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REVERSAL SHIFT PERFORMANCE AND THE ABILITY TO REPRESENT STIMULUS FEATURES

A thesis submitted in partial fulfilment
of the requirements for the degree of
Doctor of Philosophy

by

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ABSTRACT

This thesis is concerned with the developmental trends in reversal shift performance demonstrated by the Kendlers. Chapter 1 presents the early evidence for the developmental trend together with the "pre-theoretical" model proposed by the Kendlers to deal with the phenomenon. Chapters 2, 3, 4 and 5 attempt to summarize recent evidence which, it is felt, generally confirms the early findings of the Kendlers and their colleagues with the reversal shift problem. Chapter 6 presents a more detailed account of the Kendlers' theory and attempts to make clear the implicit assumptions underlying their position. Chapters 7, 8 and 9 review the findings of studies with animals and young children which demonstrate attentional phenomena in paradigms other than the reversal shift, and thus cast serious doubt on the Kendlers' model.

In Chapter 10 the Tighes' perceptual differentiation theory of age related changes in the reversal shift paradigm is presented. Evidence pertinent to the theory is reviewed, and it is concluded that this model does not provide a satisfactory account of the data available.

In Chapter 11 the extinction rate theory is described. This theory deals with developmental trends in the reversal shift by postulating age-related changes in the relative difficulty of extinguishing attentional and instrumental responses. It is concluded that the theory provides the best explanation of evidence previously reviewed. Chapter 12 links the change in relative extinction rates of the two types of learning (attentional and instrumental) with developments in the child's ability to *represent* the relevant cues in a discrimination problem. Evidence supporting developmental

changes in the child's representational skill is cited, together with some evidence linking this skill with performance in discrimination problems.

In Chapter 13 a recognition test is developed as a measure of a child's ability to represent a particular class of cues - shapes made up of four lines meeting at a common centre. Marked developmental trends - and individual differences - are demonstrated in performance on the recognition test and on a matching test using the same stimuli. Chapter 14 attempts to relate scores on the recognition test to the learning performance of 6 and 7 year olds in reversal shift problems - involving the class of stimuli employed in the recognition test. Level of recognition score is found to be unrelated to either the initial or reversal learning if the relevant stimuli are reasonably different. However if the learning tasks that make up the reversal shift involve stimuli that are difficult to discriminate then recognition level is strongly related to performance in the initial learning task but rather weakly related to reversal learning ability. Possible reasons for this pattern of results are discussed.

In Chapter 15, 7 year olds' ability to cross-classify shape and colour is related to their learning ability in reversal shift problems made up of paired associate learning tasks (PAL.s). The stimuli for the PAL.s are colour form compounds. It is found that a child's classificatory ability is strongly related to learning performance in both initial and reversal PAL.s. The results are interpreted within the framework of a two stage model of the learning tasks and the extinction rate theory.

DEFINITIONS

1. Discriminandum (stimulus): The description (list of attribute values) which the investigator applies to a pattern of physical energies (corresponding to an object) which he supposes to impinge on the subject's sensorium during a discrimination learning trial.

2. Attribute value (cue): Class of stimuli e.g. all red things regardless of shape, size, etc.

3. Attribute (dimension): A class of the stimulus classes of definition 2 e.g. shape, colour, number etc.

CHAPTER 1

The Kendlers' Developmental Hypothesis: an Introduction

Over the past 15 years, one of the hypotheses most influential in research on children's learning has been the Kendlers' idea that infra-human subjects and very young children (4 years and younger) solve discrimination problems in a way markedly different from older children and adults (H. H. Kendler and Kendler, 1962; H. H. Kendler and Kendler, 1970). More specifically, the Kendlers postulated that the younger children's (and animals') discrimination learning could be adequately described by the single unit continuity theory proposed by Spence (Spence, 1936). According to this theory - originally proposed to explain the behaviour in rats in a simultaneous two-choice discrimination task - the subject was under relatively direct stimulus control. Given that a certain pattern of stimulation was impinging on the subject's receptors when a response was reinforced, *all* the cues in that stimulus pattern became associated with that response - although not necessarily all to the same degree (H. H. Kendler and Kendler, 1966, p.284). The subject did not significantly alter the nature of the effective stimulus by "filtering" or selectively encoding the input, and, in this sense, Spence's theory did not propose an attentional mechanism.

The Kendlers further asserted that, as the child became older, he was more likely to be active and self-regulating in his approach to discrimination tasks (H. H. Kendler and Kendler, 1968, p.218). The older child was seen as having a repertoire of *representational* responses which he could use to encode the cues in a stimulus pattern (T. S. Kendler and Kendler, 1970, p.24). Thus, faced with a stimulus setting

in a typical simultaneous discrimination (e.g. a large blue square and a small red circle), and asked to make a choice, such a subject has several different ways that he can represent this decision. For example he can understand his problem as selecting the red object or the blue object. Alternatively he might consider that he is to choose either a square or a circle, the large object or the small object, etc. Here, problem solution is a matter of the adult or the older child finding the appropriate representation or description of the stimuli and then learning to make the appropriate response (i.e. choose the correct cue). The representational responses mentioned above were thought of as implicit (covert) responses to the discriminanda. These responses produced, in turn, stimuli that controlled the choice responses (T. S. Kendler, 1963, p.34). Thus the *representational responses* were said to mediate (or provide a link) between the external stimulus situation and the overt instrumental response, and were termed *mediators*.

The Kendlers' hypothesis, henceforth termed the developmental hypothesis, was the product of studies that employed human adults (H. H. Kendler and D'Amato, 1955) or rats (Kelleher, 1956) as subjects. These experiments attempted to assess which of the above two types of learning processes were operating in the subjects by means of the transfer shown from an initial (training) to a second (test) discrimination task. Depending on the relation holding between the first and second discrimination tasks the transfer paradigm was termed either a reversal shift (RS) or an extra-dimensional shift (EDS). The nature of these transfer problems and their relevance to the developmental hypothesis

might best be explained by a description of the procedures used by the above investigators.

Kendler and D'Amato (1955) had college students indicate one of two responses (tapping below either a large orange diamond or a small grey ellipse) in response to a number of cards presented successively. The cards bore designs which varied in form (four forms; two rectilinear, two curvilinear) colour (two chromatic, two achromatic) and size (1 inch or 2 inches high). If subjects were assigned to a colour concept they were told that they were correct if they tapped below the large orange diamond in response to chromatic designs (irrespective of their shape etc.) or if they tapped below the small grey ellipse for achromatic designs. If assigned to a shape concept, subjects were reinforced for tapping the large orange diamond for rectilinear shapes (regardless of colour) and for tapping the small grey ellipse when shown curvilinear shapes.

After a subject in either of the two experimental groups had reached a criterion of 15 successive correct responses in the initial problem (training discrimination) he was shifted to a new problem *without warning*. Half the subjects in each group were now reinforced for responding in the *reverse* manner to subjects trained on a shape concept in initial learning (i.e. tapping the small ellipse for rectilinear forms etc.). The other half were reinforced for responding in the opposite fashion to those trained on the colour concept during initial larning (tapping the small grey ellipse for chromatic designs etc.). Control group subjects were given either of the two second problems without the subjects experiencing the training discrimination.

If a subject was given a shape concept in both the training and test discrimination tasks, this procedure was termed a reversal shift. More generally, an *RS problem* is a series of two discrimination tasks (training phase, test phase) in which the same attribute (e.g. shape) and cues (e.g. circle, triangle) are relevant (i.e. related to reinforcement / non-reinforcement) but the subject has to switch his responses to the cues during the test discrimination task.

The condition in which subjects were shifted from a shape to a colour concept (or vice-versa) was termed an extradimensional shift. An *EDS problem* is a series of two discriminations in which different dimensions are relevant. The dimension relevant in the test discrimination may have been variable and irrelevant in the training discrimination, constant in the training discrimination, or novel to the situation. If either of the first two possibilities hold, E has the option of employing new cues within the relevant dimension during the test phase of the shift problem.

In the experiment just described the subjects given an RS problem performed better than the appropriate control group during the test phase while subjects given an EDS performed markedly worse than their control group.

Kendler and D'Amato argued that their subjects' behaviour on any given trial could best be described as a two stage process: (a) the subjects would implicitly label the card shown by the experimenter, i.e. choose a cue representation from his repertoire, (b) and then make his overt (tapping) response. Learning was a matter of finding the appropriate stimulus labels (straight sides, curved sides - if the subject

was assigned to a shape concept) and then associating them to the correct tapping response. Within the framework of this theoretical analysis, subjects should find an RS problem easy because, when they reached criterion on the training phase they would have "established" the cue labels or representations that were appropriate for the test phase. These symbolic responses - or rather the implicit stimuli to which they gave rise - would merely be connected to the wrong tapping response. On the other hand such subjects should find an EDS relatively difficult since they must first discard the symbolic responses appropriate to the training phase, find the cue labels relevant to the test phase, and then associate them with the appropriate tapping response.

Kelleher (1956) ran white rats in a simultaneous discrimination task in which the relevant dimension (the attribute correlated with reward/non-reward) and the non-spatial irrelevant dimension (variable *within* trials, and uncorrelated with the presence/absence of reinforcement) were drawn from the following pair: brightness (black, white), or the presence/absence of chain curtains. After the subjects reached criterion on the training phase the experimenter either switched the cue-reward contingencies while keeping the same dimension relevant (RS), or correlated reward/non-reward with the previously irrelevant dimension (EDS).

Describing the above experiment at a more concrete level, equal numbers of subjects were assigned one of the cues black, white, chains, no chains, as the reinforced (positive) cue in the initial discrimination. Thus one quarter of the experimental animals were rewarded for entering a white (rather than black) goal box on any one trial, whether or not it contained chain

curtains, or appeared on the left or right position in the maze. During the second discrimination task, half of these animals were consistently rewarded for entering the *black* goal box (RS), one quarter were rewarded for entering the box without chain curtains (latter two groups were given EDS problems).

Kelleher found that the RS groups took significantly longer than the EDS groups to reach criterion on the test discrimination. Further, both these groups took longer than a control group that had been given an initial discrimination on an attribute (hurdles/no hurdles) not appearing in the second problem.

The Kendlers (H. H. Kendler and Kendler, 1962, p.7) argued that these results supported a single unit S-R analysis of the rats' discrimination learning. The line of reasoning was as follows. If a subject's learning process was accurately described by Spence's (1936) theory then such a subject finished the training phase of a shift problem with a high tendency to approach the positive cue and a low tendency to approach the negative cue of the relevant dimension. The tendency to approach either cue of the irrelevant dimension was somewhere between these extremes (H. H. Kendler and Kendler, 1968, pp.210-211). If the subject was assigned to an RS condition then the previously negative due had to attain the level of approach tendency elicited by the originally positive cue (i.e. the reinforced cue of the training phase) - and vice-versa. This difference in "excitatory potentials" (to be reversed) was large. On the other hand if the subject was allotted to an EDS problem then the new (test phase) positive cue already had a *medium*

tendency to elicit the correct response at the beginning of the second discrimination. In other words the test phase positive cue had a stronger tendency to elicit the correct response in EDS groups than in RS groups at the beginning of the second phase of the shift problem. The prediction was therefore that the EDS groups should outperform RS groups in shift problems. These were, of course, Kelleher's results with the white rat.

The different pattern of results obtained with rats and adult human subjects led the Kendlers (H. H. Kendler and Kendler, 1962, p.8) to hypothesize that, ". . . somewhere on a hypothetical evolutionary continuum between the rat and college student there should be a point where a transition is made from a single unit to mediational control. An obvious place to locate this point would be in the behaviour of young children." A number of studies were initiated to test the validity of this idea (T. S. Kendler and Kendler, 1959; T. S. Kendler, Kendler and Wells, 1960). The specific expectancy was that very young children might find an RS harder than an EDS, whereas for older children the reverse would be the case. Since the latter result had already been obtained with adults, interest was primarily centred on whether the first prediction would hold.

T. S. Kendler and Kendler (1959) gave kindergarten children (age 58 to 78 months) a simultaneous discrimination problem with the relevant and irrelevant non-spatial dimensions for any one group selected from the brightness and size dimensions. The irrelevant dimension varied *within* trials so that on a given trial the subject was shown two discriminanda differing on *two* attributes. The discriminanda used were black or white metal tumblers either $4\frac{3}{4}$ inches or $6\frac{1}{4}$ inches high.

After the subjects reached criterion on the above problem, they were divided into two groups matched on speed of learning in that phase. One of these groups was then assigned to an RS, the other to an EDS. It should be noted however that the irrelevant dimension only varied *between* trials during the test phase of shift i.e. on a given trial the discriminanda differed on only one attribute while over trials the pairs of discriminanda differed on the irrelevant attribute. The EDS and RS groups did not differ significantly in speed of learning the test discrimination.

The Kendlers speculated that they may have sampled a "transitional" age range, with some children using mediators and some not. The opposing tendencies predicted by the two modes of learning would tend to cancel out within each group, producing no difference between the two types of shift. In support of this idea, these investigators noted that when subjects were divided into fast and slow learners on the basis of their training phase performance, the fast learners performed as predicted by mediation theory (RS easier than EDS) while slow learners performed as would be expected from a single unit learning theory (EDS easier than RS). On the assumption that the tendency to employ mediators in discrimination learning produces (or, for that matter, reflects) an overall increase in efficiency of learning, this finding can be construed as support for the developmental hypothesis. Since mediation is seen as an indication of cognitive maturity, this assumption is plausible. However as will become clear later the proposition is not a necessary part of the Kendlers' hypothesis.

The first evidence strongly supporting the specific predictions of the Kendlers concerning young children, was

provided by T. S. Kendler, Kendler, and Wells (1960). Proceeding on the idea that five year olds *were* in the process of developing mediators (but that neither mediation nor single unit learning was dominant) these experimenters argued that it should be possible to find a younger population (3 and 4 year olds) in which the majority of subjects did not mediate. These subjects should show more evidence of *negative transfer* from the training to the test phase of an RS problem. As in the study with 5 year olds, the nursery schoolers were given a simultaneous discrimination task with either brightness or size as the relevant dimension. In this study, however, the *visual* irrelevant dimensions were *constant* both within and between trials. The only variable irrelevant dimension was the position of the positive cue (left/right) which, of course, varied randomly from trial to trial. After each subject reached criterion (9 of 10 successive trials correct), he was simply given an extra ten trials on the problem or given 10 trials in which he was instructed to tell the experimenter which stimulus contained the reward and which did not, before he made his choice. The subjects were given the test discrimination and were assigned either to an RS or EDS condition. The control group of subjects continued with the same dimension relevant and the same cue positive. A feature of the second discrimination was that a previously constant dimension (shape) was now variable and irrelevant within trials for RS, EDS, and control groups. In addition for subjects in the EDS group the dimension that had been relevant in the initial discrimination was *constant* within and between trials, and set at a value not shown during original learning.

A transfer score was calculated for each individual by subtracting his trials to criterion on the test discrimination from the number of trials he had taken to reach criterion on the initial discrimination. It was found that the RS group showed negative transfer while both the EDS and control groups showed marked positive transfer. There was no effect of instructions to verbalize. The investigators concluded, "These results . . . give credence to the conception that immature human organisms respond, like rats, on the basis of single unit S-R relationships".

In summary, the developmental hypothesis suggests the following set of predictions:

(a) Infra-human subjects will find RS problems more difficult than EDS's.

(b) Children, 4 years of age and younger, should exhibit *negative* transfer within an RS provided that variables such as "warm up", learning to learn etc. do not overwhelm the factor discussed previously. These subjects should find RS problems more difficult than EDS's.

(c) With increasing age of human subjects, there will be an increasing trend towards *positive* transfer from training to test phase of an RS. There will be no comparable age trend with the EDS and, therefore, RS problems will become increasingly easy with age, relative to EDS's.

The present chapter has described early confirmations of all these propositions. Chapter 2 attempts to evaluate predictions (a), (b) and (c) in the light of more recent evidence.

CHAPTER 2

Reversal Shift and Extradimensional Shift Performance of Infra-human Subjects, Three and Four Year olds, and Older Children: Recent Studies

Kelleher's (1956) finding, that rats found an RS more difficult than an EDS, has generally been confirmed by later studies covering a range of species: pigeons, chickens, monkeys and rats (see H. H. Kendler and Kendler, 1968, pp.207-208; and Sutherland and Mackintosh, 1971, ch.9 p.307, for brief reviews of these studies). However there is some indication that the difference in difficulty of the two types of shift problem is reduced if the non-spatial irrelevant dimension varies *between* rather than *within* trials during the test phase of the shift problem (see the second reference mentioned above).

In contrast, the basic finding of T. S. Kendler et al. (1962) - that 3 and 4 year olds show negative transfer within an RS problem, and that the RS is harder than the EDS for such children - has received only moderate support from later studies.

A series of investigations by Gollin (Gollin and Liss, 1962; Gollin, 1964, 1965 and 1966; Landau and Gollin, 1966) confirmed the developmental trend in transfer expected by the Kendlers within the RS problem. In a typical study (Gollin and Liss, 1962) subjects at three age-levels (3 years 6 months to 4 years, 4 years 6 months to 5 years, and 5 years 6 months to 6 years) were given a simultaneous shape discrimination with no variable non-spatial irrelevant dimension. Both relevant cues (circle, triangle) appeared on the *same*

distinctive background. After the subject reached criterion the reinforced cue was switched and the background for both cues was changed. After the child had solved the RS problem, a third stage of training was introduced with *both* backgrounds appearing over a series of trials. During this final phase the subject, on any given trial, was rewarded for choosing the cue that had been positive for the particular background exposed i.e. he had to make a *conditional discrimination*.

Gollin found that the three age groups did not differ in speed of learning the training discrimination. However the RS problem produced significant negative transfer between training and test phases for the youngest age groups, but *not* for the two older groups. The youngest subjects were also inferior to the older children during the final testing phase. Further research (Gollin, 1964) indicated that over-training on the initial discrimination *increased* errors during the test discrimination for the 3 years 6 months to 4 years group, while the *opposite* was true for the older children.

Marsh (1964) replicated the findings of T. S. Kendler et al. (1960) with his criterion trained group of 3 year olds. Simultaneous brightness and size discrimination tasks again formed the basis for RS and EDS problems (however, apart from position, there was no variable irrelevant dimension in either the training or test phases of the shifts). The subjects in the 3 year old, criterion trained group that were assigned to EDS learned the test discrimination more quickly than did subjects assigned to an RS. Moreover, the subjects given an RS showed negative transfer from training to test discrimination while the EDS subjects showed a very slight

positive transfer. In contract with Gollin's (1964) result, over-training *reduced* the negative transfer of the subjects given an RS.

Campione, Hyman, and Zeaman (1965) had retardates (mean M.A. = 51.2 months) learn a simultaneous discrimination with the relevant dimension and the non-spatial irrelevant dimension (variable within trials) chosen from colour and form. In the condition of interest here, subjects were assigned to an RS on solving the first discrimination (in the test discrimination the irrelevant dimension continued to vary within trials). These subjects showed marked *negative* transfer from the training to the test phase of shift.

In a pilot study, Trabasso, Deutsch, and Gelman (1966) found that although a younger group of children (median age, 4 years 3 months) solved the training phase of an RS faster than an older group (median age, 8 years 1 month), the reverse was true for the test phase. The younger group showed marked negative transfer (and the older group marked positive transfer) between the training and the test phases of the RS problem. Further, in Experiment 1, these investigators found that a group of nursery schoolers (median age 4 years 4 months) performed better on an EDS problem than on an RS (the discrimination tasks were simple colour or form discriminations position being the only variable irrelevant dimension). The group assigned to an RS problem showed negative transfer between the two phases of shift while this was not true for the group given the EDS. It should be noted, however, that when the stimuli were changed from two dimensional patterns to objects (wooden blocks of varying colour and size) the difference between the EDS and RS groups disappeared.

Tighe and Tighe (1967) compared the relative difficulty of RS and EDS for 4 year olds and 10 year olds. The shift problems were made up of brightness and height simultaneous discriminations with the non-spatial irrelevant variable *within* trials for the training phase. For half the subjects at each age, the irrelevant dimension was variable within trial during the test phase; for the other subjects, the irrelevant dimension was constant *within* trials but variable between trials during the test phase. Irrespective of the state of the irrelevant dimension during the test discrimination, the 4 year old children found the RS more difficult than the EDS. If the irrelevant dimension varied within trials, 10 year olds performed much more efficiently on the RS as opposed to the EDS. However with the irrelevant dimension constant in the test discrimination, 10 year olds performed equally well on the two types of shift.

Saravo and Gollin (1968) estimated the relative difficulty of the EDS and RS problems for naive subjects, 3 years 6 months to 5 years 6 months, with a mixed list, *within subjects* comparison of the two types of transfer problem. The subjects were shifted from a form or colour training discrimination to a test problem in which half of the settings were exactly as in the original learning - with however the previously negative cue now rewarded - while the other settings presented a discrimination problem in the dimension that had not been relevant for the subject in the training phase. In this latter type of setting the originally relevant dimension was constant. Naive subjects made more errors on the RS than EDS test phase while sophisticated subjects (who had been subjects in an over-learning reversal experiment, four months before) found the two types of shift equally easy.

The preceding group of studies supported the Kendlers' predictions outlined at the end of Chapter 1. The following experiments offer contrary evidence.

House and Zeaman (1962) performed an experiment in which retardates of two mental age groups (M.A. 4 to 6 years; 6 to 8 years) were compared on RS's and EDS's. The shifts were made up of colour and form simultaneous discrimination tasks with the irrelevant dimension (colour or form) either constant or variable within trials. Subjects were given 25 trials per day and run to a criterion of twenty correct out of 25 successive trials. In the training problem all subjects were then given 125 trials over-training. If the subject did not reach criterion he was given training trials with the negative cue replaced by a "junk" object varying multidimensionally from the positive cue. If he continued to fail, the experimente showed the subject the positive cues together and said, "These blocks are always right. The candy is always under these blocks". The procedure was repeated with the negative cues. The experimenter said, "These blocks are always wrong, the candy is never under these blocks".

Both the M.A. groups found an RS easier than an EDS. However, as House and Zeaman pointed out, this effect appears to have been at least partly due to the fact that these subjects learned a form problem more easily than a colour problem and that only a minority of these children, in fact, solved the latter problem. Thus for most subjects an RS was a shift from an "easy" to an "easy" dimension (form - form) while an EDS was a shift from an "easy" to a "hard" dimension (form - colour).

Dickerson (1966) gave pre-school children (mean age 56.1 months) RS or EDS problems made up of form or colour simultaneous discrimination tasks (the irrelevant non-spatial dimension, variable within trials, was also either form or colour). If the subject had not reached criterion on the initial discrimination within 40 trials, the experimenter gave special training highly similar to the *second* procedure used by House and Zeaman (1962). The young subjects used in this study learned the test discrimination more quickly if given an RS rather than an EDS problem. Dickerson concluded that ". . . preschool children make mediational responses to the relevant dimension of discrimination problems, and that they transfer these responses to subsequent problems".

Saravo (1967), using the mixed list design described in connection with Saravo and Gollin's (1968) study, found that 4 year old children performed better on the EDS rather than RS settings in the second discrimination *if there was no variable irrelevant (non-spatial) dimension*. They found the RS and EDS settings equally difficult if at least one irrelevant dimension varied within both types of setting (a different dimension, of course, for each type of setting). On the other hand 7 year olds found the RS settings easier than the EDS settings irrespective of whether the irrelevant dimensions varied within settings or were constant.

Mumbauer and Odom (1967) studied the effects of verbalizing and over-training on the RS and EDS performance of pre-school children (ages 3 to 6 years, mean age: 5 years). The relevant dimension and the non-spatial irrelevant dimension (which varied within trials during both phases of shift) were either shape or colour. The results indicated (among other things)

that these subjects found an RS easier than an EDS across all conditions - including the group that received no over-training in the training phase. These investigators concluded that, ". . . the transition in human development from unmediated to mediated behaviour either occurs at an earlier age than was hypothesized by Kendler and Kendler (1962), or does not occur at all".

Fritz and Blank (1968) supported the T. S. Kendler, Kendler and Wells (1960) findings with nursery schoolers (mean age: 4 years 3 months) and colour and size discriminations i.e. these children found an RS harder than an EDS. However this result only held if the subject was given both the initial and training discriminations with the irrelevant dimension varying only *between* trials. Another group, shifted from an initial task, with an irrelevant dimension varying within trials, to a test discrimination with the irrelevant dimension varying between trials, showed precisely the opposite result: these subjects found an EDS problem markedly harder than an RS. Fritz and Blank argued that the findings of Kendler et al. (1960) were due to a design that kept the irrelevant dimension constant for the subjects during the training phase of shift.

Caron (1969), in an experiment designed primarily to assess the role of dimensional salience on the discrimination learning of 3 year olds, ran a control group that was not assessed for dimensional preference until after the usual shift problem - an important point of procedure, as will be seen later. The RS and EDS problems were composed of brightness and height discriminations with the irrelevant dimension varying *within* trials during both phases. Subjects assigned to an RS learned significantly faster than those assigned to an EDS during the test phase of the shift problem. However

both types of shift generated negative transfer from the first to the second discrimination. Caron argued that, ". . . the data support the attentional proposition that very young children do indeed mediate".

What is one to make of this array of contradictory results? One way of explaining the contrasting findings is to note that they tend to differ on one point of method. Results supporting the Kendlers' developmental hypothesis generally occurred in experimental conditions which kept non-spatial irrelevant dimensions *constant within trials* for either the training phase only (Kendler et al., 1960), the test phase only (Saravo, 1967; Saravo and Gollin, 1968), or for both phases of the shift problem (Gollin and Liss, 1962; Gollin, 1964; 1965; 1966; Marsh, 1964; Trabasso et al., 1966; and Fritz and Blank, 1968 - their "constant" condition). The two exceptions are the studies of Campione et al. (1965) and T. J. Tighe and Tighe (1967).

In contrast, experimental conditions giving negative results generally had a non-spatial irrelevant dimension varying within trials for both the training and test phases of the shift problems. The only exception is the study of Fritz and Blank (1968). These investigators found results contradicting the Kendlers' hypothesis in a condition in which subjects were shifted from a training discrimination with an irrelevant variable dimension to a test discrimination in which the irrelevant non-spatial dimension only varied *between* trials.

In support of the above interpretation Eimas (1965) noted that if one assumes that 3 and 4 year olds can mediate, the effect of holding the non-spatial irrelevant dimension constant

during the test phase of a shift problem should be to reduce or eliminate the interference expected for the subjects given an EDS. It will be remembered that this negative transfer was due to the subject having to discard a mediator that had been appropriate to the training phase but not relevant to the test phase of the EDS. A test phase in which the subject was not given any systematic basis for responding on the previously relevant dimension should result in very rapid rejection of the inappropriate mediator. This, in turn, should reduce the superiority of the RS subjects during the test phase of shift, since holding the irrelevant dimension constant is unlikely to help RS subjects.

Eimas restricted himself to the above suggestion but his line of reasoning would have to be expanded to deal with the results summarized. It is not clear, for example, how the above factor would make an EDS easier than an RS, since a mediation model would still predict positive transfer for RS subjects irrespective of the state of the irrelevant dimension during the test phase of shift. However if the further assumption is made that having only *one* non-spatial dimension vary within trials made the relevant dimension *obvious* for a given discrimination, then the data might be explained. It could then be argued that a shift problem that used this type of discrimination task in both phases of shift would, in fact, "reduce" a two stage (i.e. mediation) theory to the single unit model. From such a point of view, the single unit model is a special case of the more general two stage model; this special case occurring when a subject is confronted with a problem in which dimension and cue selection (i.e. attending to the relevant cues) are trivially easy stages of task solution.

In such a problem the chief difficulty for the subject is to associate the "obvious" cues with the correct responses. Thus 4 year olds' learning might be adequately described by Spence's (1936) model when special procedures are used, even though such children employ mediators.

An implicit (and implausible) assumption in the above argument is that the positions of the discriminanda are not effective cues in discrimination problems, for 3 and 4 year olds. Allowing for this however, the hypothesis still has its problems. Firstly it does not explain the results of T. S. Kendler, Kendler and Wells (1960), or those of T. J. Tighe and Tighe (1967). Both these experiments found the RS markedly more difficult than the EDS for 4 year olds, with an irrelevant non-spatial dimension variable within trials during the test phase. Most damaging to the explanation is Tighe and Tighe's study which was designed as a direct test of Eimas' (1965) proposal and included both "constant" and "variable" conditions. It will be recalled that the state of the irrelevan dimension did *not* affect 4 year olds' performance.

Secondly the explanation cannot deal with the age trends that Gollin revealed in transfer *within* the RS (Gollin and Liss, 1962; Gollin, 1964, 1965, 1966) when no irrelevant non-spatial dimension was involved. If the latter design feature reduces the two stage theory to the one stage model, this should have been equally true at the three ages tested.

Thirdly, the studies that seem to produce results directly favourable to Eimas' hypothesis (Saravo, 1967; Fritz and Blank, 1968), in fact, contradict one another. It may be recalled that Saravo found the EDS superior to the RS performance only when there was no non-spatial irrelevant dimension varying

within trials during the test phase. Subjects in this experiment were shifted from a training phase *with* a non-spatial irrelevant dimension variable within trials. This result may be contrasted with Fritz and Blank's finding that 4 year olds only found an EDS superior to an RS, if they had been given a shift problem with no non-spatial (variable) irrelevant dimension in *either* phase of the shift problem. If the subject was exposed to a variable irrelevant dimension during the training phase, and then shifted to a test phase with no non-spatial irrelevant dimension varying within trials, he found an RS easier than an EDS. It is clear that the experimental condition that supports the Kendlers' developmenta hypothesis in Saravo's study yields precisely the opposite result in Fritz and Blank's experiment.

Finally it should be noted that Eimas' (1965) interpretation cannot explain the pattern of results found by Fritz and Blank (1968). In that study, the introduction of an irrelevant dimension in the *training* phase of the shift problem increased the difficulty of an EDS but markedly decreased the difficulty of an RS for 4 year olds - the irrelevant dimension in the test phase being constant within trials over *all* conditions. Both of the above effects can really only be explained by assuming either that a 4 year old is more likely to mediate, or that his mediator is somehow more strongly established, in a discrimination problem with a non-spatial irrelevant dimension variable within trials. This last assumption is not easily deduced from more basic principles (but see the later discussion of differentiation theory) and is certainly not covered by Eimas' vague characterization of mediation theory.

An alternative interpretation of the series of results previously cited would attempt to explain away the findings that failed to support the developmental hypothesis. Mandler (1962) has suggested that subjects who have solved a problem by learning simple S-R connections will tend to develop cognitive structures - analogues or covert representations of the overt behaviours - during over-training. This idea need not be extended too greatly to produce the hypothesis that 3 and 4 year olds could develop or strengthen "structures" representing the cues in the stimulus patterns (i.e. mediators) during the over-training of a discrimination. Thus over-trained 3 and 4 year olds would tend to respond in mediation fashion on the test phase of an EDS or RS. This naturally would not invalidate the Kendlers' proposition that 3 and 4 year olds, trained to a typical criterion of 9 correct in 10 successive responses, would respond according to a single unit theory in EDS or RS problems. Such considerations would indicate that the results of studies which over-trained subjects (e.g. House and Zeaman, 1962) would not produce results directly relevant to the Kendlers' developmental hypothesis.

