Challenging “Early Competence”:
A Process Oriented Analysis
of Children’s Classifying

STEPHANIE THORNTON
Developmental Psychology,
Cognitive Studies Program,
University of Sussex, England

In some circumstances, children of 5 produce identical classifications to 10 year olds when asked to sort a collection of objects. This has been interpreted as meaning that the process of constructing classifications is very similar at 5 and 10 years. But this conclusion rests on a comparison of the product of children’s sortings, rather than on a study of their activity in producing sortings. The present paper argues that the process of classifying is in fact very different for 5 and 10 year olds: whereas the older children treat the whole classification as a single unit composed of interrelated classes, the younger children proceed as though each class were independent of the others. At around 7 years, there is evidence for a transitional phase, in which children directly work on the relations between classes and so organize their initially “juxtaposed” procedures into more coherent systems. The tendency to work on the relations between elements in the process of classifying is not, however, simply an age-related phenomenon: evidence for a similar effect can be observed in children throughout the age range of 5 to 10 years, during the course of short experimental sessions. Furthermore, the effect is not merely a response to errors or difficulties: the tendency to work on classifying relations can be seen in 5-year-old children in a task in which they are already successful. It seems that children spontaneously discover and use information about their procedures and the relations between them. This process is an end in itself. It occurs whether or not its results yield more successful performance. The approach taken in this paper is not confined to one area of behavior. This analysis of children’s classifying fits closely with work in a very different domain, i.e. Karmiloff-Smith’s work on children’s language and other representational systems. The analysis has implications for computer models of skill acquisition, as well as for psychological theories of development.

I. INTRODUCTION

It is a fact that young children fail in experimental tasks which are supposed to test their grasp on logicomathematical concepts such as classificatory
logic. The traditional explanation for the failure (Inhelder & Piaget, 1964) has been that these children have not yet developed the intellectual structures essential for success. However, this whole approach has recently been challenged. Various studies have been set up to demonstrate that very young children can succeed in certain versions of Piagetian-type tasks. For example, 5 year olds are usually defeated by Piagetian class inclusion questions, yet they succeed when details of the procedure are changed (Donaldson, 1978; McGarrigle & Donaldson, 1974), or when part-whole relations are simplified (Markman & Siebert, 1976). Furthermore, while young children do not construct classifications when asked to sort typical experimental objects, again, it has been recently shown that they are as likely as older children to construct classifications when modifications are made to the object collection (Rosch et al., 1976). In other words, simplifying either the procedure, objects or relations involved in a task seems to allow the small child to demonstrate greater competence than hitherto suspected (Donaldson, 1978; Fodor, 1972; Gelman, 1978; Johnson-Laird & Wason, 1977).

However, the emphasis on early competence is as open to challenge as the traditional approach. A major objection can be put forward: the argument for early competence has taken for granted that equivalent task performance is evidence for equivalent underlying processes. In other words, when a 5 year old succeeds in a modified version of a task, it is maintained a priori that she does so by the same process as used by the older child in succeeding in the traditional version of the task. However, (1) this inference is not a necessary one, (2) it is questioned by the fragile nature of younger children's success even when tasks are altered, and (3) modified tasks are, in any case, not strictly equivalent to their traditional versions (Dean, Chabaud, & Bridges, 1981). Thus, in stressing the similarity between older and younger children's competence, it is my view that the recent approach has underestimated developmental changes in processing.

The purpose of this paper is to present an alternative to the "early competence" view of children's classifying. The paper is divided into four sections. The first presents an analysis of children's sorting procedures, drawing on theoretical work in other domains (Karmiloff-Smith, 1979). Predictions from this analysis are tested in a constrained sorting task described in the second section. The third section examines the processes by which children begin to use classifications as an aid in problem solving, drawing on data from a Twenty Questions task. Theoretical implications of these studies are discussed in the final section.

