific results (same/different; horizontal row/vertical column). Thus a row similar on that property, and a column differing on that property can both be characterised by the same set of abstracted procedures:

PERCEIVE pr 5 $\rightarrow$ P_5
COMPARE $\rightarrow$ COMPARE (P_5)
PUT TOGETHER $\rightarrow$ PUT TOGETHER (P_5)

These abstractions can generate the specificities of the row and the column. This accounts for the new appearance at this stage of children using "different criteria" for continuing a collection. For the first time there is the abstract comprehension of the structure of a collection with respect to one of the relevant properties: eyes, mouth or head. These abstractions give an understanding that not only must all items in, say, the row be the same on property n, but that all items in the column must be *different* on property n.

However, there is no ability to unite with a single abstraction, a row similar on one property, and a column similar on a second property, e.g.

row: eye shape similar,
column: mouth shape similar.

Two abstractions are required for this:

1. row: eye shape similar
   column: eye shape different;
2. row: mouth shape different
   column: mouth shape similar.

There can be switching between comparisons on mouth shape and comparisons on eye shape because of the procedures they have in common (procedures 3 and 4).

Thus for any single property considered, there will be a correct continuation of an existing collection. However, there is an inability to co-ordinate the abstractions for several properties at once. This means that when completing a matrix which varies on three properties, each property has to be considered successively, with a *post hoc* attempt to integrate these successive considerations. This leads to a lack of consideration of all the relevant properties, and hence to the belief that several items can complete the matrix.

9.4.7 Developmental Period G: Stage 5

The child at Stage 5 could usually complete a matrix correctly, however he also considered that alternative items would go as "second best". He had no unique criterion of how the matrix should be completed. This behaviour is generated by the procedures at Developmental Period G.

A new PERCEIVE abstraction at Developmental period F (P_8) enables the achievement of new COMPARE and PUT TOGETHER abstractions at Developmental Period G (COMPARE (P_8), PUT TOGETHER (P_8)). Procedure 8 analyses the shape of the Fgr. Abstracted, it can generate any spatially related Fgr cluster, of any shape. Hence the properties: eye shape, nose shape, mouth shape and the shape of the features as a whole, can be united in thought by this one abstract procedure. Thus:

PERCEIVE	pr 8 $\rightarrow P_8$
COMPARE	$\rightarrow$ COMPARE (P_8)
PUT TOGETHER	$\rightarrow$ PUT TOGETHER (P_8)

can generate any comparison for a row or a column, with respect to any of the shapes of the eyes, nose, mouth, or features as a whole. Hence it can unite in thought all of these collections. For instance,

row:	eye shape similar
column:	mouth shape similar

can be simultaneously considered by this one abstraction.

Therefore in a matrix varying on eye, mouth and head shapes, the eye and mouth requirements can be united by the abstraction just described, while a separate abstraction is necessary to characterise the head shape requirement. Thus there is far less likelihood than at Stage 4 of the child omitting to consider one property when completing a matrix. However, since there is no single abstraction to characterise the structure of the whole matrix, the child cannot fully understand how his separate abstractions (one for the Fgr properties, the other for the Bgr property) should be co-ordinated to form the matrix structure. Therefore he is happy to complete the matrix with partially correct items, even though he knows they are "second best".

9.4.8 Experimental Stage 6

At Stage 6, the final stage investigated experimentally, partially correct items would not be considered for a matrix because there was a complete understanding of the structure of the matrix. This can be accounted for by the theoretical model as follows.

The PERCEIVE abstraction (P_{10}) achieved at Developmental Period G (Stage 5) integrated all the relationships utilised in constructing the perception of a whole item in a single abstract form. This abstraction can generate any particular set of perceptual relations, and hence can unite simultaneously in thought all the parts of an item. At Stage 6, the COMPARE and PUT TOGETHER procedures can be considered dissociated from content, when processing this abstraction. Thus:

PERCEIVE pr 10 $\rightarrow P_{10}$
COMPARE $\rightarrow$ COMPARE (P_{10})
PUT TOGETHER $\rightarrow$ PUT TOGETHER (P_{10})

can generate the specificities of any row or column of a matrix, with any combination of properties the same, and any combination of properties different. The structure of the whole matrix can be characterised by this single abstraction. This means that the child can understand that to complete the matrix only one item obeys the structure of the whole matrix, and thus only that item will do.

Table 9.2 summarises the achievements of COMPARE and PUT TOGETHER at each stage. At every stage, analysis of the items begins at the specifics detailed on the left. The specific classification procedures are then abstracted to the greatest degree possible for the stage of development reached. These abstractions are used to generate the particulars for classification of individual items to ensure consistency. Thus a classification involving a new item and an item in an existing

Table 9.2: The level of abstraction of COMPARE and PUT TOGETHER achieved at each stage.

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
pr 1	Use of specific clusters		Abstract use of the clustering relations			
pr 2	UNDIFFERENTIATED	Use of specific Fgr and Bgr clusters		Abstract use of the relations between Fgr and Bgr clusters		
pr 3	UNDIFFERENTIATED	Use of specific spatial relations between Fgr clusters		Abstract use of spatial relations between Fgr clusters, Fgr specified	Abstract use of Fgr-Bgr relations co-ordinated with the spatial relations between the Fgr clusters	
pr 4	UNDIFFERENTIATED		Use of specific spatial relations between all the Fgr and the Bgr clusters			
pr 5	Use of specific shape of "top Fgr clusters" (eyes)			Abstract use of shape, "top Fgr clusters" specified		
pr 6	Use of specific shape of "middle Fgr cluster" (nose)			Abstract use of shape, "middle Fgr cluster" specified	Abstract use of spatial relations of the Fgr clusters co-ordinated with their shape, Fgr clusters specified	Abstract use of the co-ordination of all relations
pr 7	Use of specific shape of "bottom Fgr cluster" (mouth)			Abstract use of shape, "bottom Fgr cluster" specified		
pr 8	Use of specific shape of total Fgr clusters					
pr 9	Use of specific shape of "Bgr cluster" (head)			Abstract use of shape, "Bgr cluster" specified		
pr 10	Use of specific shape of total item					

collection must obey the requirements of the abstractions which are common to the whole collection, although the specifics eventually generated will be different for each item in the collection.

9.5 DISCUSSION

This theoretical model, and the experimental work from which it is derived, exemplify a number of criteria important to Piaget's concept of "*Stage*" [Piaget 1956, Pinard and Laurendeau 1969].

The *hierarchization* criterion, which is a necessary prerequisite for the other criteria, involves the necessity for a fixed order in the developmental sequence of stages. Wohlwill [1966] has criticised the usefulness of this criterion because of the limited number of stages (usually lower, intermediate, and higher), investigated in verification experiments. The present work would seem to overcome Wohlwill's criticisms, and to indicate the importance of this criterion. Six stages of development were described. Empirically, scale analysis of the behaviours investigated and the stages to which the children were assigned, showed evidence of a unidimensional sequence of development. This fixed sequence of development was theoretically necessary since the behaviour of each stage was accounted for by the level of abstraction of the child's schemes. Each new abstraction was dependent on the prior abstractions of the previous stage.

The process of abstraction described involves the second criterion of Piaget's concept of stage: *integration*. This requires that the acquisitions of one stage should integrate those of the previous stage, rather than simply substituting for them. This would involve the differentiation of the "domains *a* and *b* ... at first indistinguishable within an *ab* whole" [Pinard and Laurendeau 1969, p.128], as well as "the coordination of more and more differentiated schemata" [p.129]. This describes exactly the principles used to account for development in the present model.

The third criterion of the concept of stage, *consolidation*, requires that each stage of development, n, simultaneously involves the achievement of the incomplete abilities of stage n-1, and the preparation for stage n+1. This seems a somewhat redundant addition to the previous two criteria. Wohlwill [1966] and Pinard and Laurendeau also have trouble with this characteristic, although the latter try to clarify the consolidation criterion by relating it to the concept of horizontal décalage. While they provide a valuable discussion of horizontal décalage, the way in which it elucidates the preparation-achievement relationship of consolidation is not clear.

The notion of "*structure d'ensemble*" is very important to Piaget's concept of stage. Piaget argues that the schemes or operations of a given stage are not simply juxtaposed in an additive fashion, but are united into a total structure. The strong form of this criterion requires that the acquisition of a concept at a particular stage implies simultaneous mastery of all related concepts. Piaget does at times argue for this strong position: for the structural isomorphism of apparently quite dissimilar concepts, for instance the various concrete operations. The completed elaboration of such structures d'ensemble would not be expected before the end of the appropriate stage. This gives rise to the circular argument that the end of a stage has not been reached until all concepts are fully developed, hence by definition, there must be a structure d'ensemble at the end of the stage.

Experimental investigations of this structural characteristic have revealed an inconsistent set of results. Piaget and his associates report many cases of synchronism; for instance a synchronism between additive and multiplicative classifications and seriations [Inhelder and Piaget 1964, pp.289-290]. However, this, and other, claims of synchronism are typically based on the similarity of ages of emergence of the concepts in different groups of children. When the development of the various concepts is tested within the same group of children asynchronisms have been observed [e.g. Kofsky 1966, Shantz 1967, Dodwell 1962, Tuddenham 1970].