T. J. Tighe and Tighe (1967) pointed out that Dickerson's (1966) study had used a special training procedure for subjects having difficulty during the training phase of shift. Since various supplementary training procedures (over-training - Marsh, 1964; perceptual pretraining - L. S. Tighe, 1965; McConnell, 1964; verbalizing - H. H. Kendler and Kendler, 1961) had facilitated RS problems, Dickerson's finding might not have been representative of 4 year olds who had solved the initial discrimination unaided.

Again, in view of the marked changes in the relative difficulty of RS and EDS that the Kendlers (T. S. Kendler and Kendler, 1959; T. S. Kendler, Kendler and Wells, 1960) had observed between the ages of 4 and 5 years, it might be argued that Mumbauer and Odom's (1967) result was not really relevant to the developmental hypothesis. These investigators used subjects with an age range 3 to 6 years and a mean age of 5 years. According to the Kendlers, such an age range would contain children in all stages of mediational development. Presumably no attempt would be made to predict the overall performance on the RS and EDS problems.

Allowing for all the above points however, the studies of Fritz and Blank (1968) and Caron (1969) remain. Presumably the explanation here is that the 3 and 4 year olds used in these studies happened to be more cognitively mature than the samples used by T. S. Kendler, Kendler and Wells (1960) and T. J. Tighe and Tighe (1967). This type of argument brings up the point made by Morrisett (1963, p.50) in his commentary on T. S. Kendler's (1963) paper: that the ease of reversal shifting might be more profitably related to indices of *cognitive development* rather than to chronological age.

It is the present writer's view that the studies reviewed above lend *mild* support to the Kendlers' hypothesis - at least to their prediction (b), given at the end of Chapter 1. It seems true that a finding of negative transfer within an RS problem, together with the related finding that EDS is easier than the RS problem, is more common with 3 and 4 year olds than it is with adult subjects.

The evidence for later age trends in the relative difficulty of the RS and EDS (i.e. developmental trends after the age of

6 years or so: prediction (c)) is not strong. Wolff (1967, p.379) has listed results that he considers unfavourable to a developmental hypothesis which predicts developmental trends in mediational ability over a wide age range. However some of these studies used adjacent age groups (Willer, 1963; Cobb, 1965; and perhaps Eimas, 1966 - the latter compared the performance of 5 and 7 year olds) while others (Youniss, 1964) used a wide age range but not the appropriate shift comparison. Youniss compared an *intra-dimensional shift* (IDS) with the usual EDS problem (the intradimensional shift is a transfer problem in which the *same dimension* but *different cues* are relevant in the training and test phases. Thus the subject might be trained to approach red and avoid green in the trainin phase and then to choose blue and avoid yellow in the test discrimination). While Youniss's finding that the relative difficulty of IDS and EDS problems does not change between ages 7 and 13 years will markedly affect how a *change* in the relative difficulty of RS and EDS problems is interpreted, it is not directly relevant to the empirical problem of whether the latter trend exists.

The final study reviewed by Wolff is that of Milgram and Furth (1964). These experimenters gave 6 and 9 year olds a rather atypical problem. In both the training and test phases, the subject had to choose one of *three* stimuli on each trial and in the training phase the relevant non-spatial dimension (form, colour or size) was confounded with position during the training problem. In the experimental conditions of interest, the subject was shifted to a test discrimination in which position was no longer relevant but either a previously negative cue from the originally relevant non-spatial dimension

(RS) or a cue from a previously irrelevant dimension (EDS) was the positive cue. The RS was easier than the EDS for both 6 and 9 year olds, and there was *no* interaction of transfer problem with age. There is no obvious explanation of these results. Milgram and Furth's procedure differed on a number of points from the usual shift problem and any of these might have been effective in preventing a developmental trend emerging.

In summary, studies using transfer within an RS or relative difficulty of RS and EDS problems, as indices of the presence or absence of mediation, have tended to support the Kendlers' proposal that infra-human subjects do not employ mediators. This same type of study has provided *moderate* support for the idea that 3 and 4 year olds do not mediate. However, studies employing the above methodology have not shown age related increases in the tendency to employ mediators beyond the first grade level (6 years of age). Such developmental trends *have* been indicated by a different experimental paradigm: the optional shift problem.

CHAPTER 3

The Optional Shift Problem: Developmental Trends

Early in the 'sixties the Kendlers changed their research strategy. Rather than running EDS and RS groups at various ages to check their developmental hypothesis, they adopted a technique which enabled them to gauge an *individual* child's preference for an RS over an EDS. The experimental design, adapted from Buss's (1956) work, was termed an *optional shift problem* (OS). The shift problem might best be described by giving an account of an experiment by T. S. Kendler, Kendler and Learnard (1962). These investigations gave 3, 4, 6, 8 and 10 year olds a simultaneous discrimination problem in which either brightness or size were correlated with reward/non-reward while the irrelevant non-spatial dimension (brightness or size) varied within trials. Thus, on any given trial, the subject was presented with either (a) a large black square and a small white square, or (b) a large white square and a small black square. If black was the positive cue for this subject he was rewarded for consistently choosing the black square in each pair, irrespective of its size. After the subject reached criterion on the training problem (9 correct of 10 consecutive responses) a second problem was presented without warning. During this problem (second phase) the subject was shown only one of the pairs of discriminanda that had appeared in the training problem (first phase) - for example the large white and small black squares - and rewarded for choosing the previously negative stimulus (the large white square for the hypothetical subject). When the subject had reached criterion in phase 2 (as strict as for phase 1), a final test series

(third phase) was introduced in which *both* the pairs of discriminanda of phase 1 were presented in alternation for a total of 20 trials. The reinforcement pattern of the pair of stimuli presented in the second phase was maintained in the final test phase, but the subject was rewarded for choosing either discriminandum in the other (test) pair.

It is apparent that the brightness *and* size cues were both relevant and redundant during the second phase of the optional shift problem. The point of the third (test) series was to discover whether the hypothetical subject had been responding to the whiteness or the large size of the cue that was positive in the second phase; or, alternatively, whether his choice response had been controlled by both of these cues. If the subject had been responding to whiteness in the second phase then he would consistently choose the small white square when shown the test pair in the third phase. If he had been responding to the cue "large" then he would consistently select the large black square when confronted with the test pair. Finally, if both cues had been controlling the subject's behaviour in the second phase, he would not consistently select either stimulus in the test pair.

Thus, with the OS design, the experimenter wishes to know whether the subject's second phase learning is controlled by:

(a) the cue from the relevant dimension of the first phase which had been consistently non-reinforced during that phase;

(b) the cue from the irrelevant dimension of the first phase that had been reinforced 50 per cent of the time during that phase; or

(c) both of the above cues.

A mediation model would predict the first alternative since the implicit responses, representing the relevant cues, developed by the subject in the first phase would remain appropriate in the second phase, and it is assumed that mediating subjects can rapidly shift their choice responses. On the other hand the predictions from a single unit S-R theory are not so clear (H. H. Kendler and Kendler, 1968, pp.210-213). The key postulate of Spence's (1936) theory - that the subject learns something about all cues, relevant *and* irrelevant, that impinge on his receptors during a given trial - will be recalled, together with its corollary that the subjects end the training discrimination with three levels of approach tendency: highest to the positive cue, intermediate to either cue from the irrelevant dimension, and lowest to the negative cue. For such a theory the first trials of the second-phase discrimination involve two simultaneous processes: the difference between the approach tendencies of the cues from the first-phase relevant dimension is eliminated; and differential reinforcement establishes differential approach tendencies towards cues from the previousl irrelevant dimension. If learning proceeds long enough, however, new differential approach tendencies will be set up for the cues within the relevant dimension of the first phase. On the assumption that the approach tendency for a given cue eventually approaches an upper or lower asymptote, it can be predicted, for the second-phase learning, that the approach differential for cues within the dimension relevant for *both* first and second phases (brightness in the example above) will eventually approximate the approach differential of cues within the first-phase irrelevant dimension. Now the test

stimulus pair of the third phase brings the approach differential developed for brightness into conflict with the differential developed for size. Only if one such approach differential clearly outweighs the other, will the subject exhibit a consistent choice in the third phase. Considering the above, this will only occur if learning has *not* gone "too far" at the end of the criterion run for the second phase. However, if it does occur, such consistent choice behaviour should be controlled by the cues from the dimension irrelevant during the first phase. The single unit formulation predicts, therefore, that the hypothetical subject, rewarded for selecting black squares regardless of size in the first phase, and a large white square in the second phase, will either prefer a large black square to a small white square or exhibit no consistent preference at all during the third stage. This prediction is in marked contrast to the expected preference for the small white square derived from a mediation model. For convenience the third phase pattern of responding expected by a mediation theory will be termed optional reversal; the consistent pattern expected by single unit theory, optional extra-dimensional shift; and the irregular response pattern will be termed inconsistent shift.

The different choice patterns expected in the third phase of the optional shift problem by mediation and single unit theories, when coupled with the Kendlers' developmental hypothesis, lead to the prediction that an increasing proportion of children will make optional reversals with increasing age. T. S. Kendler, Kendler and Learnard (1962) found that the proportion of subjects choosing an optional reversal (at least 8 choices of the appropriate object in 10

trials) was a negatively accelerated increasing function of age: the proportion of optional reversals rising from 37.5 per cent of 3 year olds to 62.5 per cent of 10 year olds. The percentage of subjects that made an optional extradimensiona shift remained constant across age groups (at about 23 per cent) and the percentage of subjects classified as inconsistent dropped from slightly over 40 per cent at 3 years to just under 10 per cent at 10 years. It was also found that the ability to correctly verbalize the cue that had guided subjects' behaviour in the second and third phases of shift performance was highest among subjects making optional reversals.

Wolff (1967 p.380) has questioned the Kendlers' mediational interpretation of the age trend found by T. S. Kendler, Kendler and Learnard (1962). He has pointed out that the percentage of subjects making optional reversals seemed to be reaching a relatively low asymptote as a function of age, and that it was implausible that "30 to 40 per cent of normal human adolescents are still incapable of mediation".

T. S. Kendler et al. (1962, pp.583-584) recognized the above problem and argued that there might be a learning process more advanced than simple mediation. It was thought that a minority of the older children could respond to more than one dimension, not through the primitive single-unit mechanism, but rather by "integrating" more than one mediator. This idea was supported by the finding that a significant minority of older children verbalized *both* the second phase relevant dimensions. (It is also supported by studies which indicate developmental trends in children's "attention span" [Pascual-Leone and Smith 1969; Eimas, 1969; Inhelder and Piaget, 1964]).

Children who had the ability to deal with more than one mediator simultaneously would be able to shift easily between different representational responses aroused by the stimuli. This, in turn, might make an EDS much more likely.

Wolff's (1967) reply to this rather interesting hypothesis was that since either an optional reversal or an optional extra-dimensional shift could result from mediation, the comparisons of the two response types over age was not relevant to the mediation-single unit learning issue. It is felt that this argument is spurious. A three stage developmental theory of discrimination learning ((a) no mediator, (b) single mediator capacity, (c) multiple mediator capacity), with a time lag of some years between the two mediator stages, *would* predict the T. S. Kendler et al. (1962) pattern of results. Further, Wolff does not provide a plausible alternative explanation. The above three stage theory at least has the merit of suggesting further lines of research. Further studies could be aimed at relating available measures of cognitive development (e.g. Piagetian cross-classification tasks) to the subjects' OS performance. The above theorizing would suggest that the proportion of reversals would tend to be an inverted U shaped function of cognitive development.

If the three stage mediation model has any applicability it seems limited to discriminanda that are size-brightness or size-colour compounds. T. S. Kendler and Kendler (1970) gave an optional shift problem to kindergarten, grade 2, grade 6 and college students. For any child, one of the following pairs of dimensions was involved in the shift problem: (a) colour and form; (b) colour and size; (c) size and form.

As in the T. S. Kendler et al. (1962) study the proportion of children choosing an optional reversal was an increasing function of age. Also in line with the latter study, the dimension pair (colour-size) that most nearly matched that used by T. S. Kendler et al. (brightness and size) tended toward a low asymptote of about 75 per cent optional reversals. However, when the data were averaged across all dimension pairs, it was clear that the overall asymptote indicated was closer to 85 or 90 per cent. In general, therefore, the data supported the Kendlers' simpler two stage developmental hypothesis and, incidentally, answered Wolff's (1967) criticism of the earlier study.

Despite the replicability of developmental trends in the proportion of optional reversals (André, 1969) some doubts do remain as to its significance. Wolff (1967) cited a study by Jeffrey (1965) which involved the optional shift problem and produced some rather disturbing results. Jeffrey found that when he changed an irrelevant dimension (form) from the first to the second phase (the irrelevant dimension had been constant both *within* and *between* trials during the first phase, and remained so during the second and third phases although, of course, fixed at a different value) then a developmental trend, obtained between 4 and 10 year olds with the standard procedure, disappeared. The majority of subjects (about 75 per cent) at all ages chose a reversal shift in this condition. This finding is difficult to explain. From the point of view of mediation theory, the variable manipulated should have had no effect at all on the percentage of optional reversals. On the other hand, the outcome does not support any alternative theory (Jeffrey's (1965) explanation is flawed - see Wolff

(1967, pp.395-396)). The net effect, however, is to shake one's faith in the robustness of the developmental trend demonstrated by the Kendlers.

To counter the doubts aroused by Jeffrey's study, there is considerable evidence that the OS problem is sensitive to training variables that might be expected to affect a child's tendency to use mediators. This type of evidence provides some construct validation for the paradigm.

T. J. Tighe and Tighe (1966) found that 100 trials overtraining on the initial problem significantly increased the proportion of optional reversals in a group of 4 year olds. Three year olds showed a non-significant increase while 200 to 300 trials overtraining tended to *decrease* the proportion of optional reversals in rats. One interpretation of this result would involve Mandler's (1962) assumption of cognitive structures (a mediator) developing during overtraining for the 4 year olds. This explanation would assume that subjects would only be affected by the additional learning trials if maturation and previous experience had enabled the subject finally to produce the mediator. Another interpretation would assume that overtraining had strengthened a mediator that had been present during early learning trials but was at less than asymptote strength at the end of the criterion run (Lovejoy, 1966).

T. S. Kendler (1964) asked one group of 5 year olds to label the "winner" and the "loser" (i.e. the positive and negative cues within the relevant dimension) during the training discrimination. Verbalization facilitated the first (but not the second) phase of the shift problem and increased the percentage of subjects making optional reversals from 33 to 79

per cent. An obvious interpretation is that encouraging the subject to describe the relevant cues overtly makes it more likely that such a stimulus description will mediate the learning of the discrimination. There is evidence, however, that the stimulus description (or mediator) need not involve verbal processes. André (1969) reported that deaf 7 and 12 year olds (i.e. subjects markedly retarded in the development of verbal skills) chose an optional reversal just as frequently as subjects with normal hearing.

T. J. Tighe and Tighe (1970) gave groups of 4-, 6-, 8- and 10- year olds a "perceptual" pretraining procedure. This procedure involved the subject making same-different judgements to pairs of stimuli successively presented. These stimuli were combinations of three height and three brightness values and included the discriminanda of the OS problem. Overall, the pretraining increased speed of learning in the second phase of the problem and increased the percentage of subjects making optional reversals. There was some indication that the training was ineffective for the four year olds.

Again, this training technique can be interpreted plausibly as providing the subject with an opportunity to establish or strengthen representational responses to the dimensions and cues that he was shown in the later discrimination. The ineffectiveness of the procedure with 4 year olds suggests that the availability of the mediator is also dependent on the child's level of cognitive development.

Summarizing the results of studies using the optional shift problem, certain conclusions may now be drawn. Firstly, the fact of an age trend in choice of optional reversals seems established (T. S. Kendler, Kendler and Learnard, 1962;

André, 1969; T. S. Kendler and Kendler, 1970; T. J. Tighe and Tighe, 1970). It is also true that such an age trend is predicted on the assumption that with increasing age, an increasing proportion of subjects tend to mediate in discrimination problems. Therefore, the optional shift paradigm has provided solid support for the Kendler's developmental hypothesis. Confidence in the OS paradigm is increased by evidence that it is sensitive to various training procedures that can be interpreted (plausibly) as affecting the probability that the subject will employ a mediator. (T. S. Kendler, 1964; T. J. Tighe and Tighe, 1966; and T. J. Tighe and Tighe, 1970).

CHAPTER 4

Reversal and Half-Reversal Shifts: Developmental Trends

As their research programme progressed, the Kendlers (H. H. Kendler and Kendler, 1968) realized that shift studies that employed discriminanda varying in form, size, colour, brightness etc. were not well suited to specifying the precise nature of the mediator. The first stage (cue identification or selection) of the basic two stage theory had been variously described as (a) *an observing response* - gross or more fine-grained adjustment of receptor orientation, e.g. head and eye movements (Wyckoff, 1952); (b) *an attentional response* - a mechanism that filters and organizes the stimulus pattern impinging on the receptors so that only a subset of the available cues is effective in learning (Mackintosh, 1965); (c) *a perceptual response* - the subject becomes "sensitive" to the variables present in the stimuli and "isolates" the relevant distinguishing feature (L. S. Tighe and Tighe, 1966); and (d) *a representational (symbolic) response* - the subject *thinks* about the stimuli and selectively encodes certain features of the stimulus array. This encoding process is dependent on subjects' *cognitive ability* and verbal processes are probably, though not necessarily, implicated (H. H. Kendler and Kendler, 1968, p.225). The Kendlers preferred the last interpretation and attempted to demonstrate a developmental trend in ease of reversal shifting when the influence of observing response and attentional or perceptual mechanisms was minimized. To this end they employed a successive discrimination problem (H. H. Kendler, Kendler and Sanders, 1967; H. H. Kendler, Kendler and Marken, 1969) and a different

type of shift comparison. Reversal shifts were compared with half-reversal shifts (HRS). The observing responses made to the individual stimuli (animals, articles of clothing, types of fruit - presented as pictures, spoken words, or both) was considered to be the same in both types of shift.

H. H. Kendler, Kendler and Marker presented subjects aged 4, 5, 7 and 18 years with a series of stimuli (four or eight). Half the stimuli were from one category (e.g. clothing) the remaining stimuli were examples of a different concept (e.g. food). As the experimenter presented each stimulus (in, say, pictorial form) the subject had to respond in one of two ways (the 5, 7 and 18 year olds pressed a white or black button; the 4 year olds "posted" each picture in either a white or black box). The subject then received feedback about the correctness or otherwise of his response. In the training discrimination all the instances of one category were assigned by the experimenter to one response and the stimuli in the other category were assigned to the remaining response (thus the subject might be reinforced for placing "articles of clothing" in the black box and "types of food" in the white box). After criterion was reached, however, subjects were either assigned to an RS or an HRS group.

In an HRS, half the instances of each category were assigned by the experimenter to the response different from the one rewarded in the training phase, while the subject was rewarded for responding to the remaining instances in the same way as in the training discrimination. In the hypothetical case above, the subject might have been rewarded for pressing the white button for the items dress, coat, pants and shirt in the training phase. In the test phase,

pressing the white button would remain correct for (say) "coat" and "pants", but pressing the black button would now be correct for "dress" and "shirt".

In the RS test phase, *all* the instances of each category were assigned to the response different from the one that the subject had been rewarded for giving in the training phase. The subject may have been rewarded for pressing the black instead of the white button (correct in the training phase) for items of clothing in the test phase of shift.

These two types of shift are readily analyzed in terms of single unit and two stage theories of learning. If the subject learns the training discrimination by directly associating each stimulus item to the appropriate response, the HRS should be easier than the RS. Clearly, in the HRS, the subject has to learn to switch only half as many items as in an RS. On the other hand if the subject is mediating, i.e. representing the stimulus *categories* and associating them to the appropriate responses, then an RS should be easier than an HRS. In the RS, the symbolic responses that represent the stimulus categories are still appropriate, i.e. they enable the subject to predict perfectly the response that will be reinforced once he realizes that he has to switch responses. Following the now familiar line of argument, marked positive transfer would be expected from the training to the test phase of the RS shift. For the HRS the stimulus categories are not appropriate (i.e. cannot be used to predict reinforcement) during the test phase. The subject has either to reject his previous "organization" of the stimuli and relearn the single item-response associations, or develop a rather more unwieldy

mediator (e.g. a rule such as, "All clothes except the dress and shift go with the white button"). In either case, positive transfer would not be expected.

If the above theory is linked with the developmental hypothesis, it can be predicted that with increasing age the speed of making an RS will increase relative to the speed of an HRS. H. H. Kendler et al. (1969) reported that the HRS and the RS were equally difficult for 4 year olds while college students solved the test phase of an RS in one third of the time needed to solve the test discrimination of an HRS. The 5 and 8 year olds occupied intermediate positions on the scale of relative difficulty of the two types of shift. Overall, the ease of the RS (relative to the HRS) was a monotonically increasing, negatively accelerated function of age. This clearly supported the notion that, in the training phase of the shift problem, older children and adults were more likely to produce the two mediators that represented the stimulus classes relevant for solution. Further evidence that it was the increasing availability of the relevant concepts (e.g. clothing, animals) that produced the developmental trend came from the results of an earlier experiment (H. H. Kendler, Kendler and Sanders, 1967). In that study, college subjects found an RS much easier than an HRS with conceptually linked words but had performed equally on the test phase of an RS and an HRS, if the stimuli were unrelated consonant trigrams. These latter stimuli could not be readily grouped into categories to aid problem solution and it could be plausibly argued that a large number of subject would be reduced to associating each single item with its appropriate response. Thus, the argument runs, college student

learned to sort consonant trigrams in much the same way as 4 year olds learned to sort conceptually linked pictures.

The Kendlers' developmental hypothesis seems quite plausible when applied to material such as the conceptually linked pictures. It seems eminently reasonable to expect age trends in the child's capacity to abstract and operate with super-ordinate concepts such as "food" or "animals". Indeed Piaget (Inhelder and Piaget, 1964, chs. 1, 2, 3 and 4) has shown developmental trends (up to 8 years of age) in the ability (or tendency?) to use such concepts to exhaustively and consistently sort toy animals, houses, people etc. into separate piles. In such sorting tasks, the child is presented with all the material and asked to "put together the things that are alike, that go together". The young child (below 5 years of age) does *not* sort by super-ordinate categories but creates what Piaget calls graphic collections. He might select elements from all the above mentioned categories and form a model village or farm; or put a man and a child with a pig because "the baby is playing with the pig" and "the man is looking after the pig".

Bruner and his colleagues (Bruner et al., 1966, ch.3) have also demonstrated developmental trends in the ability to use super-ordinate concepts in a slightly different classification task. Shown a line of four pictures (banana, peach, potato, and meat) and asked, "How are they all alike?" a six year old might answer (see p. 70), "A banana is yellow, and a peach is yellow, sometimes red and sometimes just yellow, and a potato is light flesh, and meat is brown". The more mature response (typical of 9, 11 and 16 year olds) is, of course, "They're all food".

The above two studies of the child's developing classification ability provide convincing support for the developmental hypothesis. The mediators appropriate to the successive discrimination task previously described are clearly more available to older children and adults than they are to young children. There is also independent evidence that older children are more likely to make use of stimulus categories in learning or memory tasks.

With increasing age (5 to 11 years) increasing degrees of clustering have been shown in children's free recall of categorized lists (Rossi, 1964; Vaughan, 1968). These lists are composed of items drawn from a limited number of categories (e.g. animals, food, parts of the body, and clothing) and the degree of clustering in a given child's recall is the degree to which he recalls items from the same category together, when tested. These findings support the idea that older children are more likely to use higher order categories to aid the storage and/or retrieval of the type of item used by H. H. Kendler et al. (1969) in their discrimination problem.

CHAPTER 5

Individual Differences: Measures of Cognitive Development related to Reversal Shift and Optional Shift Performance

It may be recalled that Morrisett (1963) indicated a weakness in an early statement of the developmental hypothesis. He noted that the Kendlers had related changes in the probability of mediation to *chronological age*. It was more likely, he argued, that measures of mental age and level of cognitive functioning would be more useful in predicating a child's tendency to activate a mediator. The following group of studies attempted to assess the validity of this proposition.

As has been previously mentioned, T. S. Kendler and Kendler (1970) demonstrated marked increases in percentage of optional reversals with increasing age. These investigators also calculated the correlations between Peabody Picture Vocabulary Test (PPVT) scores and trials to criterion in the first and second phases of the OS. Separate correlations were calculated for kindergarten, grade 2 and grade 6 subjects and for the different dimension-pair groups within each age level. While there was no sign of a relation between IQ and speed of learning in the first phase, all the correlations between IQ and second phase performance were in the right direction and 2 (of 9) reached significance. This, concluded the Kendlers, indicated a small but reliable relationship between IQ and the shift discrimination. However, IQ was of no value in predicting what type of shift (reversal, extra-dimensional, or non-selective) a subject would make.

The Kendlers cautioned that the PPVT might be insensitive to the cognitive processes involved in mediation but that the WISC or Stanford Binet might be more appropriate measures.

In fact, the above result reflects a general trend in the literature; a trend holding over a variety of intelligence tests. The studies reviewed by Wolff (1967, pp.380-384) indicate a weak to non-existent relationship between performance on standard intelligence tests and the ease of making a reversal shift. This is particularly true for studies that varied IQ within the normal range. The evidence for a positive relationship was somewhat stronger in studies that compared normals with retardates. In both types of study there was no sign at all of a positive relationship between IQ and ease of EDS.

This pattern of results - a weak positive relation between IQ and RS performance, and no relation between IQ and EDS performance - is in the direction expected from an hypothesis that relates a tendency to mediate to level of cognitive functioning. However, the frequency with which the positive relationship between intelligence and ease of the RS problem failed to appear can only be viewed as discouraging.

There have been, however, a number of studies supporting the cognitive development hypothesis published since Wolff's review. A distinctive feature of these studies has been that the researchers have chosen their measures of cognitive development from theoretical considerations, i.e. they had started with an analysis of the cognitive processes that might underly mediation and have designed or chosen cognitive tests to tap these processes.

Johnson and White (1967) were impressed by an early demonstration of the efficacy of the Tighes' pretraining technique (L. S. Tighe, 1965) in reducing the difficulty of the RS problem. "This finding", they argued, "may be interpreted to suggest that training children to differentiate particular stimulus values, and to perceive them as ordered points along a dimension, facilitates R shift performance. Going a step further it may be hypothesized that the concept of dimensionality underlies the appearance of mediational responding." They therefore devised a series of brightness and size *seriation* problems (six values for each dimension) designed to measure the child's understanding of the two dimensions. The subject was shown six masonite squares varying in either area or brightness and then (a) asked to put them in the right order; (b) shown the extreme values "in position" and asked to place correctly the other squares; (c) told to arrange the squares according to size (or brightness); and (d) shown the blocks arranged in their correct order which the experimenter then scrambled: the subject was asked to arrange the squares in the same way. The subject was given a score for each dimension which reflected how closely his constructions approximated the correct order over the four sub-tests.

In the study under consideration, 6 year olds were tested on the seriation problems *and* given an RS problem with brightness relevant and size irrelevant and varying within trials during training and test discriminations. It was found that although the brightness seriation score was *not* related to speed of learning in the *training* phase it *was* related to speed of learning in the test phase of the RS,

i.e. those subjects who succeeded at seriating the six levels of brightness made significantly fewer errors in reversing a black-white discrimination.

White and Johnson (1968) extended the above findings by testing a wider age range (3 to 6 years) on the seriation tests and by making either brightness *or* size relevant in the initial discrimination. The subjects were given an OS problem similar to that used by T. S. Kendler and Learnard (1962). Analysis of results revealed that a child's total seriation score (based on his ability to seriate both dimensions) was a good predictor of whether or not he would make an optional reversal. The seriation score was not related to either first or second phase learning speed. Ability to seriate was positively related to age but it was found that age, as such, was not related significantly to type of shift made by the subject. There was also a significant positive correlation between seriation scores for the two dimensions. However, seriating size was somewhat easier than seriating brightness for these children.

The results of these two experiments offer some support for the idea that ease of the RS problem should depend on the child's level of cognitive development. Inhelder and Piaget (1964, Chs. 9 and 10) have produced ample evidence that the ability to order values within a dimension (seriate) increases markedly, with increasing age, into the stage of concrete operational thought. The "concept" of a particular dimension, as measured by this technique, is, therefore, a considerable cognitive achievement. A possible implication of the above results is that this super-ordinate concept (super-ordinate in the sense of referring to an attribute rather than

an attribute value) forms part of the chain of symbolic responses that mediate between stimulus and response in the discrimination learning of the older child - at least when the discriminanda are similar to those used by T. S. Kendler et al. (1962).

Kastner (1969) tested the idea that quite young children (4 years) might be able to use "perceptual responses" to mediate between stimulus and response in discrimination learning while, for older children, the mediator would involve verbal processes. Children in the age range 4 to 7 years were first given an OS with discriminanda varying in size and brightness. At each age level (4, 5, 6 and 7 years) 10 subjects who made optional reversals and 10 subjects who made a non-reversal (extra-dimensional or inconsistent) shift were selected. These subjects were tested on the PPVT and four tests selected from the ITPA: Visual Decoding, Auditory Decoding, Motor Encoding, and Vocal Encoding.

Although age level was not related to proportion of optional reversals in the population initially tested for Kastner's study (T. S. Kendler et al. (1962) reported no difference between 4 and 6 year olds in proportion of optional reversals) it was found that, over all ages, reversers were superior to non-reversers on visual decoding, motor encoding and vocal encoding tasks. Further the best predictor variables changed with age. For the 4 year olds the only variable significantly related to type of optional shift was Visual Decoding. At age 5 years, Motor Encoding scores were the only effective predictors. For six year olds both Motor Encoding and Vocal Encoding were related to type of shift, while for the 7 year olds only Vocal Encoding was effective. The basic

experimental hypothesis was supported. Younger children making optional reversals (4 and 5 year olds) differed from their "single unit" counterparts mainly on non-verbal abilities. Older mediating subjects (6 and particular 7 year olds) were mainly distinguished from their non-mediating counterparts by superior verbal abilities.

These results seem to indicate that different codes may underlie the mediator at different age levels. One possible interpretation is that with increasing maturity the child's concept of a dimension such as brightness progresses from a largely non-verbal representation to one involving verbal processes to an important degree.

General Conclusions: Chapters 1 to 5

Wolff (1967) concluded that there was no compelling evidence in the literature to support the Kendlers' developmental hypothesis - at least as it applied to RS-EDS comparisons and OS studies. It is felt that the general impact of the studies reviewed (particularly those in Chapters 3 and 5) is to reverse this verdict. Ease of making an RS, and tendency to choose an optional reversal, do tend to increase with age and with the cognitive development of the subject. This finding, in turn, is *consistent* with the Kendlers' proposal that the discrimination learning of younger subjects is adequately described by a single unit model, while older subjects will tend to produce mediators, i.e. their discrimination learning is best described by a two stage model.

The discrepancy between Wolff's assertion and the writer's conclusion is readily explained. Much of the most convincing evidence in support of the developmental hypothesis post-dates

the period covered by Wolff's review. T. S. Kendler and Kendler's (1970) confirmation of the age trend in optional reversals and White and Johnson's (1968) demonstration of the link between seriation ability and optional reversals are cases in point.