II. A THEORETICAL ANALYSIS OF CHILDREN'S SORTING PROCEDURES

The usual way in which developmental psychologists have studied children's classifying is by using the free sorting task (e.g., Denney, 1972; Gelman,
The child is given a collection of objects and asked to: "put together all the things which are alike, or which go together". Judging by their behavior in free sorting tasks, children of 5 and 10 years seem to have very similar procedures for sorting. Children of both ages normally sort the collection of objects they are given into a system of exhaustive and logically related classes (Kofsky & Osler, 1967; Thornton, 1979). The tempting inference is that both 5 and 10 year olds' sorting procedures to handle such logical classificatory systems are organized analogously. However, phenomena exist which question this conclusion: first, the observation that 5 and 10 year olds produce ostensibly identical sortings only holds true for some collections of objects and not others (Rosch et al., 1976). Second, it is only the case where the child's initial efforts to sort the objects meet with no difficulties. When a first attempt to sort the objects encounters a problem (such as inability to sort the as yet unsorted objects into classes complementary to those already completed, i.e. using the same dimension of variance as that used in forming the earlier classes), the 10 year old aborts her initial sorting and starts afresh, producing a new system of complementary classes. By contrast, the 5 year old does not throw away her initial efforts: she retains them, and abandons similarity as a criterion for grouping the remaining classes, producing instead random "jumbles", at least from the point of view of the observer (Thornton, forthcoming). Third, the way in which 5 and 10 year olds access classifying knowledge is quite different. For example, the younger children may show evidence of hierarchic classificatory structures in semantic memory (Harris, 1975; Mansfield, 1977; Steinberg & Anderson, 1975), though they show no other evidence of understanding such structures. Young children sort objects into classifications but cannot, in contrast to older children, go beyond this and construct alternative ones. Moreover, classifying is only used as an overt aid in problem-solving by children of 9 or 10 (Denney, Denney, & Ziobrowski, 1973; Harris, 1978). Fourth, 7-year-old children seem to be much less competent in producing classifications in free sorting tasks than are 5 year olds. Where the 5 year old typically produces a seeming system of logically related classes (e.g. red, blue, green), many 7-year-old children sort all the items into pairs, juxtaposing pairs matched on quite different criteria, e.g. 2 red objects, then 2 square objects, then 2 big objects, then 2 objects with wheels, then 2 green objects (Thornton, forthcoming). A pairing stratagem has also been described for 7 to 8 year olds by Annett (1959).

All of these phenomena suggest that classifying procedures are organized in very different ways at 5 and 10 years. The fourth counterargument is particularly convincing: it is hard to explain the apparent regression of 7 year olds, if 5 and 10 year olds' sorting procedures are in fact organized identically. Similar "regressions" in competence in other domains of cognitive development have been convincingly interpreted as the visible sign of a
reorganization of the child's procedures (Karmiloff-Smith, 1979; Karmiloff-Smith & Inhelder, 1974).

Karmiloff-Smith has suggested that the procedures adequate to a task are very often simply "juxtaposed" in younger children. For example, 3-year-old children correctly use the French word "un" in both its meanings ("a" and "one"). But they are not aware of the dual function: the child uses "un" as a series of separate, unfunctional homonyms. The procedures for each meaning are unconnected, or "juxtaposed" (Karmiloff-Smith, 1979). Similarly, in a block-balancing task, the young child may balance one block by using weight cues, and the next by using cues from its length. The two procedures are simply juxtaposed, so far as the child is concerned. They function quite independently and not as part of the broader system of torques (Karmiloff-Smith & Inhelder, 1974).

Development is a matter of connecting these juxtaposed procedures, so that they become integrated into a coherent system. In Karmiloff-Smith's view, children work on the connections between their procedures whenever these are functioning well. This "metaprocedural" activity (Karmiloff-Smith, 1979) occurs spontaneously, rather than solely in response to errors or difficulties, and is not necessarily conscious. The child may be quite unable to articulate either the process or its results. Nevertheless, there is evidence for metaprocedural activity in children's behavior. For example, although 3 year olds use the word "un" correctly in various contexts, 5-year-old children do not (Karmiloff-Smith, 1979). They reserve it for one of its meanings ("a"), and use the slightly ungrammatical form "un de" for the other ("one"). This is taken as evidence that the child has become aware of the connection between the two formerly juxtaposed procedures, and is demarcating them in the surface lexicon, in order to work out their relationship. When this has been done, she reverts to the correct, but now pluri-functional, use of "un".

This theory extrapolates easily to children's classifying. My hypothesis is that the 5 year old's sorting procedures are, in Karmiloff-Smith's terminology, simply juxtaposed: the child has procedures for sorting objects by a variety of their properties. But each of these procedures is separate from, and unconnected with, any other. For example, the child sees no connection between the procedure for sorting reds and the procedure for sorting blues. Each procedure functions quite independently. When the child forms a class of reds and then follows it with a class of blues, it is not because the classes are logically complementary. From her point of view, they are only perceptually similar.

The crucial fact about real classes, however, is that they are not independent. Once a given class has been formed in sorting, it constrains the other classes which may be formed next. For example, if one forms the class "reds," one can still form the class "blues," but one often cannot form the
exhaustive class "squares" without encroaching on the original class "reds". My hypothesis is that the 7 year old's curious "pairwise" sorting style is a response to discovering those connections between sorting procedures. By pairing objects instead of forming exhaustive classes, the child can represent all the alternative (and otherwise incompatible) groupings possible with a given collection of objects. Such an "external memory" makes it easier to explore the relations between classes and the procedures which form them. Eventually, the child's sorting procedures are integrated into coherent systems, corresponding (by definition) to the logic of class relations. She reverts to forming exhaustive classes, but now the successive classes she forms in sorting are logically, rather than perceptually related.

