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, $\left(PPR_t = \dfrac{R_t - MMR_t}{1 - MMR_t}\right)$:	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.

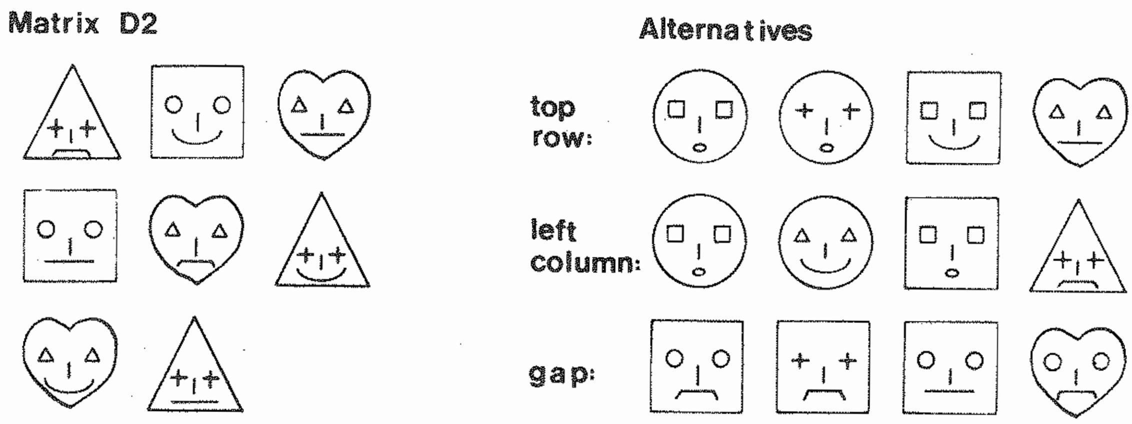
If "same" and "different" are dependent on the abstraction of the same internal schemes, then tasks where differences have to be used should produce the same developmental stages as those for similarity tasks. Each child should be at the same stage with similarity and difference tasks.

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.

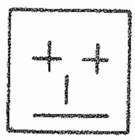
The abstraction of the classificatory schemes has been hypothesised to be dependent on the prior abstraction of the relations between the parts and whole of an individual item. Thus the first step in the development of the theory is to characterise the perception of an item, and the development of the 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.

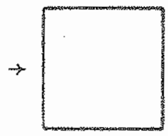
9.2.2 Developmental Period B

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.

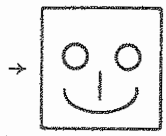
The procedures which construct the total global event can be restructured to enable a part of the whole event to be constructed independently. The first procedure would compute the relationships involved in one part of the total event, the second would utilise this result in computing the total event. 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

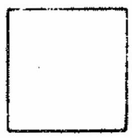
Procedure i': Find the foreground of the item, and compute shape

→ 

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

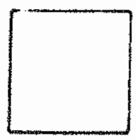
→ 

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

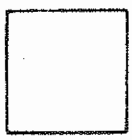
In developmental period B, method 1, procedure (i) computes all the relations for the background (hence abbreviated to Bgr), ignoring what must have been incidentally computed about the foreground (hence abbreviated to Fgr). The Fgr was analysed in relation to the Bgr in the following procedure. Similarly, 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

→ 

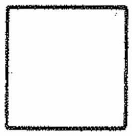
Method 2

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: 

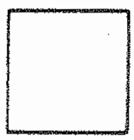
9.2.4 Developmental Period D

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 → 

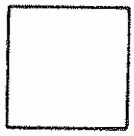
pr v: Relate the results of pr iii to pr iv → 

Method 2

pr i: Register input and cluster → description of clusters

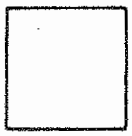
pr ii: Analyse into Fgr and Bgr clusters → description of Fgr clusters, and of Bgr clusters

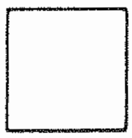
pr iv: Compute the shape of the Fgr clusters → 