Pinard and Laurendeau argue that these problems can partly be overcome by reducing the range of a structure d'ensemble to a consideration of the constituent relationships which structure one specific concept. Additionally, investigation of this should involve homogeneous objects to limit the influence of horizontal décalage.

The present experimental work has shown close correlations between performance on a variety of tasks measuring different aspects of classificatory ability, using the same sets of materials. This synchronism supports the criterion of a structure d'ensemble, at least within a single conceptual field.

The concept of *equilibration* is the most fundamental, and indispensable criterion of Piaget's concept of stage. Within an ensemble of stages there is a succession of levels of equilibrium.

One way of investigating equilibration is to intervene (e.g. by training) in the development of a concept. Hopefully, this would enable an analysis of the factors responsible for accelerated development to be made. However, as Pinard and Laurendeau point out, many training studies do not model themselves on Piaget's concept of equilibration, but confine themselves to classical learning situations, which are foreign to Piaget's theory. Nevertheless, even if the equilibration process is tapped by the training situations, the problem of the authenticity of the acquisitions remains. It is important to make the distinction between the rote learning of a pseudo-concept and the acquisition of a logical structure. This may be done by testing the generality of the concept acquired. However, this generalisation criterion has its own dangers because of the possibility of horizontal décalage.

The results of the present experiment perhaps could be used fruitfully in this context. A sequence of stages of classificatory behaviour has been established which shows close correspondences to exist between a number of behaviours at each stage of development. If training on one task induced development of logical structures, there should be transfer to the other tasks, which in spontaneous acquisitions develop in parallel.

For instance, transition between Stages 1 and 2 involves greatly improved ability to switch between comparing various properties, to construct items USD, and to sort items into faces and nonfaces. Transition between Stages 3 and 4 involves the use of the structure of the total collection when continuing any row or column, or when cross-multiplying two collections. It also involves understanding the structure of a collection based on differences.

Flavell and Wohlwill [1969] have proposed an alternative model to describe behaviour at different stages of development. In analogy to Chomsky's [1965] distinction between competence and performance in linguistic behaviour, they distinguish two determinants of the child's behaviour in a cognitive task:

(i) The structures of mental operations embodied in the task (competence);

(ii) The actual mechanisms required for processing input and output (automaton/performance).

During the transition between stages, these two determiners of behaviour have a probabilistic character. This is to account for the vacillation of the transitional child between correct and incorrect behaviour, and for the occurrence of horizontal décalages.

However, this model omits any consideration of the change in nature of the internal structures themselves, other than that the probability of their use changes. They are either in competence or they are not. There is no account of the constant restructuring, and the progressive co-ordination of the child's schemes which is an essential part of Piaget's theory, and which forms the crux of the model presented here. The omission of this constructivist aspect from Flavell and Wohlwill's account means that they provide no insight into the developmental process itself; although they may accurately describe at a statistical level the number of correct performances at each stage of development.

For instance, the probability of correctly continuing the left column of the "B" matrices increases with stage of classification (and with age). However, if this is merely described in probabilistic terms the fact that children at different stages seem to perform correctly for different reasons is missed. It seems that when the younger children are correct it is due to a chance fixation on the correct property, at the expense of attention to the other properties; while the older children are correct because they understand the relationships between the properties, and hence classify with respect to one, without forgetting the others.

In the present model, the vacillation of the transitional child, and the lack of generality of schemes across all content, are not dependent on the probability of using a fully developed operation. They occur because the operation is not fully developed. The progressive abstractions of the classificatory schemes (COMPARE and PUT TOGETHER) are always dependent on the prior abstractions of the relationships involved in the specific materials being used (PERCEIVE). Thus the lack of generality of the classificatory schemes across the various contents would not be for probabilistic reasons, but because the schemes are not yet fully differentiated from content.

It must be stressed that the present model represents an initial attempt to specify the progressive abstractions involved in the development of classificatory ability for one set of materials. There is an obvious need for more work of both a theoretical and experimental nature to be directed at this model. However, it is felt that such work will be profitable, and should result in a much sounder analysis of the developmental process than that presented by Klahr and Wallace [1970] or by Flavell and Wohlwill [1969].

CHAPTER 10

GENERAL REVIEW

This study was originally motivated by the difference between two types of theory concerning the development of classificatory behaviour in children. On the one hand, there are those who argue that the child who fails to classify logically does not have the requisite hierarchically ordered semantic features: Bruner [1966] and Anglin [1970] provide examples of this approach. On the other hand, Inhelder and Piaget [1964] argue that from infancy onwards there is some appreciation of similarity between items, but that this appreciation is achieved at different levels of thought depending on the stage of development. The development of concrete operational thought is necessary if the appreciation of similarity is to be used to generate consistent classifications.

If Inhelder and Piaget are correct it would be possible for the child who fails to classify logically nevertheless to exhibit the use of the principle of similarity, but at a lower level of thought. Bruner and Anglin would not predict this since they would argue that such a child would not have the appropriate semantic features.

The difference between these two types of theory was investigated in Experiment 1, which showed that children who failed to classify logically nevertheless showed a build-up of, and a release from, proactive inhibition when items belonging to similar taxonomic classes were manipulated in a short-term-memory task. This result indicated that such children had available the appropriate semantic features for their classifications, and hence that a theory such as Piaget's was required to account for the appreciation of similarity at different levels of thought.

The only alternative way to explain this result is to postulate, as Klahr and Wallace [1970] would do, that the child who fails to classify logically has the appropriate semantic features but lacks additional procedures concerned with classification. However, it was argued that Klahr and Wallace provide no explanation of how the child understands the task and hence works out what he has to do. They merely provide a mechanical set of procedures which the child carries out with no knowledge of why their product is correct.

The inadequacies of Klahr and Wallace's model emphasise the need for an analysis of how equivalence relations are generated, and of how this ability develops through different levels of thought. Piaget provides the most appropriate theory within which to begin such an analysis.

For Piaget, cognitive development involves "a growing dissociation between form and content, form being the generalizable inner aspect of behaviour and content its particular situational manifestation." [Furth 1969, p.190]. However, in his analysis of cognitive development, Piaget is much more concerned with describing the structural nature of "form" than with analysing its relationship to "content". The study reported in this thesis has been concerned primarily with the latter. It was hypothesised that the development of concrete operational thought structures is dependent on the understanding of the materials being manipulated. There is some confusion as to Piaget's position on this issue. On the one hand, he maintains that there is a structural isomorphism between all the concepts acquired at a given stage [Piaget 1956]. This means that the development of the structure of concrete operations implies the simultaneous mastery of all the problems dependent on these operations. On the other hand, he points out the dependence of concrete operations on the content they manipulate:

> "At the level of concrete operations, classes, relations and operational numbers are forms which can be manipulated in their own rights, but ... these manipulations are still tied to content in that the advance is made area by area (from quantity, to weight and then to volume), with a considerable interval between the steps and without immediate or formal generalisation. Only the formal combinatorial structure finally emancipates forms from their content." [Piaget 1969, p.303]

This quotation indicates the two senses in which concrete operations are dependent on content. Firstly, as discussed at length in this thesis, each advance in the abstraction of particular structures, e.g. classificatory schemes, is dependent on the prior advance in the understanding of the specific materials on which they are operating in any given instance. This accounts for the horizontal décalages when the same schemes are applied to different materials.

Secondly, concrete operations, even when fully developed for all content (i.e. there is a "structure d'ensemble"), still cannot be used unless they are operating on actual materials. In contrast, formal operations can be used hypothetically without direct application to any actual situation.

Most experimental studies of these issues have concentrated on the "structure d'ensemble" aspect. Here Piaget's theory has been held to imply that the acquisition of a particular concrete operation with one set of materials must necessarily be accompanied by the simultaneous acquisition of other such operations applied to different sets of materials. When asynchronous development of several concrete operations is found, this is interpreted as a disproof of Piaget's theory [Tuddenham 1970, 1971, Berzonsky 1971].

Pinard and Laurendeau [1969] discuss the problems associated with such investigations. They argue the dangers both of rejecting Piaget's theory on such grounds and of postulating horizontal décalages *post hoc* to explain away all such inconsistencies.

The present study has tried to reconcile the "structure d'ensemble" aspect of concrete operations with their dependence on the content manipulated, by investigating those two factors in the development of classification.

It was hypothesised that the development of classification is dependent on the understanding of the materials being manipulated as well as on the interiorisation of the classificatory schemes. To investigate this hypothesis, materials were constructed which enabled measurements to be made of the child's comprehension of the relationships between part and whole of an individual item, as well as of his ability to classify a number of such items. The child's performance on a series of tasks in Experiment 2 supported the hypothesis that the child's classificatory ability is dependent on his understanding of the relationships within an individual item.

Application of scale analysis to these results indicated that there is a unidimensional sequence of development on all these tasks, and validated the stages of classification developed. However, there were the occasional children whose performance on several tasks was at variance with the general pattern of development. This was especially true of the up-side-down task. Once the general patterns of development have been established, in experiments such as this, future work could most profitably concentrate on children who deviate from this general pattern. Study of such children may help elucidate the specific factors involved in each task, as well as the general cognitive structures which underlie performance on several tasks. There is also a need for the verification by longitudinal studies of the developmental sequences derived from cross-sectional studies such as the one presented here.

In addition to investigating the relationship between understanding an individual item and classificatory ability with a series of such items, the abstraction of the classificatory schemes themselves was investigated.