III. EVIDENCE FOR THE CHANGING ORGANIZATION OF CHILDREN'S CLASSIFYING PROCEDURES

Two predictions follow from the above analysis of children's classifying. Even where 5- and 10-year-old children's initial sortings look like a coherent system of logically related classes:

1. only the older children will treat their classifications as a single integrated system of classes. The younger children will treat each class as if it were independent of the other classes.
2. at an intermediate phase, children will be responsive to the intersections between one class and another, though they do not yet treat their classification as a single system.

These predictions were tested in a constrained sorting task, described more fully below. Briefly, concrete elements of the task (the use of boxes, the design of the cards to be sorted) constrained children to form a system of related classes. The cards were designed so that first attempts to sort them would often fail. Children's stratagems in trying to correct these errors should reveal the organization of their sorting procedures.

The Constrained Sorting Task

Four shallow cardboard boxes were placed on the table. Each has 3 "slots" -shallow depressions in the base, which will each hold one card. The child is given a pack of 12 cards, which vary in the colors, shapes, and patterns printed on them. She is asked to sort all 12 cards into the boxes, so that all the cards within a box are "the same in some way". In fact, this can only be done by sorting systematically by a particular variable attribute (e.g., color). Sorting by one of the other two variable attributes would allow
some, but not all, of the boxes to be successfully filled. To correct an initially unsuccessful sorting, the child must reject the classes which apparently fill a box successfully, since retaining them would prevent the remaining cards from being sorted. In other words, she must treat the four classes to be formed as related, i.e. interdependent. Figure 1 shows an example of the task.

Each child sorted a number of different packs of cards. The attribute which would allow a successful sorting differed from one pack to another.

Figure 1. An illustration of the Constrained Sorting Task.
The children resorted each pack until they had succeeded, or until they believed the task to be impossible, before passing on to the next pack. In fact, there were no “impossible” packs. When a child gave up trying to sort a given pack without having succeeded, the experimenter showed her the correct solution. This was done to ensure that all the children would continue to construe the problems as potentially solvable. It would be hard to interpret developmental changes in children’s protocols, if the younger, and less successful children came to believe that the task is often unsolvable, while their more successful elders retained the assumption that there was always a solution.

In fact, the problem of knowing what the child assumes about a task is a general difficulty for developmental psychologists (Donaldson, 1978). Most sorting tasks are highly ambiguous. It is not at all clear that even adult subjects are sure of what they are supposed to do in such tasks (Thornton, 1979). This is a serious problem. Obviously, one cannot interpret the organization of a child’s procedures, unless one knows what the child is trying to do. In an attempt to surmount this problem, the children in this experiment were asked whether or not they considered each of their sortings to be successful. This technique has not been used before in developmental research, so it is worth noting that even 5 year olds will very readily make such judgements. In fact, none of the children included in this study were ever wrong in judging their success or failure.

The results reported here are drawn from observations of 120 5- to 10-year-old children. The data are in fact drawn from two separate studies which used the same basic methodology, but varied in two respects: (1) the distribution of the variable attributes across cards was altered in the second study (see explanation below), and (2) the children in the first study sorted eight packs of cards, whereas those in the second study sorted nine.

**Developmental Effects**

Virtually all the children started out by sorting the cards in each pack systematically by a single attribute. Objectively, therefore, they produced logically complementary classes. But there were marked developmental changes in their efforts to correct errors when these initial sortings would not allow all the cards to be successfully sorted. These developmental effects closely support the predictions which motivated this study.

Figure 2a shows the three different procedures children used in trying to correct unsuccessful sortings. (It should be noted that the children were asked to take all the cards out of the boxes before beginning again, when they noticed an error).

**Type A:** Children use procedures which treat each class as though it existed independently of all the others. One class is retained on the second
<table>
<thead>
<tr>
<th>Type A</th>
<th>Type B</th>
<th>Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Sorting state at the point where the child reported an error</td>
<td>(b) Subsequent sorting procedure at the point where the child reported an error</td>
<td>(b) Subsequent sorting procedure at the point where the child reported an error</td>
</tr>
<tr>
<td>Box 1: contained 3 red cards</td>
<td>Box 1: contained 3 red cards</td>
<td>Box 1: contained 3 cards bearing squares</td>
</tr>
<tr>
<td>Box 2: contained 2 blue cards</td>
<td>Box 2: contained 3 yellow cards</td>
<td>Box 2: contained 3 cards bearing circles</td>
</tr>
<tr>
<td>Boxes 3 &amp; 4: were empty</td>
<td>Box 3: contained 2 green cards</td>
<td>Box 3: contained 2 cards bearing stars</td>
</tr>
<tr>
<td>7 cards remained unsorted. There was no 3rd blue card available among them.</td>
<td>Box 4: was empty</td>
<td>Box 4: was empty</td>
</tr>
<tr>
<td>4 cards remained unsorted. There was no 3rd green card among them.</td>
<td>3 cards remained unsorted: these were dissimilar on all variable attributes. The red cards which had been grouped in box 1 on the initial attempt were distributed across boxes 2 and 3 on this attempt.</td>
<td>4 cards remained unsorted. There was no 3rd card bearing a star among them.</td>
</tr>
</tbody>
</table>