CHAPTER 6

The Kendlers' Developmental Hypothesis: A Closer Examination

In the previous chapters the evidence reviewed generally indicated developmental trends in RS-EDS comparisons and the OS problem. This finding was said to be consistent with the Kendlers' developmental hypothesis and, indeed, in several instances the link between the general hypothesis and the predicted RS-EDS performance was outlined. It may have been noticed that the arguments linking theory with data were - in places - somewhat less than rigorous, particularly when the performance of children employing mediators was being predicted. Moreover such "tightness" as there was in this latter theorizing was gained at the expense of committing the Kendlers to a fairly specific form of the two stage or mediation model; albeit one that fitted their general specifications for such a model.

The present chapter sets out the developmental hypothesis that is definitive in the sense of embodying the propositions to which the writer considers the Kendlers *are* committed - to varying degrees. It becomes obvious that it is not possible to deduce rigorously the predictions set out in Chapter 1 from this basic set of propositions and an attempt is made to specify the type(s) of mediation model that would "work" i.e. behave in the way required by the Kendlers.

The Kendlers' position can be fairly represented by a recent statement of their developmental hypothesis (H. H. Kendler and Kendler, 1970, p.77). Reviewing the results of OS studies they state, "The single-unit continuity theory of discrimination learning (Spence, 1936) accounts for infra-

human behaviour while the S-R mediational formulation accounts for the behaviour of college students. The probability that a child's choice will fit one formulation or the other depends on his age; the younger he is the more likely he is to behave according to the single-unit theory, while the older he is the more likely his performance will be consonant with the mediational formulation". Elsewhere the Kendlers (H. H. Kendler and Kendler, 1968, p.218) have described their developmental law as follows: "We have hypothesized that as human beings mature the system of relatively simple S-R associations changes to a system that includes one or more mediating links which results in a new structure with an increased capacity for self-regulation."

At the beginning of the Kendlers' research programme, their description of the nature and functioning of the mediator(s) was relatively broad. T. S. Kendler (1963) defined the mediator as "a response, or a series of responses which intercede between the external stimulus and the overt response to provide stimulation that influences the eventual course of behaviour. These responses may be overt, but they are usually presumed to be covert." As H. H. Kendler and Kendler (1968, pp.206-207) later stated when this mechanism was postulated to describe the discrimination learning of older children and adults, ". . . the exact nature of the (mediational) response, whether it was a verbal response naming a dimension (e.g. brightness), or a specific verbal label (e.g. black or white), or a perceptual attending response, or something else was left unspecified." The Kendlers ". . . simply made the general assumption that a mediating response appropriate to the pre and post reversal shift occurred and

this mediating response was the source of positive transfer in reversal learning".

A description of the specific mechanism underlying the mediator was left to future research. However, H. H. Kendler and Kendler (1962) clearly favoured an interpretation of the mediator in terms of verbal processes. They speculated that a child began to mediate when he commenced to use speech to regulate his behaviour - a development in the relationship of speech to problem solving that had been noted by Luria (1961) in his research with children. The evidence in the literature has been equivocal concerning the validity of this proposition.

T. S. Kendler, Kendler, and Learnard (1962) reported that children who made optional reversals were more able to verbalize the dimension that had controlled their performance during the second and third phases of the shift problem. Inconsistent responders were much more likely not to verbalize *either* of the non-spatial dimensions than were children making either optional reversals or optional extra-dimensional shifts. T. S. Kendler et al.'s findings have been confirmed by André (1969) - at least for children with normal hearing.

H. H. Kendler and Kendler (1961) had groups of 4 and 7 year olds verbalize the positive cue within one of two relevant and redundant dimensions during a training discrimination. In a second discrimination one of these non-spatial dimensions became irrelevant and variable within trials for all subjects. The experimental groups were then assigned to either an RS or an EDS (relative to their verbalizations in the training phase).

It was found that subjects, who verbalized a cue in the training phase that was *not* from the dimension relevant for problem solution in the test phase, performed less efficiently than a control group on the test discrimination. Children who had verbalized a cue from the relevant dimension of the second phase either (4 year olds) outperformed or (7 year olds) were no different from control groups (in the latter case some sort of ceiling effect appears to have operated).

T. S. Kendler (1964) showed that asking kindergarten subjects to verbalize the cues within the relevant dimension (e.g. "The white is the winner, the black is the loser.") during the first phase of an OS problem markedly increased the probability that the subject would make an optional reversal.

Each of the above studies offers some support for the notion that the mediator is dependent on verbal processes. Some facts, however, did not fit the hypothesis so readily. H. H. Kendler and Kendler (1962, p.9) noted that it was ". . . not uncommon for children to verbalize spontaneously the correct solution while simultaneously making an incorrect choice." These investigators interpreted this to mean that in children of a certain intermediate cognitive level the correct mediator (verbal habit) might be acquired *independently* of the correct instrumental response. However, T. S. Kendler (1964) reported some results that do not support this interpretation. During the second phase of the optional shift, 42 per cent of the subjects in her verbalization condition continued with the verbal "formula" appropriate to the first phase - even though their overt cue choices had been reversed;

42 per cent changed to the appropriate verbal habit (i.e. transposed "winner" and "loser"); and the remaining subjects either wavered between the two rules or stopped verbalizing. If the Kendlers' explanation of this discrepancy between verbal and instrumental habits is correct, those subjects whose verbal habit continued incorrect during the second phase should have made extradimensional and inconsistent shifts. This would be so since these subjects would have non-functional mediators. In fact no relation was found between type of shift made and whether or not the subject consistently gave an incorrect verbal rule during the second phase of learning. As T. S. Kendler (1964) realized, these results raised the possibility that the only function of the verbal rule was to encourage the subject to *attend* to the relevant dimension i.e. the effect of verbalization was itself mediated by the activation of a perceptual or attentional response.

Such a two phase (verbal response → attentional response) mediator would be in accord with the Kendlers' general position. However, one may yet ask whether it is *necessary* for a subject to verbally encode a stimulus before an effective mediator is activated. Evidence from experiments comparing the performance of deaf and hearing children on discrimination transfer tasks, suggests that verbal mechanisms are *not* necessary for mediation to occur. Reference has been made to Youniss's (1964) study. That investigator demonstrated that both 7 and 13 year old subjects performed better on IDS than on EDS problems. He also found that groups of 7 and 13 year old deaf children performed on the transfer problems in an essentially identical fashion to children of the same age with normal hearing.

Similarly André (1969) has shown that deafness in 7 and 12 year olds has no effect on the tendency to make an optional reversal. Because of the generally backward verbal skills of the deaf subjects - and the fact that, when prompted, very few verbalized the labels for cues that had guided their behaviour during the second and third stages of the shift - André argued that some non-verbal symbolic system provided the mediator for these subjects.

Apart from proposing the involvement of verbal processes, the Kendlers have tested no other specific ideas about the mediator produced by older human subjects *in the discrimination problems based on "figural" dimensions: size, shape, colour and brightness.* Indeed one might wonder whether 15 years' research based on the RS-EDS comparison and OS problem had contributed at all to our understanding of what happens between stimulus onset and overt response for "mature" subjects during simple discrimination learning. However, a careful examination of the functioning of the mediator in the training and test phases of transfer problems *does* provide some useful clues as to the type of mechanism involved; and it is possible to specify certain minimal requirements which must be met by any mediation theory.

1. The proposed mediator must provide a basis for *differentiating* the cues within a given dimension on each trial.
2. The theory must indicate how the mediator produces positive transfer from the training to test phases of RS problems.

3. It must be postulated that the component of the mediator that operates to produce positive transfer in the RS problem survives the extinction of the instrumental response controlled by the mediator.

The first requirement is simply a corollary of the assumption that the mediator "produces cues that elicit the overt response" (T. S. Kendler, 1963, p.36). Since in a discrimination problem the subject must learn to respond differently to the different cues within the relevant dimension, the mediator must represent these intra-dimensional cue differences.

Model A. One theory could satisfy this first requirement by assuming that the subject encodes a *list* of the cues within the relevant dimension, together with the response appropriate to each cue, during the training discrimination. Thus, in a simultaneous discrimination, the subject would store a rule or plan of the form:

$$\begin{bmatrix} \text{Square} \rightarrow \text{Approach} \\ \text{Circle} \rightarrow \text{Avoid} \end{bmatrix}$$

The rule would be stored in some readily accessible part of memory. In a successive discrimination, the rule would take the form:

$$\begin{bmatrix} \text{Square} \rightarrow \text{pull handle} \\ \text{Circle} \rightarrow \text{push handle} \end{bmatrix}$$

In the above examples, features of *both* stimuli *and* responses are encoded by the subject i.e. form part of the mediator. Here the overt (instrumental) response becomes simply the execution of a sensori-motor scheme (behaviour pattern) previously represented by the subject, while the actual

decision to make one response rather than the other occurs at the symbolic level. Alternatively it could be assumed that the subject only encodes stimulus features: Each item on the list of cues would then be linked directly to the appropriate sensori-motor scheme (overt response) rather than to a covert response that represents that particular action.

T. S. Kendler (1964) appears to have been employing a mediation model of the above type. At least she attempted to induce mediation in subjects by having them recite a rule of the type "White wins, black loses" before making a choice during the initial discrimination.

Model B. A second model that satisfies the first criterion does not require that the subject construct a cue list. Consider the simultaneous discrimination problem outlined above. Conceivably, when confronted with each stimulus setting, the subject merely learns to produce the covert mediator corresponding to "square" and proceeds to select the appropriate discriminandum. The rule learned by the subject is reduced to the form:

$$[\ \text{Square} \rightarrow \text{Approach}\ ]$$

As previously described the response term can be considered as either a (covert) symbolic response or an (overt) instrumental response.

In the successive discrimination, the subject presumably learns to produce the mediator (square) when shown either a white or black square, and the mediator (circle) when shown the corresponding circles. This problem is solved without the rules:

[square → pull handle] ; [circle → push handle]

becoming integrated into the overall plan:

$$\begin{bmatrix} \text{Square} \rightarrow \text{pull handle} \\ \text{Circle} \rightarrow \text{push handle} \end{bmatrix}$$

characteristic of Model A.

Both Lachman and Sanders (1963) and T. S. Kendler and Kendler (1970, pp.24-25) have described models similar to Model B.

Model A and Model B can satisfy the second of the three criteria in somewhat different ways. For example, Model B demonstrates that a subject may use an appropriate mediator in both training and test discriminations of a shift problem without necessarily finding an RS easier than an EDS. Consider, again, the above simultaneous discrimination from the viewpoint of this model. During the training phase the subject has learned to produce the mediator (square) to guide his choice behaviour. During the test phase the subject must replace (square) with either (circle) - an RS- or, for example the mediator (black) - an EDS. Clearly the mediator *and* instrumental response must be replaced in both the EDS and RS problems. Unless additional assumptions are made concerning the relative ease of mediator replacement in the two types of shift then superiority for the RS condition cannot be predicted. One theoretical mechanism that would enable more rapid mediation replacement - and consequently more rapid learning - in the RS is the concept of *associative networks* linking mediators representing cues from a given dimension. In the above example, the subject would enter the experimental situation with considerably higher association strength between (square) and (circle) than between (square) and (black). When the established

mediator (square) leads to non-reinforcement, the subject rejects it and samples one of the other mediators elicited by the stimulus setting (circle, black, or white). It is postulated that the sampling process is affected by the previously correct mediator. The first new mediator which controls the subject's behaviour will be the one most likely to be elicited by the old mediator and in this case - ex hypothesi - it will be (circle). An RS will therefore be performed more efficiently than an EDS.

Model B, supplemented by the above mechanism, has been proposed as a mediation theory of shift behaviour (Lachman and Sanders, 1963; T. S. Kendler and Kendler, 1970). While providing an ingenious explanation of shift performance when *simultaneous* discriminations are used in training and test phases, it would appear to have difficulty in dealing with RS superiority in transfer problems that involved *successive* discriminations. A high probability of resampling the old mediator - in the absence of other cues from the same dimension - would have to be postulated, and this resampling tendency would have to persist over a series of extinction trials.

The *higher-order mediator* is another theoretical construct that - in conjunction with Model B - can provide a basis for predicting relative ease of an RS problem. Mediators representing the cues are considered to be ". . . nested in a superordinate set of symbolic responses representative of the dimensions" (T. S. Kendler and Kendler, 1970). The subject may only activate a higher-order mediator when sampling a new lower order mediator (one representing a particular cue) to guide his behaviour; or mediation responses representing both

dimension and *cue* might control the subject's behaviour on every learning trial. In both cases a given super-ordinate mediator is assumed to be strengthened in a particular situation if it is correlated with reinforcement in that situation (i.e. reward can be predicted on the basis of cues belonging to that dimension). It is further assumed that when the subject is not rewarded for responding to the previously positive cue, he will sample cues within the previously relevant dimension for a number of trials before responding to cues from other dimensions i. e. the subject will switch lower order mediators - and the instrumental responses they control - before rejecting the super-ordinate mediator. Together these assumptions enable one to predict that an RS will be easier than an EDS.

Model A can satisfy the second requirement for a mediation theory relatively simply. If the subject learns a rule of the form:

$$\begin{bmatrix} \text{Square} \rightarrow \text{approach} \\ \text{Circle} \rightarrow \text{avoid} \end{bmatrix}$$

during the initial discrimination then he has encoded a list of cues $\begin{bmatrix} \text{square} \\ \text{circle} \end{bmatrix}$ that is relevant for the test phase of an RS but irrelevant for an EDS. It is necessary to assume however that the response terms of the rule are switched before the subject rejects the rule as a whole, produces a cue list based on another dimension $\begin{bmatrix} \text{white} \\ \text{black} \end{bmatrix}$, and proceeds to attempt to link these cues to appropriate responses. Thus the "cue column" of the rule that the subject uses to guide his behaviour must extinguish more slowly than the "response column".

Although no explicit mention has been made of super-ordinate mediators in connection with Model A, their existence is implied in the above discussion. The subject is said to produce a cue list based on a *dimension* i.e. he is clearly attending to only one dimension when producing his plan or hypothesis for testing. The basis of this selective attention could be either a perceptual mechanism (e.g. Sutherland's stimulus analyzers - see the discussion in the next chapter) or a symbolic response representing a dimension. The super-ordinate mediator might be activated only during hypothesis production or on every trial.

In any case Models A and B agree on the general way that mediation theories will explain adult human perfromance in RS and EDS problems. Discrimination learning involves two processes

(a) the subject learns to attend to a subset of the available cues; and

(b) the subject learns to associate appropriate responses to cues within this subset.

It is further supposed that during the test phase of an RS problem some aspect or component of the first (cue-selection) process will survive the extinction of the second (cue-response association) process and guide the necessary re-learning.

The latter assumption of mediation theory - the third requirement outlined previously - was first made explicit by H. H. Kendler and Kendler (1962, p.7 footnote) and has since been pointed out by a number of investigators (Mackintosh, 1965; Trabasso et al., 1966; Halford, 1969). However, elsewhere H. H. Kendler and Kendler (1966) have argued that it is not necessary for mediation theory to postulate that mediating

responses extinguish more slowly than overt responses. To support this assertion, they presented two stage theories which they claimed dealt with the RS superiority while not specifying relative extinction rates in the above fashion. In fact, one of these models *does* make the critical assumption - once it is admitted that cue selection may involve the suppression of attention to irrelevant cues. Further, on analysis the other theory proposed ("a simple one trial probability model") makes little sense. It hinges on the strange (implicit) proposition that a subject may emit a given overt response after the mediator that controls it has been extinguished. The writer therefore finds the Kendlers' arguments on this point unconvincing. The extinction rate assumption appears necessary before a mediation theory can predict rapid reversal performance.

An important point has been made in the above discussion. It is clear that a mediation theory need *not* predict that adult human subjects should find an RS easier than EDS problems. Whether such a prediction can be made will depend firstly on the type of mediation postulated (for example, as discussed previously, Model B need not predict RS superiority). The prediction will also depend on what the theory assumes about the relative resistance to extinction of the *cue selection* and the *cue-response association* processes. The fact that auxiliary assumptions must be made about the nature and functioning of the mediator before two stage theories will predict efficient reversal learning is worth careful consideration. It raises the possibility that developmental changes in the speed of an RS may be due not to age related changes in the tendency to mediate *per se* but, rather, to a change with age in the validity of the auxiliary assumptions.

CHAPTER 7

A Critique of the Kendlers' theory: Two Stage Discrimination Learning in Infra Human Subjects

The developmental hypothesis, as outlined at the beginning of the last chapter, has two anchor points. The first is the proposition that a version of Spence's (1936) single unit continuity theory accounts for the discrimination learning of infra-human subjects. The second is the proposal that a two stage (mediation) theory is needed to describe the discrimination learning of adults. Both of these propositions have been challenged by other theorists.

Wolford and Bower (1969) ran a Monte Carlo simulation of Spence's theory of simultaneous discrimination learning. They systematically manipulated parameters of the model corresponding to the habit strengths of the cues (stimulus components) at the outset of learning. For each particular array of habit strengths for cues within the relevant and irrelevant dimensions, one group of "subjects" was allotted an RS problem, another an EDS problem. For 20 per cent of the combinations of parameter values, an RS problem was *easier* than an EDS problem. Wolford and Bower concluded that, ". . . demonstration that reversal learning proceeds faster than non-reversal learning does not invalidate Spence's model."

This attempt to resuscitate the single unit theory appears misguided. Reversal was faster than EDS when the initial habit strengths were high for the cues from the relevant dimension and low for the cues from the irrelevant dimension. However, the studies that have demonstrated an RS to be easier than EDS problems for adults and older children, as a standard

and elementary feature of experimental design, have assigned each of the non-spatial dimensions as relevant to equal numbers of subjects. Granting the possibility of very marked dimensional preferences for individual subjects, it is most unlikely that a study employing counterbalanced assignment to dimension and cue in initial learning would produce a mean starting set of parameter values similar to the range of combinations of parameter values producing RS superiority in Wolford and Bower's study. That a series of studies (see Wolff, 1967) should consistently do this, is incredible. It can be concluded that Spence's (1936) theory cannot reasonably be extended to deal with the shift performance of adults.

The Kendlers' proposal that Spence's theory provides an accurate account of the discrimination learning in animals and young children is less defensible. It may be recalled that studies which employed RS-EDS comparisons with infra-human subjects generally supported the prediction from Spence's theory that an EDS should be easier than an RS. Further support for the single unit interpretation of the learning of infra-human subjects was provided by three experiments which ran rats in OS problems.

T. S. Kendler, Kendler and Silfen (1964) and T. J. Tighe and Tighe (1966) found a minimal tendency for rats to choose optional reversals (83 to 93 per cent of subjects made extra-dimensional or non-selective shifts). Sutherland and Mackintosh (1966) gave rats a variation of the OS problem and did *not* oppose the second phase positive cues during the third phase of shift. Rather, they dissociated the cues. The cue pairs from each dimension of the second phase problem were presented

separately (no irrelevant, non-spatial dimension within trials), each for 20 trials, during the final phase. The rats responded randomly to the cue pair that had been relevant in the first phase, but systematically responded to one of the cues in the pair that had been irrelevant in the first phase. This was, of course, one of the positive (redundant) cues of the second phase. These results indicated that the rats' second stage performance had been controlled by cues from the previously irrelevant dimension i.e. the animals had made an optional EDS.

Overall, these three experiments show that the white rat is somewhat less likely to choose an optional reversal than is the 3 or 4 year old child (see H. H. Kendler and Kendler, pp. 75-76). Further, in two of the studies overtraining either had no effect (Sutherland and Mackintosh, 1966) or a negative effect on the percentage of subjects making an optional reversal. Both of these findings are in line with predictions from Spence's theory and thus directly support the Kendlers' hypothesis.

In contrast, over the past two decades evidence has accumulated from a variety of experimental paradigms which suggests that Spence's (1936) theory does not provide an accurate description of discrimination learning of infra-human subjects (see Sutherland and Mackintosh (1971) for an extensive review of these studies. Shorter and more selective reviews are given by Mackintosh (1965), Lovejoy (1968), and Honig (1970)). Before proceeding with [yet another] selective review of this literature however, a re-presentation of the assumptions underlying Spence's theory will prove useful.

The following three key postulates of Spence's model may be stated:

(1) The subject learns something about *each* cue (relevant or irrelevant) in the stimulus compound that he approaches on a given learning trial - *provided each cue impinges on the subject's receptors.*

(2) On any learning trial, a subject's tendency to approach a stimulus is a simple linear function of the approach and avoidance tendencies to *all* the cues in that compound that impinge on receptors.

(3) Given that the stimulus input (pattern of stimulation striking the receptors) corresponding to a particular *cue* remains constant, the amount learned about this cue, over a series of trials, is independent of the amount learned about any other cue.

It will be noted that Spence's model makes no appeal to the concept of *selective attention.*

Honig (1970) has reviewed a number of studies of animal discrimination learning that show that the amount learned about a particular cue, over a series of trials, is inversely related to (a) the amount learned about other cues in the situations, (b) the salience of these other cues, and (c) the "validity" of the other cues i.e. whether they are good predictors of reinforcement. One such group of studies (see Kamin, 1969) has demonstrated the "blocking" of the redundant relevant cue introduced after the subject has learned a discrimination using another cue. Kamin has used a conditioned suppression technique to study this phenomenon. In the basic design, rats were first trained to press a bar

for food-reward dispensed on a variable interval schedule. After this training, a number of experimental groups were given varying numbers of conditioning trials (conditioned stimulus (CS) - unconditioned stimulus (UCS) presentations). The UCS for each group was an electric shock which suppressed responding for food. The CS was white noise presented for 3 minutes prior to the shock. Learning occurred when the rats' rate of bar pressing dropped during the 3 minutes of CS - in comparison with the rate in the previous 3 minutes. After this phase, all experimental groups (plus a control that had not been conditioned to the noise) were given the same number of conditioning trials with a compound CS: one component was the previous CS for the experimental groups i.e. white noise; the other component was a light. Finally all groups were tested for the amount of response suppression in the presence of the light alone. It was found that the amount of conditioned suppression to the *light* on the test trials was a smoothly *decreasing* function of the number of sound-shock presentations that had preceded the compound CS conditioning trials. Only partial blocking of conditioned suppression to the light was obtained if the conditioned suppression to the sound alone had not reached asymptote before the introduction of the compound CS. This blocking phenomenon has been demonstrated in a variety of situations involving both classical and instrumental conditioning techniques.

Another group of studies has shown that if animals are given a discrimination problem in which the cues from two dimensions are relevant and redundant from the beginning of learning, the cues from one dimension tend to "overshadow"

the other cues i.e. when the cue pairs from each dimension are presented separately, the animal demonstrates marked learning for one cue pair, and little or none for the other. Further the amount of control demonstrated by a given cue pair is directly related to the difficulty of the discrimination within the other cue pair, i.e. it depends on how similar to one another are cues in the other pair (Miles and Jenkins, 1965).

Other evidence indicates that the degree of behaviour control exercised by a cue pair (light/no light) depends on the degree to which another cue pair in the situation (tone/no tone) is correlated with reinforcement (Wagner, Haberlandt and Price, 1968). Wagner et al. found that rats responded at a high level to a light that had been associated with a 50 per cent reinforcement schedule - provided that a tone (which had occurred with the light on 50 per cent of the trials) was also associated with 50 per cent reinforcement. If the tone became a perfect predictor of reinforcement, the rats ceased responding to the light on trials when it was presented alone. This occurred even though the pattern of reinforcement for the light cue was the same in the two conditions. A feature of these experiments was the care taken ". . . to minimize the importance of gross receptor-orienting acts by insuring that L (the light) was reflected in a relatively homogeneous fashion from all surfaces of S's chamber." (Wagner et al., 1968, p. 179).

The evidence reviewed above suggests a view of animal discrimination learning markedly different from Spence's model. The animal's central nervous system is considered as an information processing system with limited channel capacity.

In a discrimination task a number of cues compete for this limited capacity and a significant part of what the animal must learn is to achieve an optimum distribution of information processing among these cues. The subject therefore learns more about a *subset* of the available cues - to the detriment of other cues - over a series of trials and, on any given trial, may be *controlled* by an even smaller set of cues (a distinction is made here between whether a subject learns something about a cue over a series of trials and whether or not this learning determines, at least partially, response selection on these trials - see Sutherland and Mackintosh, 1971, p.38; Lovejoy, 1968).

It is apparent that from this viewpoint the animal does not merely learn to approach some cues and avoid others in the discrimination situation. In addition, increased processing capacity - more attention - is directed to "relevant" dimensions (i.e. those most highly correlated with reinforcement) while attention is withdrawn from less relevant dimensions (see Wagner et al., 1968, above). Clearly the subject also begins learning with *attentional biases*. Other things being equal, he will attend dimensions whose cues are easily discriminable (see experiments on Overshadowing) Further he will continue to attend to cues that have previously been useful in the situation to the exclusion of a newly introduced redundantly relevant cue (see experiments on Blocking).

Theories of discrimination learning that fit the above (rather loose) description will be termed *attention theories*. A significant dimension of difference among such theories is the "breadth" of attention attributed to the subject.

Zeaman and House (1963) and Lovejoy (1966) proposed "one-look" models: on any given trial a subject's response selection was controlled by only one dimension and the subject would only learn about the cues within that dimension on that trial. In later theorizing Lovejoy (1968) continued to assume that the subject's response was determined by cues from only one dimension on a given trial, but he postulated that there was a certain probability that the subject would "forget" the controlling cue while responding, resample a cue from another dimension and learn about this new cue. In their most recent model Sutherland and Mackintosh (1971) allow the possibility that the subject learns about cues from several dimensions on a single learning trial. However, the amount learned about a cue within a given dimension depends on the degree to which the subject is attending to that dimension which, in turn, depends on the degree of correlation between the dimension and ". . . events of importance to the animal." (op. cit. p. 39). Further, response selection on any trial is solely *controlled* by the dimension to which the subject is paying *most* attention (there may be multiple cue control if there is no dimension clearly superior in salience and/or "validity" in the situation).

Despite the above variations, these attention theories can all be characterized as two-stage (mediation) models. The two processes involved in a typical discrimination problem are (c) *cue selection* - learning to attend to the dimension that predicts reward perfectly while reducing or eliminating attention to irrelevant dimensions; and (b) cue-response association: the cues within the relevant dimension are linked to the correct responses.

The cue-selection process is variously conceived of as:

(1) the subject learning to "*switch in the stimulus analyzer*" corresponding to the relevant dimension while switching out other analyzers (Sutherland and Mackintosh, 1971, p.33 and p.55) - an analyzer being a superordinate perceptual mechanism which classifies stimulus input in a particular way (e.g. identifies *shape* variations in a stimulus setting); or

(2) the subject learning to select the correct "abstract description" of the stimuli presented - an abstract description being a representation of a stimulus feature stored within the perceptual system (Sutherland, 1969).

However it is described, cue-selection clearly does take place in animal discrimination learning. Experiments on stimulus Blocking and Overshadowing (see Honig, 1970) have shown that cue selection occurs when more than one dimension is relevant to the solution of a discrimination problem. Other studies using infra-human subjects have demonstrated cue selection in transfer designs rather more closely related to the shift problems used by the Kendlers to support their developmental hypothesis. For example, in an important study Lawrence (1949) showed dimension-specific transfer between a *simultaneous* discrimination problem and a subsequent *successive* discrimination task. On the initial (simultaneous) discrimination rats were run with either brightness, width of goal box, or texture of the goal box floor relevant.

There was no non-spatial irrelevant dimension varying within or between trials. AFter 40 trials on this problem (at this point all groups averaged more than 90 per cent correct choices) each of the three groups of rats was given a successive discrimination in a T-maze under one of three conditions: (a) the dimension that was relevant in the simultaneous discrimination continued to be relevant while one of the other dimensions mentioned above was introduced as an irrelevant dimension; (b) the previously relevant dimension was now irrelevant and variable while one of the other two dimensions was relevant; or (c) the previously relevant dimension was held constant at a different (intermediate) value during the successive discrimination - the other two dimensions provided the (variable) relevant and irrelevant dimensions. In these three conditions the *same cues* were used within a given dimension for both the simultaneous and successive problems.

The first group (relevant-relevant) performed better than either of the other two grups (which did not differ) over the ninety trials of the successive discrimination problem. It was argued that this superiority could not be explained on the basis of transfer of simple instrumental responses. In the simultaneous discrimination, the relevant-relevant group had learned (say) to approach white (as opposed to black) irrespective of whether it appeared on the left or the right. They had therefore been rewarded for going to the left and right equally often in selecting the black goal box. When this same group learned the successive problem, they had to learn (say) to go right if the cross alley of the T-maze was black, and left if it was white. These latter response

patterns had obviously not been differentially reinforced in the initial discrimination.

Of course, a plausible explanation is that during the simultaneous discrimination the animals in the relevant-relevant group had *learned to attend* to the cues that were to be relevant in the successive discrimination. Thus, although *no* transfer between the problems would be predicted on the basis of the cue-response phase of learning, the cue-selection learning of the simultaneous problem would be expected markedly to affect a subsequent discrimination involving the same dimension and cues. Later research has confirmed Lawrence's result (see Sutherland and Mackintosh (1971 pp.172-181) for a review of these studies).

Experiments comparing IDS and EDS problems have also supported the notion of a cue selection process in animals' discrimination learning. It may be recalled that in this design the subjects are shifted to a discrimination in which the relevant dimension was either the same as, or different from, the dimension relevant in the training phase during the second phase of the shift problem. If the relevant dimension is the same in both phases of shift (IDS) the cues within that dimension are different for the two problems. If the subject is assigned to an EDS then the dimension (and perhaps cues) relevant in the training phase may continue as irrelevant and variable within trials during the test discrimination.

Shepp and Eimas (1964) overtrained rats on either a stripe or form discrimination with the remaining (irrelevant) dimension varying within trials. The criterion was 20 correct out of 25 trials on 4 successive days. Within each

group animals were then shifted to either a new form or a new stripe discrimination (i.e. the cues within both dimensions were changed) with the irrelevant dimension again varying within trials. Animals that had the same dimension relevant in both training and test discriminations solved the test problem considerably faster than EDS groups. The implication is that IDS groups had either learned to attend to an appropriate dimension or ignore an irrelevant one (or both). More recent research (Shepp and Schrier, 1969) indicates that overtraining on the training phase of shift may be necessary before IDS groups show a marked superiority over EDS groups on the test discrimination. Further, IDS superiority may disappear if there is no irrelevant non-spatial dimension variable in the training phase of the shift problem (Turrisi, Shepp and Eimas, 1969).

The first of the latter two findings points up to an assumption often made about the cue selection process i.e. the attention or observing response generalizes from the relevant *cues* in the training discrimination to other cues within the same dimension (Zeaman and House, 1963, pp.168-169). It would appear reasonable, however, to expect some generalization decrement in the strength of the attending response when the cues from a relevant dimension are changed while that dimension continues to provide a basis for predicting reward. Generalization decrement should occur since the introduction of new stimulus patterns alters the whole situation or context which, in turn, presumably controls the selection of the appropriate stimulus analyzer. This consideration leads to the hypothesis that an attentional response (in animals) might need to be firmly established,

perhaps overlearned, in a given situation to produce marked transfer in an IDS versus EDS design. It is notable that Lawrence (1949) showed significant transfer between training (simultaneous) and test (successive) discriminations without overtraining his animals. The same *cues* as well as the same *dimensions* were relevant in both phases for his superior group.

The second finding concerning IDS and EDS comparisons with animals (Turrisi et al., 1969) could be interpreted to mean that cue selection for rats is largely a matter of learning what dimensions to ignore. If this hypothesis is valid and the subject is not trained with a non-spatial irrelevant dimension variable within trials during the training discrimination problem, IDS and EDS groups would have largely the same "experience" to transfer to the test discrimination i.e. both groups would "know" that *position* was an irrelevant cue.