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 → 

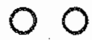
pr v: Relate the results of pr ii, pr iii and pr iv → 

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	UNDIFFERENTIATED	Differentiated → $P_1(I,i)$	Abstracted → P_1		Abstracted spatial relationships between the Fgr and Bgr clusters → P_4	All relationships abstracted → P_{10}
2. Fgr and Bgr clusters			UNDIFFERENTIATED	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	
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 imcompatible, 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 $\rightarrow P_n$		$P_n(C,c)$; $P_n(D,d)$
COMPARE	$\rightarrow$ COMPARE (P_n)	$P_n \neq P_n$	$P_n(C,c) \neq P_n(D,d)$
PUT TOGETHER	$\rightarrow$ 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 $\rightarrow P_n$
COMPARE	$\rightarrow$ COMPARE (P_n)
PUT TOGETHER	$\rightarrow$ 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 → P_8
COMPARE → COMPARE (P_8)
PUT TOGETHER → 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
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.

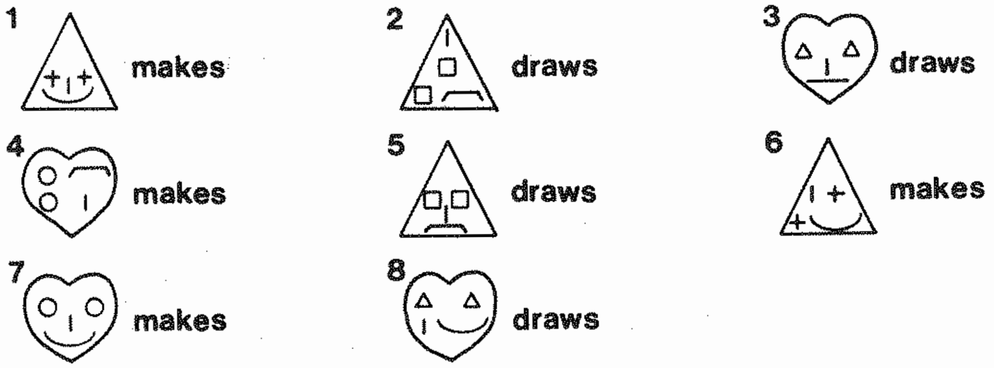
D2. ORDER OF PRESENTATION OF THE TASKS OF EXPERIMENT 2