| (a) Sorting state at the point where the child reported an error | (b) Subsequent sorting procedure at the point where the child reported an error |
| Box 1: contained 3 yellow cards | Box 1: contained 3 yellow cards |
| Box 2: contained 3 yellow cards | Box 2: contained 3 cards bearing squares |
| Boxes 3 & 4: were empty | Box 3: contained 3 cards bearing circles |
| 6 cards remained unsorted. These could not successfully be sorted into 2 groups of 3 by color. | Box 4: was empty |

Figure 2a. Illustrations of the Three Patterns observed in children's attempts to correct their unsuccessful sortings.
attempt, though the other is rejected. Typical of this type of procedure is that the child keeps any grouping which successfully fills a box, and rejects only the groupings which have too few members to fill a box. When children use this procedure they show no sign of taking the interdependencies between classes into account.

Type B: Children show some understanding of the relations between classes via the procedures they use. Again, the child retains one class and rejects the other. But the class which is rejected from the initial sorting is not rejected because it will not fill all the slots in a box, as would be typical of a type A procedure: it did fill all the slots in the box. Rather, this class is rejected so that its members may be cannibalized to form other classes, allowing more of the boxes to be filled than was managed on the first attempt. But though this procedure responds to interdependencies between classes, the response is of a limited, local nature. There is no sign here of handling a system of complementary classes as a single unit.

Type C: Children using these procedures, in contrast, do handle the whole system. If one class is changed in correcting an error, all the classes are changed. A system of complementary classes is treated as a single, coherent, unit.

Individual children's protocols were not "pure." At any one time, several types of response might occur in swift succession. Nevertheless, a developmental pattern emerges from the data as a whole: Type A procedures dominated the protocols of the youngest children, declining between 5 and 7 years, from about 60 to 30%. The frequency of this type of procedure was not different at 7 and 9 years. Type B procedures were less common, at all ages. However, there was a quadratic trend relating these procedures to age: Type B procedures were more common among 7 year olds than among either 5 or 9 year olds (who did not differ from one another in this respect). Twenty per cent of 7 year olds' procedures were of this type, as opposed to 6 to 10% of the procedures of the 5 and 9 year olds. Type C procedures increased in frequency linearly with age. Thirty-seven per cent of 5 year olds' procedures were of this type, as opposed to 50% of 7 year olds' procedures, and 70% of 9 year olds' procedures. (All of these effects were statistically significant at the 1% level, with techniques from the MANOVA package of SPSS). Figure 2b summarizes the data.

In summary, younger children tend to treat each class as if it were independent of the other classes. Only the older children treat their classifications as a single integrated system of classes. Furthermore, there is evidence for an intermediate phase at which children are responsive to the intersections between one class and another, though they do not yet treat their classification as a single coherent system. These results clearly confirm the predictions of the theoretical analysis of children's sorting presented in an earlier section of this paper.
The second of the two studies from which these general results are drawn provides additional, and striking, support for these conclusions. By altering the distribution of values of the several attributes varying on the cards, it was possible to construct two types of pack: In some packs (type i), incorrect attributes would not allow any of the boxes to be filled successfully, because there were less than three cards of each value of these attributes. For other packs (type ii), incorrect attributes would allow all but one of the boxes to be filled successfully. If the account of children’s classifying procedures presented here is correct, then the two types of pack should have very different effects on the youngest children’s behavior, but no differential effect for the older children. Should the youngest children be unaware of the interdependencies between classes, then they should be completely defeated by errors occurring with packs of type ii. The boxes which can be filled by sorting by an incorrect attribute (i.e., one which will not allow all
the boxes to be filled successfully) should be considered by these children as correctly filled. Hence, the children should repetitively reproduce these three apparently successful classes in their attempts to correct the error. By contrast, even a child who has not yet noticed any connection between one class and another should be able to correct errors occurring with packs of type i. Here, each class can be judged on its own merits without reference to its relation to other classes. So the youngest children should be much less likely to repeat incorrect classes with type i than with type ii packs. No such differential effect for the two types of pack should occur for the older children for the following reasons. I have argued that both 7 and 9 year olds recognize interdependencies between classes, even though the 7 year olds do not treat their groupings as systems of complementary classes. Hence, these older children should neither repeat incorrect classes with type i packs, nor get trapped into reiterating the three incorrect classes with type ii packs. Once one knows that classes can intersect, one can recognize that it may be advantageous to reject apparently successfully filled boxes, even if one has no grasp yet on the systematic relations between classes.