To summarize to this point: there is a considerable body of research that suggests that a two stage theory is needed to describe the discrimination learning of even infra-human subjects. This evidence casts considerable doubt on the Kendlers' assertion (H. H. Kendler and Kendler, 1968, p.213) that Spence's (1936) *single-unit* continuity model ". . . is able to predict rat behaviour".

The Kendlers have been aware for some time of animal studies which seemed to require the postulation of some attentional or cue selection mechanism. In a brief reply to criticism by Mackintosh (1965), H. H. Kendler and Kendler (1966) defended Spence's theory. They pointed out that although continuity theory postulated that all stimuli impinging

on the receptors on a given trial would be associated to a reinforced response, this did not mean that the animal was considered to learn *equally* about each cue in the stimulus pattern. Thus evidence that animals learned more about some cues than others could not be said to contradict continuity theory. To emphasize this point a later study (T. S. Kendler, Basden and Bruckner, 1970) demonstrated that a continuity theory that incorporated assumptions about stimulus generalization could deal with the phenomenon of *dimensional dominance* in an optional shift problem.

Further, the Kendlers maintained that although cue selection might take place ". . . with more complicated discrimination tasks of the kind that Mackintosh attempted to cope with", (H. H. Kendler and Kendler, 1966, p.285): (a) such cue selection might be dealt with by postulating the involvement of overt observing responses (receptor orientation) rather than covert attentional mechanisms; and (b) there were certain simple discrimination tasks (e.g. black-white discriminations in T-mazes) in which stimulus selection was not a problem. Finally H. H. Kendler and Kendler (1968, p.224) asserted that attention theories imply that learning during the test phase of an RS ". . . should be rapid when an organism is observing or attending to the appropriate stimulus dimension. "Why," they asked, "cannot it be demonstrated unequivocally, as it has with adult humans, that a rapid reversal is possible after an infra-human organism has learned a discrimination *for the very first time?*"

The Kendlers' defence of Spence's single unit theory appears unconvincing to the writer. It is agreed that continuity theory can explain why unequal amounts are learned

about various cues that might be (redundantly) relevant for problem solution. However continuity theory *cannot* deal with the finding that variables which increase the amount learned about one cue *reduce* the amount learned about other cues. This loss of behaviour control for a particular cue has occurred in experiments where particular care was taken to ensure that this cue was equally "intense" wherever the subject oriented his receptors, i.e. it could be assumed, reasonably, that the cue impinged on the subject's receptors equally effectively under the various experimental conditions (Wagner et al., 1968). There therefore exist data that cannot be interpreted by assuming that the cue selection mechanism is an overt observing response. However, even conceding the possibility that receptor orienting acts are the main dimension selecting device for infra-human subjects, serious problems remain for the Kendlers' position. To explain data requiring a two stage (mediation) explanation, H. H. Kendler and Kendler (1966, p.285) assume that observing response and attentional formulations are functionally equivalent two stage theories. They then propose that in many "simple" discrimination problems the cues are *obvious* and learning to observe them a trivial task. In such circumstances, they argued, a one stage model of learning will apply. The argument is not supported by the evidence. Lawrence (1949) and Wagner et al. (1968) both found evidence supporting a two stage model using experimental situations just as simple and at least as obvious as those used by Kelleher (1956) whose results the Kendlers cited in support of a one stage model of animal discrimination learning.

As a final point it should be noted that both Lawrence (1949) and Kamin (1969) demonstrated attention responses in animals that were not overtrained.

The simplest interpretation of the above results is that the RS-EDS comparison is a rather insensitive index of whether or not there is cue selection learning involved in the solution of a simple discrimination. Overall, it appears that the problem is not to explain away the results suggesting the need for a mediation analysis of animals' discrimination performance. The real question is why animals whose learning of the training discrimination is a two stage process (i.e. involves both cue selection and cue-response association processes) find a RS more difficult than an EDS. Chapter 8 attempts to answer this question.

CHAPTER 8

Two Stage Discrimination Learning in Infra-human Subjects II

Consider an animal's performance in an RS or an EDS. If a mediation analysis of learning is appropriate then, when a subject has attained criterion on the training discrimination, the animal has learned both to attend to the relevant dimension and to respond to the positive cue within that dimension. During the test discrimination of an EDS, both the attention emphasis and the instrumental response acquired in the training phase must be extinguished and new attention and instrumental responses learned. However, during the test phase of an RS the attention response remains appropriate, while the subject must learn to respond to the negative cue of the training phase. In the RS, therefore, the subject's previously correct instrumental response undergoes extinction and an approach response must be conditioned to the new positive cue. As has been noted previously, the Kendlers (H. H. Kendler and Kendler, 1962) deduced RS superiority - within the framework of a two stage theory - on the grounds that in an EDS *both* stages of the original habit had to be extinguished, while in an RS only extinction of the instrumental response was necessary. Two stage theories (Zeaman and House, 1963; Lovejoy, 1966, 1968) generally, however, assume that the attention response is also undergoing extinction during the early stages of the test phase of an RS, i.e. while the subject's previously correct instrumental response is not being reinforced. If this plausible assumption is valid, it can be seen that both attentional and instrumental processes are being extinguished

in EDS *and* RS problems. Following this line of argument, whether or not a subject will show superior performance on an RS will depend on the *relative rates of extinction* of the attention and instrumental responses (Zeaman and House, 1963, p.190).

One possibility is that the attention emphasis acquired during the training discrimination survives the extinction of the instrumental response during the first blocks of trials of the test discrimination. If this occurs, the subject, during the remaining trials of the test phase, should learn most efficiently a habit that requires the attention response of the training phase, since a shift to another dimension would necessitate further extinction of the previous attending process after the instrumental habit had reverted to its base level. Two stage theories would therefore predict that an RS would be an easier problem than an EDS if the attention response is extinguished more slowly than the instrumental response it controls.

A second possibility is that the attention and instrumental responses of the first phase extinguish at approximately the same rate. If this occurs, then (other things being equal) RS and EDS problems should be approximately equal in difficulty, since, after the initial extinction trials of the test phase, the subjects would have no remaining attentional bias. Their subsequent test discrimination performance should be independent of the reinforcement history of the dimension on which problem solution is based.

For the purposes of the present discussion the final possibility is the most interesting. If the attention response of the first phase extinguishes markedly more quickly than the

instrumental response, then, according to a mediation theory, an RS should be *more difficult* than an EDS. As before, it is assumed that a subject assigned to an EDS faces two types of interference in the test phase: (a) he is attending to an irrelevant dimension, and (b) he has learned to approach a cue within that dimension. Clearly, however, the second source of interference (the cue-response associations developed in the training phase) will be limited by the persistence of the first source. The key idea is that if a subject stops attending to a dimension then - ex hypothesi - the cues in that dimension will no longer affect performance, even if the subject retains strong (latent) tendencies to approach some cues, and avoid others, within that dimension. Therefore the amount of negative transfer within an EDS problem is chiefly dependent on the resistance to extinction of the attention bias developed in the training phase: it is not affected by the rate of extinction of the instrumental response. Since the attention response is assumed to revert rapidly to its pretraining level of availability, the total negative transfer within an EDS problem should not be great.

In an RS Problem, the interference experienced during the second phase is due solely to the incorrect cue-response associations transferred from the training discrimination. In this case, the process of eliminating the negative transfer due to the instrumental response cannot be short-circuited by the rapid extinction of the attention response controlling this response. Indeed, a rapid rate of extinction of the attention response will tend to magnify the negative transfer in an RS. By the very nature of the RS Problem, the subject must have re-established the first stage attention emphasis, and have

completely reversed his pattern of approach and avoidance responses to cues within that dimension, to reach criterion on the test discrimination. Therefore the extent of negative transfer in the RS problem will depend on the number of trials that it takes to extinguish fully the cue-response associations established in the first phase. Further, this extinction process is likely to be slowed by the rapid reduction in strength of the controlling attention response. As this latter attention response reverts to its pretraining strength, trials on which it (as opposed to attentional responses to other dimensions) controls behaviour will become less and less frequent. Since extinction of the first phase cue-response associations can only proceed during trials on which the subject is attending to the dimension containing these particular cues, this process correspondingly slows down. Finally, the relatively rapid extinction of the attention response means that when the first phase cue-response associations are finally extinguished, the attention value (strength) of the relevant dimension will be below its "base" value i.e. the subject will be less likely to attend to this dimension than he was at the beginning of the training phase. Re-establishing the dominance of the relevant dimension during the test phase would therefore be a long process.

To summarize: in the second phase of an EDS problem the subject must reject his previous attention emphasis, learn to attend to the relevant dimension, and learn to approach the positive cue within that dimension. In the second discrimination of the RS problem, the subject must fully extinguish the first phase instrumental response, re-establish the attentional response that has been reduced to below

base-level strength during this extinction process, and learn to approach the new positive cue within this dimension. On the assumption therefore that it is harder for the subject to switch instrumental (in this case, approach) responses, the EDS will be solved *more quickly* than the RS.

As it happens, there is independent evidence that this last assumption is justified for *animal* discrimination learning. There are a number of studies which suggest that for infra-human subjects the attention response is extinguished more quickly than the instrumental response it controls. For example, experiments by Lawrence and Mason (1955) and Goodwin and Lawrence (1955) have demonstrated that rats will retain a preference for a cue within a given stumulus dimension even though they have learned a subsequent discrimination with this same dimension (and cues) irrelevant and variable within trials. In the latter study the animals were first trained to criterion (13 correct of 15 successive trials) on a simultaneous brightness discrimination with height of hurdles in the goal boxes as the variable irrelevant dimension. All subjects were then given a discrimination problem with the height of hurdles relevant and the previous brightness cues (black, white) irrelevant to task solution. Different groups of animals were either trained to criterion or given 20, 40, or 100 trials overtraining. At the completion of this second phase, all animals were trained on a *brightness* discrimination. For half the subjects, the positive cue during the final phase was the same as the positive cue of the first phase. For the remaining subjects, the new positive cue was the one that had been negative during the initial discrimination. It was found that this latter group performed markedly worse on the

brightness discrimination on the final phase and that this effect did not interact with the amount of overtraining on the second (hurdle) discrimination.

Goodwin and Lawrence (1955, p.442) concluded that a two stage theory gave the best explanation of these results, "One (process) . . . would involve the identification and reaction to a dimension or set of stimuli, and the second would involve the establishment of preferences between stimuli within a set". However, more to the present point, it would have to be further assumed ". . . that the first of these processes is established and extinguished more rapidly than the other". This was so since it was clear that the rats had stopped attending to brightness and had learned to attend to the height of the hurdles *without* fully extinguishing their preference for the initially positive cue within the brightness dimension. When the attention response to the brightness dimension was reactivated (during the third discrimination), there was a marked tendency for the animals to approach the cue within that dimension that was positive for the first discrimination - a tendency that had been "latent" or "potential" during the hurdle discrimination.

Subsequent research has confirmed Goodwin and Lawrence's findings and the theoretical interpretation presented above (see Sutherland and Mackintosh, 1971, pp.265-270, for a review of this evidence). In particular Mackintosh (1963) has shown that the superiority of "same" over "reversal" groups in the third phase was still significant (although reduced) if rats were overtrained on the initial discrimination. Indeed the effects of overtraining on the same-reversal contrast (i.e. overtraining on the first discrimination *reduces*

the difference, while overtraining on the second discrimination has no effect) are particularly embarrassing for Spence's theory. On the basis of Spence's (1936) theory, overtraining on the initial problem would be predicted to *increase* the difference between "same" and "reversal" groups while overtraining on the second task should *reduce* this difference. In contrast, the effects of overtraining are accurately predicted by an Attention Theory of discrimination learning (see Sutherland and Mackintosh, 1971, pp.265-266, 269, for these derivations).

Overall, when results from a wide variety of experimental paradigms are considered, a two process (mediation) model would appear to provide the most accurate description of animal discrimination learning. The Kendlers' proposal, that Spence's single unit continuity theory accounts for infra-human behaviour, is not supported by the evidence. The finding that an EDS is easier than an RS for infra-human subjects can be explained by assuming that animals switch attention responses more easily than they do the instrumental responses. This assumption has empirical support.

CHAPTER 9

A Modified Form of the Kendlers' Hypothesis

If the conclusions at the end of Chapter 8 are valid then the ". . . hypothetical biological continuum . . . between the rat and college student" (H. H. Kendler and Kendler, 1968, p.208) clearly should *not* be conceptualized in terms of a gradual transition from single stage to two stage learning, since the evidence indicates that a two stage model accounts for the learning of both rat and adult human.

The Kendlers, of course, could concede the validity of a two stage analysis of animal learning while maintaining that Spence's single stage theory accounted for the behaviour of young children. As before, cognitive development would involve the increasing probability that a subject's discrimination learning would involve *two* stages or processes. Considering the data reviewed thus far this modified position is tenable, although it lacks the scope and plausibility of the Kendlers' original theorizing. However, the proposition that a single stage theory accounts for the learning of young children would seem to be rather weakly supported since evidence favouring it is limited to demonstrations that these children find reversal shifts relatively difficult. As was pointed out in connection with the animal studies, such a demonstration does not rule out a two stage interpretation of learning. For the two stage theorist the difficulty of an RS problem will depend very much on the assumption he makes concerning the relative extinction rates of the attention and instrumental responses.

If the Kendlers' developmental hypothesis is to be accepted in the above modified form, it is clearly desirable that developmental trends be demonstrated in paradigms more sensitive to the differences between single stage and two stage learning than is the RS problem. As indicated previously, several such paradigms were developed by researchers studying animal discrimination learning: Blocking, Overshadowing, IDS-EDS comparisons etc. One of these techniques - the IDS-EDS comparison - has been used reasonably extensively with human subjects. Further, subjects at widely different stages of development (nursery school to college students) have been used with this design. Results from the IDS-EDS paradigm should therefore enable an evaluation of the modified developmental hypothesis.

As has been noted previously, a two stage theory predicts positive transfer for the IDS problem on the grounds that the subject has developed an appropriate attention response during the initial discrimination (this prediction is made, however, on the assumption that the subject learns to attend to the *dimension*, as well as the specific cue pair, relevant in the training phase). Since the subject has learned to attend to a dimension that is irrelevant for the test discrimination negative transfer is predicted for an EDS. In contrast, a single stage theory predicts no specific transfer in either IDS or EDS problems, provided the cues within all non-spatial dimensions are changed from the training to the test discrimination and the effects of primary stimulus generalization are neutralized by counterbalanced assignment of positive cues to subjects within the relevant dimensions. Presumably non-specific factors (e.g. "warm up" or "learning

to learn") will produce equal amounts of positive transfer in both types of transfer problem. From the point of view of the Kendlers' developmental hypothesis, 3 and 4 year olds might be expected to find IDS and EDS equally difficult, while older children (or adults) could find an IDS somewhat easier than an EDS Problem.

Evidence in the literature supports the latter proposition (see Wolff (1967, p.377) for a review) while failing to provide convincing evidence for the former proposition. Dickerson (1966) reported that 4 year olds found an IDS problem markedly easier than an EDS task. Garber and Ross (1968) confirmed this result using a successive discrimination task in both phases of the shift problem. Indeed in the latter experiment the superiority of IDS over EDS for 4 year olds was significantly more marked than it was for 7 year olds. Further, Campione (1969) demonstrated that retardates (mean M.A.: 50 mo) performed better if assigned to an IDS rather than an EDS. It should be emphasized that each of these results was obtained *without* overtraining the subjects on the training discrimination. Even so, these studies are open to criticism.

As has been indicated previously in connection with Dickerson's (1966) RS condition, that investigator gave slow learners a *special training* procedure. T. J. Tighe and Tighe (1967) have pointed out that this violates the boundary conditions of the Kendlers' developmental hypothesis. Since in Garber and Ross's (1968) experiment, slow learners during the training phase were also given special instructions (not described), and since on the average the 4 year olds were slower to learn, both of the above studies could be considered

of questionable relevance to the hypothesis under consideration. Campione (1969) eliminated 8 (of 40) subjects for failure to learn the initial discrimination. T. S. Kendler and Kendler (1970, p.2) have criticised this procedure: on the assumption that children not using mediators learn the training discrimination more slowly than those employing mediators, elimination of non-learners after a fixed number of trials would tend to reduce the number of subjects behaving according to the single stage model. While it is true that evidence contradicting the developmental hypothesis on this point is flawed, evidence supporting the notion that 3 and 4 year olds will not show positive transfer within an IDS problem is considerably weaker.

Trabasso, Deutsch and Gelman (1966) found no difference in difficulty of the IDS and EDS problems for nursery school children when the stimuli were patterns (i.e. cut-outs centred on paper plates). However, when the discriminanda were objects (wooden blocks), four year olds found an IDS problem significantly easier than an EDS. Trabasso et al. argued that the latter condition was more likely to elicit an observing response. It is interesting to note that the IDS-EDS contrast was related to the RS-EDS differences in the two conditions. With pattern stimuli, IDS and EDS problems were equally difficult while RS was significantly more difficult than both: with "object" stimuli, IDS was easier than EDS which was equal in difficulty to RS. In other words, when the IDS-EDS comparison indicated that the nursery schoolers were using mediators the RS-EDS contrast changed appropriately i.e. the RS became less difficult relative to the EDS condition. This finding could be construed as supporting the developmental

hypothesis. Trabasso et al. took a different view. They pointed out that if there was independent evidence (IDS-EDS comparison) that subjects were employing mediators then, strictly speaking, the Kendlers should predict that the RS problem would be *easier* than the EDS. They concluded that mechanisms other than the presence of a mediator were needed to account for efficient reversal performance.

One can conclude that IDS-EDS comparisons provide little solid evidence supporting the hypothesis that single unit S-R theory explains the discrimination learning of 3 and 4 year olds. The developmental hypothesis also receives no support from IDS-EDS contrasts over a wider age range. Youniss (1964) failed to find any significant difference between 7 and 13 year olds: both age groups found IDS easier, and, in fact, the IDS superiority was slightly greater for the 7 year olds - a trend similar to that reported by Garber and Ross (1968) and contrary to the developmental hypothesis. Further, in a recent study, Campione (1970) has shown that 4 year olds are just as likely to make *optional intra-dimensional shifts* as are 8 year olds. Campione used a novel variation of the usual optional shift design: instead of the same dimensions and cues being retained for all three phases, the experimenter introduced new cues within the same dimensions for the second and third stages of the shift problem. During the first phase, subjects were trained on either a form (square, triangle) or colour (red, green) discrimination with one of these dimensions being irrelevant and varying within trials. In the second phase, all the subjects had to learn a discrimination involving only one cue pair: a yellow T and a blue circle. Finally, during the third stage, the subject

was given two types of stimulus setting: yellow T and blue circle, or yellow circle and blue T. The subject's pattern of choice with the second type of setting enabled the experimenter to gauge which dimension had controlled the subject's behaviour during the second phase. A two process model would predict that the controlling dimension would be the one correlated with reinforcement during the first stage, i.e. the subject would make an optional IDS.

Campione *did* find a significant tendency for subjects to choose an IDS. The Kendlers' developmental hypothesis would predict this tendency to be significantly greater among 8 year olds than it would be for 4 year olds (see H. H. Kendler and Kendler (1970, p.76) for results with the standard optional shift design employing colour-form compounds as discriminanda, and a comparable age range). In fact, the proportion of subjects making an optional IDS was virtually identical (approximately 64 per cent) for each age group. Thus this experiment offers no support for the idea of a gradual and age dependent increase in the proportion of "two process" learners and a corresponding drop in the number of "single unit" responders. Unfortunately, however, Campione's study cannot be considered decisive since he employed Dickerson's (1966) special training procedure during the initial discrimination. There is a clear need for a study, using Campione's variation of the optional shift paradigm, covering a wider age range, and *not* employing either special training procedures or overtraining in the first learning stage.

Summarizing the results of experiments using IDS problems with children of varying ages, it is reasonable to conclude that the developmental hypothesis receives no convincing support

The evidence is not as compelling as it might be - for reasons discussed above - but a two stage model would seem to provide the best description of children's discrimination learning at *all* ages tested. There is no evidence from this type of transfer problem (i.e. IDS-EDS comparisons) that the younger the child the more likely it is that single unit continuity theory can account for his learning.

Conclusion. A transition from a single stage to a two stage learning process does not appear to provide a valid explanation of either the phylogenetic *or* the ontogenetic differences that have been demonstrated in the RS performance of subjects. The problem remains of formulating an adequate explanation of the developmental trends in experiments employing optional shift problems or RS-EDS comparisons. In particular it must be explained why young subjects who apparently employ mediators (as indicated by IDS-EDS comparisons and optional IDS performance) do not tend either to make optional reversals or to find the RS easier than EDS problems. Why *does* the child become more efficient at reversal learning as he grows older?

CHAPTER 10

The Tighes' Differentiation Theory

In a series of papers, the Tighes (L. S. Tighe, 1965; L. S. Tighe and Tighe, 1966; T. J. Tighe and Tighe, 1968) have proposed a *perceptual differentiation theory* to explain age and species differences in the relative ease of the RS in problems employing stimuli which vary in brightness, size, shape etc. Consider a typical simultaneous brightness discrimination with white as the positive cue and height as an irrelevant dimension varying within trials. According to differentiation theory, infra-human subjects and young children will learn the discrimination as *two* habits or object-reward relations. They will learn that reward is associated with (a) the *large-white* object and (b) the *small-white* object. Thus, for these subjects, the single objects are the effective stimuli and the subject learns to approach each rewarded object more or less independently of learning to approach the other object that is reinforced. In contrast, when older children reach criterion on a discrimination, they are likely to have abstracted the relevant dimension (brightness) and to have associated the positive cue from this dimension (white) with reward. The older subjects therefore simply learn to approach the single positive cue and not the two distinct objects as above. Relatively rapid reversal learning is predicted for a subject who has isolated the relevant dimension since this dimension ". . . remains relevant in a RS and he has only to learn a relation between *one* aspect of this feature and reinforcement while in an EDS he must first redirect his attention to . . . the formerly irrelevant feature of size before learning the appropriate

stimulus reward relationship" (L. S. Tighe and Tighe, 1966, p.366). For younger children an EDS will be easier because, for this transfer problem, the subject need only stop responding to *one* of the previously reinforced objects (e.g. large white discriminandum) and choose the alternative stimulus pattern (small black object) in that setting. In an RS the young child has to learn not to respond to *both* of the previously reinforced objects and learn two new object-reward relations.

To sum up: the older child performs better than the young subject on an RS problem because he has only to "switch" *one* cue-reward association. The young child must "switch" *two* object-reward associations. As a controlling stimulus in the usual discrimination problem, the cue is clearly more efficient than the object or *stimulus pattern*. As outlined above, learning one cue-reward association produces the same result as learning two object-reward relations. Therefore, abstracting a dimension sugh as brightness and responding to one of its *cues* produces the same type of learning economies that the subject uses in the RS involving stimuli such as egg, meat and cheese when he grasps the common food quality of these stimuli.

The Tighes see the transition from *stimulus pattern* control to *dimension* (and cue) control of discrimination performance as the product of *perceptual learning*. Young subjects react to each stimulus object as an undifferentiated whole, a stimulus pattern that he does not analyze into its component cues. After more extensive experience with objects that exhibit differences and similarities over a number of dimensions the child comes to see that objects may be identical in some features (e.g. shape and colour) while varying in another

(e.g. size). Through such object comparison, he can eventually analyze a stimulus pattern into its component features or cues. He becomes more sensitive to the stimulus variables in an array of discriminanda and is able to detect differences among objects within one dimension independently of differences and similarities along other dimensions. The child is now capable of isolating the stimulus dimensions that the experimenter readily perceives. It should be noted that this process of abstracting stimulus features takes place "at a perceptual level rather than on the level of higher thought processes" (L. S. Tighe and Tighe, 1966, p.362-363).

To provide support for their theory the Tighes devised a training procedure based on the above analysis. It may be recalled that, typically, the subject was required to make same-different judgements about stimuli presented successively. The two stimuli might be identical or they might vary in height, brightness or both. The subject was not given feedback concerning the correctness or otherwise of his judgements. Six year olds - the age group most intensively studied - made most errors of judgement when the two stimuli were identical on one of the two features but different on the other. However, all types of error declined significantly during training.

The Tighes believed that the above training procedure gave the subject practice in seeing that objects could vary on one feature while being identical on another. The subject might therefore learn to dissociate the different features that make up a stimulus pattern - and be capable of utilizing one such cue in a discrimination problem independently of the other available cues. In any case, the above training method

proved remarkably effective in increasing the speed of the RS and the proportion of optional reversals for 6 year olds (L.S. Tighe, 1965; T. J. Tighe and Tighe, 1968 b; L. S. Tighe and Tighe, 1968; T. J. Tighe and Tighe, 1969b; T. J. Tighe and Tighe, 1970). The procedure also increased the amount of relational responding in transposition tests with this age group (T. J. Tighe and Tighe, 1969 a; T. J. Tighe and Tighe, 1969 b). However, in each of the above studies performance on the initial discrimination was *not* facilitated by the training technique described.

H. H. Kendler and Kendler (1970, p.72) have described the Tighes' differentiation formulation as ". . . structurally a single-unit theory since the subject is presumed to respond directly, as a result of perceptual differentiation, to the significant stimulus cues". However the Tighes' description of the discrimination learning of the perceptually sophisticated subject is properly characterized as a *two* stage theory. Consider a 12 year old who, through prior experience, has differentiated the dimensions of brightness and size. If he is now given a simultaneous discrimination problem, with size the relevant and brightness the irrelevant dimension, then learning is not a matter of ". . . responding directly . . . to the significant stimulus cues". Even supposing that no further differentiation of either dimension is necessary, the subject must learn to *attend* to the size dimension and to ignore the "differentiated" cues from the brightness dimension. Thus the model clearly makes use of a selective attention mechanism: only one of the available dimensions controls behaviour. Further, it is clear that within the theory an attention bias acquired during a training discrimination

provides the basis for positive transfer during the test phase of an RS and negative transfer during an EDS (see the passage quoted above from L. S. Tighe and Tighe, 1966). Therefore the Tighes make the (implicit) assumption that the attention response conditioned during initial learning is *persistent*: that it is more difficult for a subject to switch his attention from one dimension to another than it is for him to switch responses to cues within a dimension.

From the above it can be seen that differentiation theory has much in common with the attention theories described in Chapter 7; particularly if "familiar" stimulus materials are employed and subjects are perceptually experienced. The two positions have come even closer together with a recent proposal from Sutherland and Mackintosh (1971, pp.52-55) that perceptual learning has an important role in setting up complex stimulus analyzers. However, the Tighes' theory has a number of features which set it apart from other attention theories based on perceptual mechanisms. The first of these has just been noted above. The Tighes must make the *extinction rate assumption* discussed in connection with the Kendlers' two stage model. This assumption is needed to account for the persistence of the attention bias which produces superior RS performance in older children. The second feature of differentiation theory is that it suggests a specific training procedure that increases the capacity of the subject to "see" or detect dimensions in a stimulus setting.

The third characteristic of differentiation theory is that, like the Kendlers, the Tighes have proposed a single unit theory to describe the discrimination learning of animals and young children. Of course this theory is different from

Spence's (1936) model - the single unit continuity theory favoured by the Kendlers. It will be recalled that in Spence's theory the tendency of a given discriminandum to elicit an approach reaction is a simple linear function of the excitatory and inhibitory potentials of its component cues. The excitatory and inhibitory potential of a given component is, in turn, a function of that *cue's* reinforcement history i.e. the particular pattern of reward and non-reward associated with that cue. In contrast the Tighes have opted for a theory in which the tendency of the subject to approach a given discriminandum is primarily a function of the reinforcement history of that *particular object* or cue pattern.

Wolff (1967 pp.394-397) has made a number of criticisms of differentiation theory and the Tighes (T. J. Tighe and Tighe, 1968) have replied at some length. Only certain of these arguments and counter-arguments will be considered here.

Wolff (1967) argued that there was abundant evidence in the literature that young children "dimensionalized" the stimuli in discrimination problems rather than responding to stimulus patterns. This evidence came chiefly from studies which assessed the subjects' *dimensional preferences* before learning. Dimensional preference was typically measured by presenting the subject with a standard stimulus (e.g. red circle) and two comparison stimuli (e.g. red square, blue circle). The subject would be asked to point to the comparison that was "just like" the standard. Over a series of such trials, with different cues being used from each dimension, the experimenter could gauge whether the subject's judgements of similarity were influenced by colour, shape, or both. It was generally found that subjects subsequently given a

discrimination problem with their preferred dimension relevant performed better than subjects assigned to their non-preferred dimension. This was true even though both groups had been exposed to the same stimulus patterns.

The fact that young children could consistently respond to (say) colour similarity rather than shape similarity in the dimension preference test could be interpreted to mean that even young subjects were capable of isolating stimulus *dimensions*. Further the children's subsequent discrimination performance would seem to indicate that young subjects could utilize such *dimensions* in the learning situation. This, then, was evidence against the Tighes' notion that perceptually "naive" subjects saw stimuli as undifferentiated wholes and were incapable of analyzing stimulus patterns into their component cues.

The Tighes (T. J. Tighe and Tighe, 1968, pp.758-759) replied that a young child's consistent choice in the dimension preference test could be produced by primary generalization among stimulus patterns. However it was also possible that the subject found it easier to abstract dimensions when relieved of the extra cognitive processing (discovering stimulus-reward relations etc.) of a problem solving task. Finally they argued that the preference test itself might increase the child's tendency to differentiate and attend to a given dimension. This last suggestion has received recent support.

L. S. Tighe, Tighe, Waterhouse and Vasta (1970) assessed the dimensional preference (height or brightness) of 6 year olds either before or after the subjects were given an OS problem. If the preference test preceded the transfer problem, then subjects assigned to their preferred dimension during

the first phase were superior to those initially trained on their non-preferred dimension. On the other hand, if the preference test followed the learning task, then subjects who by chance had been assigned to their non-preferred dimension during the training discrimination reached criterion as rapidly as those assigned to their preferred dimension. The percentage of subjects making optional reversal shifts was approximately the same in groups training either on their preferred or non-preferred dimension during the training phase. Tighe et al. concluded that ". . . dimension preference tests may not only reveal selective response to aspects of the stimulus situation but may also instate or augment such selective response".

In his critique of differentiation theory, Wolff suggested that the theorizing that led the Tighes to predict superior reversal shift performance for perceptually pretrained subjects also implied that these subjects would out-perform untrained subjects on the initial discrimination. He noted that this had not happened in Tighe's (1965) experiment. At first this result does seem puzzling from the point of view of differentiation theory. The trained subject should be able to take advantage of the same learning economies in both training and test discriminations i.e. they should be able to respond on the basis of a single positive cue rather than learning to respond to the *two* stimulus patterns associated with reward. However, as T. J. Tighe and Tighe (1968) have pointed out, the pretrained subject must first *detect* and *attend* to the relevant dimension before he can respond to the positive cue during the *training discrimination*. If the number of stimulus patterns to which the untrained subject

must attach responses is not large, then these subjects might well learn the phase one discrimination as rapidly as trained subjects. Of course, during the test phase of the RS problem the trained subjects have already acquired the appropriate attention emphasis and can make full use of the learning economies previously described.