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	

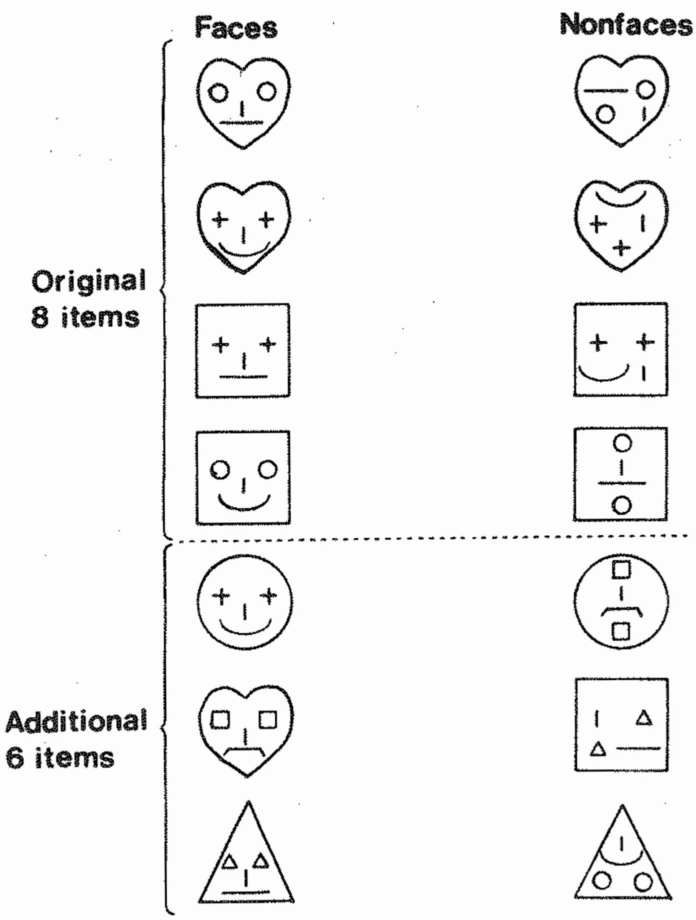
APPENDIX E

MATERIALS USED IN EXPERIMENT 2

E1. UP-SIDE-DOWN ITEMS

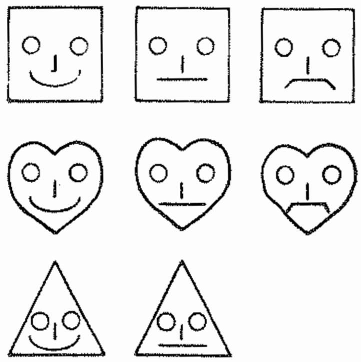


E2. FACE/NONFACE SORT



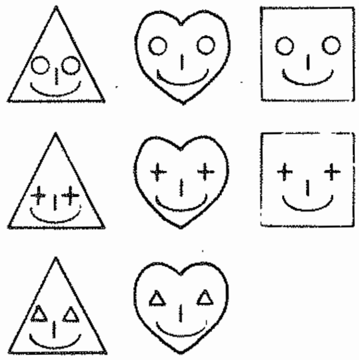
E3. "A" MATRICES – TWO PROPERTIES VARIED

Matrix A1



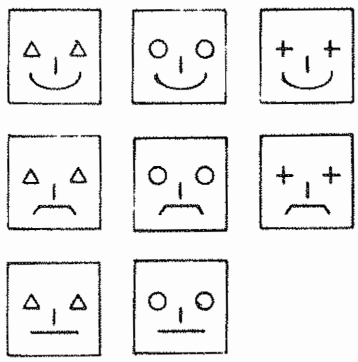
alternatives:

Matrix A2

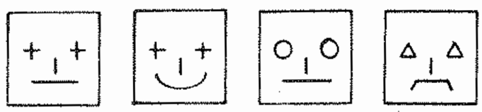


alternatives:

Matrix A3

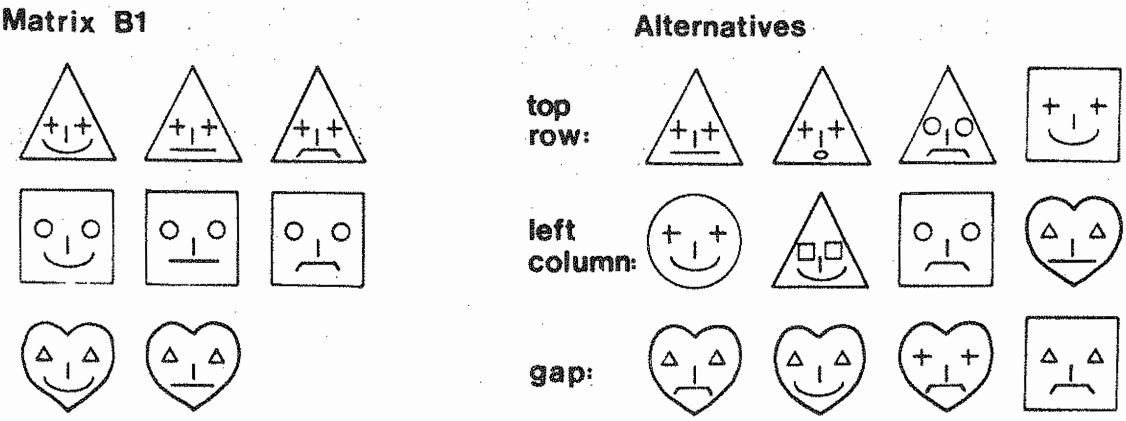


alternatives:

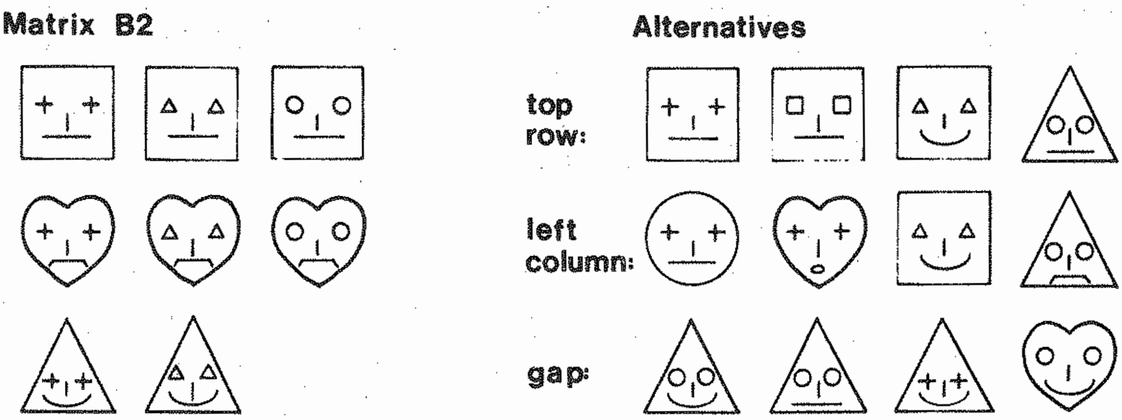


E4. "B" MATRICES — THREE PROPERTIES VARIED

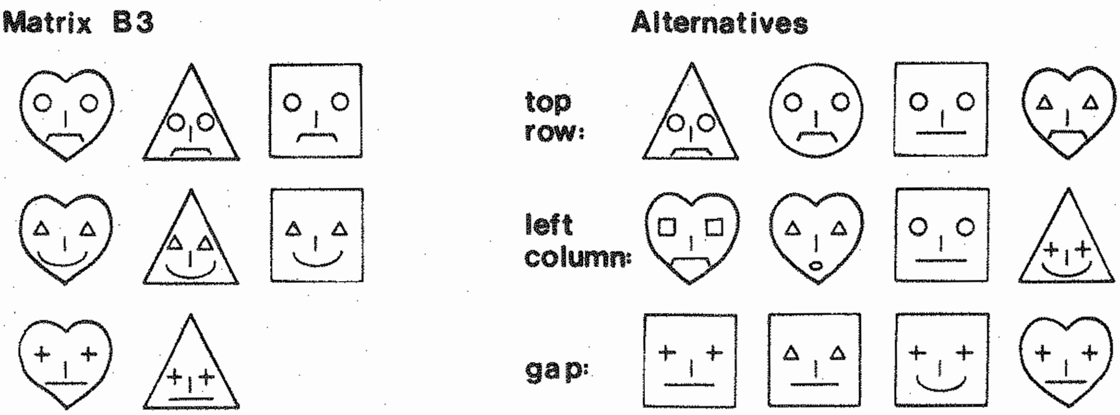
Matrix B1



Matrix B2



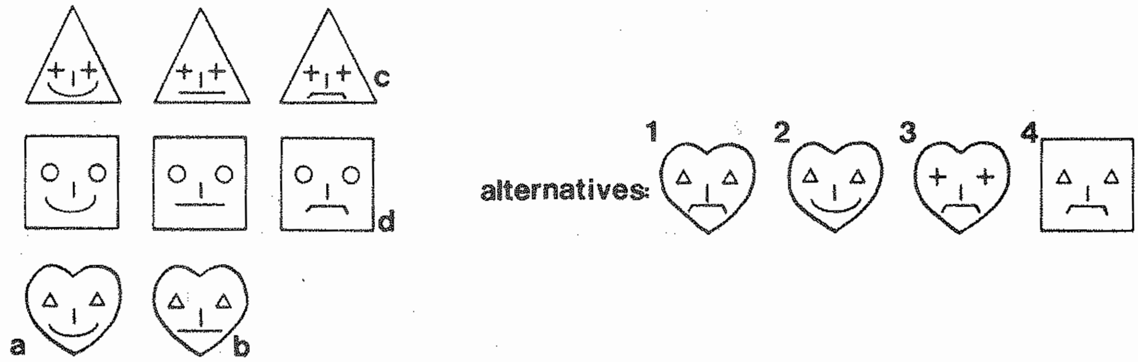
Matrix B3



APPENDIX F

PROTOCOLS OF BEHAVIOUR WHEN COMPLETING MATRIX B1

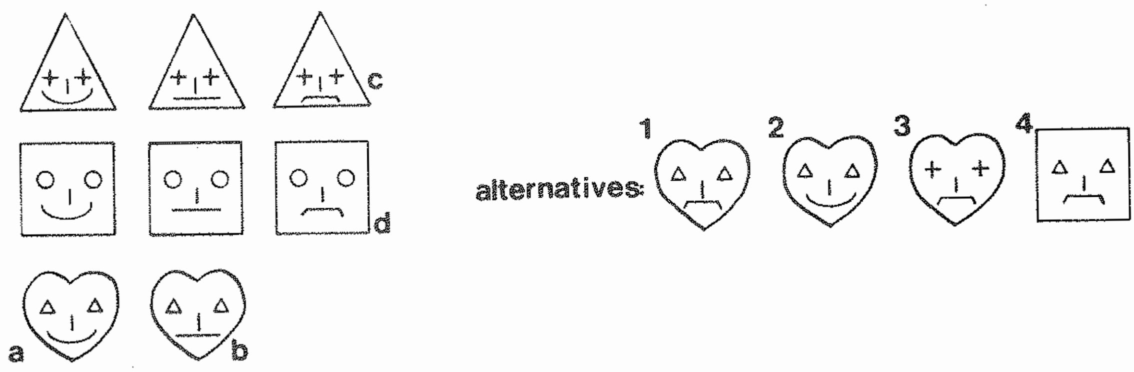
Matrix B1



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



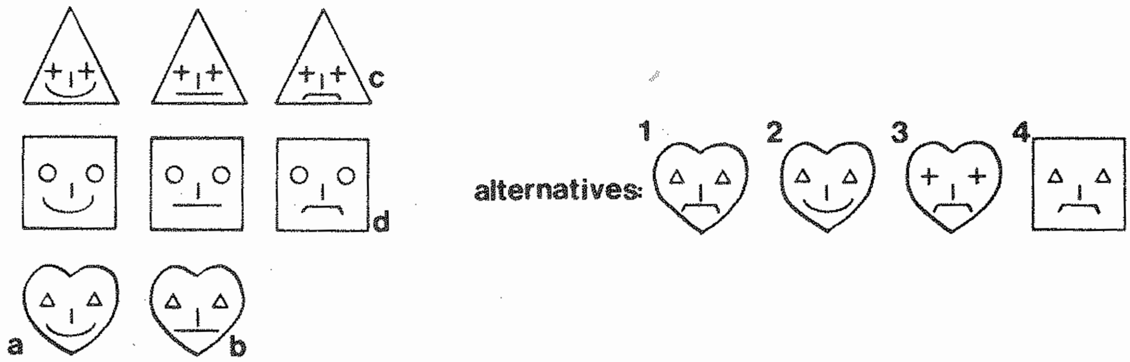
STAGE 3

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