These predictions were fully supported by the data. The two types of pack had exactly the expected differential effect on the youngest children's attempts to correct their errors. This argument can be made with group data (Thornton, 1979), but is more eloquently made by looking at individual children's protocols. Figure 3 shows part of the protocol of a 5-year-old boy, Luke, dealing with errors in type i and type ii packs: Luke is able to reject incorrect classes with a pack of type i, using the cue that there are too few cards to fill a box. It is important to stress that this protocol effectively rules out the possibility that the youngest children's behavior in this constrained task is the result of (1) failing to notice alternative ways of sorting the cards, (2) inability to switch attention to new attributes, or (3) failure to conceive that such attention switching is a possible stratagem. Luke does all three and eventually produces a correct sorting. In striking contrast, he is quite unable to deal with the error in a pack of type ii. Here, he repeats the same three incorrect classes over and over until he finally gives up the task. It is notable that this failure came after his success with the type i error. As predicted, no parallel effect was observed for the 7- or 9-year-old groups. Children at these ages very rarely repeated the three incorrect classes with type ii packs.

**Within-session Effects**

Thus, there is strong evidence for a changing organization of sorting procedures, between the ages of 5 and 10 years. Particular types of sorting procedure may not, however, be tied to particular age levels. Children's sorting procedures also changed during the course of the experiment: at all
A. SORTING A PACK OF TYPE I

1st attempt
Box 1: contained 2 green cards
Boxes 2, 3 & 4: were empty

2nd attempt
Box 1: contained 2 brown cards
Boxes 2, 3 & 4: were empty

3rd attempt
Box 1: contained 2 yellow cards
Boxes 2, 3 & 4: were empty

4th attempt
Box 1: contained 2 gray cards
Boxes 2, 3 & 4: were empty

5th attempt
Box 1: contained 2 blue cards
Boxes 2, 3 & 4: were empty

6th attempt
Box 1: contained 2 cards bearing shapes
Boxes 2, 3 & 4: were empty

7th attempt
Box 1: contained 2 cards bearing circles
Boxes 2, 3 & 4: were empty

8th attempt
Box 1: contained 3 cards bearing the arrow pattern
Box 2: contained 3 cards bearing the arrow pattern
Box 3: contained 3 cards bearing the arrow pattern
Box 4: contained 3 cards bearing the arrow pattern

This was the second pack of cards the child sorted. He took 3 minutes over this pack. The 8th attempt was correct.

SORTING A PACK OF TYPE II

1st attempt
Box 1: contained 3 yellow cards
Box 2: contained 3 blue cards
Box 3: contained 3 green cards
Box 4: was empty

2nd attempt
Box 1: contained 3 blue cards
Box 2: contained 3 green cards
Box 3: contained 3 yellow cards
Box 4: was empty

3rd attempt
Box 1: contained 3 yellow cards
Box 2: contained 3 blue cards
Box 3: contained 3 green cards
Box 4: was empty

4th attempt
Box 1: contained 3 green cards
Box 2: contained 3 blue cards
Box 3: contained 3 yellow cards
Box 4: was empty

This was the fifth pack of cards the child sorted. He took 6 minutes over this pack. The child gave up after the fourth attempt.

Figure 3. Luke's Attempts to correct errors with a Type i and a Type ii Pack: Each "attempt" shows which cards had been put into boxes at the point where the child abandoned a particular effort and began his sorting again.
ages there was a decline in type A procedures for correcting errors, and an
increase in Type C procedures. But, most interesting of all, type B proce-
dures showed different patterns of change at different ages. While type B
procedures declined for both 7- and 9-year-old children, they increased in
frequency among 5 year olds (again, these effects were all statistically
significant, with techniques from the MANOVA package of SPSS).

These within-session effects are very similar to the developmental
effects described above. In particular, the increase in type B procedures at 5
years suggests a growing sensitivity to the interdependencies between classes.
It is hard otherwise to see why this increase should occur: type B procedures
are not very effective, and involve breaking from perceptual continuity in
forming successive classes, even though that strategy is both initially pre-
ferred by the younger children, and also reinforced in this task. However,
the task puts strong constraints on the child, and it is possible that the
within-session effects observed here are the result of task-specific processes
different from the developmental effects operating across a span of years.

IV. EVOLVING A CLASSIFYING STRATEGEM
IN THE TWENTY QUESTIONS GAME

The within-session effects in the constrained sorting task may or may not
parallel the larger scale developmental changes. But it is clear that the devel-
opment of classifying skills does not result solely from external pressures of
the type imposed by the constrained sorting task. Children spontaneously
work on and modify their procedures even when they are already successful
for the task in hand. This is evident from the results of a study of within-
session change in children's use of classifications in the Twenty Questions
game. The basic Twenty Questions game involves two players. One secretly
picks an object, either from the world at large, or (particularly with children)
from a select display of objects. The second player must discover which
object it is, by asking questions. These questions can only be answered by a
"yes" or "no."