The Tighes' refutation of Wolff's (1967) criticisms is convincing for the most part. However the writer feels that differentiation theory is untenable - at least in its present form. There is other evidence that the choice behaviour of animals and young children is controlled by *dimensions* (and cues) when the subjects reach criterion on a typical discrimination problem. Lawrence's (1949, 1950) findings, demonstrating transfer between simultaneous and successive discrimination for rats, *cannot* be explained in terms of primary stimulus generalization between cue patterns or compounds. Further, it will be recalled, Youniss (1964) showed that the relative difficulty of EDS and IDS problems was the same for 7 and 13 year olds, and Campione (1970) demonstrated that 4 and 8 year olds showed the same degree of preference for optional IDS's. Taken together these two latter studies suggest that stimulus variables or dimensions (shape, colour etc.) play a significant role in the discrimination learning of children from a wide range of developmental levels. This type of evidence offers no comfort to a proposal that dimensions are only gradually differentiated and therefore only become effective stimuli during the second half of the 4 to 13 year age range.

On the other hand a modified form of the differentiation hypothesis might do somewhat better. The description of

discrimination learning of older subjects would be as set out in differentiation theory. However, it would be proposed that when young children and infra-human subjects reached criterion on the training phase of a shift problem, the behaviour of these subjects would be jointly controlled by (a) the cues within the relevant dimension (i.e. stimulus components), and (b) the stimulus patterns (compounds) formed by the combinations of cues from relevant and irrelevant dimensions. Increasing ease of an RS would result, not from children learning to respond to stimulus components, but rather from a tendency for older children to suppress responding to the cue compounds during discrimination learning. Thus the Tighes' training technique might be seen not so much as practice in isolating and independently utilizing dimensions, but rather as giving the subject an opportunity to reject overall object similarity or difference as a basis for performance in the learning situation.

Although it loses the simplicity of differentiation theory, the above theory can deal with Youniss's (1964) and Campione's (1970) results since it does not necessarily predict age related changes in the probability of dimensional control in discrimination learning. In addition, the assumption that children can learn about both stimulus compounds and components in a discrimination problem has received support in experiments with retardates of varying M.A. (House and Zeaman, 1963) and normal kindergarten subjects (Eimas, 1965). There is also considerable evidence that animals learn about stimulus compounds as well as component cues (Baker, 1970).

To set against these credits is the fact that much of the evidence for compounding in infra-human subjects comes from

classical conditioning experiments. It might be argued that these results could not be generalized to deal with experiments such as Kelleher's (1956), i.e. simultaneous discrimination problems with an irrelevant non-spatial dimension variable within trials. The latter paradigm surely presents the subject with a markedly different type of cue selection problem.

The experiments of House and Zeaman (1963) and Eimas (1965), with children, gauged the effectiveness of compounds and components in simultaneous discrimination problems but used a rather atypical design: a limited number of subjects was given a long series of 2 or 3 trial problems. Again, one would like to know whether stimulus compounds partly control subjects' performances at criterion in a typical discrimination task, i.e. where the subject is given an extended series of trials on a single problem. It is clearly possible that some stimulus features, which control behaviour during initial trials, might "drop out" in later phases of learning.

Thirdly, the only studies to relate cue and compound responding to developmental level (House and Zeaman, 1963, experiments one and five) found *both* tendencies to increase with M.A. Unfortunately the methods used to estimate response strength in the two experiments do not allow a direct comparison to be made of increments in the two types of stimulus control over a given M.A. range.

Finally, the theory does not deal well with the results of an experiment by T. J. Tighe and Tighe (1970), previously described. In that study, experimental subjects were given perceptual or perceptual-plus-verbal pretraining designed to encourage the subject to differentiate the dimensions of

height and brightness, and to stop responding to height-brightness compounds. The training, while having no effect on performance in the training phase, significantly increased the proportion of subjects making optional reversals. More to the present point, pretraining produced significantly faster learning during the second phase. It will be recalled that during the second (reversal) phase of the OS problem, the subject was presented with only *one* pair of height-brightness compounds. If the subject is responding on the basis of object (i.e. Compound) - reward relations then, in the second phase, he must stop responding to the previously rewarded stimulus pattern and learn to respond to the other discriminandum. Similarly, if the subject is responding to a stimulus dimension, he must learn to reject the positive cue of the first phase and respond to the previously negative cue. For *both* types of subject, *two* learning steps are involved. It seems clear that the effect produced by pre-training on performance in the second phase of the OS problem cannot be attributed to a reduction in the learning load for trained subjects. During this phase, *compounds* would be just as "economical" as cues for problem solution. Therefore it is likely that a *rapid reversal shift* does not depend solely - if it depends at all - on the relative efficiency of cue, as compared with compound, responding. Since this is the key explanatory mechanism of any version of the Tighes' differentiation theory, the result should be viewed as decidedly damaging to this position.

The above finding is not an isolated one. André (1969) found no difference in speed of first phase learning between optional reversers and non-reversers in an OS problem.

However, children making optional reversals solved the second phase problem significantly faster than non-reversal subjects. Kastner (1969) reported that reversers from his 4, 5, and 6 year old groups outperformed non-reversers during both phases of an OS. The only learning differences between reversers and non-reversers in his 7 year old group occurred during the *second phase*. Reversers showed a higher frequency of "once wrong then all right" response patterns in the latter phase. Because of the first phase findings, it could be argued that the second phase results for Kastner's younger groups were due to differences between children using mediators and those not using mediators in general learning ability rather than in the specific mediation process. However there was only evidence for a general learning factor among the 4 year olds. Only in this youngest group were the speeds of learning the first and second phases of the OS problem correlated.

In general, it can be concluded that performance in the second phase of the optional shift is related to the reverser-non-reverser dichotomy and sensitive to training techniques which increase the proportion of subjects making optional reversals. As explained above, this sensitivity is damaging to theories which predict the developmental trend in RS on the basis of a transition from compound to cue responding. It appears that differentiation theory does not provide the answer to the questions raised at the end of Chapter 9.

CHAPTER 11

The Extinction Rate Theory

In Chapter 8 it was pointed out that two stage theories could predict superior performance on either RS or EDS (or no difference).

(1) If it was postulated that the cue selection process was extinguished more quickly than the cue-response association process, subjects were expected to find an EDS easier than an RS.

(2) If the two processes reverted to their pretraining strengths after approximately the same number of trials, it was expected that RS and EDS problems would prove equally difficult.

(3) Finally, two stage theories predicted superior RS performance if the cue selection process survived the extinction of the cue-response association.

Read in the above order, the change in the expected relative difficulty of RS and EDS problems parallels the developmental trend documented in Chapters 2 and 3. What is proposed here is an explanation of the age trend in the RS-EDS comparison in terms of a changing relationship between the extinction rates of the two processes involved in discrimination learning. Campione (1970) has recently suggested this possibility. That investigator was attempting to explain why he found no developmental trend in the proportion of subjects making optional intra-dimensional shifts over an age range where the Kendlers had demonstrated such trends in the proportion making optional reversals. He concluded; "If the relative rates at which attentional and instrumental

responses extinguish differ at different ages, it would be possible to predict developmental changes in the R-ED comparison even if the probability of subjects making a mediating response is assumed to be unity at all ages".

The above explanation of age trends in the relative difficulty of RS problems is attractive from several points of view. Firstly, it provides a framework for comparing the reversal learning of animal and human subjects. The model proposes that, for very young children, the cue selection response is extinguished more quickly than the cue-response association that it controls. This was precisely the assumption that attention theories found necessary to deal with the reversal learning of infra-human subjects. The present theory therefore deals with the similar RS performance of infra-human subjects and very young children without appealing to Spence's single unit theory. This gives the model a distinct advantage over the Kendlers' theory, since Spence's theory appears untenable for either type of subject.

Secondly, the theory indicates that RS and IDS problems tap somewhat different abilities in a given subject. During the test phase of an *IDS*, previously reinforced cue-response associations do not have to be extinguished since the first phase cues of the relevant dimension have been replaced. The difficulty of an IDS will depend on whether a *dimension selection* component of the overall cue selection process was conditioned during the training discrimination. It will also depend on the difficulty that the subject experiences in acquiring the new cue-specific component of the mediator. Neither of these factors need be influenced by the relation holding between extinction rates of components of the cue

selection process and the extinction rate of cue-response associations. Developmental changes in the latter could leave the relative difficulty of IDS and EDS unchanged - and this appears to be the case.

The present model deals well enough, then, with the finding that IDS-EDS comparisons and RS-EDS comparisons do not show parallel developmental trends. In contrast, the Kendlers seem compelled to predict synchronous developments in the two types of comparison: since efficient performance in both RS and IDS depends on the subject producing some sort of mediator during the training discrimination, then the Kendlers should predict that a general increase with age in mediator production (as opposed to single unit responding) would produce similar increases in efficiency of making both types of shift.

Finally, the above theory is testable even in its general form, i.e. without the particular mechanisms involved in the developmental changes in the relative extinction rates of the two processes being specified. The general research strategy would involve training human subjects of varying developmental levels on the three stage EDS problem used by Goodwin and Lawrence (1955). It may be recalled that in this transfer problem the subject is given an EDS problem with the first phase relevant dimension irrelevant and variable within trials during the second phase. After the subject had learned the second discrimination he was given yet another EDS. The dimension relevant during the third learning phase was the one that was relevant in the first phase, and the subject was assigned, as the positive cue in the third phase, either the cue that was positive or the cue that was negative in the first phase.

The third phase indicates how well the cue-response associations of the first phase survived the extinction of the attention (cue selection) response during the second phase. If these cue-response associations had survived the second phase, then the subject would solve the third phase problem more easily if assigned the positive cue of the first phase. Such a result would suggest that the cue-selection process extinguishes more quickly than the cue-response associations. The present theory would lead to the prediction that a class of subject that responded in this manner would also find an RS *harder* than an EDS. One simple way of checking this prediction would be to allot subjects randomly to an RS or an EDS after completion of the first phase. Only the EDS subjects, however, would continue into the third phase. According to the present model, if the EDS group outperformed the RS group during the second discrimination, then the EDS subgroup assigned the same positive cue in first and third phases would be superior to the other EDS subgroup during the third phase. On the other hand, if the RS group learned more quickly in the second discrimination then there should be no performance difference between the EDS subgroups during the third phase.

The problem remains of selecting subjects of the two developmental levels contrasted above. The literature reviewed in Chapter 2 suggests that chronological age is a fairly unreliable predictor of RS-EDS performance - at least within restricted ranges. However, White and Johnson's (1968) findings suggest that if dimensions such as height and brightness are used in the discriminations, then *seriation* ability might provide a useful basis for selecting groups at

different levels of mediation efficiency. The contrast in mediation level, between those children who made few mistakes in seriating and those who made many mistakes, could be further heightened by giving the former group the Tighes' *pretraining* procedure (see L. S. Tighe and Tighe, 1968). The assumption here would be that this training technique accelerated "natural" development in mediation level.

To the writer's knowledge the above experiment has not yet appeared in the literature. Cunningham (1969) has reported a study in which a version of the Goodwin and Lawrence (1955) transfer task was given to retardates (M.A. range: $5^1/_2$ to $10^1/_2$ years). The EDS group assigned to the same positive cue in the first and third phases performed better than other EDS groups during the third stage. Cunningham concluded that Goodwin and Lawrence's (1955) notion of a rapidly extinguished cue selection process received support. In fact, the experimental design did not allow an estimate of the relative extinction rates of the cue-selection process and cue-response associations to be made. A critical feature of Goodwin and Lawrence's transfer problem was that the mediator and the instrumental responses of the first phase underwent a certain number of extinction trials in the second phase. To enable this, the initially relevant dimension *and cues* became irrelevant in the second phase. In contrast, Cunningham, while having the first phase relevant dimension irrelevant and variable within trials, replaced the cues within both non-spatial dimensions for the second discrimination. This meant that the specific cue-response attachments of the first phase did not undergo *any* extinction trials. In the circumstances, it was not surprising that subjects showed

the first phase cue preferences when they began to attend to the relevant dimension during the third phase: these preferences for specific cues had not been weakened at any stage of the transfer problem so, naturally, they "survived" the extinction of the attention response.

In summary, infra-human subjects and human subjects from a wide range of developmental levels appear to use mediators. It is felt, therefore, that the Kendlers' developmental hypothesis does not provide a valid explanation of the age related trends summarized in Chapters 2 and 3. The question is not whether children of varying ages produce a mediator while solving the discrimination. Rather, the important issues are as set out below.

(1) Can the mediator that the child does produce be detected by the transfer designs typically employed by psychologists?

(2) What properties of the mediator produce this detectability for each of the paradigms (EDS-IDS comparisons etc.)?

(3) Are age trends found for each of these properties?

(4) What specific mechanisms might account for these age-related changes?

An advantage of using mediator property, or component, as the unit of analysis is that one is sensitized to the different ways in which mediators can influence subsequent performance. Take, for example, the series of studies that compared subjects' performance on RS and HRS problems over a wide age range (H. H. Kendler, Kendler and Sanders, 1967; H. H. Kendler, Kendler and Marken, 1969). It may be recalled that in a typical problem the subject was presented with eight

pictures of familiar objects, one at a time, and asked to indicate one of two possible responses (press white button or press black button) for each picture. The objects could be sorted into two mutually exclusive categories (e.g. clothing or fruit) and, during initial learning, the correct response for an item could be predicted on the basis of the category to which it belonged (e.g. all items of clothing → black button; fruit → white button). Subsequently, one half of the subjects were given a discrimination problem in which the response appropriate for *all* items was switched (i.e. fruit → black button; clothing → white button) - an RS. For the remaining subjects only *half* the items in each stimulus category were switched - an HRS. With increasing age of subjects, it was found that the RS condition became increasingly easy relative to the HRS condition. The Kendlers argued that the RS-HRS comparison reflected the extent to which subjects of a given age were producing a common symbolic mediating response for the items of a given category. This common response ". . . represents the characteristics shared by the instances of a conceptual group" (H. H. Kendler and Kendler, 1968, p.235).

The writer has no argument with this interpretation of the results. However, the Kendlers (H. H. Kendler, Kendler and Marken, 1969, pp.325-326) have noted that the results with the RS-HRS comparison are "consistent" with the developmental trend found using the OS design and shape-colour-size patterns as discriminanda. Both types of developmental progression, they argued, reflected an increasing ability ". . . to reverse responses in a discrimination task".

The tone of the Kendlers' argument in these few pages indicates a belief that the same type of mediation mechanism is involved in both RS-HRS and RS-EDS comparisons - allowing, of course, for differences in mediator content due to the different stimulus material. Now, as was seen in the discussion of the Tighes' differentiation theory, it *is* possible to explain the developmental trend in the RS-EDS comparison while making use of the same mediator property that the Kendlers invoke to deal with the trend in the RS-HRS comparison. However both the Kendlers' developmental hypothesis and the extinction rate hypothesis just presented make use of a somewhat *different* mediator property in explaining the developmental progression in RS-EDS comparisons.

Firstly, it should be clear that subjects who produce the "common symbolic response" find an RS easier than an *HRS* because the former problem allows them to use the mediator to reduce the amount of learning necessary. The essential function of the mediator here is to enable the subject to "chunk" the stimuli into larger units. The subject can then associate these larger units with the appropriate response rather than make the more numerous connections between individual stimuli and the two responses. This is precisely the function that the Tighes gave the "differentiated" cue in discrimination problems using brightness-size compounds as discriminanda.

In contrast, the Kendlers do *not* propose a chunking mechanism to explain why subjects who use mediators tend to find the RS easier than the EDS problem. In their model, older subjects perform better on an RS because,having successfully predicted reward by encoding the stimuli one way (e.g. white;

black) during initial training, they are less likely to use alternative codes (square; circle) in learning a second discrimination. The relevant codes in the test discrimination of an RS or an EDS are *equally efficient mnemonics* i.e. they both impose the same information processing load on the subject. The only advantage held by the code (mediator) used in the RS task is that it was primed or strengthened during the initial (Training) discrimination. Admittedly, the mediators appropriate to the RS are also primed during the training phase of RS-HRS designs; however, during the test phases of the RS and HRS, the crucial comparison is between one condition in which the *primed* mediators of the first phase provide an *efficient* basis for organizing the stimuli (RS), and another condition in which *none* of the available mediators enable the subject to organize effectively the stimulus material (HRS). In brief, the RS-HRS comparison confounds two distinct properties of the mediators produced. These are: (a) whether the mediator has been previously strengthened in the situation and survives the extinction of the instrumental response it controls (*mediator preservation*); (b) whether the mediator enables the subject to organize the stimuli into categories so that learning is most "economical" (*Mediator efficiency*).

This confounding is unnecessary. In one of their experiments, H. H. Kendler et al. (1967) gave adult subjects an initial problem in which the reinforced response for an item was not related to item category. The subjects were then given a second problem in which either the appropriate response for all items was changed and categories remained unrelated to reward, or responses for half the items were

changed so that the stimulus categories (clothing, furniture) predicted the reinforced response perfectly. The latter condition, although technically an HRS, was markedly superior during the test discrimination, presumably because the subject could represent the stimulus categories and make use of the learning economies outlined above. This unsurprising result shows that the second (organizing) property of the mediator will produce a large effect on the speed of learning this type of task whether or not the mediators involved have been reinforced in a previous problem. Since this is so, and since the Kendlers seemed chiefly interested in discovering developmental trends in the accessibility of the mediators representing *stimulus categories* in the RS-HRS comparison, then one might ask why they bothered to give their subjects a training discrimination at all. Why did they not simply compare the performance of their subjects on the two types of discrimination task described above - stimulus categories correlated or uncorrelated with rewarded response? It seems highly likely that they would have discovered the same developmental trends: with increasing age the "correlated" discrimination problem would become easier compared with the "uncorrelated" problem since older children would be more likely to produce the symbolic response that enabled them to organize the stimuli in the former problem. An alternative, and even simpler, procedure would have been to give all subjects the "correlated" problem and to then test for concept generalization by presenting each subject with *new* instances of the two categories of stimuli. If the subject had been learning the original list as single items, then there would be no sigificant generalization and the subject would have

responded randomly to the new items. If the subject had been learning category-response associations then he should have responded appropriately to new items from these categories. Once again, a developmental function similar to that found by H. H. Kendler et al. (1969) would be expected.

If the Kendlers wish to demonstrate that the mediating responses representing the item categories not only enable the subject to solve any given "correlated" problem in a highly efficient manner, but also provide a basis for inter-problem transfer, then this latter mediator property should be gauged by the following type of comparison. The subject would be presented with pictures of familiar objects which could be sorted into mutually exclusive classes in at least two ways (e.g. male-female; child-adult). All subjects would be assigned to a "correlated" problem based on one of the possible category pairs. After criterion was reached on the training problem, half the subjects would be presented with new instances of their categories to which they would have to respond. All subjects would then be assigned to either an RS condition - the appropriate responses switched but the two categories still relevant - or to a category-pair shift condition - reinforcement could only be predicted on the basis of a new category pair. As pointed out above, the amount of generalization to new category items provides an estimate of the degree to which the group is producing a mediator that is *efficient* in the sense that it enables the subject to operate with stimulus groups rather than specific items. On the other hand, the RS - category-pair shift comparison gives some idea of the "persistence" of this mediator - the tendency

of a subject to continue to produce the mediators developed in the training discrimination through a series of non-reinforced trials when there are competing, potentially efficient mediators available. Mediator perseveration and mediator efficiency can therefore be distinguished operationally.

CHAPTER 12

Extinction Rate Theory and the Representation Hypothesis

For the reasons expressed in the preceding chapters, the writer has a marked preference for the extinction rate theory of the developmental trends in speed of reversal shifting. To recapitulate briefly, the theory holds that when subjects of any age group learn a simple discrimination, the overall habit can be roughly divided into two component habits. These are (a) cue selection - the subject learns to attend to the relevant cues in the situation; and (b) cue-response learning - the subject learns to associate the correct response with each cue. The age-related changes in RS performance are due to changes in the relative degrees of extinction of these two habits during the string of non-reinforcements that characterize the early trials of the test phase of the shift problem. For very young children (3 to 4 years), the first (cue selection) habit is likely to be extinguished more quickly than the second. With increasing age it becomes more probable that the second (cue-response) association will be extinguished more quickly than the first. This developmental change could come about, of course, in a number of ways. Does the change in relation between extinction rates come about chiefly because the cue selection habit is extinguished more slowly in older than younger children; or mainly because the cue-response association is extinguished more quickly in older children than in very young children; or do both of these developments occur?

The second or third of the above possibilities are more likely than the first. The evidence suggests that for subjects

of higher developmental levels the "switching" of responses to attended cues is a very rapid process. In many cases the cue-response associations of the training discrimination are extinguished in one trial (Gollin, 1964; Johnson and White, 1967; Kastner, 1969; T. S. Kendler and Kendler, 1970). The studies of Johnson and White (1967) and Kastner (1969) are particularly impressive in this respect. The former investigators found that, of the 12 subjects who had demonstrated their seriation ability on the relevant dimensions, 10 subjects made only one "error" during the test discrimination This error, on the first trial of the test phase, was naturally inevitable since the subject was not told of a change in problems. In comparison, only 4 of the 13 subjects with low seriation scores exhibited this response pattern. Kastner found that children who made optional reversals were considerably more likely to respond in a "once wrong then all right" pattern during the second phase of the OS than were non-reversers.

The assertion that the resistance to extinction of the cue selection response increases with age is more difficult to test and, perhaps not surprisingly, receives equivocal support in the literature. The proposition implies that older children find it more difficult than younger children to switch attention responses after a training discrimination. This would seem to entail the counter-intuitive prediction that with increasing age (or with increases in other indices of cognitive development), the difficulty of an EDS problem will *increase*. However, a definite prediction cannot really be made since increasing difficulty of switching cue selection habits must be offset, at least partially, by increased ease

of acquiring the new cue-response associations. In fact, Youniss (1964) found that 13 year olds were slightly, although not significantly, *better* than 7 year olds in an EDS Problem. A similar result was reported by Eimas, although the age range employed (5 to 7 years) was narrow. Contrasting with these findings, T. J. Tighe and Tighe (1967) found that 10 year olds were markedly *inferior* to 4 year olds in the test phase of an EDS problem if there was an irrelevant non-spatial dimension variable within trials during both phases of shift. Only this last result supports the notion of a slowly extinguishing cue selection response for older subjects.

Whether or not there is an age related increase in the resistance to extinction of the cue selection response, it seems fairly clear that adults and older children acquire cue-response associations more quickly than subjects from younger age groups. An adequate model of the developmental changes in ease of reversal shifting must predict a fairly high probability of "once wrong then all right" response patterns for subjects of high developmental levels in the test phase of RS problems.

The extinction rate theory just outlined provides an explanation of the developmental trend in the RS problem only in a general sense. What is needed is some idea of the specific mechanisms that bring about the change in the relation between the extinction rates of the two learning stages. In the remainder of this chapter an attempt is made to provide a description of these mechanisms.

The Representation Hypothesis

Two recept papers (H. H. Kendler and Kendler, 1970; Kastner, 1969) have attempted to link developmental changes in RS performance with a transition between Piagetian stages of cognitive development. The Kendlers speculated that rapid RS learning might be produced when the child changes from a sensori-motor mode of operating on, and "understanding", the world to a mode of cognition in which he can symbolically represent objects (see Piaget, 1952). Now, Piaget asserts that children are making this transition in mode of cognitive operation during the age range 18-24 months. One might therefore be tempted to reject the hypothesis out of hand since marked changes in RS performance continue at least through the years that children spend at primary school (T. S. Kendler and Kendler, 1970). However, in other work, Piaget (Piaget and Inhelder, 1956, chs.1-3; Inhelder and Piaget, 1964) has shown that the child's ability to represent the *cues* and *dimensions* (shape, colour, size etc.) typically used in simple discrimination problems develops into the stage of concrete operational thought (7 to 11 years). Thus the Kendlers' proposal retains some plausibility.

The above speculations point up what is perhaps the most important issue raised by the Kendlers' theorizing. Are the psychological processes that underly the discrimination learning of children essentially similar over a wide age range, or are there radical changes in the nature of the cue selection and cue-response habits with increasing age? Theories that make the former assumption (e.g. Caron, 1969) also tend to assume that the cue selection habit is dependent on perceptual mechanisms (stimulus analyzers, observing responses)

over the age range of interest. The developmental changes in RS performance are predicted on the basis of an increment in the "strength" of these attention responses which occurs during repeated experience with stimulus variables in a variety of situations. This type of theory might be termed a quantitative model of the developmental trends in question (Van Den Daele, 1969). The alternative position is that qualitative changes in functioning produce the age related increases in speed of reversal shifting, and, of course, the representation hypothesis described above is an example of this type of model. A key assertion is that *at higher levels of cognitive development the cue-selection response involves the subject thinking about or representing the relevant cues, and possibly the dimension, in discrimination tasks.*

The Kendlers' version of the representation hypothesis proposes that young children learn a simple discrimination as a sensori-motor scheme and that such learning can be adequately described by Spence's single unit continuity theory. The evidence does not support the latter proposition since subjects over a wide age range (as well as infra-human subjects) appear to be capable of learning to attend to relevant dimensions and cues. However another version of the representation hypothesis could allow the possibility of a cue-selection component of a sensori-motor scheme, while asserting that such attentional phenomena were produced by perceptual mechanisms e.g. the "switching in" of certain stimulus analyzers. Naturally, the model would have to explain why the cue selection component of a sensori-motor scheme was less effective in producing rapid RS's than a cue selection habit which involved *cue representation.*

The distinction between *cue perception* and *cue representation* was critical to the above analysis. Although theoretical separation of the two types of process seems plausible on intuitive grounds, such a separation has been ignored by some theorists studying developmental changes in the way children encode a given stimulus input (e.g. Zaporozhets, 1965). Most researchers seem to agree that the child is "thinking" if he has verbally encoded the stimuli. On the other hand the perception-representation distinction is often blurred in theoretical discussion if the child is employing some sort of non-verbal code or representation such as a "visual" image. Both Kastner (1969) and André (1969) have proposed that some sort of non-verbal symbolic system can play a role in rapid reversal shifting, and have produced evidence to support their contention. Therefore, if the representational hypothesis is to be taken seriously, an attempt must be made theoretically and operationally to distinguish perception from non-verbal representation.

Such an attempt could well take its starting point from Piaget's detailed description of developments in the child's ability to form non-verbal representations or images (Piaget and Inhelder, 1956; Piaget and Inhelder, 1971). In this work, Piaget has been chiefly interested in developmental trends in the capacity to form and manipulate spatial images. Most relevant to the present discussion are his general findings of a developmental progression in the "imagination" of static configurations (geometric shapes and other less well organized spatial systems). In his theoretical treatment of these results, Piaget (Piaget and Inhelder, 1956, ch.1-3; Piaget and Inhelder, 1971, ch.7 + 10) has been at pains to

distinguish "organizations" achieved by perceptual processes from those dependent on thought or imagination. For example, Piaget and Inhelder (1956, p.17) state that, "Perception is the knowledge of objects resulting from direct contact with them. As against this, representation or imagination involves the evocation of objects in their absence or, when it runs parallel to perception, in their presence". Again, (op. cit. p.37), "In the case of visual perception, shapes are recognized through an almost instantaneous structurization ... As against this, the visual image of such shapes presupposes a mental representation, conjured up while the object is out of sight". Further, although Piaget believes that both perceptual schemata and images develop with age - and that in both cases development results from sensori-motor activity - he also believes that the child's, ". . . ability to perceive forms . . . (straight lines, curves, squares, circles etc.) is far in advance of his capacity to reconstruct them at the level of mental images or representational thought". (op. cit. p.13). Thirdly, although this is not made very clear, developments in the image appear to depend more heavily on what Piaget terms *imitative analysis* than does perceptual learning. This imitative analysis is made up of the eye movements and tactile explorations by which the child acquaints himself with a given object or shape. As the child carefully traces the contours of a shape, with eye and hand, a sensori-motor scheme is built up (integrated) which is an overt "copy" or imitation of the shape in question. As this action scheme is short circuited or internalized, it forms the basis of the child's image or representation of that shape. Thus for Piaget

(op. cit. p.17) ". . . the image is an internalized imitation . . . and is consequently derived from motor activity, even though its final form is that of a figural pattern traced on the sensory data". Finally, as should be fairly obvious from the last quotation, Piaget considers the image ". . . a fact of consciousness", (op. cit. p.42) and ". . . simili sensible", (Piaget and Inhelder, 1971, p.364). Apparently he identifies the form of non-verbal representation that he has studied with the "picture in the mind" available to introspection.

In the above, it was proposed that a child could only form an image of a shape if he was capable of a precise sensori-motor imitation or "tracing" of its contours. Piaget and Inhelder (1956) have shown that the child's ability to explore the contours of a cardboard shape systematically using active touch (i.e. the shape was hidden from sight behind a screen) increases markedly over the age range 3 to 8 years. This development of a systematic tactile exploration of shapes was correlated with a marked improvement in the child's capacity to *draw* and to *construct* models of the same shapes presented visually. These developmental progressions in active touch, drawing, and model construction have been confirmed in a series of studies reported by Zaporazhets (1965). In addition Zinchenko and Ruzskaya (in Zaporazhets) have demonstrated parallel developments in the eyemovement patterns of children (age range: 3 to 7 years) as these subjects scanned various shapes under instructions to memorize the figures presented.

From the present viewpoint, the most interesting of Zinchenk and Ruzskaya's findings was the correlation between a subject's

scanning strategy and his later success at *recognizing the shapes*. A child only achieved a perfect recognition performance if his, ". . . eyemovement followed, in the main, the outline of the figure, as if reproducing or modelling its form". (op. cit. pp.87-88). Six to seven year olds generally reached this performance level while the scanning strategy of 3 and 4 year olds was unsystematic and their recognition performance generally poor. This link between the development of imitative analysis and performance on a recognition memory task is important since it correlates two of the properties of the image postulated by Piaget: persistence over time and dependence (at least initially) on imitative analysis. It will be recalled that one property that distinguishes the image of an object from its perception is that the former process may "persist" after the object has been removed and that it may be retrieved or activated in the object's absence. Clearly the subject must be able to store the image of an object in both short- and long-term memory. The memory image need not be lost nor become inaccessible as rapidly as material in the very short term visual storage investigated by Sperling (1960, 1963). Rather the amount of forgetting will depend on the degree to which the subject concentrates on encoding the object as an image and maintains that image in a short term store (Posner, 1969), thus presumably increasing the probability that the "copy" of the object will be stored in a relatively permanent form (Atkinson and Shiffrin, 1968).

In any case, the child's ability to form a relatively stable memory trace of a given shape (i.e. his capacity to recognize or reproduce the shape after a period of seconds

or minutes) would be, from Piaget's point of view, a valid index of whether or not he could form an image of that shape. If performances on drawing, modelling and recognition tests are used as indices of imagery ability, then children below the age of about $4^{1}/_{2}$ years are incapable of forming accurate images of simple gestalts such as triangles, squares, and rectangles (Piaget and Inhelder, 1956; Zaporazhets, 1965). Piaget would argue that younger children can perceive (i.e. "see") triangles, rectangles etc. before they can represent or imagine them. Indeed, by the use of an ingenious operant conditioning technique, Bower (1967) has shown that infants (36 days of age) are capable of perceiving triangles as wholes. This finding strongly suggests that the perceptual mechanisms that enable infants to perceive simple gestalts are innate. However, elsewhere Bower (1966) has reported data which suggest that infants *learn* to perceive more complicated stimulus patterns as *wholes* (although, in the case of the patterns used, the learning seems evident by the age of 5 months). The latter finding is more in line with theories of perceptual learning propounded by Hebb (1949, 1968) and Piaget (Piaget and Inhelder, 1956).