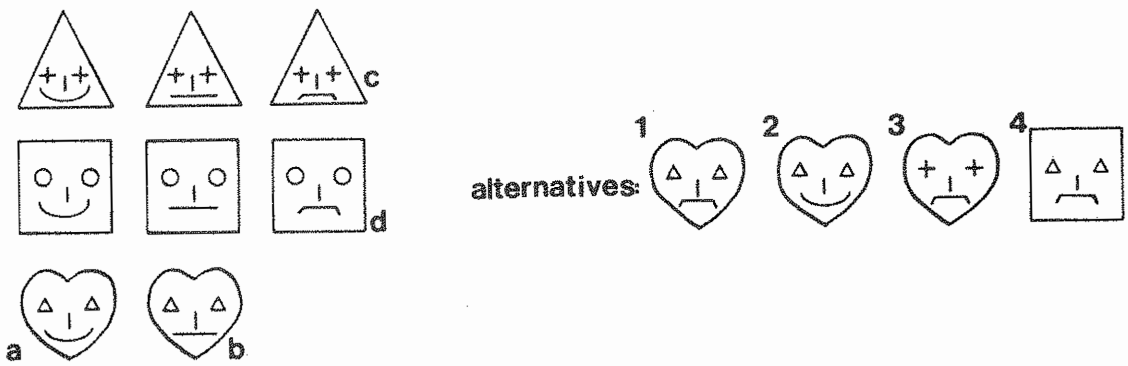


"*Because those* (a, b, 2) *have all got triangle eyes ....*" "Does it go for another reason?" "*No.*" "Can it go in the gap?" "*No, only with those two* (a, b) *it can.*" "Is it as good as this one (3)?" "*No.*" Alternative 1 can go "*Because those* (a, b, 1) *have all got triangle eyes, and those* (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

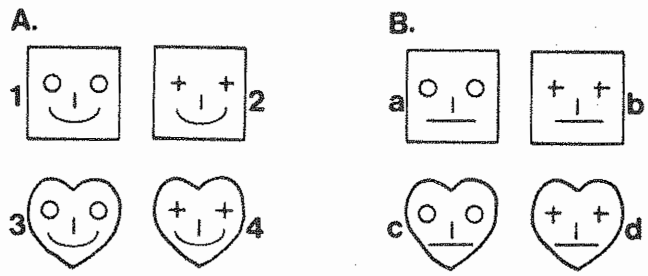


Figure G.1.

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.