Descriptions of performance in the Twenty Questions game usually
rest on two measures: the number of questions the child needed to ask to
find the solution; and the form of the questions she asked. There is a strik-
ing developmental decrease in the number of questions children need to
solve the Twenty Questions problem, associated with an increase in the
sophistication of their questions (Denney, Denney, & Ziobrowski, 1973;
Mosher & Hornsby, 1966). With respect to the form of the questions, two
general types of question can be asked in the Twenty Questions game: (1)
so-called hypothesis-testing questions (e.g., is it this blue mug?), and (2)
constraint-seeking questions (e.g., is it one of the blue ones?). Usually,
5-year-old children ask very few constraint-seeking questions in this task (Denney et al., 1973, suggest that 10% or less of 5 year olds' questions are of this type, for example). The general consensus in the psychological literature is therefore that 5-year-old children do not use classifying as a device to help solve the Twenty Questions problem; the use of classifying in this way is generally regarded as first beginning at around 8 years (e.g., Denney et al., 1973; Mosher & Hornsby, 1966).

The present study examined children's procedures in rather more detail than is usually reported. The aim was to trace the origins of constraint-seeking questions, by exploring the within-session changes in children's strategies.

Twenty 5 year olds each played four games of "Twenty Questions", two games in each of two sessions 7 days apart. The children were shown colored drawings of 16 objects (drawn to scale), shown in Figure 4. They were told that the experimenter was thinking of one of these objects, and that they had to discover which it was by asking questions. They were told that the experimenter was only allowed to answer "yes" or "no."

It is sometimes difficult to know, from the form of the words alone, exactly what a child's question is intended to mean. To get around this problem, the experimenter asked the children to turn face down, after each question, any pictures which could be eliminated. Thus it should be possible to identify the information the child actually took from the reply to her questions, rather than simply guessing from the form of her words.

Changes in Questioning Procedures

Before describing the within-session changes children made to their procedures in this task, it is worth noting one discrepancy between the results of the present study and the results of the majority of published studies of 5 year olds' performance in the Twenty Questions task. Forty-nine per cent of the questions in the present study were constraint-seeking, a rather higher figure than is normally reported (cf. Denney et al., 1973; Mosher & Hornsby, 1966). The discrepancy is hard to interpret. It may reflect differences in the populations studied (American children in most studies, but English ones here), in the objects used, or other details of the tasks. However, this issue is of little relevance in the context of the present research. What is of interest is the form of the changes observed in children's approach to the task over successive attempts to solve the puzzle. Six different types of change were observed.

A. Eliminating redundant words. There was a tendency for the children's questions to become more terse and economical. For example, a child who initially asked:
Figure 4. Objects used in the Twenty Questions Game.
"Is it this one? ..... Is it this one?"

later asked:

"This one? ..... This one?"

and still later:

"This? ..... This?"

This progressive terseness was characteristic of both children using hypothesis-testing questions (as in the above example), and those using constraint-seeking questions. For example, a child who at one point asked:

"Is it red? ..... Is it green?"

later asked:

"Red ..... Green?"

B. Eliminating redundant questions. The second kind of modification is rather similar, except that instead of using a more economic string of words in asking her question, a child would drop out an entire redundant question. Again, this happened both with children asking hypothesis-testing questions and with children asking constraint-seeking questions. For example, a child asking hypothesis-testing questions who had initially continued to ask:

"Is it this one?

even when only one object was left to be considered, on a later attempt pointed to the last object and said:

"So it's this one"

Similarly, a child asking constraint-seeking questions, who had earlier asked:

"Is it a yellow one?"

even though all the objects left to be considered were yellow, on a later attempt dropped this question and instead said:

"So it must be yellow"

Some children dropped even this comment and just began directly considering the individual remaining objects.

C. Expanded descriptions. Children who were pointing to objects and asking?

"This one?"

began to name the objects, for example, saying:

"The mug?"

 Similarly, children who were naming the objects, to which their successive hypothesis-testing questions referred, began to expand these descriptions. For example, a child who initially named the objects as she pointed to them:
"The cup? ..... The boat?"
later expanded her descriptions to:
"The red mug? ..... The little green cup?"
It is interesting that this type of modification involves a redundant expansion of the child's questions in contrast to the contraction of the questions observed in modification (A).

Another kind of apparently dysfunctional expansion was also observed. Several children began to refer more abstractly to the color of the objects, although they did not use this information to narrow down their search. For example, one child whose questions had been of the form:
"Is it this one?"
later asked:
"Is it this color?"
still pointing to an individual item. She rejected only the item she had pointed to, when the experimenter said "no," retaining three other items of the indicated color. It is perhaps worth noting that the occurrence of this type of "psuedo" constraint-seeking question underlines the need for caution in interpreting children's questions in the Twenty Questions task from their linguistic output alone. Only the injunction to turn over all the eliminated cards possible allowed the "psuedo" nature of this constraint-seeking question to emerge. Similarly, another child who used hypothesis-testing questions, testing objects in no discernable sequence, suddenly said to the experimenter:
"I know, I'll do all the blues and yellows next"
though she went on testing objects in no discernable pattern, not grouping her questions round blues and yellows.