Since very young children seem capable of discriminating (and therefore perceiving) simple gestalts *before they can form stable memory images of these figures*, one may ask whether development in the capacity to form accurate images changes what is learned in a simple shape discrimination. An experiment by Ruzskaya (in Zaporazhets, 1965) indicates that it does. Children, of 3 to 7 years of age, were trained to criterion on a successive discrimination problem with a triangle and a rectangle as relevant cues. All subjects were then given

generalization trials on which they were presented with ". . . different variations of the figures in various positions . . ." (op. cit. p.99). The number of errors on the generalization trials was inversely related to age. Three and four year olds, particularly, made numerous errors. After this test phase, each child was ". . . taught to follow the outline of the figure with his finger, stressing the change of direction at the angles and counting (the sides)". Such training markedly improved the child's capacity to generalize the triangle-rectangle discrimination. During the second test phase, subjects initially needed to trace the outline of each figure with their hands before making the proper response; however this imitative analysis was later reduced to ". . . hand modelling the form of the object at a distance". A still later stage of "imitation" of the shapes was reached when the subject relied solely on extensive eye-movements which traced the outline of the figure presented. Finally, even these exploratory eyemovements were reduced.

These observations directly support Piaget's contention that the image is an internalized imitation. It also seems that the action schemes that produce the image of the triangle or rectangle constitute a more *abstract* description of these figures than do the structures underlying the *perceptual* gestalts. At least, in this simple discrimination, only the discriminative response of the older children (and *trained* younger subjects) was controlled, during the test phase, by a concept of triangle and rectangle free of subsidiary features (orientation etc.) of the cues used in the training discrimination.

Extinction Rate Theory and the Ability to Represent Cues

The above considerations make plausible the notion that children can learn a simple discrimination problem either in a *pre-representational* or in a *representational* mode of cognitive operation - and that the latter mode becomes more likely with increasing age. They therefore offer general support for the representational hypothesis. The next step in the present argument is to link the representational hypothesis with the extinction rate theory presented at the beginning of the Chapter. In particular, can one explain why the older child's capacity to form stable representations of the relevant cues would tend to produce a particularly rapid response shift during the test phase of an RS problem? In what follows such an explanation will be attempted.

It should be noted that the ability to represent the relevant cues is necessary if the subject is to produce a *cue list* of the sort described in connection with model A (Chapter 6). Working within the general framework of Model A, the problem becomes that of explaining why the cue-response habits can be switched rapidly given that the "stimulus" controlling response selection on a given trial is a "list" of cue representations that the subject has stored as a reasonably stable and readily accessible memory trace. A number of reasons can be suggested.

(1) Task Orientation. The child who represents the relevant cues is chiefly responding to *self-generated* stimuli which effectively restrict his attention to the section of the laboratory in which stimulus patterns are displayed and rewards dispensed. In other words, the child operating with

a cue list is more or less pre-occupied with his *formulation* of the problem that he has been asked to solve. His *thoughts* are tuned to problem solution and therefore there is less likelihood that irrelevant trains of thought will interrupt learning. Again, since his attention is largely turned "inward", extraneous noises etc. are unlikely to distract him from problem solution. In sum, the task is likely to have the undivided attention of a child who has established, and is operating with, a cue list. Such a subject is therefore likely to extract the maximum information from the feedback that the experimenter gives him concerning the correctness or otherwise of his responses. In turn, this will speed the learning of the correct response for each of the relevant cues. It should be noted that this greater task orientation of subjects who represent cues need not mean greater attention to relevant cues vis à vis experimenter controlled irrelevant cues i.e. those features of the presented stimulus patterns that are uncorrelated with reward.

(2) Rehearsal. Children who represent the relevant cues in a discrimination problem can presumably also represent the responses appropriate (i.e. rewarded) to those cues. Such a subject may utilize the feedback provided by the experimenter over a series of trials to formulate a rule of the type $\begin{bmatrix}\text{Square} \rightarrow \text{approach} \\ \text{Triangle} \rightarrow \text{avoid}\end{bmatrix}$. Now, each of the elements of this rule may be activated in the *absence* of the stimulus patterns and any opportunity to perform the overt responses. Therefore this rule or plan of action may be *rehearsed* by the child during the inter-trial intervals. This rehearsal capacity, in effect, gives the subject extra learning trials in comparison with

children who can only learn while the discriminanda are present. Thus it will enable relatively rapid learning of the cue-response associations.

(3) Inference. The way in which this representation-dependent capacity might affect rapid reversal learning is perhaps best illustrated in connection with a *successive* discrimination problem. At the end of a training discrimination the older child will have learned a rule of the form $\begin{bmatrix}\text{square} \rightarrow \text{push right button} \\ \text{Triangle} \rightarrow \text{push left button}\end{bmatrix}$. When, on the first trial of the test discrimination, the experimenter corrects the subject (e.g. tells him that the left button is correct after the subject has responded to the square) then the child may not simply commence to learn the single new cue-response habit (square → push left). Since he has previously represented *both* relevant cues together with the two possible responses, he may realize that one new cue-response association implies its complement: in the above case (triangle → push right). Therefore, on the basis of a single feedback trial, the child operating at the level of representation can reformulate the whole rule that guides his behaviour and learns to rehearse the new "plan". Rapid cue-response learning is again indicated.

Any combination of the above three properties of representational learning could be effective in producing a rapid RS. However it should be possible to evaluate the contribution of each property by appropriate experimentation. For example, the child responding to *represented cues* is hypothesized to learn during *both* stimulus presentation and *inter-trial* intervals (the rehearsal property). Increasing the inter-trial interval during the test phase of shift should

further improve the RS performance of children employing cue representations relative to those subjects not employing symbolic mediators. An assumption, implicit in the above discussion of the role of *rehearsal* should perhaps be made clear at this point. The older child is thought to be capable of rehearsing information stored as either a verbal or a non-verbal memory trace. Evidence that mature subjects are able to rehearse material stored in *non-verbal* memory codes has recently been reviewed by Posner (1969). The third property of representational responding mentioned above should be sensitive to rather different experimental manipulations. The effect of a capacity to *infer* cue-response relations should be *reduced* by increasing the number of cue-response associations to be learned.

It appears that the representation hypothesis can explain rapid switching of cue-response associations by a variety of mechanisms. However, if the hypothesis is to explain why subjects who produce representations of the relevant cues find an RS easier than an EDS, it must be assumed that the developments in the efficiency of switching cue-response associations are not matched by as rapid an improvement in the child's ability to switch cue selection habits. This requirement is a simple corollary of the basic assumption that if an RS is to be easier than an EDS, the cue selection habit must survive the extinction of the cue-response association during the early trials of the test discrimination. Apparently *the process of selecting and establishing a list of cues is relatively inefficient compared with the process of forming cue-response associations within the framework of such a cue list.*

It could be argued plausibly that the capacity to replace rapidly one cue list with another would depend on the subject's ability to produce a complex mediator - *a list of cue lists*. The production of this mediator would depend, in turn, on the child's being able to represent the stimulus *variables* or *dimensions*, potentially relevant to task solution, *simultaneously*. It is known from Piaget's work on the development of classificatory skills (Inhelder and Piaget, 1964) that this capability is acquired within the age range 7 to 9 years,i.e. it is a product of concrete operational thought structures. However, if the list of lists is to produce efficient switching from one cue list to another, the subject must also be able to "keep his place" in the superordinate list: he must somehow keep a record of which dimensions have been tested as a basis for task solution, together with the outcome of each test. This, of course, must be done to ensure that previously tested dimensions are not resampled. Now the ability to operate on the products of concrete operational structures is one of the features of formal operational thinking (Inhelder and Piaget, 1958). It is therefore conceivable that an efficient mechanism for switching cue lists is not available to the child before 11 years of age. It is also possible that, because of the cognitive load involved (or because of related motivational factors), adult subjects do not normally construct and operate with the complex mediator during the training discrimination, or do so only at a relatively slow rate. This may be the explanation of the general finding that overtraining facilitates *EDS* as well as RS problems for adult subjects while only facilitating RS problems for younger children (Wolff, 1967,

pp.384-390). In any case, the assumption of the representation hypothesis that the process of selecting and establishing a cue list should be a relatively slow process for cognitively mature subjects would seem to be supported by the above theoretical considerations. What is being said here is that, although the cognitively mature subject represents the cues (and perhaps the dimension) that more or less directly control response selection, he generally does *not* represent the stimuli which elicit these particular mediators. Thus mediator selection, paradoxically, does not enjoy the three advantages of stimulus representation that it bestows on subsequent segments of the problem solving "chain", and therefore is a less efficient (i.e. slower) process than these subsequent habit acquisitions. From the above considerations the superiority of an RS over an EDS can be predicted for mature human subjects under typical testing conditions.

Further problems must be solved before a version of the representation hypothesis becomes acceptable. About a year after the child can draw, model and recognize simple shapes, he becomes able to sort, consistently and exhaustively, colour-size-form stimuli by shape (Inhelder and Piaget, 1964). The former tasks presumably measure developments in the capacity to represent individual cues or values from the shape dimension. The latter task would seem to indicate whether or not the child can represent the dimension itself - whether he has the "concept" of the shape dimension. Clearly the ability to represent individual cues is a pre-condition for the production of a cue lists, and, as was pointed out during the discussion of model A, some sort of *dimension selector* would also seem to be a necessary condition for a cue list.

It is less clear that this latter attentional response need occur at the level of thought or representation. One may therefore ask whether rapid reversal learning depends on the child's ability to "organize" a dimension (as indexed by sorting and seriating tasks).

Evidence presented by Johnson and White (1967) and White and Johnson (1968) does seem to indicate that developments in the child's *concepts* of the *brightness and size dimensions* are correlated with increasingly rapid learning in the test phase of an RS. in addition, the Tighes' training technique (L. S. Tighe, 1965; L. S. Tighe and Tighe, 1968) may well be effective because it strengthens the child's concepts of these same dimensions. However, it appears likely that developments in the capacity to seriate cues within the size and brightness dimensions confound changes in representational ability at the *cue and dimension* level. The evidence for this is admittedly indirect. T. J. Tighe and Tighe (1969(a); 1969(b)) have shown that their training technique not only increases the speed of reversal learning in problems based on the brightness and size dimensions, but also increases the frequency of *relational responding* in transposition tests. Assuming that the training technique operates by strengthening the particular mechanism that Johnson and White (1967) tapped with their seriation tests, the organization of the dimensions in question is apparently accompanied by a change in the type of cue effective in size and brightness discrimination problems. Arguably, it is this change to responding on the basis of relative rather than absolute cue properties that somehow results in rapid reversal learning. One must conclude that there is no decisive evidence on this point. The superordinate

attention response ("dimension selector"), that enables the cue list to be produced, may occur at the level of perception or of representation or of both. Whichever is the case, there is evidence that this attention response does *not* invariably provide a basis for positive transfer between two discriminations based on cues from the same dimension. Therefore the terms "dimension selector" or "observing response to a dimension" must be qualified somewhat - at least for young children learning shape discriminations.

Blank (1967) trained 5 year olds on one of the following simultaneous discriminations: (a) blue triangle - blue circle; (b) red triangle - yellow triangle; (c) complex shape *1* - complex shape *2*; (d) complex shape *3* - complex shape *4* - (the complex shapes were all coloured blue during the initial discrimination and were many sided. Shapes *1* and *3* were irregular, i.e. asymmetrical). After reaching criterion on the training discrimination, all subjects were then trained on a shape discrimination with complex shapes *1* and *2* as the relevant cues and with texture as an irrelevant dimension variable within trials. The subjects that had been trained to discriminate complex shapes *1* and *2* during initial training were now rewarded for selecting the previously negative cue i.e. these subjects were given an RS. In the test discrimination , the RS group markedly out-performed the other groups which did not differ from each other. The fact that groups (a), (b), and (d) did not differ during the test phase is important. It implies that the mediator component that, in a number of experiments, provided a basis for positive transfer in shape IDS problems does not generalize to all shapes. It may in fact be limited to simple gestalts typically used to

demonstrate the "dimensional" nature of the mediator - at least for young children. It is interesting to note that there was apparently no basis for positive transfer, even between the two complex shape discriminations. Also of interest was the rapid learning of the RS group during the test phase. Apparently these subjects could produce a cue list without having an abstract concept of the shape dimension (or a functionally equivalent perceptual response). The superordinate attention response acquired in the complex figure discriminations must have been restricted to shapes quite similar to those that occurred in the training discrimination.

The final problem for the representation hypothesis was alluded to at the beginning of this Chapter. The representational skills that the child needs to produce effective symbolic mediators would seem to be in his repertoire by the time he is 8 or 9 years old. Yet there is evidence of (slower) improvement in RS performance beyond this age.

There are a number of possible answers to this criticism. Perhaps the simplest is that according to the representation hypothesis, rapid reversal learning depends not only on the subject's capacity to represent the relevant cues, but also on his efficiency in using these representations as a basis for rehearsal and inference. The representational capacity is a *necessary* rather than a sufficient condition for a rapid RS. One could reasonably expect the ability to produce spontaneously, and to exploit efficiently, representational skills in a problem solving situation to improve beyond the age of 9 years. A child's efficiency in utilizing cue representations would presumably depend in part on the degree

to which the schemes underlying these representations were well integrated through *overlearning*. From this viewpoint, the ability to represent cues is not all or none but is best described as a continuum, with older children only gradually approaching the high efficiency of information processing described earlier in the Chapter.

CHAPTER 13

The Development of a Test measuring a Particular Representational Ability

In the present investigation the broad aim was to test the representational hypothesis. The general experimental hypothesis was that *individual differences in children's ability to represent a class of cues are reflected in the relative efficiency with which they reverse a discrimination based on these cues.*

A subsidiary aim was to test this hypothesis with a cue category whose representations would be based chiefly on a non-verbal memory code. Therefore the initial step in the present investigation was to find a class of cues (a) for which marked differences in representational ability between individuals and age groups could be demonstrated; and (b) for which labels and/or accurate verbal descriptions were not readily available. A test measuring representational ability for these cues was then developed.

Piaget and Inhelder (1956) showed that children aged 6 years and younger were unable to draw and recognise *swastika-like figures* which they had felt previously but not seen. The drawings produced were simple concaternations of "arms" with no overall plan of construction evident. Piaget and Inhelder argued (op. cit. pp.35-37) that ". . . attempts at the swastika end in complete failure because the child is unable to relate the arms bent at right angles, either with one another or with a common centre". Further, these authors asserted that if children were to understand figures or spatial systems that consisted of irregularly related elements, their encoding strategies would need to be ". . . directed by

an operational method which consists of grouping the elements perceived in terms of a general plan, and starting from a fixed point of reference to which the child can always return". The child's understanding of spatial co-ordinates develops, therefore, with age, and this development depends, in turn, on the development of an encoding strategy based on mental *operations* - an operation being defined as ". . . an action which can return to its starting point, and which can be integrated with other actions also possessing this feature of reversibility ... At this level it (reversible co-ordination) takes the form of a systematic return to a point of departure in such a way as to group all the parts of a figure around one or more stable points of reference". On the basis of results reported by Zaporozhets (1965) and Piaget and Inhelder (1956) it would seem that the above serial "construction" of a spatial whole is correlated, at least initially, with more extensive and systematic perceptual activities (eyemovements etc.). However, if Ruzkaya's findings (in Zaporozhets, 1965) are accepted, then the (overt) perceptual activities become more schematic - are reduced - as the older child becomes more experienced with the particular class of shapes.

Additional evidence that pre-operational children (i.e. children younger than 7 to 8 years of age) do not have a well developed spatial reference system was provided by Piaget, Inhelder and Szeminska (1960). They reported that if a 6 year old child was asked to build a model of his home town using well known land-marks (school, church, river, bridge etc.) he could correctly reproduce the relative positions of *two* of the landmarks but was unable to place *three* correctly. Likewise, the pre-operational child was unable to conceive of locating

a point in space using co-ordinates i.e. integrating measurements in *two* or *three* dimensions.

The above findings indicated the possibility of generating a set of shapes complex enough to require a systematic picture encoding stragegy for accurate representation. Developmental trends in the capacity to represent such shapes would presumably reflect the child's growing ability to organize a number of parts into a spatial whole around one or more reference points. It would be expected from the above cited works that this representational skill would develop most rapidly at the onset of the stage of concrete operational thought (i.e. 6 to 8 years).

A test of representational ability was devised in which the shapes were "Stick" figures, each made up of four "arms" meeting at a centre (see Figure 1). Two of the arms (the lower left and upper right) were in the same position for each figure while the remaining two could each occupy any one of three positions. In this way, a set of nine figures was generated.

A test of the child's recognition memory for the figures was used as a measure of his representational ability. In a typical *item*, the subject visually inspected a single figure for 15 seconds. After a retention interval of 4 seconds he was presented with a recognition set which was either (a) the target stimulus plus five other figures judged by the experimenter to be most readily confused with it, or (b) the entire set of nine figures. The child was then asked to pick out the figure he had just inspected. A recognition test was made up of a number of such items.

The range of distractors with each recognition item ensured that the subject would have to encode the position of *both* variable arms of the test figure, relative to fixed reference points or lines, before he could consistently select the correct figure from the recognition set. It was thought therefore that the child's recognition score would depend on his ability to organize the parts of a figure about reference points either internal or external to that figure. It was predicted that the recognition test would show the developmental trends described above.

Study 1

Method

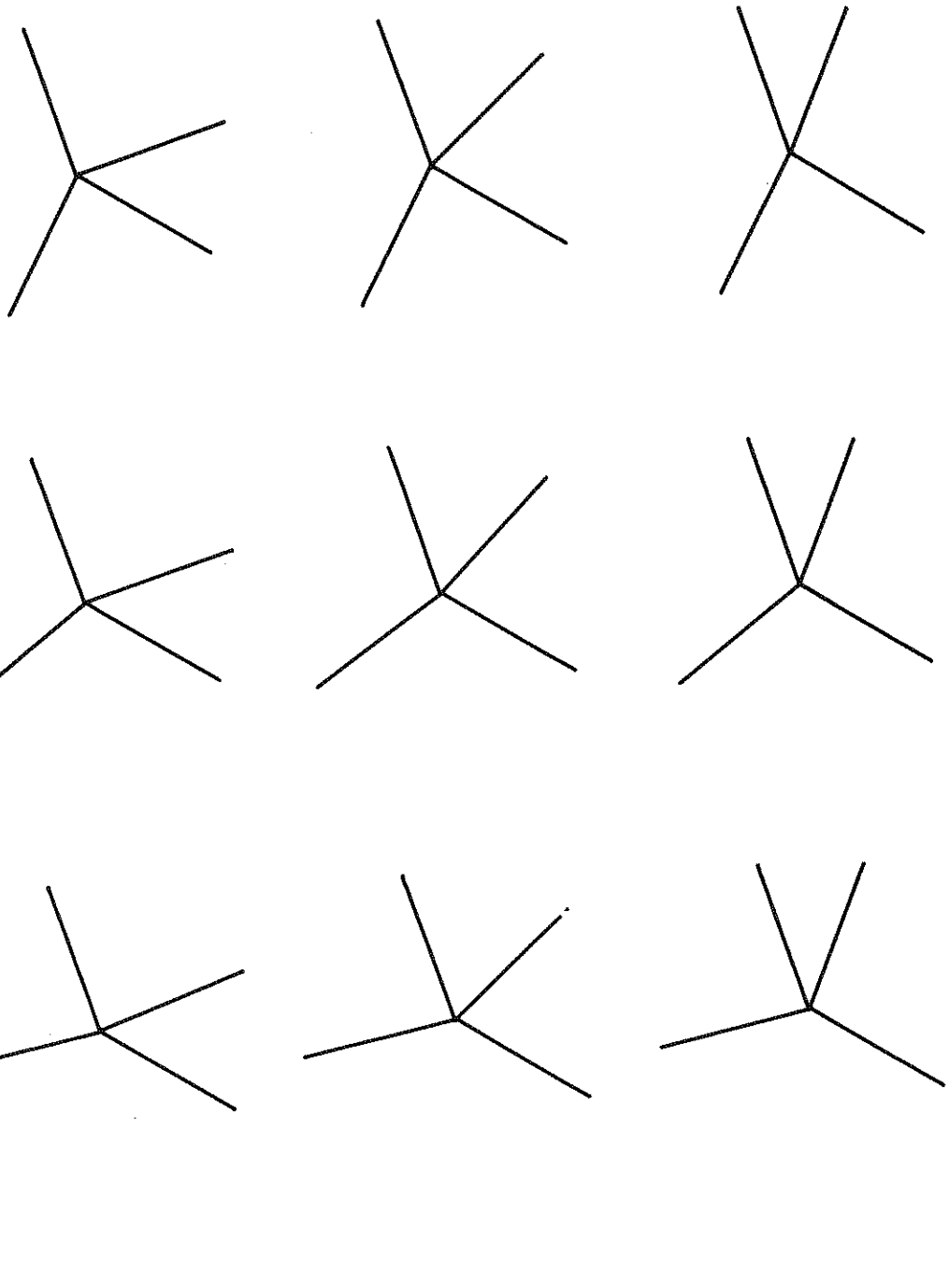
Sample. The subjects were as described in Table 1.

Table 1

Composition of the Sample for Study 1

Grade	Age Range	Number of Males	Number of Females
Kindergarten	5.0-5.11	9	9
Grade One	6.0-6.11	11	10
Grade Two	7.0-7.11	9	9
Grade Three	8.0-8.11	9	8
Grade Four	9.0-9.11	9	9

The 92 children were selected from Watson Primary School, Watson, A.C.T. On the basis of scores on an individual intelligence test administered by the experimenter, subjects were selected who had IQ's within the range 85 to 130 points.



The children came mainly from working class and lower middle class families.

Test material and apparatus. The stimuli used in the recognition test were shown in Figure 1. For future reference, a number from one to nine will be assigned to each of the stimuli in Figure 1 in reading order, i.e. from left to right and top to bottom. A specification of each of the nine stimuli, in terms of the angles between the four arms, will be found in Appendix A.

The stimuli were drawn in black ink, each centred on a white cardboard rectangle. These figures were photographed either individually (test stimuli) or in groups of six (recognition sets) and mounted on 35 mm. slides for presentation by a Kodak Carousel Projector. The recognition set for each test stimulus consisted of the stimuli from its *row* and *column* in Figure 1 together with stimulus five (an exception occurred when stimulus five was the test stimulus. In that case stimulus seven was the additional distractor).

The recognition test was made up of 18 *items* (test stimulus - recognition set sequences). The items and their order of presentation were the same for all subjects, and a full description of the test items is given in Appendix A. In brief, each of the stimuli in Figure 1 served as test stimulus twice, each being used once before any other was used a second time. A minimum of four items intervened between the two presentations of a given test stimulus and for these two presentations there were two different spatial arrangements of the target stimulus and distractors in the recognition set. Over the 18 items the target stimuli

occupied each of the six possible positions in the recognition according to an "unpredictable" sequence.

The test stimuli and recognition sets were rear projected through a translucent screen with a viewing area 24 ins. high and 36 ins. wide. As projected on the screen, both test stimuli and the recognition array (two rows of 3 stimuli) were centred in the child's field of vision. The arms of the projected images of the test stimuli *and* of the stimuli in the recognition arrays were 4 ins. long. The subject viewed the screen from a distance of $4\frac{1}{2}$ ft. and indicated his choice from the recognition set with a pointer. When the test stimuli were viewed, the border of the stimulus card was not visible. However, when the recognition set of six stimuli were presented, the borders of the cards were visible.

The experimenter sat 2 ft behind and to the left of the subject and controlled the projector through three timers connected in series. The timers and appropriate associated relay equipment (placed out of the subject's sight) enabled the experimenter to initiate the following automatic sequence: (a) a 10 second inter-item interval with the screen blank; (b) a 15 second test stimulus presentation period; and (c) a 4 second retention interval with the screen blank. The last interval was, of course, the period from the offset of the test stimulus to the point at which the recognition set became visible.

Procedure. The subjects in the sample were individually tested by the experimenter in a mobile laboratory parked in the school grounds. There were two test sessions, the first session occurring approximately a week before the second session.

During the first session - of 15 to 20 minutes duration - the child was given an individual intelligence test: the Columbia Mental Maturity Scale (1959 revision; hereafter CMMS). In the second session the *recognition test* was administered.

At the beginning of the second session the child was seated facing the rear projection screen. The projector was switched on but the screen was blank. The experimenter gave the following instructions:

> This is a game to find out how good you are at remembering pictures. Here's how we play. I will show you *one* picture on the screen. You will try to remember what it looks like. After a while, the picture will go away and then I'll show you six pictures. You will look at all the six pictures carefully and try to pick out the one I gave you to remember. You will then point to the right one with the pointer.

The experimenter then showed the subject a practice recognition set and continued the instructions:

> The six pictures will look like this. Be careful became some pictures will look like the right one but they won't be exactly right. The right one can be anywhere on the screen so you should look at all the six pictures before you pick it out. Now, point at each one of these six pictures (the experimenter corrected the subject's pointing behaviour).

At this point the experimenter repeated the first paragraph of instructions and added, "After you pick the picture out we'll keep playing the game with different pictures". The experimenter then initiated the first three interval sequence. A few seconds before the presentation of the first test stimulus, the experimenter said, "Here is the first picture coming now. Try to remember exactly what it looks like. Keep looking at it until it goes away". On subsequent trials this instruction was reduced to, "Ready to remember?" If the subject had not selected a stimulus within 20 seconds of the onset

of the recognition array, the experimenter prompted, "Which one do you think it is?" After the subject had indicated his choice this was recorded, and the experimenter initiated the next three interval sequence.

The recognition test was presented in three blocks of six items. Rest periods of $1\frac{1}{2}$ minutes were given after items 6 and 12. During the first of these periods, the subject was asked to tell the experimenter all the boys' (or girls') names that he (or she) knew. In the second period the subject was asked to name all the animals that he could remember. Total testing time for the second session was 20 to 25 minutes.

Results and Discussion

Table 2 gives the mean and standard deviation of the number of items correct on the recognition test for each age group. The means and standard deviations of the IQs are also shown.

Table 2

Means and Standard Deviations of Recognition Scores and IQ.s For Five Age Levels

Age	I.Q.		Recognition Test		No. of Subjects
	Mean	S.D.	Mean	S.D.	
5	104.6	10.0	4.83	1.83	18
6	105.2	10.3	6.57	2.11	21
7	105.8	11.0	7.83	1.74	18
8	107.1	8.9	8.47	2.12	17
9	103.4	11.1	9.00	2.94	18

A one-way analysis of variance of the recognition scores indicated a highly significant effect of *Age* ($F, (4,87) = 9.93, p < 0.001$). Although inspection of the mean recognition

scores in table 2 suggested that recognition performance might be a negatively accelerated growth function of age, virtually all the between groups variance was accounted for by the linear component, the departure from linearity not approaching significance ($F(3,87) = 0.83$, N.S.). Therefore a product moment correlation coefficient provides an appropriate index of the strength of the relation between recognition score and age level. The coefficient was + 0.54.

Product moment correlations between IQ and recognition score were calculated for the five age groups. The coefficients for 5, 6, 7, 8 and 9 year olds were: -0.05, 0.18, -0.10, 0.00 and 0.39 respectively. Only the last of these coefficients approached significance ($t = 1.70$, 16 d.f., $0.10 > p > 0.05$, two tail test.)

Three types of error were possible in the recognition test. The subject might select a distractor that differed from the target stimulus by only 25^{o} angular displacement in *one* of its arms (type 1 error). Such distractors were one step removed from the target stimulus in the stimulus space described in Figure 1. Alternatively the subject might select a distractor that differed from the target stimulus by 50^{o} angular displacement in *one* of its arms (a type 2s error) or a distractor that differed from the target stimulus by 25^{o} displacement in *both* of the "variable" arms (a type 2c error). The frequencies of these three types of distractors were in the ratio 8 : 4 : 3 (for type 1, 2s, and 2c errors respectively) across the 18 recognition sets of the test.

In an attempt to throw some light on the reasons for

children failing recognition test items the relationship between a child's total recognition score and the types of errors he made was examined. Not surprisingly a significant negative correlation was found between recognition score and proportion of type 2 (s and c) errors ($r = -0.42$, $p < 0.001$, two tailed test). As may be seen from Table 2b, type 2s and 2c errors together constituted approximately one in three of the errors made by children scoring 2, 3, or 4 items correct on the test. There was then a linear decline in the proportion of type 2 errors as recognition score increased, until such errors made up only one in seven (approximately) of errors made by children scoring 10 or more items correct on the test.

Table 2b

Means and Standard Deviations of Proportions of Type 2s and Type 2c Errors as a Function of Recognition Score.

Recognition Score	Type 2s errors		Type 2c errors		No. of Subjects.
	Mean	S.D.	Mean	S.D.	
2,3,4 (mean = 3.47)	0.21	0.12	0.12	0.07	15
5	0.12	0.08	0.13	0.08	11
6	0.08	0.12	0.14	0.08	10
7	0.09	0.08	0.14	0.11	9
8	0.08	0.07	0.12	0.14	17
9	0.08	0.11	0.10	0.11	14
10 (mean = 11.25)	0.09	0.09	0.05	0.08	16

When type 2s and 2c errors were separately expressed as proportions of total errors, some interesting further

trends appeared with increasing recognition score (v.Table 2b). It appeared that virtually all the decline in type 2s errors occurred between scores of 2 and 6 on the recognition test. For higher recognition scores 2s errors constituted a more or less stable proportion of total errors (about 8 per cent). Type 2c errors on the other hand constituted a fairly stable proportion of errors over the score range 2 to 8 (approximately 13 per cent) and thereafter declined to 5 per cent of errors for children scoring 10 or more recognition items correct. However both the *curvilinear* trend for 2s errors ($F(5, 85) = 1.58$) and the *curvilinear* trend for 2c errors ($F(5, 85) = 0.70$) failed to approach significance. Proportion of type 2s errors was significantly and negatively related to recognition score ($r = -0.31$, $p < 0.001$) as was the proportion of type 2c errors ($r = -0.24$, $p < 0.02$).

Of the 92 subjects 79 made at least one type 2 error (either type 2c or 2s.) for each of the latter subjects the number of 2s errors was expressed as a proportion of the number of type *2* errors made. Table 2b suggests that this proportion should firstly fall then rise as a function of recognition score. Table 2c confirms this expectation. However the F ratio corresponding to the calculated correlation ratio (eta = 0.30) did not reach significance ($F(6,72 = 1.31$, $p > 0.25$).

Table 2c

Type 2s Errors Expressed as a Proportion of the Total Number of *Type 2 Errors* (2s plus 2c) as a Function of Recognition Score.

Recognition Score	Type 2s errors Mean	S.D.	No. of Subjects.
2,3,4	0.60	0.26	15
5	0.45	0.30	11
6	0.32	0.34	9
7	0.41	0.37	8
8	0.53	0.36	14
9	0.47	0.39	10
10	0.71	0.43	12

In a final analysis of errors the proportions of type 2c and type 2s errors were compared with their respective expected values for the lowest scoring group in Table 2b (i.e. those subjects who scored 2, 3, or 4 recognition items correct.) On a chance basis type 2s errors should constitute 26.7 per cent of all errors. The lowest scoring group did not average significantly fewer than the expected proportion of 2s errors ($t = 1.85$, 14 d.f., $0.10 > p > 0.05$). However, this group consistently scored fewer 2c errors than the 20 per cent expected by chance ($t = 4.55$, 14 d.f., $p < 0.005$). Taken together, these two findings are of some interest. They are consistent with the notion that the low scoring group tended to accurately encode the position of only one of the variable arms of the stimulus figures. If that were so, confusions in the recognition test would be with distractors

that had *one* of the variable arms positioned identically to the corresponding arm of the target stimulus but differed by one or two displacements in the other variable arm i.e. the confusions would tend to be type 1 or 2s errors. The above results reflect just such a tendency and therefore support to some extent the conceptualization of developmental trends in the encoding of spatial systems presented at the beginning of the chapter.