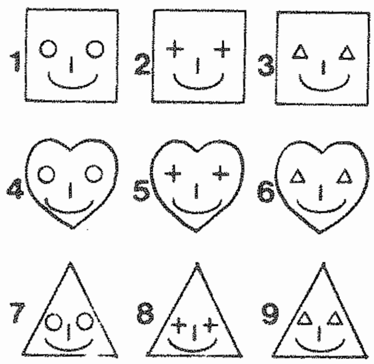


Figure G.2.

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.*"

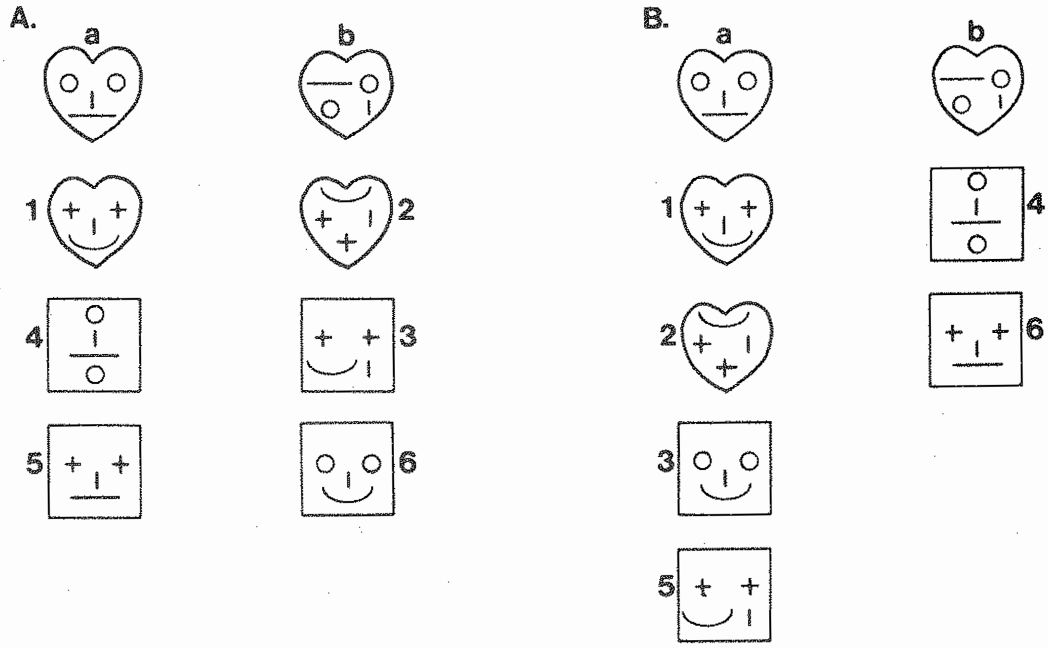
E asks S to make the two items from a set of individual felt pieces. S correctly makes both, including using a different head for each. "Is there anything different about those two that you've just made?" "*That one is the Dad one, and that is the Mother one.*" "When you made this one did you use anything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