It was hypothesised that classifications using similarities, and those using differences are generated by the same internal structures, and hence that each child should be at the same stage of classification when using similarities or differences. The results of Experiment 4 supported this hypothesis.

These results tie in with those of Experiment 1, in emphasising that the most profitable way to approach the problem of language development is to refer linguistic abilities (in this case the understanding of "same" and "different") to the underlying thought structures. This cognitive approach to language is gaining popularity [e.g. Sinclair 1969, 1971, Olson 1970, Macnamara 1972], and there is a move away from the syntactic approach such as that elaborated by McNeill [1970].

The current investigations have provided evidence, for one set of materials, that the following two factors are important in the development of classification:

(i) The progressive abstraction of the relationships involved in the construction of individual items;

(ii) The progressive abstraction of the classificatory schemes.

A theoretical model was developed to indicate the co-ordination of these two types of abstraction in the development of classification. This model provides the first attempt to conceptualise the process of abstraction in an explicit manner, and it should be examined in this light. It in no way provides a complete theory. However, it does indicate how such models should be developed, and, therefore, it provides a counter to models such as those developed by Klahr and Wallace, where no attempt is made to explain how the child understands the problem and constructs the relevant task specific routine. Such understanding must be provided by a single abstraction which is common to many specific actions, and hence can combine those actions in thought. Klahr and Wallace fail to provide any mechanism for abstracting common components from similar procedures. The model provided here attempts to do so; this attempt is compatible with Piaget's concept of Stage.

APPENDIX A

MATERIALS USED IN EXPERIMENT 1

A1. CLASSIFICATION TASK

Animals	Food	Clothing	Vehicles	Body-parts	People	Furniture
dog	cake	coat	ship	arm	man	bed
cat	egg	dress	plane	foot	woman	chair
lion	carrot	trousers	bicycle	eye	baby	table
cow	meat	shoe	car	mouth		
sheep	milk	hat				
rabbit						

A2. SHORT-TERM-MEMORY TASK

Animals	Food	Clothing	Body-parts
cat	carrot	jumper	hair
rabbit	egg	hat	leg
horse	apple	skirt	head
sheep	cake	shoe	nose
pig	bread	dress	arm
cow	milk	trousers	foot
dog	meat	shirt	eye
rat	cheese	coat	mouth
bear	potato	sock	ear
lion	jam	tie	face
tiger	biscuit	scarf	hand
monkey	butter	glove	knee

APPENDIX B

THE SCORES OF INDIVIDUAL SUBJECTS IN EXPERIMENT 1

NONCLASSIFIERS

Name	Age	Group	Trials 1	2	3	4	Group	Trials 5	6	7	8
AA	6.0	Ex_1	4	4	2	1	$C'o_1$	2	1	1	1
DB	5.7	"	2	1	1	2	"	0	2	1	1
DB	5.6	"	1	1	0	1	"	2	1	0	2
BC	6.2	"	1	1	1	2	"	2	1	0	0
SH	5.5	"	1	1	2	1	"	2	1	0	1
PM	5.4	"	2	1	1	3	"	2	2	1	2
JM	5.3	"	3	2	2	0	"	4	1	0	0
RW	5.3	"	4	1	2	2	"	2	2	4	2
AL	6.5	"	2	1	0	2	"	2	2	1	1
KM	6.4	"	2	1	0	3	"	1	2	0	1
GR	6.0	"	4	2	1	2	"	4	2	1	1
SW	6.3	"	4	1	0	4	"	2	2	4	2
JH	5.2	"	1	1	1	2	"	1	0	0	1
DP	5.1	"	2	0	0	1	"	2	2	0	0
KA	5.1	"	3	1	1	1	"	1	0	2	1
JL	6.6	"	2	2	1	4	"	2	1	1	1
Total	5.8 (Av.)		39	21	15	31		31	22	16	17

Name	Age	Group	Trials 1	2	3	4	Group	Trials 5	6	7	8
SM	5.5	Co_1	2	2	1	2	$E'x_1$	2	2	0	2
PM	5.7	"	4	4	2	0	"	1	1	2	1
PO	6.0	"	1	1	1	2	"	2	1	1	1
EB	5.6	"	2	1	1	0	"	2	0	0	0
AP	6.0	"	3	2	1	0	"	2	2	2	2
RR	5.7	"	4	3	2	4	"	4	0	1	4
SV	5.8	"	2	1	0	1	"	4	1	0	2
MW	5.5	"	2	1	1	2	"	2	2	0	2
RW	6.2	"	2	2	1	0	"	4	2	0	1
RB	6.3	"	2	1	2	2	"	4	3	2	4
CK	6.0	"	4	1	4	1	"	4	2	4	4
KO	4.11	"	4	1	1	1	"	2	0	0	1
CW	4.11	"	4	1	0	0	"	2	1	1	0
DC	5.2	"	2	0	0	1	"	0	1	0	1
JB	5.7	"	2	2	0	0	"	1	0	0	1
JC	5.10	"	2	0	0	0	"	2	1	0	1
Total	5.8 (Av.)		42	23	17	16		38	19	13	27

Appendix B (continued)

NONCLASSIFIERS

Name	Age	Group	Trials 1	2	3	4	Group	Trials 5	6	7	8
CG	5.7	Ex_2	2	2	4	4	$C'o_2$	4	2	1	1
RM	5.10	"	2	0	0	1	"	4	1	1	1
RL	5.8	"	4	1	0	4	"	2	1	0	0
AM	5.9	"	3	1	1	1	"	4	1	0	0
PW	5.6	"	1	0	1	2	"	2	3	0	0
CD	6.0	"	2	1	1	2	"	2	0	0	0
JB	5.6	"	4	0	1	0	"	2	2	1	0
KD	5.2	"	4	2	1	2	"	3	2	0	0
TH	5.4	"	2	2	0	3	"	2	1	1	1
TK	5.0	"	4	0	2	2	"	2	1	0	0
AO	5.0	"	2	1	0	1	"	1	0	0	2
JW	6.5	"	2	0	2	4	"	4	1	2	1
BP	5.0	"	2	0	1	4	"	2	0	0	4
DH	6.10	"	4	3	2	3	"	4	0	2	0
JW	6.5	"	2	2	1	4	"	1	1	0	2
LN	5.6	"	2	1	2	1	"	2	0	2	1
Total	5.8 (Av.)		42	16	19	38		41	16	10	13
MC	5.7	Co_2	1	0	1	1	$E'x_2$	4	2	1	2
JF	5.7	"	2	1	0	2	"	2	2	0	1
MF	5.7	"	2	1	0	1	"	2	0	0	2
NG	5.5	"	2	1	2	1	"	2	1	0	0
CH	5.7	"	2	2	0	0	"	1	0	0	0
KR	5.8	"	4	1	0	0	"	4	0	1	1
SS	5.10	"	1	4	0	4	"	4	1	0	0
JH	5.1	"	3	1	0	1	"	2	1	0	2
FT	5.0	"	2	1	0	0	"	2	0	0	2
DR	5.6	"	3	2	0	1	"	2	1	0	3
MH	5.9	"	3	0	2	1	"	2	0	0	0
LN	5.8	"	2	4	2	2	"	4	4	1	4
NB	5.8	"	4	1	1	1	"	2	1	1	2
GM	5.6	"	2	2	1	2	"	4	2	1	2
PP	5.7	"	4	4	1	1	"	4	2	2	2
CB	5.7	"	4	2	2	0	"	4	4	2	4
Total	5.7 (Av.)		41	27	12	18		45	21	9	27

Appendix B (continued)

CLASSIFIERS

Name	Age	Group	Trials 1	2	3	4	Group	Trials 5	6	7	8
CG	6.5	Ex_1	4	0	2	3	$C'o_1$	2	1	1	1
AC	5.10	"	2	1	1	4	"	1	2	0	1
BC	5.9	"	1	1	2	1	"	4	2	0	1
SB	5.8	"	1	2	1	2	"	2	1	1	1
BD	5.5	"	1	2	0	2	"	2	1	0	2
LC	6.6	"	4	2	2	3	"	4	2	1	1
RS	6.2	"	4	1	1	3	"	2	2	2	1
AM	6.4	"	4	2	0	4	"	2	2	0	0
JC	5.9	"	2	1	0	2	"	2	1	0	0
LC	6.2	"	2	2	1	2	"	2	0	0	0
DC	6.2	"	2	0	1	4	"	2	1	0	0
SW	6.1	"	4	2	4	4	"	4	1	1	4
JW	6.8	"	4	4	2	2	"	2	2	4	0
SB	6.8	"	2	4	2	2	"	4	2	2	1
GL	6.9	"	4	2	4	4	"	4	3	2	1
FC	6.4	"	4	2	2	2	"	4	2	4	2
Total	6.1 (Av.)		45	28	25	44		43	25	18	16
DL	5.9	Co_1	4	4	0	1	$E'x_1$	4	2	2	3
BS	6.4	"	4	2	1	2	"	2	3	2	1
CR	5.8	"	2	2	1	1	"	2	2	2	0
GR	5.7	"	4	4	0	0	"	3	2	3	3
KS	5.3	"	2	0	1	0	"	3	2	1	0
SE	6.7	"	4	1	2	4	"	2	1	0	2
MF	6.6	"	2	1	0	2	"	4	4	4	4
MG	6.2	"	4	2	1	0	"	2	1	0	4
RE	5.10	"	4	4	2	4	"	4	1	1	2
JH	6.10	"	4	2	1	1	"	4	2	2	2
KK	6.1	"	2	4	2	1	"	2	0	1	1
ST	6.11	"	2	1	1	1	"	1	0	0	1
JW	6.6	"	4	2	1	2	"	2	1	3	2
SM	6.4	"	3	1	0	2	"	2	2	1	2
RF	6.0	"	4	1	0	0	"	4	1	1	2
MH	6.6	"	4	1	4	4	"	4	4	2	1
Total	6.2 (Av.)		53	32	17	25		45	28	25	30