It is clear that the ability to represent the stimuli develops over the age range tested. It is also clear that children of all age levels found the recognition test difficult. The 5 year olds performed at a level not markedly superior to chance (random selection from the recognition arrays would have produced an average score of 3 items correct) while the 9 year olds had only a mean probability of 0.5 of selecting the correct figure from a recognition set. The theoretical rationale for the test laid stress on the child's increasing ability to *encode* the stimuli as the basis for the developmental trends. It was proposed that encoding of the stimuli would depend on *concrete operational* spatial abilities. Therefore, the poor performance of the 5 year olds on the recognition test was to be expected. However, the modest performance of the 8 and 9 year olds, who should have attained the first sub-stage of concrete operational thought, raised the possibility

that the difficulty of encoding the figures had been underestimated. An alternative interpretation would suggest that, in general, the older children could accurately encode the stimuli but that a significant amount of stimulus information was lost from memory (or became inaccessible) during the retention interval and during the period that the subject was scanning the recognition array. This second interpretation was tested in a study which compared developmental trends on a recognition task and a matching task, both of which used the stimuli depicted in Figure 1. If the latter hypothesis is correct, then 8 and 9 year olds should make few errors on this test.

Study 2.

Method

Sample. The subjects were as described in Table 3.

Table 3

The Sample for Study 2

Grade	Age Range	Number of Males	Number of Females
Grade one	6.0-6.11	11	9
Grade two	7.0-7.11	11	10
Grade three	8.0-8.11	8	10
Grade four	9.0-9.11	9	7

The children were from St. Joseph's Primary School, O'Connor, A.C.T. Apart from the above age restrictions for each grade, selection of subjects was unsystematic.

The children were from roughly the same band of socio-economic spectrum as the Watson Primary School sample. There was, however, a higher proportion of working class families.

Test Material. The stimuli used in the matching and recognition tests were essentially the same as those used in Study 1. The figures were slightly modified in that small lines were drawn at right angles to the extremities of the main arms and pointing in a clockwise direction on all figures.

The figures were drawn in black ink on white cardboard rectangles ($8\frac{1}{4}$ ins high, 10 ins wide). The main arms of the figures were 4 ins long and the small lines at right angles to these arms were 3/4 ins long. Each stimulus card was sprayed with Letraset Waterproofing. Two complete sets of stimulus cards were produced in this way and the test stimuli were selected from one of these sets.

Procedure. As before, subjects were individually tested in the mobile laboratory parked in the schoolgrounds. During an initial session of 15 to 20 minutes the children were given an intelligence test. Approximately a week later the matching and recognition tests were administered to each child in two sessions separated by a day. These two test sessions each lasted for approximately 15 minutes. The order of administration of the matching and recognition tests was counterbalanced as far as possible within each age group.

Matching Test. The subject stood facing the centre of a low platform (4 ins high) on which the full set of nine stimuli was displayed in a three-by-three array. The experimenter gave the following instructions: "Look at these pictures (indicating the array). There is only one of those that is exactly the same as this picture that I'm giving you (the experimenter then gave the subject the first test stimulus). Now I want you to look carefully at all of these and pick out the one that's exactly the same as the one I gave you.

Take your time". (The experimenter asked the subject for the "right one" if he had not made a selection within 30 seconds).

During inspection of the 3 x 3 array, the subject stood on a line, 1 foot from the stimulus platform. The experimenter instructed the subject to hold the test stimulus card at waist level and parallel to the floor. After the subject had made his selection from the stimulus array, he walked to a chair from which he could see neither the stimulus set nor the experimenter's activities. The experimenter then randomized the positions of stimuli within the 3 x 3 array. For the second item, the subject again faced the stimulus array, was given the second test stimulus and asked to "pick out the one that was exactly the same as this one". In this manner, each subject received *six* test stimuli (numbers 2, 3, 4, 5, 7 and 8). The order of presentation of these stimuli was randomized across subjects.

Recognition Test. The subject sat facing a small table that had been placed against one of the walls of the laboratory. The experimenter then told the subject that he would be shown a picture and that he should look at it carefully and try to remember what it looked like. The experimenter continued "After a while I'll take the picture away and you will walk down there (the experimenter indicated a screen that hid the display platform located 10 feet to the subject's left) just as quickly as I do".

At this point the subject was given practice at pacing, with E, the distance from the viewing chair to the selection point in front of the recognition set - the 3 x 3 array of

stimuli. The experimenter held a stopwatch and carefully regulated his pace so that the walk took 4 seconds.

With the subject viewing the recognition set, the experimenter continued, "After you come down here with me, you will try to pick out the picture you saw from among these" (indicating the recognition array). The subject then returned to his seat and the experimenter briefly summarized the instructions. The first item was then presented. The experimenter placed the test stimulus card on the table against the wall so that the subject viewed the stimulus from a distance of $4^{1}/_{2}$ ft. The stimulus was presented at eye level and at right angles to the subject's line of regard. The experimenter presented the stimulus card for 15 seconds (timed by stopwatch) then placed the card face down on the table and walked with the subject to the recognition set. If the subject had failed to select a figure within 20 seconds he was asked "Which one do you think it is?" After the subject had made his selection, he returned to his seat while the experimenter re-arranged the recognition set for the next item.

As in the matching task, *six* items were given. The test figures (stimuli 2, 3, 4, 5, 7, and 8) were presented in random order across subjects.

Results and Discussion

Table 4

Means and Standard Deviations (in Parentheses) of the Number of Items correct on the Matching and Recognition Tests at Each Age Level and for the Two Orders of Presentation

Age (yrs)	Number of Subjects	Recognition Test		Matching Test	
		Tested First	Tested Second	Tested First	Tested Second
6	20	1.40 (1.02)	2.40 (1.11)	2.10 (1.04)	2.80 (1.40)
7	21	2.10 (1.04)	2.55 (1.16)	3.55 (1.23)	3.80 (1.78)
8	18	2.89 (1.59)	3.67 (1.05)	5.00 (0.82)	4.33 (1.94)
9	16	2.37 (1.32)	3.50 (1.12)	4.38 (0.86)	5.38 (0.70)

The data were subjected to an analysis of variance with *Age* as a between subjects factor and *Type of Test* (Recognition, Matching) as a within subjects factor (since the cell frequencies were unequal due to random factors an unweighted means solution was employed).

The main effect for *Age* was highly significant ($F(3,71) = 11.98$, $p < 0.001$) as was the effect of *Type of Test* ($F(1,71) = 45.88$, $p < 0.001$). The interaction of these two variables approached significance ($F(3,71) = 2.21$, $0.10 > p > 0.05$).

As expected, older children performed better on both the recognition and the matching tasks. Also the matching task was generally found to be less difficult than the recognition task. The latter effect was particularly marked. Of the 75 subjects, 50 achieved higher scores on the matching task,

16 had equal scores on the two tasks and 9 had higher scores on the recognition task. The relation holding between scores on the matching and recognition tasks can best be seen by an inspection of Table 5 which gives the frequency distribution of scores on the recognition test at each level of matching test performance. As an approximate description of the relationship depicted in Table 5, a child's matching score provided an *upper bound* for his recognition score. However, for the middle and upper ranges of matching scores there was a good deal of individual variability in the extent to which children's recognition scores fell short of their matching scores.

Table 5

Frequency Distributions of Recognition Scores at each Level of Performance on the Matching Test

Recognition Score	Matching Score						
	0	1	2	3	4	5	6
6							1
5				1	1	2	2
4		1		2	3	2	4
3		1		1	9	4	4
2	2	1	4	2	3	6	
1		5	2	3	1	2	
0				2	1		

Finally, it should be noted that while the recognition performance of 8 and 9 year old subjects was quite comparable to the recognition performance of 8 and 9 year olds in Study 1 (mean percentages of items correct: 52.0 and 48.6 respectively) the matching performance of this age group approached the ceiling of the test. Of the 34 eight and nine year olds, 11 achieved the maximum score of 6 items correct, another 11 scored 5 items correct and 9 had a score of 4 correct items. There were single scores of 3, 2, and zero.

A separate analysis of the recognition test scores was carried out with *Age* and *Order of Presentation* as variables. The main effect for *Age* was significant ($F(3,67) = 5.08$, $p < 0.01$) as was the effect of *Presentation Order* ($F(1,67) = 9.36$, $p < 0.01$). The *Age* x *Order* interaction was not significant ($F(3,67) = 0.03$ N.S.). A similar analysis of the matching test scores yielded a highly significant effect for age ($F(3,67) = 13.45$, $p < 0.001$). However neither the main effect for *Order* ($F(1,67) = 1.13$, $p > 0.25$) nor the *Age* x *Order* interaction ($F(3,67) = 1.44$, $p > 0.10$) was significant.

From the above it can be concluded that there was positive transfer from the matching to the recognition test but that the reverse was not true. However the latter result was at least partly due to the near ceiling matching performance of 8 and 9 year olds who received the matching test before the recognition task. For this age group, there was little possibility of a marked improvement in matching scores.

Product moment correlations between IQ and recognition score were calculated for 6, 7, 8 and 9 year olds. The

coefficients were -0.18, +0.26, +0.16, and +0.15 respectively. None of these approached significance. The corresponding correlations between IQ and matching performance were: -0.13, +0.38, -0.14, +0.24. The second of these coefficients was significant at the 5 per cent level.

In general, the results with the matching test confirmed the expectation that children who had attained the first sub-stage of concrete operational thought (8 and 9 year olds) would accurately encode the test figures. Their moderate recognition performance was therefore presumably due to a significant amount of forgetting of stimulus information during the retention and recognition set scanning periods.

The significant effect of presentation order on the recognition scores is difficult to interpret in the absence of controls for non-specific transfer. However, one might speculate that during the matching task the subject was developing more sophisticated encoding strategies for the test stimuli.

CHAPTER 14.

The Relationship between the Recognition Test and Speed of Learning in a Reversal Shift Problem.

It may be profitable at this point to review the concept of *representation* discussed in Chapter 12 (pp. 120-127). A representation of an event is conceived of as a schema corresponding to that event. The type of event of interest for the present discussion consists of a single object (item) embedded in an overall *context*. Following Piaget's theoretical analysis (Piaget and Inhelder, 1956) representational schemata may be distinguished from perceptual schemata in that:

(a) After the stimulus input corresponding to an object and contextual cues ceases, the representational schema may continue to be activated beyond the decay period associated with very short term sensory stores (Sperling, 1963).

(b) The schema corresponding to an event may be reactivated in the absence of the stimulus complex present during the previous exposure of the subject.

These two characteristics suggest that a child's ability to represent a set of events might be measured by memory tests with retention intervals in excess of 2 seconds. In fact, of course, Piaget and Inhelder (1956) employed both recall and recognition tests as indices of representational skill. The rationale for this usage might be clearer if a model of memory is given. The following broad conceptualization is (loosely) based on a model presented by Shiffrin (1970)

During presentation trials of memory tasks subjects are

assumed to activate, and store in memory, an inter-associated complex of schemes corresponding to the event of a particular item being shown within a particular context. Part of the complex of schemes will correspond to physical features of the object, part to its "meaning" for the subject (e.g. associations with other objects, action schemes etc.) and part will correspond to context features (time "tags", various extraneous stimuli, minor variations in the experimenter's behaviour etc.). *This complex of schemes corresponds to the event schema* mentioned above, and it is conceptualized as having gestalt properties in that it is stored and retrieved as a whole. However, retrieval of the schema - or memory trace - may be based on the activation of only a subset of component schemes during a memory search. It is assumed that the probability of retrieval of a given trace is a monotonically increasing function of the number of relevant retrieval cues employed by the subject during the above mentioned memory search. As previously indicated, these retrieval cues will usually be component schemes of the trace. However, retrieval of the schema (trace) may also be based on the reactivation of perceptual schemes which were active during the presentation trial but have no corresponding representational schemes as components of the trace.

In the above model, recall and recognition tests procedures differ chiefly in the number of retrieval cues available to the subject during memory search on test trials. In recall tasks, the subject is given some (usually limited) indication of the context in which the item originally occurred and asked to produce the item (e.g. "What was the last item shown?"). According to the present theory accurate

recall performance depends on the *context instructions*, given by the experimenter, activating a sufficient number of the contextual schemes actually incorporated in the trace to enable retrieval of that trace. In recognition tests of memory the subject is normally given the same limited context instructions together with a set of items consisting of the target (exposed) item and distractors. (He may be asked, "Which of these was the last item shown?"). Performance again depends on the subject *translating* experimenter's context instructions into contextual schemes that are part of the trace. In addition the subject has the target item for use as a retrieval cue during memory search; although this item is presented in a context different from that of the presentation trial, and must first be isolated from the distracting items. Accurate performance on recognition tasks therefore depends on subject jointly employing the *partial* contextual and *slightly altered* item information to retrieve the appropriate trace (schema) on the test trial. Additionally the trace retrieved by activation of contextual schemes together with target item schemes must be distinguished from traces retrieved by the same contextual schemes in combination with distractor item schemes.

If performance on memory tests depends on processes similar to the ones just described, then accurate responses to recognition and recall tasks imply that the memory traces involved have the two properties of representations previously described. It should be noted that recall tests depend rather more on the second property of representations than do recognition tests, since the experimenter introduces more components of the original stimulus complex to re-activate the memory trace during the latter type of test.

In the above discussion it was assumed that the *unit memory trace* in tasks such as the *stick figure recognition test* corresponded to *an event*. Thus a schema encoded, stored, and retrieved in this test was made up of a complex of components: some corresponding to the physical features of the stick figures, others to aspects of the context. The argument in Chapter 13 (pp. 138-141) linked developmental trends in the recognition test scores to increasing ability to encode and store the stick figures. However, it should be obvious that the ability to encode, store and retrieve the figure-context amalgams (events) presupposes, and should develop in parallel with, this encoding and storage ability. The theoretical discussion in Chapter 13 is therefore not affected by the above analysis of memory processes.

In Chapter 12 it was proposed that the child's ability to represent the relevant cues during a training discrimination would be related to the ease with which he solved an RS problem involving these cues. This relationship, it was suggested, was mediated by three psychological mechanisms. The child who represented the relevant cues was *less distractable* during the critical early trials of the test phase, was able to *infer* the new task solution on the basis of limited feedback, and could *rehearse* the solution to the test discrimination. These three factors meant that this child rapidly learned the new cue-response associations during the test phase of shift. This, in turn, made it unlikely that he would attempt new ways of representing the discriminanda i.e. there was only a small probability that the cue selection habit, which remained relevant during the second phase of the

RS problem, would be extinguished during an extended sequence of non-reinforcements at the beginning of the test phase of the RS problem.

Therefore it is suggested that there are two reasons why the RS performance of the child who does not represent the relevant stimulus features is inferior to that of the child responding on the basis of a represented cue list. Not only is the former child slower at unlearning the cue-response associations of the training discrimination and learning the new cue-response habits, but, as a consequence, this child is more likely to reject the correct cue selection habit during the early stages of the test discrimination. This means that

(continued on next page)

during the test phase of the RS problem the subject at the lower developmental level would have to relearn the correct cue-selection habit as well as (inefficiently) change the cue-response associations. Further, the amount of additional cue selection learning required in the test phase should directly reflect the inefficiency of the cue-response learning. In this way individual differences in the rate of cue response learning would be magnified during the test phase of an RS problem. Since it is proposed that these individual differences in cue-response learning reflect differences in representational skills, it follows that performance in the test phase of an RS should provide a sensitive index of the child's skill in representing the stimulus features relevant in both phases of the problem.

The theoretical discussion thus far has been confined to a contrast between children with and without representational skills. However the argument is simply generalized to deal with intermediate cases. As implied in Chapter 12, a child might represent the stimulus features relevant to the solution of a training discrimination and yet the memory traces might be too labile to permit much effective rehearsal of the task solution. According to the present hypothesis such a child would have an intermediate level of efficiency of cue-response learning and an RS performance somewhere between the two extreme cases discussed above. The ability to utilize cue representations in discrimination learning may be thought of as a continuum rather than as a variable with two states.

As indicated in Chapter 13, the recognition test was designed as a direct measure of the child's skill in representing the stick figures. A child's recognition score

reflects both the accuracy of the stimulus description entered into memory and the rate at which stimulus information is lost from memory or becomes inaccessible. Both of these factors should directly determine (a) the probability that the child will represent the relevant cues in a training discrimination in which the critical stimulus features are stick figures; and (b) how effective the cue-list is in producing rapid cue-response learning-given that such a list is constructed.

It is therefore predicted that *high recognition scores will be associated with rapid learning of a test discrimination of an RS problem in which the stick figures are the relevant cues. Conversely, low scores on the recognition test will be associated with slow learning in the test phase of such an RS problem.*

From the theory outlined above, no clear prediction can be made concerning the relation between measures of representational skill and rate of learning in the *training* discrimination of the RS. Individual differences in the number of trials (or errors) to criterion during the training phase presumably reflect differences in both cue selection learning and the rate of forming cue-response associations. While it would be expected that children of high representationa skill (Hi children) would be superior to those of low ability (Lo children) during the cue-response learning phase, it is possible that this advantage is offset by a relatively long cue selection phase. It could plausibly be argued that the stability of the cue representations - and consequently the efficiency of cue-response learning - depends directly on the degree to which the subject rehearses his "descriptions" of the relevant stimuli. Following this line of reasoning, the

child who develops an effective cue list is involved in rather more extensive stimulus coding operations than the Lo child. In turn, this extensive stimulus processing is likely to slow the learning of the Hi child during the training discrimination.

There is empirical support for the idea that a gain in representational skill might be accompanied by at least a partial trade-off between the length of the cue-response association phase and the length of the stimulus encoding phase of a training discrimination. It may be recalled that the Tighes' training technique (e.g. L. S. Tighe, 1965) consistently produced quite marked improvements in the speed with which children learned the test discrimination of an RS while *not* affecting the learning rate in the *training* discrimination. Similarly, Johnson and White (1967) found seriation ability related to their subjects' performance in the test phase but not the training phase of an RS problem. Investigators employing the OS paradigm have sometimes reported a relation between subject classification based on the third phase performance and speed of learning during the first phase (Kastner, 1969), and sometimes this relation has failed to appear (André, 1969). In general this evidence indicates that the learning superiority which Hi children demonstrate during the test discrimination of an RS is somehow offset during the training discrimination. The above hypothesis is therefore supported.

While the evidence in the literature and the theory under consideration are equivocal concerning a possible relationship between representational skill and performance on a training discrimination, the possibility that such a relation will be

found in the present study must be considered. If Hi children outperform Lo children during *both* training and test phases of the RS, it might be argued that higher representational skill simply meant more rapid cue selection learning during the two phases. Expressing this point another way, the Hi children might outperform Lo subjects because they would find the relevant stimuli (stick figures) more *salient* during training *and* test discriminations. If valid, such an interpretation would conflict with the representation hypothesis. As previously noted a key assumption of the latter hypothesis is that an increment in representational skill results in a rather more rapid improvement in cue-response learning than in cue selection learning. This differential improvement in cue-response learning is critical to the hypothesis since it is the basis on which developmental trends are predicted in RS-EDS comparisons and optional shift designs.

In fact, if Hi children solve the test and training discrimination with fewer errors than Lo children, the representation hypothesis makes the further prediction that the difference between the two ability groups in mean learning rate will be *greater* during the test phase of the RS. *Thus level of recognition performance is predicted to interact with phase of RS in determining the child's rate of learning.*

The predicted interaction depends on two assumptions already outlined. The first of these is that differences in representational skill are chiefly reflected in differences in *cue-response* learning. The second is that individual differences in cue-response learning are enhanced during the test phase of an RS in the manner described above.

The predictions of the representation hypothesis may be phrased in a manner more sensitive to the continuous variations in representation ability reflected in the recognition test scores. It is hypothesized that recognition performance will be significantly and positively correlated with rate of learning in the test phase of an RS problem in which the stick figures are the relevant cues. It is further predicted that the correlation between recognition test performance and test phase learning will be significantly higher than the correlation between recognition test and the training phase of such an RS problem.

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Study 3

In the present study an attempt was made to test the predictions of representation theory concerning the relation between recognition test score and performance in the training and test phases of an RS problem in which the discriminations are based on the stick figures.

The learning tasks which made up the RS were *successive* discrimination problems and the relevant cues were stimuli 4 and 8. As can be seen from Figure 1, these two stick figures differed in *each* of the variable arms by 25° angular displacement. Colour was the variable irrelevant dimension in both phases of the shift problem: each stick figure was coloured either red or blue. For obvious reasons, it was desirable that subjects be sampled from a fairly narrow age range in which there was a reasonably wide variation in recognition scores. It was also felt that there should be a fair sampling of children with low recognition scores (i.e. 5 or less items correct.

Method

Subjects. The subjects were 53 children from first and second grades of Lyneham Primary School, Lyneham, A.C.T. On the basis of an initial testing session, the children were chosen as having IQ.s in the range 85-130.

The sample consisted of 34 first graders and 19 second graders chosen from the age range 6 yrs. 6 mo. to 8 yrs. 6 mo. (median age 7 yrs 4 mo.). A higher proportion of first grade children was selected in an attempt to ensure that an adequate number of children with low scores on the recognition test would be included in the sample. Apart from this sampling bias, and the general age and IQ restrictions mentioned above,

selection of subjects was unsystematic. In general, the children came from working class and lower middle class families.

Test material and Apparatus

The discriminanda for the RS problem were constructed as follows. A number of "swastika arms" were cut from blue and red gummed-paper squares. By glueing these arms in appropriate positions around a point on a sheet of paper a stick figure could be constructed. In this way, four colour-form compounds were produced (stimuli 4 and 8, each figure in red or blue) each one on a separate sheet of thick white paper. The figures so constructed were individually photographed and mounted on 35 mm. slides for presentation by a Kodak Carousel projector. Ten slides of each form-colour compound were prepared.

The discriminanda were rear projected, one at a time, through the translucent screen described in connection with the recognition test in Study 1. The experimenter controlled the inter-trial interval (4 sec) through a single timer and associated relay equipment. As projected on the screen, the figures had the following dimensions: main arms, $4\frac{3}{4}$ ins long and 3/8 ins wide; small arms at right angles to the end of each main arm, 1 in long and 3/8 in wide. The figures were all centred in the subject's field of vision and the subject viewed the stimuli from a distance of $4\frac{1}{2}$ ft. The experimenter sat 2 feet behind and to the left of the subject - the positions described in connection with the recognition test in Study 1.

A white cardboard box and a black cardboard box of equivalent dimensions (5 ins x 7 ins x 4 ins) were placed 9 ins in front of and 9 ins to the left and right respectively of the projected image. The subject was given a pointer.

The Recognition Test. The apparatus and stimulus materials for this test were exactly as described in Study 1, i.e. the full 18 item test was presented by projector with the three timers controlling the inter-item interval, the presentation time for the test stimulus, and the retention interval.

Procedure. The children were individually tested by the experimenter in the mobile laboratory parked in the school grounds. In an initial testing session - which preceded the main sessions by from one to three weeks - the experimenter administered the CMMS.

The second block of test sessions consisted of the RS problem followed, on the day after the completion of the test phase, by the recognition test. That particular order was used since it was felt that if the recognition test preceded the training discrimination, the irrelevant dimension in both phases of the RS (colour) would be relatively ineffective.

At the beginning of the first session of the RS problem the subject was seated as described above. The experimenter gave the following instructions. "I'm going to show you some pictures. Each time there will be a picture there (the experimenter indicated the screen) and it will belong to either the *black box or the white box*. Here is the game: I want you to learn to point to the right box for each picture.

Each time, I'll show you a picture, you'll point to the box you think it goes into, and I'll tell you if you're right or wrong. If you look closely at the pictures you'll soon be able to tell which box they go into everytime.

Here is the first picture (the experimenter presented the first colour-form compound). You have to guess which is the box for this picture. After that, try to be right every time".

Irrespective of choice, each subject was told that he was correct on the first trial. Therefore, in the training discrimination the subject's first choice automatically assigned him to one of the two *sets* of stimulus-response habits:

Stimulus 4 → white Stimulus 8 → black	or	Stimulus 4 → black box Stimulus 8 → white box

The experimenter then initiated the 4 second inter-trial interval after which the subject was presented with the second colour-form compound. If the subject responded correctly then the experimenter said, "That's right. Good boy (girl)!" If the subject's response was incorrect the experimenter said, "No, that's wrong," The experimenter then initiated the next inter-trial interval.

The 40 slides (10 slides of each of the 4 discriminanda) were presented to each subject in the same irregular order (See Appendix B). The presentation order was such that any form-colour compound occurred at least twice in each of the four blocks of 10 slides. A given stick figure (e.g. stimulus 4, irrespective of colour) did not occur on more than three successive trials.

As soon as the subject reached criterion on the training discrimination (10 successive correct responses) the "correct" cue-response associations were switched without warning. The subject had then to reach the same criterion to solve the test discrimination of the RS. During both phases of the shift problem the subject was given a 1 minute rest period after each block of twenty trials. After the sequence of 40 slides had been presented once, the series was repeated. In general children were tested for a maximum of 80 trials

(testing time about 35 minutes) on any day. This was slightly exceeded for six subjects to meet the requirement that a child complete at least 20 trials of the test discrimination immediately after reaching criterion on the training discrimination. Any child who did not reach criterion on the training discrimination within two sessions (i.e. 160 trials) was simply given the recognition test in the next testing session.

The procedure for the recognition test - which was administered on the day after a given subject had completed the RS problem - was exactly as described in Study 1.

Results

Table 4 gives the frequency distribution of recognition scores for the sample.

Table 6

Frequency Distribution of Recognition Scores

Score	F
2	1
3	-
4	2
5	7
6	6
7	8
8	10
9	11
10	2
11	2
12	3
13	1
N =	53

The mean I.Q. for the sample was 103.3. The product moment correlation between I.Q. and recognition score was calculated. The coefficient was -0.01.

One subject (I.Q. = 100, recognition score = 8) failed to solve the initial discrimination within two sessions (160 trials) and was not given the test discrimination.

For the purposes of statistical analysis, the children were categorized into above (Hi) or below median (Lo) groups on the basis of their recognition scores. As can be seen from Table 6 the median recognition score was (approximately) 8 items correct. Nineteen subjects scored above the median and 24 subjects scored below the median, with 10 subjects at the median.

There was wide individual variability in errors (and trials) to criterion on the training discrimination in both Hi (19 subjects) and Lo (24 subjects) groups. In addition the distribution of errors (and trials) was positively skewed for both groups, and, to correct for this tendency, both dependent variables underwent logarithmic transformation. Two dependent variables were analyzed (log (errors plus one); log trials to criterion) and since no differences due to dependent variables were revealed in these analyses, the data reported are in terms of errors to criterion.

There was no significant difference between the Hi and Lo groups in transformed errors to criterion on the training discrimination ($t = 0.01$, $df. = 41$). As can be seen from Table 7, the two groups had virtually identical (arithmetic and geometric) mean error scores.

Table 7

Measures of Central Tendency and Dispersion of Errors to Criterion on the Training Discrimination

Group	Arithmetic Mean	Geometric Mean of Errors + 1	Median	S.D.
Hi	17.47	11.73	14.00	15.51
Lo	16.96	11.71	10.50	17.73

The distributions of errors to criterion in the test discrimination for Hi and Lo groups were rather more markedly skewed than the corresponding distributions in the training discrimination. After logarithmic transformation of the scores, the distributions remained somewhat (positively) skewed. Since the distributions of transformed errors for the two groups were similarly skewed and the variances approximately equal, a t-test (two-tail and employing the 5 per cent level of significance) with the 41 degrees of freedom of the present study would be a very slightly *conservative* test (Boneau, 1960).

There was no significant difference ($t = 0.24$, $df. = 41$) between Hi and Lo groups in transformed errors to criterion in the test discrimination. Table 8 provides a brief description of the two distributions of raw error scores.

Table 8

Measures of Central Tendency and Dispersion of Errors to Criterion on the Test Discrimination

Group	Arithmetic Mean	Geometric Mean of (Errors + 1)	Median	S.D.
Hi	7.47	4.68	2.83	7.69
Lo	7.42	5.03	3.50	9.68

Correlational analyses yielded similar results to the analyses of variance. Recognition test performance was *not* significantly correlated with log (errors plus one) in either the training phase ($r = -0.01$) or the test phase ($r = -0.13$, $p > 0.05$, one tailed test) of the RS problem. A test of the difference between two correlation coefficients for correlated samples indicated that the test phase correlation was not significantly higher than the training phase correlation ($t = 0.59$, 49 d.f., N.S.).

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Analyses of the learning data were carried out with subjects classified according to IQ level. The median IQ was approximately 101. Twenty two children had IQ.s below the median, six subjects scored at the median, and twenty five subjects had above median IQ.s. As in the above analyses the dependent variables (errors and trials to criterion) underwent logarithmic transformation to correct for positive skew of the score distributions in both training and test discrimination problems. Again, the performance of the above median group was contrasted with that of the below median group during both phases of the RS. One subject in the below median group who had failed to solve the training discrimination within 160 trials, and thus could not be given the test discrimination, was arbitrarily assigned that figure as his number of trials to criterion for the first discrimination. His number of errors to criterion on initial learning was simply the number of incorrect responses that he made during those two test sessions.

There was a significant difference between above and below median IQ groups in (transformed) errors to criterion on the training discrimination ($t = 2.15$, $df. = 45$, $p < .05$, two-tail test). The geometric means of errors to criterion for the above and below median groups were 9.11 and 17.62 respectively. When transformed trials to criterion was used as the measure of learning performance, the difference between the two groups approached significance on a two-tail test ($t = 1.75$, $df. = 44$, $0.10 > p > 0.05$).

The two IQ groups did *not* differ significantly in either transformed error scores ($t = 0.10$, $df. = 44$) or transformed trials to criterion ($t = 0.46$, $df. = 44$) on the *test* discrimination.

Discussion

The experimental hypothesis received no support from the results of the present study. There was no indication that level of representational skill - as measured by the recognition test - affected learning performance in either the *test* or *training* phases of the RS. While IQ was related to speed of learning in the training discrimination, no such relation appeared in the test discrimination.

It seems likely that all subjects, irrespective of recognition score, had available a simple memory code which enabled them to represent the relevant stimulus features in the two discrimination problems. Such a code might be based on a fairly "rough" analysis of the shapes (stimuli 4 and 8) whereas a high recognition score is presumably an index of the child's ability to enter into memory a more complete description of this type of figure. For example, several children spontaneously verbalized the solution to the training discrimination just before reaching criterion. Typical of these verbal rules was the following: "The wide one goes in the white box and the thin one goes in the black". It is clear that while characterising stimulus 4 as "wide" and stimulus 8 as "thin" would prove adequate in the discrimination problems, it would not enable the subject to later recognize these figures if stimuli 1 and 9 were distractors in the appropriate recognition sets.