D. Grouping and ordering. Children using hypothesis testing questions progressively systematized and ordered their questions. This happened both among children who were naming the objects, and those who were not. For example, a child who began by asking:
"Is it this one? ..... Is it this one?"
pointing to objects in no discernable sequence, later began to sort the items into groups and to test them in an ordered way, testing all the blue ones before going on to the red ones:
"Is it this blue one? ..... Is it this blue one?"
Another child who had been naming the objects:
"The boat? ..... The cup?"
began to sort the objects into classes, and ask systematically about each object in a group before passing on to the next group:
“The red boat . . . . the green boat . . . . the blue boat”

and so on.

As can be seen from these examples, grouping and ordering seems to be associated with the tendency to expand descriptions.

E. Chunking. Hypothesis-testing questions, which were fairly systematized, became rechunked into a constraint-seeking question. For example, a child who had begun to systematically pair her questions:

“Is it this boat? . . . . Is it this boat? . . . . Is it this blue one? . . . . Is it this blue one?”

later chunked the paired questions into one question:

“Is it one of these two boats? . . . . Is it one of these two blues?”

removing both the objects in each pair when the experimenter said “no” to each question. The pairs were typically matched on size or shape, as well as color or shape, though the child never mentioned the second matched attribute in her question. Another child whose hypothesis-testing questions were fairly (but not completely) systematized later chunked the separate questions:

“Is it this red one? . . . . Or this red one?”

into the question:

“Is it a red one?”

removing all the reds from the array when the experimenter said “no.” This rechunking was not confined to questions using classes, but could also be spatialized. One child initially asked:

“Is it this one? . . . . Or is it this one?”

pointing to items in no apparent sequence, and then later pushed groups of adjacent items into a heap and asked:

“Is it in this heap?”

Interestingly, this boy was the only child to show clear regression across sessions: he later reverted to asking questions about individual objects again. This would suggest that spatialization procedures are not at all optimal in this task, from a psychological or developmental point of view. Such a conclusion contradicts the predictions of a logician: the most effective stratagem in the Twenty Questions game, from a purely logical point of view, is precisely a stratagem based on spatial dichotomizing.

F. Increasing concern about overlapping classes. One child showed a rather bizarre change in his technique. From the outset, he had asked constraint-seeking questions, for example:

“Has it got wheels? . . . . Does it sail? . . . . Has it got a saucer?”
The experimenter answered “no” to each question, and each time, the child eliminated all the objects to which his question had referred. He never reexamined these rejected cards. However, after some experience with the task, he changed the form of his questions from reference to exclusive properties of the taxonomic categories, to questions which referred to a more heterogeneous collection of classes. For example:


Initially, this looks like an attempt to cross-classify the objects and use the cross-classification to home in on the key object. But the boy was not using a cross-classification in that way: on being told that the key object was not red, the child turned all the red cards face down. But when he asked the second question (“Has it got wheels?”), he peaked at each of the inverted cards, and turned the one with wheels face up again. Similarly, he turned all the wheeled objects face down on being told that the key object did not have wheels, but turned all the small cards face up again to await the experimenter’s answer to his third question (“Is it small?”).

This pattern of change seems to reflect not so much a changing use of the relations between classes as a changing concern about these relations.

Discussion

The first point to stress about all of these within-session changes is that they were not responses to external pressures or failures. In every case, the child’s original procedure was already successful for the purpose in hand. Thus, the modifications the children made to their procedures reflect the spontaneous properties of children’s processing.

Modifications of types A and B are of less interest than the others, from a developmental perspective. Type A, in which the child progressively drops out redundant words from her questions, seems rather like the progressive economy of surface markings observed in children’s drawings and map notations by Karmiloff-Smith (1979a); by which, for example, the words “droite” (right) and “gauche” (left) are truncated to the letters “D” and “G.” Both in this example from mapdrawing, and in modification type A in the Twenty Questions task, the child moves toward a form pared to its essentials, without any change in the information carried.

Changes of type B, in which the child drops redundant questions, have something of the same quality. In the case of a child using a constraint-seeking technique, it might be argued that the move to eliminate a redundant question involves increasing insight into the classificatory system guiding the questions. It is possible that the child drops the question about the sole remaining class, because she discovers that it is redundant in the light of preceding questions which eliminated its complements. (i.e., the key
object comes to be seen as necessarily yellow because it is not red, not blue, and not green which form the complement "not yellow" in this task). However, dropping redundant questions could arise out of a much simpler process of eliminating redundancies, and putting a "stop" on reiterative questioning procedures. For example, in the case of constraint-seeking questions, the child may drop the redundant question, because she now notices that the information it provides is already available from looking at the stimulus array. In other words, the key object comes to be seen as necessarily yellow (for example) on the pragmatic grounds that only the yellow objects are left visible. Thus, changes of type B may, like type A, be best seen as simply involving an increasing economy of form.