Appendix B (continued)

CLASSIFIERS

Name	Age	Group	Trials 1	2	3	4	Group	Trials 5	6	7	8
JV	5.6	Ex_2	2	0	1	1	$C'o_2$	1	0	1	1
PR	5.9	"	4	1	4	2	"	4	2	2	0
LW	6.0	"	4	4	2	4	"	4	2	1	2
JS	6.4	"	4	2	1	4	"	4	1	2	1
AC	4.11	"	2	1	2	2	"	4	1	1	1
CA	5.6	"	2	1	1	2	"	4	2	3	1
HM	5.3	"	4	1	0	1	"	4	1	1	2
ST	5.1	"	2	1	1	2	"	2	0	1	0
JD	6.0	"	4	0	4	1	"	4	1	1	2
PO	6.3	"	3	1	1	2	"	2	2	0	1
BS	6.7	"	4	1	2	4	"	2	1	1	2
FE	6.7	"	4	4	1	4	"	4	2	1	1
MD	6.3	"	4	2	2	2	"	2	2	0	0
MP	6.4	"	4	1	2	2	"	2	0	2	1
BD	6.9	"	1	1	1	4	"	4	1	3	0
BH	6.2	"	2	1	1	4	"	4	1	2	0
Total	6.0 (Av.)		50	22	26	41		51	19	22	15
CE	5.8	Co_2	2	2	1	1	$E'x_2$	4	2	2	3
JW	5.8	"	2	2	2	2	"	4	4	2	2
JP	6.5	"	4	1	1	2	"	2	1	1	3
CN	6.6	"	2	1	2	2	"	4	2	2	4
KH	5.6	"	4	2	4	0	"	4	1	1	2
TM	5.9	"	4	2	4	2	"	4	2	0	2
LS	5.5	"	2	2	2	1	"	2	1	1	1
PY	5.1	"	4	2	2	2	"	4	4	0	3
JA	6.7	"	4	1	1	0	"	2	1	0	2
DD	7.0	"	2	4	2	2	"	4	1	2	2
AM	6.3	"	4	4	4	4	"	2	4	4	2
DY	6.1	"	4	1	2	2	"	2	1	2	2
MS	6.1	"	1	1	1	1	"	2	1	0	2
TH	6.5	"	4	1	1	0	"	4	2	1	4
DG	6.5	"	2	4	0	0	"	2	2	2	2
JL	6.3	"	4	2	2	4	"	2	4	2	4
Total	6.1 (Av.)		49	32	31	25		48	33	22	40

APPENDIX C

SCALE ANALYSIS

Guttman's [1950] coefficient of reproducibility measures essentially the degree to which one can reproduce a subject's entire response pattern for a set of items, from knowledge of his total score, and the order of difficulty of the items.

Guttman's methods of scale analysis have been subjected to severe criticisms [e.g. Festinger 1947, Loevinger 1948], because they do not take into account all the relevant data. One of the most serious criticisms is that the coefficient of reproducibility has no unique minimal value, but is drastically affected by the difficulty levels of the items in the test. A number of alternative methods have been suggested for testing the unidimensionality of a set of items.

Loevinger's [1947] coefficient of homogeneity (H_t) is most appealing since it makes the fullest use of the information contained in the response matrix. Loevinger's concept of homogeneity corresponds to Guttman's definition of a unidimensional scale. The coefficient of homogeneity (H_t) has the advantage of fixed maximum and minimum values (unity and zero), and of being independent of the number of items used, and the distribution of item difficulty. The sampling distribution of H_t is unknown, and Loevinger advises that it should not be used as an estimate of homogeneity unless the sample exceeds 100. However, with reference to reproducibility, Willis [1954] suggests that there is no reason to assume that the proportion of error changes according to the size of the sample, so long as the sample size is large in comparison to the number of items.

Loevinger also provides a method of determining a coefficient of homogeneity between each pair of items (H_{ij}), which has a minimum of zero for statistically independent items, and a maximum of unity for perfectly homogeneous items.

Her third statistic, the coefficient of homogeneity between each item and the total test score, (H_{it}), has been criticised by White and Saltz [1957], who point out that it is not clear that a zero value of H_{it} is obtained when there is no relationship between an item and the total test. Also the sampling properties and consequently the value to be expected for a chance relation are not known. They suggest an alternative method of determining the homogeneity between each item and the total test score, derived from the ϕ coefficient (ϕ_{it}). This has the advantage of an absolute maximum of unity and an absolute minimum of zero, a known sampling distribution, and a direct relationship to conventional test procedures.

The above statistics are only applicable when two categories of scoring are used. Therefore, in the present experiments, whenever all scores for a set of items were dichotomous, the following three measures were computed:

(i) H_t: Loevinger's coefficient of homogeneity for the set of items.

(ii) H_{ij}: Loevinger's coefficient of homogeneity between each pair of items.

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

When there were more than two categories of response, different tests had to be used. Goodenough's [1944] method of scalogram analysis, cited by Edwards [1957], seemed to be the most satisfactory for these cases. This method makes a more complete account of errors than does the Cornell technique [Guttman 1947], or that suggested by Jackson [cited by White and Saltz 1957]. It also avoids the problems concerned with the ordering of subjects with the same scores, and the location of cutting points. However, it still has the disadvantage of being affected by the difficulty levels of the items. Jackson [cited by White and Saltz 1957] has developed another statistic, the Plus Percentage Ratio (PPR), which takes into account the minimum reproducibility for the entire test, as well as the coefficient of reproducibility. The PPR has an absolute maximum value of one, and an absolute minimum value of zero.

In the present experiment, when there were more than two categories of response, Goodenough's method of calculating the coefficient of reproducibility was used and Jackson's PPR was calculated for this coefficient. The following measures were computed:

(i) PPR_t: Plus Percentage Ratio for the whole test.

(ii) PPR_{ij}: Plus Percentage Ratio for each pair of items.

(iii) PPR_i: Plus Percentage Ratio for each item.

These correspond to the measures for items with two categories of response only. Both the PPR and Loevinger's coefficient of homogeneity will almost inevitably be considerably lower than the Guttman index of reproducibility. Thus Guttman's requirements of .90 as a measure of scaleability would be too strict. While an acceptable level has not been determined, Jackson suggests that the 70% level may be taken to indicate scaleability. On the other hand, Green [1956], whose index of consistency is similar to Jackson's PPR, suggests .50 as an acceptable level for scaleability, although White and Saltz [1957] maintain this is a slight over-estimate of scaleability. Since the Goodenough method, and Loevinger's employ a more complete count of errors than Jackson's or

Green's, De Lemos [1966] suggests that .60 may be an approximate indication of scaleability for those methods.

A number of studies have applied scale analysis to the investigation of Piaget's developmental stages; e.g. Peel [1959], Wohlwill [1960], Dodwell [1961], Kofsky [1966].

APPENDIX D

PROCEDURES FOR EXPERIMENT 2

D1. TASKS USED IN EXPERIMENT 2

1. Constructing items up-side-down (USD).

2. Sorting items into Face and Nonface groups.

3. Sorting items into two groups on the basis of:

   (a) head shape

   (b) eye shape

   (c) mouth shape.

4. Verbal switching between comparisons on the above 3 properties.

5. *"A" Matrices*

   There were 3 matrices, in each, one of the three properties, (head, eyes, mouth), was constant, the other two varied (cf. Appendix E3).

   Tasks: Completing the matrix.

6. *"B" Matrices*

   There were 3 matrices, in each, all three properties varied (cf. Appendix E4).

   Tasks: (i) Continuing the top row.

   (ii) Continuing the left column.

   (iii) Completing the matrix.