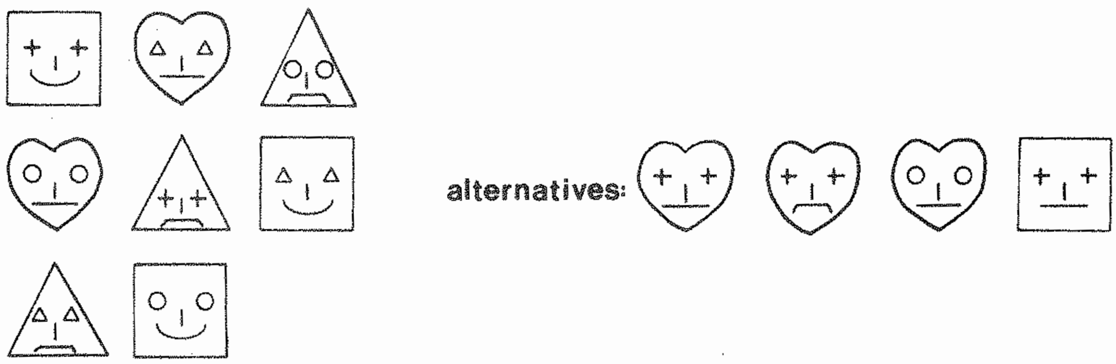
THE NUMBER OF ERRORS MADE BY INDIVIDUAL SUBJECTS IN EXPERIMENT 3

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

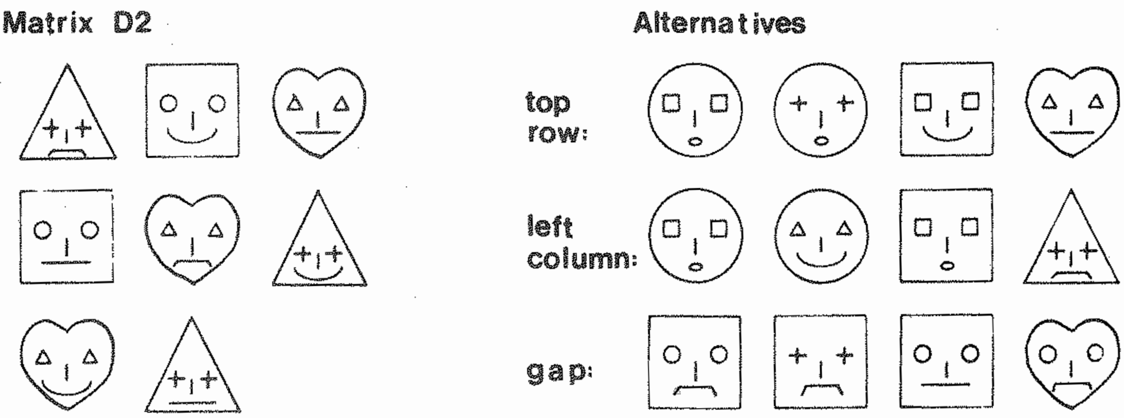
APPENDIX K

"DIFFERENCE" MATRICES

Matrix D1



Matrix D2



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