Modifications of types C, D, E, and F are more interesting. What is involved here is not an increasing efficiency in executing a single stratagem (as was the case for changes of types A and B). Rather, each of these modifications qualitatively changes the child's procedures. In fact, modifications C, D, E, and F seem to form a sequence of steps through which the child gradually evolves toward using the properties of classificatory systems to aid her problem-solving: she begins by exchanging pointing and non-specific linguistic reference for a progressively more detailed description of the objects about which she is asking (type C). She systematizes these questions, organizing them so that she comes to ask successively about all the objects of a given kind before moving on to a new kind (type D). She collapses these successive questions about similar objects into one question, which generically asks about their kind (type E). Eventually, she becomes concerned about the interrelations between successive constraint-seeking questions (type F). This developmental sequence is summarized in Figure 5.

Thirteen of the 20 protocols showed developments exactly fitting this model. It should be noted, however, that none of the children in this study passed through all of the steps in the sequence during the experiment: typically, an individual child would pass through two, or at most three, of the modifications. Of the remaining children, six made no alterations to their procedures other than economies of form (modifications types A and B). There was only one instance of a change in procedures discrepant from the sequence shown here. This was the case of the child who introduced spatialized constraint-seeking questions, and later reverted to asking about individual objects.

Two aspects of this developmental process are particularly striking. First, each of the modifications summarized in Figure 5 involves an increase in the information explicit in the child's procedures. In the first case, the child includes more information about the individual objects to which her questions refer. In the second, the child's groupings display similarities between the objects. In the third, she responds to the fact that such groupings
Pointing and non-specific linguistic reference to objects

(modification type c)

Naming and describing the object

(modification type d)

Ordering objects into groups and searching systematically through successive groups

(modification type e)

Chunking ordered sequences of questions into constraint-seeking questions

(modification type f)

Considering the relations between successive constraint-seeking questions

Figure 5. Steps in the Evolution of constraint-seeking in the Twenty Questions Game.
can be treated as classes. In the fourth, she indicates that these classes may be interrelated.

Second, for at least three of the steps, the new information is clearly included for its own sake, rather than being introduced directly to improve performance. For example, the children who expanded their descriptions of the objects gained no objective advantage. Since their previous stratagem of touching each object as they asked about it was wholly successful in communicating with the experimenter and completing the game, the expanded descriptions were in fact redundant. Similarly, the child gains no objective advantage by ordering the objects into groups if she then goes on to ask about each member of the group individually. And the child whose increased concern for the relations between classes led him to go back over already eliminated objects is clearly at a disadvantage because of modifying his stratagem to reflect this new information. Only the move from asking about individual objects to asking about groups of objects through constraint-seeking questions actually improved the child’s objective performance in the task.

In effect, the process of spontaneously uncovering and using information about procedures, and the distinctions and connections between them is an end in itself. It occurs whether or not its results yield more successful performance. The net effect is to reorganize procedures towards more coherent and integrated systems.

Like modifications of types A and B, these latter modifications (C, D, E, and F) seem to reflect processes similar to those involved in within-session changes observed in children’s drawing and map notations (Karmiloff-Smith, 1979). Paralleling the present study, children spontaneously change their mapdrawing notations to include new information. (For example, a child whose initial drawings reproduced the route to be followed later spelled out explicitly both which way to turn and which way not to turn, by two separate markers.) And as in the present study, children in Karmiloff-Smith’s study tended, within-session, to reorganize their procedures into more integrated systems (as, for example, in the tendency to later move from the several explicit unifunctional direction markers of the above illustration, to one plurifunctional one; or as in the tendency to group notes about route turnings which were previously recorded separately). These parallels between within-session changes in a map-drawing task and modifications C, D, E, and F in the Twenty Questions task suggest that the phenomena involved may be very general features of children’s cognitive processing.

In conclusion, it seems that there are indeed important developmental changes in the organization of children’s classifying procedures: Younger and older children may sometimes produce analogous performances, but they do so by very different procedures. Moreover, these developmental
changes, and the processes which produce them, are not confined to classifying alone. The analysis of children’s classifying fits closely with work in an intuitively different domain, i.e. that of Karmiloff-Smith on children’s mastery of language and other representational systems. This poses a strong challenge to the “early competence” view of development (Donaldson, 1978; Gelman, 1978). The clear implication is that an understanding of cognitive development must focus much more closely on details of children’s actual processing.

REFERENCES