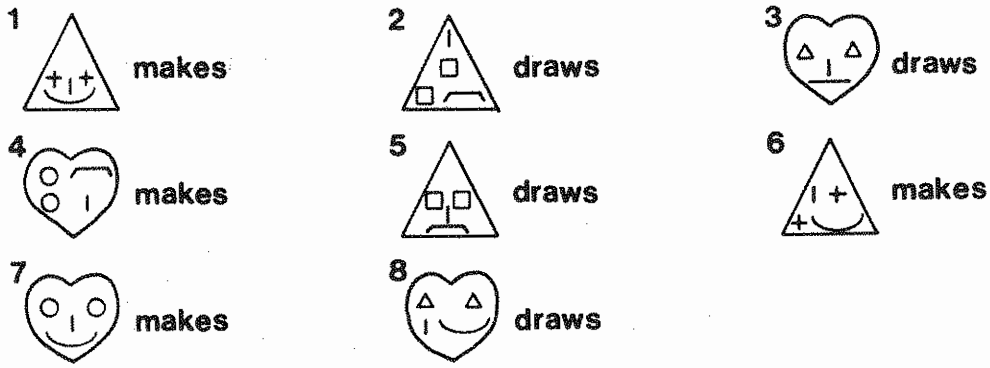
D2. ORDER OF PRESENTATION OF THE TASKS OF EXPERIMENT 2

Session 1	Session 2
1. Face/Nonface sort	1. USD item
2. USD item	2. 1st "B" Matrix
3. Head, eyes, mouth sort	3. USD item
4. Verbal switching	4. 2nd "B" Matrix
5. USD item	5. USD item
6. 1st "A" Matrix	6. 3rd "B" Matrix
7. USD item	7. USD item
8. 2nd "A" Matrix	
9. USD item	
10. 3rd "A" Matrix	

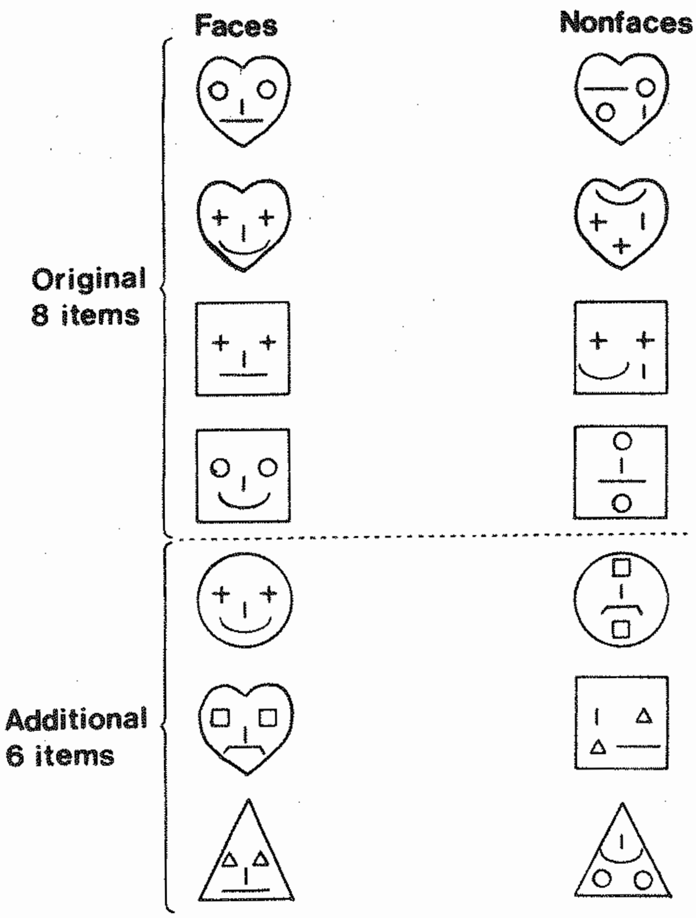
APPENDIX E

MATERIALS USED IN EXPERIMENT 2

E1. UP-SIDE-DOWN ITEMS

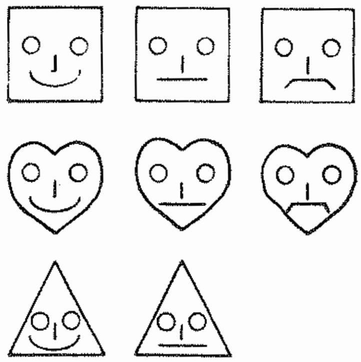


E2. FACE/NONFACE SORT



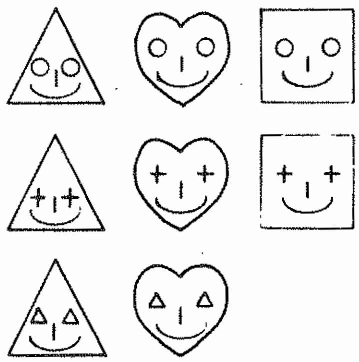
E3. "A" MATRICES — TWO PROPERTIES VARIED

Matrix A1



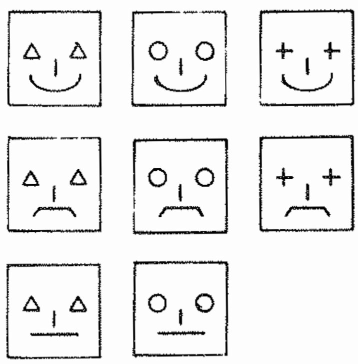
alternatives:

Matrix A2

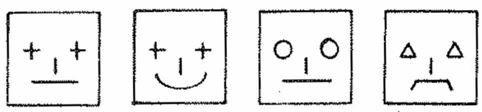


alternatives:

Matrix A3

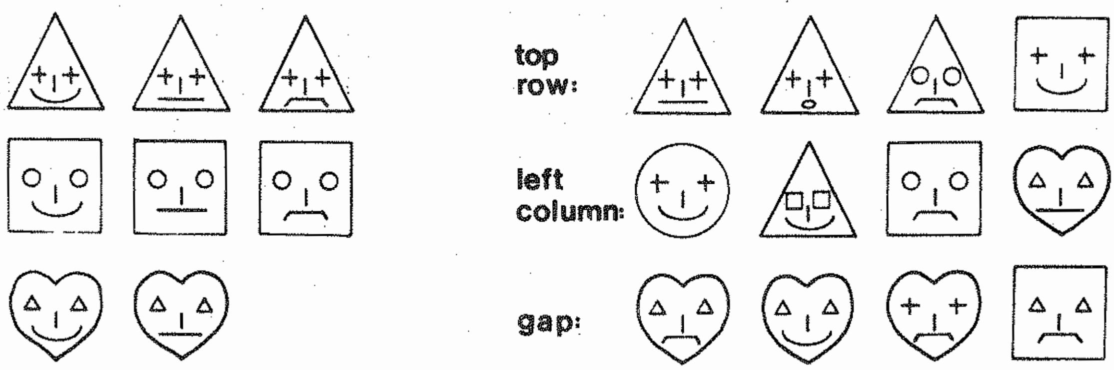


alternatives:

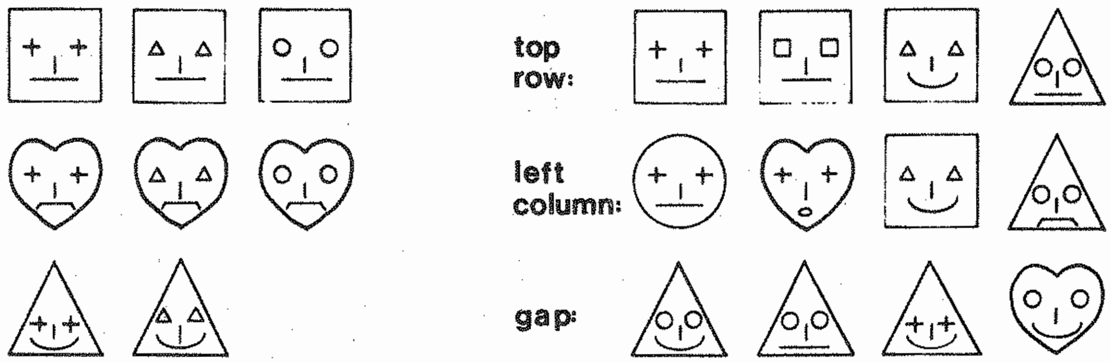


E4. "B" MATRICES — THREE PROPERTIES VARIED

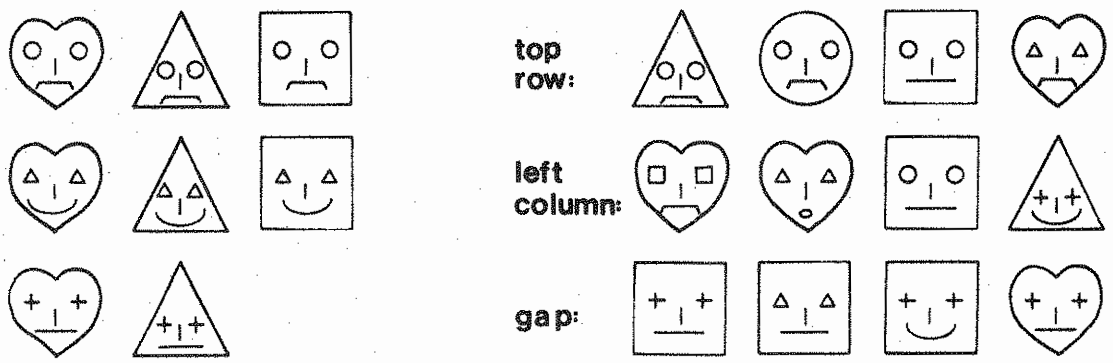
Matrix B1 **Alternatives**



Matrix B2 **Alternatives**



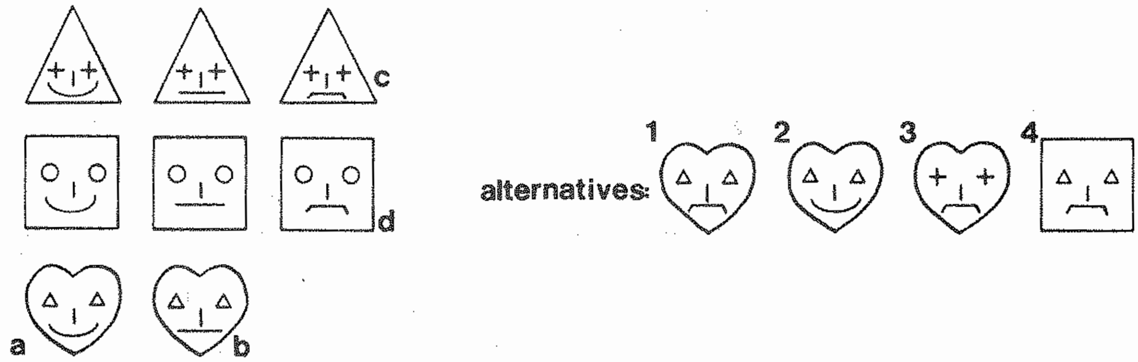
Matrix B3 **Alternatives**



APPENDIX F

PROTOCOLS OF BEHAVIOUR WHEN COMPLETING MATRIX B1

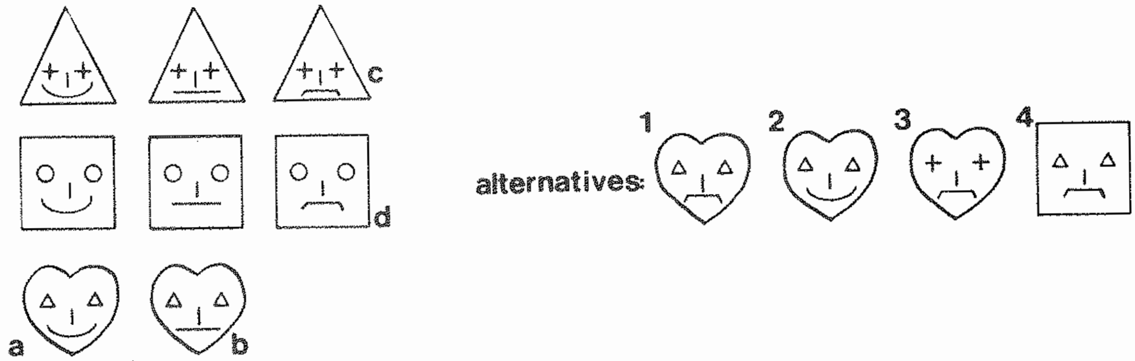
Matrix B1



STAGE 2

C.B. (6;6) chose alternative 2 to complete the matrix, "*Because it's the same as that* (a)". "Is it (2) the same as this one (b)?" "*No.*" "How are these (a, b) the same?" "*Only the eyes is, and the nose and the mouth is not.*" "I want you to find a picture that's the same as both of these (a, b) and both of these (c, d)." He chooses alternative 3, "*The shape is* (the same as a, b) *and not the ... no, the nose is and the mouth is not.*" "Is it (3) the same as these two (c, d) in any way?" "*No.*" "So what would you choose to be the same as both of these (c, d), as well as both of these (a, b)?" He chooses alternative 4. "*That's the same as that* (d) ... *because the mouth, ... the eyes is not.*" "Is it the same as this one (c)?" "*No.*" "Is it the same as these (a, b)?" "*No.*"

Matrix B1



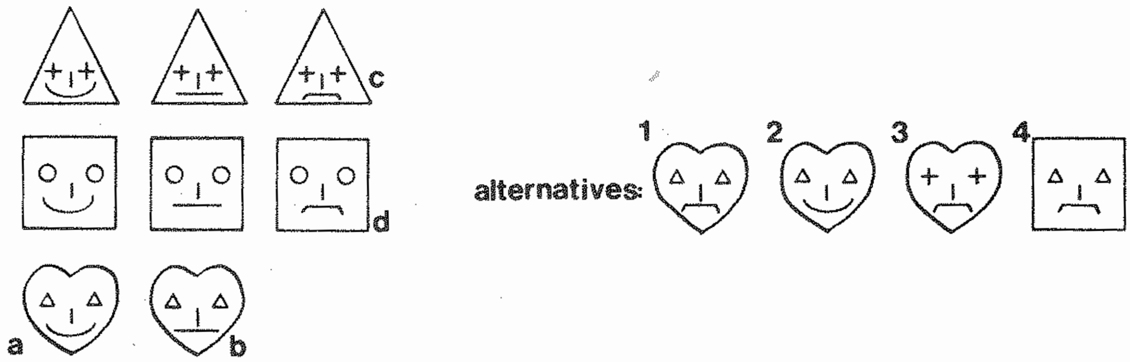
STAGE 3

R.H. (7;9) chooses alternative 3, "*Same eyes as this* (c), *same nose as all of them* (a, b, c, d). *It's the same shape as them* (a, b) *and the same mouth as that* (d)." "Are any other pictures the same as both of these (a, b) and the same as both of these (c, d)?" She chooses alternative 4, "*It's the same shape as this one* (d), *it's the same nose as all of them, it's the same mouth as these two* (c,d), *it's the same eyes as these two* (a, b)." Are these (3 and 4) just as good as each other, or does one go better with both of these (a, b) and both of these (c, d)?" "*They're both as good as each other.*" "Can any others go just as good?" She chooses alternative 1, "*It's got the same eyes as these two* (a, b), *and the same nose as all of them, the same mouth as these* (c, d), *the same shape as these* (a, b)." "Are these (1, 3, 4) just as good, or does one go better with both of these (a, b) and both of these (c, d)?" "*They're all just as good as each other.*"

STAGE 4

T.P. (7;9) chooses alternatives 3, 2 and 1. Alternative 3 can go "*Because with those* (a, b, 3), *they're all hearts, and with those* (c, d, 3), *they've all got those sorts of mouths.*" Alternative 2 can go

Matrix B1

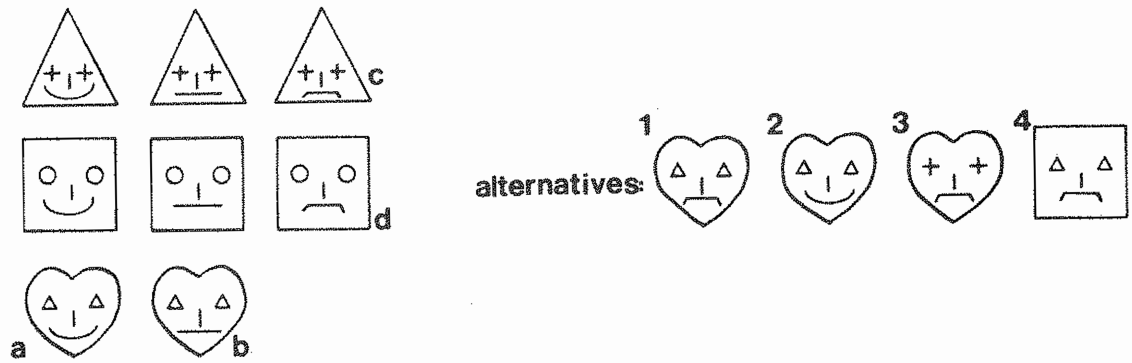


"*Because those* (a, b, 2) *have all got triangle eyes ....*" "Does it go for another reason?" "*No.*" "Can it go in the gap?" "*No, only with those two* (a, b) *it can.*" "Is it as good as this one (3)?" "*No.*" Alternative 1 can go "*Because those* (a, b, 1) *have all got triangle eyes, and those* (c, d, 1) *have all got those sorts of mouths.*" "Are these (alternatives 3 and 1) just as good, or does one go better with both of these (a, b) and both of these (c, d)?" "*They're both as good.*" "Can this one (4) go?" "*No.*" "Why not?" "*It can – Because those* (a, b, 4) *have all got triangle eyes, and those* (c, d, 4) *have all got those sorts of mouths.*" "Are these (1, 3, 4) just as good, or does one go better with both of these (a, b) and both of these (c, d)?" "*They're just as good.*"

STAGE 5

S.B. (9;6) chooses alternative 1 "*Because they've all got mouths like those two* (c, d) *and they're all lovehearts* (a, b, 1) *and they've all got the same shaped eyes* (a, b, 1), *and they've all got noses.*" "Can any other pictures go just as good?" "She chooses alternative 2, "*Because they're hearts* (a, b, 2), *and they've all got the same shaped eyes and noses* (a, b, 2)." "Are these (1 and 2) just as good, or does

Matrix B1



one go better with both of these (a, b) and both of these (c, d)?" She decides alternative 1 is better "*Because that one* (2) *doesn't go with these mouths* (c, d) ... *that's all.*" "Can any other pictures go just as good as this one (1)?" She chooses alternative 4, "*Because its got triangle eyes, and they've all got the same mouths* (c, d, 4), *and they've all got the same noses.*" "Are these (1 and 4) just as good?" She decides alternative 1 is best "*Because its a loveheart and a square can't go next to a loveheart.*"

STAGE 6

E.P. (8;8) chooses alternative 1, "*Because it has the same mouth as those* (c, d), *it has the same eyes as these* (a, b) *and the same nose.*" "Can any others go just as good?" "*No.*" "Why can't this one (2) go?" "*Because there's already a mouth like that there* (a)." "Why can't this one (4) go?" "*Because it's a square.*" "What should it be?" "*Heart, because there's a row of triangles here, a row of squares here, so it has to be a row of hearts here.*" "Why can't this one (3) go?" "*Because it has to have triangle eyes* (for a, b) *and down that way* (column) *there's already those eyes* (c)."

APPENDIX G

PROTOCOLS OF THE BEHAVIOUR OF STAGE 1 CHILDREN ON THE VERBAL SWITCHING TASK

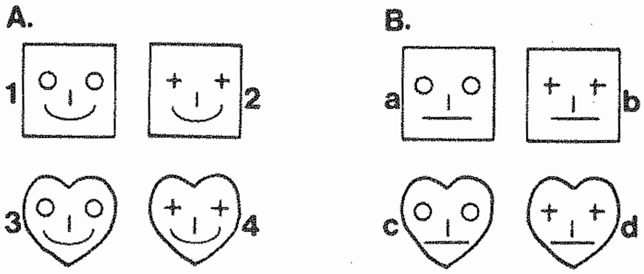


Figure G.1.

M.K. (5;7) was asked to describe the difference (mouth shape) between matrices A and B (Figure G.1).

"How are these four (1, 2, 3, 4) all the same and different from those four (a, b, c, d)?" *"Because these ones* (2, 4) *have cross eyes and these ones* (1, 3) *have round eyes."* "How are these four (1, 2, 3, 4) all the same," *"Because they have round eyes, and another round eyes, and cross eyes."*

E places 2 and 3 apart from the other items. "How are these (2 and 3) the same?" *"Because this one has round eyes and this one has cross eyes."* "Is there anything the same?" *"Not the same eyes."* "Are they the same in any other way?" *"No."* "Are they the same in any way at all?" *"No, these are not the same."*

E asks S to make items 2 and 3 from a set of individual felt pieces. S immediately makes both correctly, using the same mouth shape in both. "When you made this one (2), did you use any of the same pieces as when you made that one (3)?" "*Yes.*" "What?" "*Cross eyes and round eyes.*" "But did you use anything the same?" "*No.*"

There is no doubt that at some level M.K. is perceiving correctly the similar mouths; she makes the items correctly. However, she can only think of comparing items in terms of comparing the eyes.

Similarly, J.C. cannot compare items with respect to the head shapes.

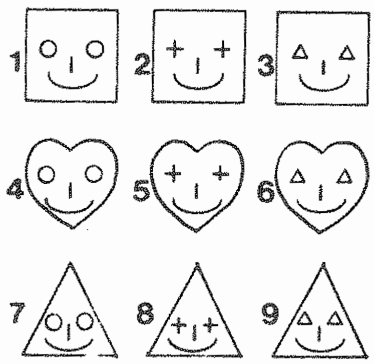


Figure G.2.

J.C. (5;6) was asked to describe how the rows of the matrix shown in Figure G.2 differed.

"How are these three (1, 2, 3) all the same and different from those three (4, 5, 6) and different from those three (7, 8, 9)?" "*That one has circle eyes* (1) *and that one has crosses* (2), *and that one* (3) *has ....*" "Triangles?" "*Triangles.*" "That's how those three are different, how are they the same?" "*That has circles* (1), *that has crosses* (2), *and that has triangles* (3)." "But that's how they're different, are they the same in any way?" "*That's the Mother one, and that's the children.*"

E places 1 and 4 apart from the other items. "What's the difference between those two." "*That one has circle eyes and that one has.*"

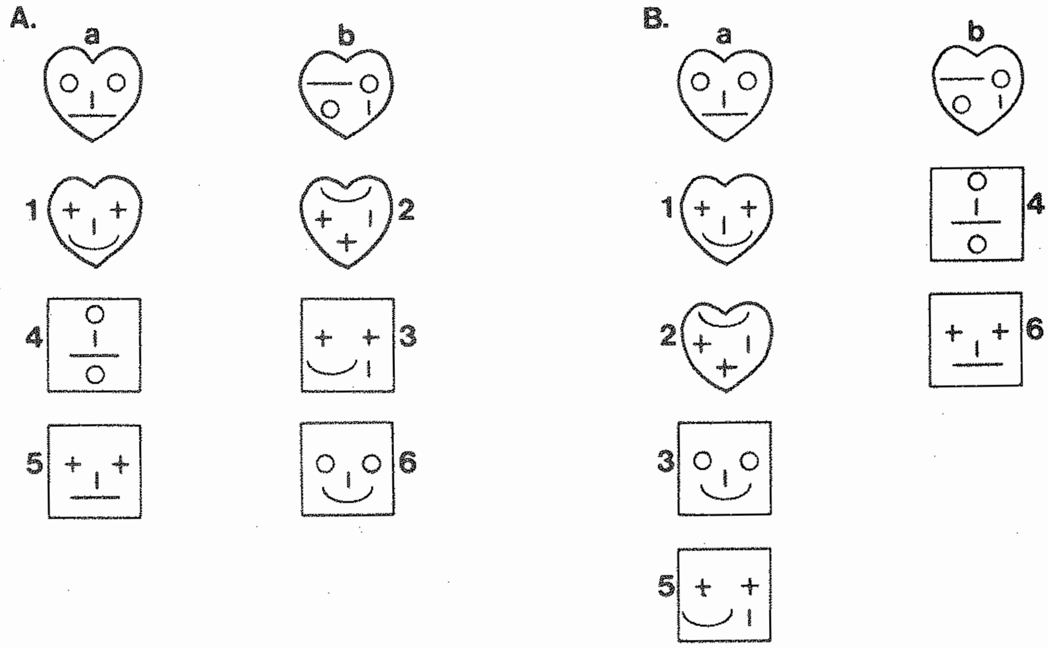
E asks S to make the two items from a set of individual felt pieces. S correctly makes both, including using a different head for each. "Is there anything different about those two that you've just made?" *"That one is the Dad one, and that is the Mother one."* "When you made this one did you use anything different from when you made that one?" *"That's a square one and that's a heart one."*

E replaces 1 and 4 in the matrix. "So how are these three (1, 2, 3) all the same?" *"That one has circles, that one has crosses and that one has triangle eyes."* "That's how they're different, how are they the same?" *"They're all the same."* "Why?" *"Because they got smiley mouths."* "Is there anything else the same?" *"That one has a smiley mouth and that one has, and that one has."* "Are these three (1, 2, 3) the same in any other way?" *"Triangle one, triangle one* (eyes of 3), *cross one, cross one* (eyes of 2), *circle one, circle one* (eyes of 1)."

APPENDIX H

PROTOCOL OF A CHILD WHO COULD NOT UNDERSTAND THE FACE/NONFACE DICHOTOMY

Figure H.1.



J.B. (5;0) is shown a and b and asked how they are different. "*That one's* (b) *got that across there.*" (Mouth in a different place). "What does this (a) look like?" "*A face I think.*" "And this one (b)?" "*A face.*" "Does it look like a face?" "*No.*"

He is asked to put the other items with "a" and "b", and he puts items 1 to 4 (in that order) as shown in arrangement "A", Figure H.1. "Is this one (4) the same as those (a and 1)?" "*No.*" "Why?" "*Because it's a square.*" "Can it go there?" "*Yes.*" He adds items 5 and 6. "Why did you put all these (a, 1, 4, 5) together?" "*They're just squares and* *they're just lovehearts.*" "What does this one (a) look like?" "*Loveheart.*" "What does it make up altogether?" "*Square.*" "Does it look like a face?" "*Yes.*" "Does this one (1) look like a face?" "*No ... Yes.*" "Does this one (4)?" "*No.*" "And does this one (5)?" "*No.*" "Is it a face?" "*No, it's a square.*" "Does it look like a face in some way?" "*No.*" E removes items 3, 4, 5, 6, "Can you put all the ones that are faces with these (a and 1), and all the ones that are not faces with these (b and 2)." He does not respond. "Are these (a and 1) faces?" "*One's a face and one isn't.*" "Are these (b and 2) faces?" "*One's a face and one isn't.*" "Is this one (2) a face?" "*Yes.*" "Why?" ... "Why does it look like a face?" "*Yes. ... because it's got a mouth and two eyes.*" E removes all items from "a" and "b", and tells S to put the faces with "a" and the ones that are not faces with "b". He arranges the items as shown in part "B" of Figure H.1. "Are these (a, 1, 2, 3, 5) all faces?" "*Because they got mouths.*" (i.e. smiling mouths.) "Are these (b, 4, 6) not faces?" "*Because they haven't got mouths.*" "Does this one (5) look like a face?" "*Yes, because it's got a mouth.*"

APPENDIX I

THE SCORES OF INDIVIDUAL SUBJECTS IN EXPERIMENT 2

Name	Grade	Stage	F/NF	USD	e × m	e × h; m × h	3 Properties	e + h; m + h	Name	Grade	Stage	F/NF	USD	e × m	e × h; m × h	3 Properties	e + h; m + h	Name	Grade	Stage	F/NF	USD	e × m	e × h; m × h	3 Properties	e + h; m + h
EP	3	6	1	2	1	2	2	2	MR	4	5	1	2	1	2	2	2	RH	2	3	1	1	1	1	0	0
PM	5	6	1	2	1	2	2	2	JH	4	5	1	1	1	2	2	2	MK	2	3	1	0	0	0	1	1
KS	5	6	1	2	1	2	2	2	JB	5	5	1	1	1	2	1	2	ST	2	3	1	2	0	0	0	0
JH	6	6	1	2	1	2	2	2	SB	4	5	1	2	1	2	2	0	TF	2	3	1	1	1	0	1	0
JT	6	6	1	2	1	2	2	2	KM	3	5	1	1	1	2	2	2	LS	2	3	1	0	0	0	0	0
GL	3	6	1	2	1	2	2	2	GS	3	5	1	2	1	2	2	0	MW	2	3	1	2	0	0	0	0
JB	2	6	1	2	1	2	2	2	AG	3	5	1	2	1	1	2	2	RH	1	3	1	1	0	0	0	0
GL	5	6	1	2	1	2	2	2	JM	3	5	1	1	1	2	2	1	VT	2	3	1	1	0	0	0	0
PL	5	6	1	2	1	2	2	2	AM	3	5	1	2	1	2	2	2	BD	1	3	1	1	0	0	1	0
MF	5	6	1	2	1	2	2	2	JA	2	5	1	1	0	2	2	1									
TL	5	6	1	2	1	2	2	2										AP	2	2	1	1	0	0	0	0
SC	4	6	1	2	1	2	2	2	AW	5	4	1	2	1	2	1	2	MK	1	2	1	1	0	0	0	0
GA	6	6	1	2	1	2	2	2	GL	5	4	1	2	1	0	0	2	GT	1	2	1	1	0	0	0	0
DH	6	6	1	2	1	2	2	2	DB	4	4	1	1	1	2	2	0	WK	1	2	1	2	0	0	0	0
JG	6	6	1	1	1	2	2	2	SP	4	4	1	2	1	2	0	2	HP	1	2	1	1	0	0	0	0
FM	6	6	1	2	1	2	2	2	JR	4	4	1	1	0	0	0	2	CB	1	2	1	1	0	0	0	0
DS	6	6	1	2	1	2	2	2	NG	3	4	1	1	1	2	2	1	WC	K	2	1	1	0	0	0	0
NR	4	6	1	2	1	2	2	2	DL	2	4	1	1	1	2	0	2	VG	K	2	1	1	0	0	0	0
KW	4	6	1	2	1	2	2	2	RP	2	4	1	2	1	1	0	2	KC	K	2	1	1	0	0	0	0
JD	3	6	1	2	1	2	2	2	TP	2	4	1	1	1	0	0	1	CM	K	2	1	1	0	0	0	0
RB	2	6	1	2	1	2	2	2	AT	2	4	1	1	1	1	0	0	BS	K	2	1	1	0	0	0	0
JT	2	6	1	2	1	2	2	2	JB	1	4	1	1	1	1	1	1	KT	K	2	1	1	0	0	0	0
SP	6	6	1	2	1	2	2	2	JD	1	4	1	1	1	1	0	2	AG	K	2	0	1	0	0	0	0
IM	4	6	1	2	1	2	2	2	RF	1	4	1	1	1	2	2	0	TQ	K	2	1	1	0	0	0	0
SN	5	6	1	2	1	2	2	2	BG	1	4	1	2	0	2	0	2	DH	K	2	1	1	0	0	0	0
JH	3	6	1	2	1	2	2	2	AT	K	4	1	1	0	1	2	1									
LW	2	6	1	2	1	2	2	2	KF	1	4	1	1	1	2	1	1	JB	K	1	0	0	0	0	0	0
									PF	1	4	1	2	1	2	0	0	JC	K	1	1	0	0	0	0	0
WS	6	5	1	2	1	2	2	2	KP	1	4	1	2	0	2	1	2	PD	K	1	0	0	0	0	0	0
GR	6	5	1	1	1	2	2	2										SD	K	1	0	0	0	0	0	0
EM	5	5	1	1	1	2	2	2	MM	5	3	1	1	1	0	0	1	MK	K	1	0	0	0	0	0	0
AR	4	5	1	2	1	2	2	2	MD	4	3	1	1	1	0	0	1	LM	K	1	0	0	0	0	0	0
PF	6	5	1	2	1	2	2	1	JM	3	3	1	2	1	0	1	0	GN	K	1	0	0	0	0	0	0
WL	6	5	1	1	1	2	2	2	MW	3	3	1	1	1	0	0	0	LS	K	1	1	0	0	0	0	0
									CC	2	3	1	1	1	0	0	0									

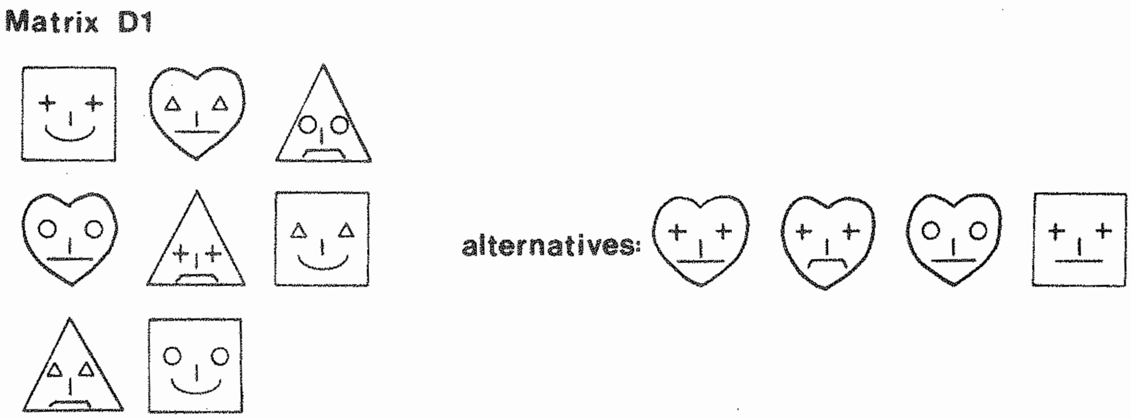
APPENDIX J

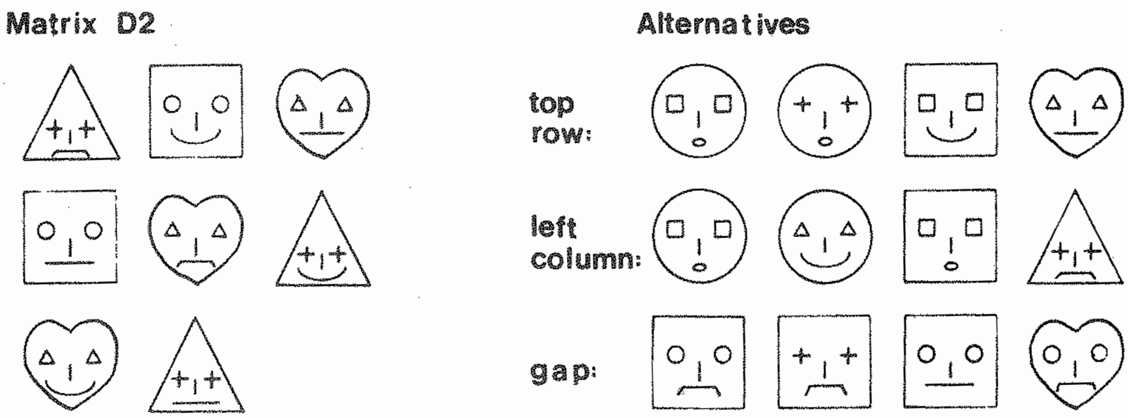
THE NUMBER OF ERRORS MADE BY INDIVIDUAL SUBJECTS IN EXPERIMENT 3

Stage	High/Low Head Ability	Head	Eyes	Mouth	Stage	High/Low Head Ability	Head	Eyes	Mouth	Stage	High/Low Head Ability	Head	Eyes	Mouth
1		1	6	5	3	H	1	3	3	5	H	1	1	0
1		4	3	1	3	H	0	2	0	5	H	1	0	0
1		1	3	2	3	H	2	3	0	5	H	1	0	1
1		3	2	4	3	H	0	0	2	5	H	0	0	0
1		5	5	4	3	H	3	2	2	5	H	0	0	1
1		5	3	3	3	H	2	3	3	5	H	0	2	0
1		2	2	4	3	L	0	3	2	5	L	1	0	0
1		4	4	4	3	L	3	2	4	5	L	0	0	0
2	H	2	2	5	3	L	0	0	4	5	L	1	0	0
2	H	1	2	3	3	L	5	0	1	5	L	0	0	0
2	H	4	1	3	3	L	3	1	0	5	L	1	2	2
2	H	5	0	1	3	L	1	3	2	5	L	0	0	0
2	H	1	2	2	4	H	0	0	0	6	H	0	0	0
2	H	0	1	2	4	H	1	0	0	6	H	0	0	0
2	L	3	2	3	4	H	0	3	2	6	H	1	1	1
2	L	2	2	1	4	H	1	0	0	6	H	1	1	0
2	L	4	3	3	4	H	1	2	2	6	H	0	0	0
2	L	0	5	2	4	H	0	1	0	6	H	0	0	0
2	L	1	4	2	4	L	2	5	3	6	L	1	1	2
2	L	2	0	4	4	L	1	4	1	6	L	1	0	0
					4	L	0	3	0	6	L	1	2	1
					4	L	1	1	1	6	L	2	1	1
					4	L	2	0	2	6	L	1	1	0
					4	L	5	1	3	6	L	1	3	1

APPENDIX K

"DIFFERENCE" MATRICES





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