If it is assumed that during the training discrimination children with low recognition scores acquired a cue list of "simple" representations based on a partial analysis of the shapes of the stick figures, then it is apparent that such a cue list enabled the subjects to learn just as efficiently

as Hi children during both phases of the RS. As can be seen from Table 8, the learning of children from *both* representational levels was particularly rapid during the *test* phase of the RS.

The present study does not allow a decision to be made as to whether the children of high representational ability did form more complete representations of the stick figures during the RS problem. If they did, then, as just noted, there was no noticeable effect on the efficiency of the subsequent cue-response learning. It is possible, of course, that these children employed the same simple stimulus code as that hypothesized for children with low representational skill. If this was the case, then the present results provide no evidence that the children of advanced representational ability could use this code any more effectively in cue-response learning than other children.

Study 4

In order to test the experimental hypothesis proposed in the present chapter more adequately, a further study was performed. In general, the design and procedure were as in Study 3. A successive discrimination problem was again used with, however, an important change being made: the shape discriminations required of the subject in both phases of the RS were more difficult in the present study. During both phases of the RS problem, the subject had to learn to associate each of three stimuli (stimuli 4, 7 and 8 - see Figure 1) to a unique response.

In stimuli 4 and 7 the two lower and the upper-right arms of the figures are identically placed while the angle between the upper arms in stimulus 4 is 25° larger than the

corresponding angle in stimulus 7. In contrast, stimuli 7 and 8 have their two upper and lower left arms identically positioned while the angle between the upper and lower right arms in stimulus 8 is 25° larger than the corresponding angle in stimulus 7. Clearly, a cue list that enabled the subject to learn the correct rule in either phase of the RS would have to be made up of fairly exact representations of the three stimuli. The stimulus descriptions making up the three representations would have to be complete enough to enable stimulus 7 to be differentiated from both stimuli 4 and 8. Thus, with the discrimination task just described, it cannot be argued that a subject with low representational skill could attain criterion during the training phase, and learn efficiently in the subsequent test phase, by producing, and operating with, a cue list of imprecise or simple cue representations.

Since it has been argued that the child's recognition score chiefly reflects his ability to encode and store *complete* representations of the stick figures, it would be expected that the recognition test *would* provide a measure of the child's capacity to produce and operate with a "precise" cue list during the above RS Problem. Following the argument presented during the introduction of the present chapter, it would be predicted that level of recognition performance should be strongly related to the subjects' speed of learning during the test phase of the RS.

The order of presentation of learning and recognition tasks for the present study was the same as in Study 3, i.e. the RS problem preceded the recognition test. In order to give some idea of the amount of transfer between the two tasks, a

control group was included in the design. The subjects in the control group were treated exactly as the experimental subjects except that the former were given a series of Piagetian classification and conservation items, and various other cognitive tests, instead of the RS problem.

As another variation in design, the experimenter gave *all* the subjects a simple practice learning problem after he had administered the CMMS. The purpose of this was to familiarize the subject with the projection apparatus and the general procedure for successive discrimination problems. A final difference from Study 3 was that in neither the practice discrimination nor the RS problem did the subject have to deal with an irrelevant non-spatial dimension. In pilot work it was found that, with the particular shape discrimination, the RS problem was a fairly difficult task even if there was no irrelevant non-spatial dimension in either phase of shift. It was feared that with an irrelevant dimension, such as colour or size, the training discrimination might prove insoluble to a reasonable number of subjects, and require an excessive number of training sessions for the majority of children.

Method

Subjects. The subjects were 53 children from the second grade of Hackett Primary School, Hackett, A.C.T. On the basis of a preliminary testing session, the children were selected as having IQ.s in the range 85-130. The age range of the sample was 81-98 mo. Apart from the IQ restriction, selection of subjects was unsystematic and the children generally came from the same socio-economic classes as those in the previous samples.

Ten children from the above sample were randomly selected as a control group. The remaining subjects became the experimental group.

Test materials and Apparatus

Learning tasks

R. S. Problem. Drawings of stimuli 4, 7 and 8 in black ink on white cardboard were individually photographed, and the transparencies mounted for presentation by a Kodak Carousel Projector. The discriminanda were rear projected singly as in Study 3, and the arms of the projected figures were $4^{3}/_{16}$ ins long. An "irregular" sequence of stimuli (40 slides) was arranged with the restrictions that each of the three stimuli occurred at least six times in each of the two blocks of 20 slides and that no stimulus occurred on more than two successive trials (see Appendix B).

Practice Problem. A solid black square and a black outlined square were drawn on white cardboard, photographed singly and mounted for slide presentation as above. An "unpredictable" series of these stimuli (20 slides) was constructed.

For both practice and RS problems the apparatus and the experimenter and subject's position were generally as described in study 3. However, for the practice problem two *black* boxes, one containing an upright wooden block visible to the subject, were positioned as in the Study 3 RS problem. For the RS problem, a cardboard box covered in yellow cloth was placed 9 ins in front and 9 ins to the left of the projected image, a box covered with blue cloth was placed 9 ins in front of (and slightly below) the image, and a box covered in red cloth was positioned 9 ins in front and 9 ins to the right of the projected image. The three boxes had the dimensions described in Study 3.

Control tasks. Stimulus materials for the *classification items* will be fully described in Chapter 15. For the *conservation*

items and *addition-subtraction tasks*, two sets of 48 small wooden cubes ($^1/_2$ ins x $^1/_2$ ins x $^1/_2$ ins) plus a reserve of 12 such blocks were used. For the weight discrimination problem two sets of weights were constructed. Each set was made by inserting lead shot and (melted) wax into six black plastic bottles of identical size and shape. The six different weights used were: 50, 100, 150, 220, 320, and 420 gm.

Two different shapes (T and +) were drawn in either purple or green ink on white cards for *the matching task*. Twenty copies of each shape-colour combination were produced, plus one extra copy of the green T and the purple +.

Recognition Test. The apparatus for the recognition test was as described in study 1.

Procedure. Again subjects were individually tested in the mobile laboratory parked in the school grounds. The model number of test sessions was four, with a maximum of six and a minimum of three. As far as possible the test sessions were given on successive days. An exception occurred for two subjects who required four sessions to solve the RS problem. These children were given their final test session (the recognition test) later on the same day that they completed the RS problem.

During the first session, the experimenter administered the CMMS and the child was then given the *practice discrimination*. In the latter task, the instructions and procedure were as for the discrimination problem in Study 3 with a slight modification of instructions because of the different response boxes used (the response boxes were indicated by gestures rather than names). The practice discrimination was invariably solved

in a few trials and the total testing time for the first session was approximately 25 to 30 minutes.

In the second session the 43 subjects in the experimental group were given the RS problem. The instructions were those used for the RS problem in Study 3, again with slight modification because of the different response boxes (the experimenter named the colours of the three boxes: yellow, blue, and red). In addition to the standard instructions, the subject was shown an array of candy bars and packets of peanuts, and told, "If you try very hard, you"ll get one of these prizes". Also in contrast to study 3, a *correction technique* was used during learning. If the subject responded correctly, the experimenter said, "Right. Good boy (girl); that's the picture that goes in the (red/yellow/blue) box". If the subject was incorrect, the experimenter said, "No. Look at the picture. That's the one that goes in the (red/yellow/blue) box. Point to the right box".

The basic procedure was similar to that used in Study 3, with an inter-trial interval of 4 seconds and a provisional maximum of 80 learning trials per test session. The latter rule could be varied to meet the requirement that the subject complete 20 trials of the test discrimination immediately after reaching criterion on the training discrimination.

During the training discrimination, all experimental subjects had to learn the associations (*Stimulus 7 → Yellow box; stimulus 8 → blue box; stimulus 4 → red box*). In the test discrimination, experimental subjects learned the associations (Stimulus 7 → red box; stimulus 8 → yellow box; and stimulus 4 → blue box). To reach criterion in either the training or test phases of the RS, the subject had to make

the correct response on *14* successive trials. During the criterion run, there was a minimum of *three* correct responses to each of the three stimuli.

A full test session of the RS lasted approximately 30 minutes. Fourteen subjects completed the RS problem in a single session, 24 subjects completed it in two sessions, three subjects required three sessions for both phases of the RS, and two subjects solved the problem in four sessions.

The 10 subjects in the control group were given a battery of Piagetian classification tests during their second test session. The procedure for these tests is described in Chapter 15. The session lasted approximately 20 minutes for each child. In the third test session, the children in the control group were given the conservation tests (Piaget, 1952), addition subtraction items (Smedslund, 1962), a weight discrimination task, and a matching task, in that order. In the matching task the subject was given the option of matching a colour form compound on either form, colour or both of these dimensions. For the control group the third test session lasted approximately 20 minutes.

Recognition Test. The recognition test was presented as described in Study 1 for both experimental and control subjects.

Results

The frequency distribution of recognition scores for the experimental group is presented in Table 9.

Table 9

Frequency Distribution of Recognition Scores in the Experimental Group

Score	F
4	2
5	3
6	2
7	8
8	5
9	5
10	4
11	6
12	4
13	2
14	1
15	1
N =	43

The median recognition score was approximately 9. Eighteen subjects scored above the median while 20 subjects scored below, and 5 children scored at the median. As in the data analyses of Study 3, the RS performance of the above median subjects (18 subjects) was contrasted with the RS performance of the below median subjects (20 children). These two groups did not differ significnatly in IQ ($t = 1.25$, $df. = 36$ N.S.).

One subject (IQ = 103, recognition score = 4) failed to solve the training discrimination in two testing sessions and therefore was not given the test discrimination. Trials and errors to criterion for this subject were assigned as in Study 3.

Training discrimination. Two dependent variables were analyzed: errors to criterion and trials to (and including) criterion. There was a significant difference between Hi and Lo groups in both number of trials ($t = 3.43$, $df. = 36$, $p < 0.05$ two tail test) on the training discrimination.

Table 10

Means and Standard Deviations of *Trials to Criterion* on the Training Discrimination

Group	Mean	S.D.
Hi	59.90	28.10
Lo	95.94	36.27

Test discrimination. In the test discrimination the variability of errors and trials to criterion was considerably greater for the Lo group than for the Hi group. A logarithmic transformation of both dependent variables provided a satisfactory correction for this heterogeneity of variance.

There was a significnat difference between Hi and Lo groups in transformed trials to criterion ($t = 2.09$, $df. = 37$, $p < 0.05$ two tail test) on the test discrimination. However the difference between the two groups in transformed *errors* to criterion did not approach significance ($t = 0.82$, $df. = 37$). It is most likely that this last finding is partly due to the fact that, although there was an overall tendency for the Lo group to make more errors during the test phase than the Hi group, this was offset, to some extent, by a slight tendency for the latter group to make more "perseverative" errors. The groups were compared on the number of errors made in the five trials that followed the first "error" of the test discrimination

On the average the Hi group made 3.33 such errors while the Lo group made 2.84. The difference in mean errors was not significant ($t = 1.27$. $df. = 37$).

Table 11.

Arithmetic Mean, Geometric Mean, and Standard Deviation of Trials to Criterion in the Test Discrimination.

Group	Arithmetic Mean	Geometric Mean	S.D.
Hi	33.50	31.07	14.94
Lo	46.16	41.35	26.93

From the above analyses (and an inspection of the means in Tables 10 and 11) it appears that recognition ability affected learning performance most powerfully during the *training* phase of the RS. To test the significance of the interaction directly, an analysis of variance, with *Level of Recognition Score* (Hi, Lo) as a between subjects factor and *Phase of RS* (Training Phase, Test Phase), as a within subjects factor was performed on the trials to criterion measure. The main effect of *Recognition Level* was significant ($F(1, 35) = 13.11$, $p < 0.01$) as was the effect of *Phase of RS* ($F(1,35) = 42.63$, $p < 0.001$). The interaction between *Recognition Level* and *Phase of RS* approached significance ($F(1, 35) = 3.99$, $0.10 > p > 0.05$).

Correlational analyses generally confirmed the results of the analyses of variance. Recognition Score was significantly related to both log (errors plus one) ($r = -0.31$, $p < 0.025$, one tailed test) and log Trials ($r = -0.34$, $p < 0.025$, one tailed test) in the *training phase* of the RS problem.

Neither dependent variable was significantly related to *recognition score* ($r = -0.19$, $p > 0.05$, one tailed test, for log (errors plus one) and $r = -0.23$, p 0.05, one tailed test, for log Trials) in the *test phase* of the RS problem. In none of the relationships examined was there anything approaching a significant departure from linearity. For example with log trials as the dependent variable the F test of departure from linearity yielded $F(6, 34) = 1.07$, N.S., for the training discrimination and $F(6, 34) = 0.73$, N.S., for the test discrimination.

As in Study 3, analyses of RS performance were carried out with subjects classified according to IQ level. The median IQ was 104 with 20 subjects scoring below, and 21 subjects above, the median. Two subjects scored at the median. There were no significant differences between the above and below

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median *IQ* groups either in trials ($t = 1.08$, df. = 39) or errors to criterion ($t = 1.40$, df. = 39, $p > 0.10$ two tail test) in the training discrimination. Similarly there were no differences between the two IQ groups in either trials ($t = 0.25$, df. = 38) or errors to criterion ($t = 0.15$, df. = 38) in the *test* discrimination.

Further analyses were conducted to determine whether or not there had been transfer from the RS problem to the recognition test for the experimental group. The recognition scores for this group (43 subjects) were compared with those of the control group (10 subjects). There was no significant difference in IQ between the two groups ($t = 0.88$, df. = 51, $p > 0.20$ two tail test). To reduce the heteroscedasticity of the two score distributions, the recognition scores underwent a logarithmic transformation.

There was a significant difference between the experimental and control groups in transformed number of items correct on the recognition test ($t = 2.45$, df. = 51, $p < 0.02$ two tail test). The means and standard deviations of the recognition socres for the experimental and control groups are given in Table 12.

Table 12

Recognition Performance of Experimental and Control Groups

Group	Mean Number Correct	S.D.
Experimental	8.95	2.72
Control	7.00	1.89

Since the preceding analysis had yielded evidence of positive transfer between the RS problem and the recognition test, a subsequent analysis was performed to determine whether the facilitative effect was specific to items on the recognition test that involved test stimuli that had been employed in the two phases of the RS (stimuli 4, 7 and 8). A simple test of this proposition would seem to be a direct comparison of the performance of experimental subjects on the six recognition items involving test stimuli 4, 7 and 8 with their performance on the six items for which specific knowledge of these stimuli would be of little use. For example, the recognition performance of a child on items involving test stimuli 2, 3 and 6 should be minimally affected by such stimulus specific transfer even if that child could eliminate stimuli 4 and 8 from the recognition sets of test stimuli 6 and 2 respectively (these distractors were virtually never confused with the respective test stimuli in control groups). However, since the two sets of test stimuli could not be assumed to generate equally difficult recognition items, and since order of presentation during the recognition test (and position of the target stimulus in the recognition sets) was not satisfactorily counterbalanced across the two sets of 6 items, the specific transfer hypothesis was formulated as follows: The difference between the mean number of correct recognition items involving test stimuli 4, 7 and 8, and the mean number of correct items involving test stimuli, 2, 3 and 6 will be greater for the experimental group (those for whom the RS preceded the recognition test) than it is for a control group. Thus *Test Stimulus Group* and *Presence/Absence of the RS problem* would be predicted to interact in determining recognition performance.

In the present analysis the control group was made up of the 10 subjects who constituted the controls for the present study and the 18 seven year olds from Study 1 who also had not performed on an RS before being given the recognition test. Naturally the experimental group was made up of the 43 subjects from the present study.

Recognition scores were subjected to an analysis of variance with *Test Stimulus Group* (Stimuli 4, 7 and 8; Stimuli 2, 3 and 6) as a within subjects factor and *Training Condition* (Experimental; Control) as a between subjects factor.

The main effect for *Training Condition* was significant ($F(1,69) = 9.31$, $p < 0.01$) indicating the overall superior recognition performance of the experimental group. Similarly the main effect of Test Stimulus Group was significant ($F(1, 69) = 41.12$, $p < 0.001$), the recognition items involving stimuli 4, 7 and 8 being easier than those involving stimuli 2, 3 and 6. The interaction between the *Training* and *Stimulus Group* factors did not approach significance ($F(1,69) = 0.02$).

Table 13 gives the means and standard deviations as a function of *Test Stimulus Group* and *Training Condition*.

Table 13

Recognition Performance as a Function of Test Stimulus Group and Training Condition

Group	Stimuli 4, 7, 8		Stimuli 2, 3, 6	
	Mean Items Correct	S.D.	Mean Items Correct	S.D.
Experimental	3.51	1.23	2.42	0.97
Control	3.00	1.39	1.89	1.01

Discussion

The results of Study 4 offered no convincing support for the representation hypothesis. The relation between recognition performance and one of the learning indices (trials to criterion) for the *test* discrimination must be interpreted in the light of the trend for a *stronger* relation between the recognition test and both learning measures in the *training* discrimination. The interaction between *Recognition Level* and *Phase of RS* that approached significance was in the *opposite* direction to that predicted.

A stronger relation between the recognition test and the initial phase of the RS could have interesting implications within the framework of a two stage model of discrimination learning. If this general theoretical model is appropriate, it would seem that the recognition test predicted the *rate* at which a child could construct an adequate cue list as distinct from the joint probability that he would construct such a list and then use it effectively during the subsequent cue-response association phase of learning. Thus the children with high recognition scores differed from children with low scores in the speed of *cue selection learning*. This proposition is in marked contrast to the hypothesis, presented in the introduction to the present chapter, that Hi children might take rather longer to establish their more effective cue list during the training discrimination because more extensive encoding and memorizing were involved in its construction. The conclusion that recogntion level was related to the cue selection phase of learning follows simply from the assumptions (a) that differences in rate of learning the *training* discrimination reflect differences in both the rate of cue list

acquisition and in the rate of forming cue-response associations, and (b) that differences in the rate of learning the test discrimination depend chiefly on differences in the speed of cue-response learning magnified in the manner previously described. A greater difference in learning performance in the training phase between Hi and Lo recogntion groups must reflect the source of variation in learning speed which can plausibly be theorized to have more influence in the training rather than in the test discrimination. This is, of course, cue selection learning.

From the above considerations it may be concluded that the recognition test measured - at least in part - the rate at which children could form accurate representations of the stick figures and/or the rate at which labile stimulus descriptions could be transformed into fairly *long term* memory traces. The prime purpose of the recognition test was to measure the extent to which a child could form stable and accurate memory traces of the test stimuli if he were given ample time to encode and memorize the stick figures. Thus the recognition score of a child was supposed to reflect the *asymptotic strength* of the memory traces that the child was capable of forming. This asymptotic strength was in turn supposed to determine the effectiveness of the trace or stimulus representation during the cue-response learning phase. In order that the recognition test *should* measure asymptotic strength of the memory traces rather than the rate at which this asymptote was approached, the child was given a fairly long inspection period for each test stimulus (15 seconds). Perhaps the inspection period was not sufficient; but it seems more probable that subjects found it difficult to concentrate

for the full inspection period and used only a fraction of this time in actively encoding and memorizing the test stimulus.

In contrast to the link between recognition ability and the cue selection phase of learning, there was no direct evidence that a high recognition score tended to produce efficient cue-response learning. It could be argued, for example, that the marginally significant effect of recognition level on learning rate in the test phase of the RS was due to a general *partial* extinction of the cue lists during the early string of non-reinforced trials in that phase. The subsequent reinstatement of the cue lists would again depend on the rate of cue selection learning, and consequently on recognition level, although to a lesser degree than in the original discrimination. However, if it is supposed that the difference between Hi and Lo groups in the test discrimination did partly reflect differences in cue-response learning, it is clear that such differences were not as large as expected.

If Hi and Lo groups differed sufficiently in the asymptotic strength of cue representations in addition to the differences in the rate of approach to these asymptotes, greater learning differences between the two groups would still be expected in the test phase of an RS. This follows directly from previous theorizing. In the *training* phase, differences in cue selection and cue-response learning would both contribute to the difference in learning performance between the two recognition groups. In the test phase, the difference between these groups would be a function of the difference in cue-response learning plus the number of trials needed by the Lo group to reinstate the appropriate cue selection habit.

Assuming, therefore, that the Hi group needed a negligible amount of relearning of the cue selection response during the test phase, their advantage over the Lo children in this phase should have been greater than the difference shown during the training phase of shift by at least the number of trials that the Hi children had needed to produce the correct cue list during that first phase.

Apparently, however, in the recognition test individual differences in the rate of forming stable memory traces outweighed individual differences in the asymptotic strength of the memory traces. In more concrete terms, the Lo children took longer than Hi children to form an adequate cue list but, once it had been formed, that cue list was almost as effective (was perhaps equally effective) in producing efficient cue-response learning as the cue list of Hi children.

Taken together, Studies 3 and 4 indicate that the recognition test was only a useful predictor of learning performance if the discriminations involved in the RS Problem were difficult i.e. if the figures that were relevant cues in the discrimination tasks were as readily confused as the test stimuli and their closest distractors in the recognition items. It also seems that the role of IQ in affecting performance on the training discrimination may be reduced if the experimenter's instructions are supplemented by a practice problem. Thus the significant relation between IQ and errors to criterion in the training discrimination of Study 3 did not appear in Study 4. Another factor which conceivably contributed to the latter result was the absence of an irrelevant non-spatial dimension in the discrimination problems of Study 4. The assumption here is that intelligence played an important role in the inhibition

of responses to the colour dimension during the RS problem of Study 3. Finally, a significant - if unsurprising - result of the present study was the finding of marked positive transfer from the RS to the recognition test. Appropriate controls demonstrated that the facilitation could not be attributed to differences between trained and non-trained groups in rapport or familiarity with the experimenter. In addition, comparisons between trained and non-trained children on different groups of items within the recognition test established that the facilitative effect of discrimination training was not limited to the actual stick figures used as relevant cues in the learning tasks. Indeed, the amount of positive transfer was equally great for recognition items involving test stimuli quite different from the figures used in the RS Problem. It seems reasonable to conclude that, during the learning tasks, the children were acquiring improved strategies for encoding and/or memorizing the test stimuli.

CHAPTER 15

The Relationship between the Ability to Logically Multiply Classes and Speed of Learning an RS involving Stimulus Compounds

In Study 4, the recognition test appears to have measured a type of representational skill that influenced the *cue selection* phase of learning rather than the *cue response* association phase. This finding indicates that not all measures of representational ability can be expected to be related to RS performance in the manner described in Chapter 12. Therefore, the representation hypothesis cannot be valid for all tests that would be accepted as measures of representational skill in some sense. However, the hypothesis may well be valid for a subset of such measures. It is reasonable, therefore, to try to find support for the representation hypothesis in a study employing a markedly different measure of representational skill. A fifth study was planned with a marked change in the type of stimulus material used in both the test of representational skill and the RS problem. The measure of representational ability was a set of four Piagetian classification items. The items measured (a) the child's ability to re-sort a set of elements by a second criterion (shape or colour) after he had completed an initial sort, (b) the ability to comprehend a 2 x 2 matrix constructed with stimuli varying in colour and shape, (c) the capacity to compare the number of elements in classes and their sub-classes, and (d) the child's ability to identify the intersection of two classes. Each item was intended to measure the child's ability to "integrate" two classificatory criteria (shape and colour) i.e. his capacity to represent a

particular discriminandum as (say) being simultaneously a member of the class of red objects and the class of triangles.

It may not be immediately obvious why the above test items measure representational ability as defined in Chapter 14. However, inspection of the procedure employed in the classification items (pp. 198 - 201) indicates that solution of each of these problems requires that the subject "hold in his mind" at least two classification schemes for organizing a set of stimuli. Clearly, a successful subject must encode and store one such classifying scheme in memory, and then bring the results of this procedure to bear on the second classifying scheme either during or after the formation of the latter scheme. Problem solving of the type measured by the piagetian classification items clearly requires that classifying schemes be entered into a "working" short term memory. Following familiar lines of argument, these schemes therefore qualify as representations. General support for the idea that the child capable of integrating two classificatory criteria *represents* these classificatory rules comes from Inhelder and Piaget (1964). These investigators reported (op. cit. p.220) that children approaching the concrete operational stage of performance with classification tasks were able to anticipate a classification (write the names of the piles-to-be-created on corresponding envelopes) while children at lower cognitive levels could not - even though some of these latter children finally completed a classification successfully. These parallel developmental trends in the ability to anticipate a future classification and the ability to "integrate" two classificatory criteria, clearly indicate that classifying schemes employed by children at the level of

concrete operations satisfy criterion (b) - see p. 157 - of a representation.

The RS Problem was made up of two paired associate learning tasks (PAL.s) presented successively. In both PAL.s there were four stimulus-response pairs, and for each PAL the stimuli were a red triangle, a red rectangle, a blue triangle, and a blue rectangle. A correct response was the selection of a drawing of an animal that the experimenter had arbitrarily associated with the stimulus being tested. Naturally the pairing of stimuli and responses was different for the two PAL.s.

It is clear that for a child to reach criterion on the PAL, his choice behaviour must be controlled by cue *compounds* or *patterns*. It is also clear that to be able to respond to such gestalts, subjects must be able to attend to the component cues simultaneously at some stage of the stimulus selection phase of learning. It is *not* clear that such simultaneous attention (or stimulus processing) need occur at the level of representation or thought. Indeed, in previous discussion a publication (Baker, 1970) has been cited which reviews considerable evidence that a variety of infra-human species can react to cue compounds. Further, a recent study (Watson and Danielson, 1969) has produced some evidence that 2 year old children can respond to *compounds* such as a red circle. According to Piaget, this age group should not have been capable of representing *one* of the component cues (circle) accurately let alone the cue pattern. Watson and Danielson's data must be treated cautiously since only four children out of an initial sample of 24 (who in turn were "volunteers" from a population of 300) did, in fact, finally demonstrate

"compound responding". The generality of the finding therefore may be questioned, although the high subject drop-out rate may have been due to the reasonably complex motor responses required of the subjects rather than difficulties in stimulus processing.

However, even if it is conceded that the behaviour of children 24 months of age can be controlled by cue compounds and that such controlling stimuli are chiefly the products of perceptual structures, there are data which can be interpreted as indicating developmental trends in the child's ability to *represent* cue compounds (see Wolff, 1967). Two studies seem to demand such an interpretation. King (1966) and King and Holt (1970) demonstrated that the facility with which children learned a *conjunctive* classification rule increased over the age range 6 to 12 years. Briefly, these investigators, on a given trial, presented the child with a single discriminandum drawn from a population of stimuli which varied along three dimensions, each dimension with three values. The subject was to classify the stimulus as good or bad and, over a series of trials, had to learn that a discriminandum with a particular combination of *two* attribute values (e.g. triangle and blue) was "good" and that the other discriminanda were "bad" (one of the dimensions was therefore irrelevant). Six year olds were markedly worse than 9 and 12 year olds in solving the problem, at least partly because 6 year olds tended to persist in "unidimensional hypotheses" (King and Holt, 1970 p.106). Such data agree nicely with Inhelder and Piaget's (1964) findings. As is well known, these latter investigators carefully and comprehensively documented the difficulty that young children

(below 7 to 8 years of age) have in integrating two or more dimensions in various types of classification task.

It would seem plausible that the ability to comprehend a discriminandum as the intersection of a number of classes (which is presumably measured by the Piagetian classification items) would produce a marked increment in the child's ability to represent such cue compounds in a learning task. This might be particularly true for complex "compound discriminations" such as conjunctive rule learning (King, 1966) or the PAL.s described above. It is proposed that such an increment in cue pattern representational skill produces an increasing ability to "operate" with cue lists composed of representations of compounds. That is, in the type of PAL described above, more advanced children can produce a cue list which is more effective in enabling inference and rehearsal, and, consequently such children are capable of more rapid cue-response learning. Following the line of argument set out in Chapter 14, it is predicted that learning performance in the *second* PAL will be related to the child's ability to solve the Piagetian classification items. If learning performance is related to classification ability in both PAL.s then classification ability is predicted to interact with learning phase (First PAL; Second PAL) in affecting the rate of learning. That is, the learning performance differences between groups of varying classificatory ability should be larger in the second PAL.

Method

Subjects

It had been decided to select (as nearly as possible) equal numbers of children at three levels of classification

ability - hereafter termed High, Transitional and Low children: High children were those with at least three classification items correct, Transitional children were partly correct on at least one item but not fully correct on more than two, while Low children failed all items.

It was decided to include a sizeable sample of Transitional children since Inhelder and Piaget (1964) had reported that, at least in some tasks, this group had performed *worse* than the Low group (though both had performed worse than the High group). There was reason therefore to expect *Classification Level* to be curvilinearly related to performance on the PAL.s. Since time limitations prevented an adequate sampling of subjects at each level of intermediate performance it was decided to collapse these levels into a single Transitional group.

A pilot study on the initial sample (Grade Two, North Curtin Primary School, Curtin, A.C.T.) indicated (a) that if subjects were randomly selected, High children would be under-represented, and (b) that the experimenter could administer the full testing programme to ten subjects per week. In order, therefore, to execute the above sampling plan, selection of subjects was unsystematic with the restriction that at leasttwo High children and two Low children were included in each sample of 10 subjects. This meant that a few transitional were dropped from the sample after two test sessions (i.e. after the experimenter had administered the CMMS and classification items) because the quota for Low and Transitional children had been filled for a particular week.

The above selection rule held for the early weeks of

testing. During the final few weeks of testing, selection was more drastic (i.e. more Transitional and some Low children were dropped from the sample after two sessions) to enable an adequate number of High children to be fully tested. An initial sample of 65 children was given the classification items. Forty eight of these constituted the final sample i.e. those given CMMS, classification items and PAL.s. The final sample was made up of 27 boys and 21 girls. The median age was 91.7 mo. with a range of 81 to 98 months.

(Continued on next page)

Children attending North Curtin Primary School generally came from families drawn from a rather wider socio-economic spectrum than those in previous samples. Middle and Upper middle socio-economic strata were more strongly represented, the fathers of a considerable number of the children being academics, professional men, or middle to senior executives in private enterprise or in the public service. In any case, IQ.s of 130 plus (as measured by the CMMS) were not uncommon in the sample used in the present study. The mean and standard deviation of the IQ scores for the final sample were 116.5 and 19.9 respectively.

Stimulus materials and Apparatus. During all testing sessions, the experimenter sat facing the subject across a long table 24 ins wide in the mobile laboratory previously mentioned.

Classification items. All geometric shapes were drawn (in pencil) on white cardboard and coloured with poster paint. The surfaces of the cards were protected by an adhesive, transparent plastic sheeting.

Re-sort. A set of eight stimuli (colour-size-form compounds) were constructed by selecting one from each of the following pairs of attribute values in all possible combinations: purple-orange, large-small, and diamond-half circle. The large and small half-circles were 3 ins and 2 ins in diameter respectively. The longer diagonals of the large and small diamonds were 3 ins and 2 ins respectively, while the shorter diagonal of the large diamond was 2 ins and that of the smaller diamond $1\frac{5}{16}$ ins. The stimuli were presented on 3 ins x $3\frac{3}{4}$ ins cards and two each of the stimuli were produced, making a pack of 16 *cards*. Apparatus for the re-sort item also included two black cardboard boxes ($9\frac{1}{2}$ ins x $9\frac{1}{2}$ ins x $2\frac{1}{2}$ ins) and the shallow cardboard box described fully in connection with the next sub-item.

Cross Classification. The following set of four stimuli were made up: a green circle, green square, yellow circle, and yellow square. The squares had sides of $1\frac{1}{2}$ ins and the circles were $1\frac{11}{16}$ ins in diameter. The stimuli were presented on cards $2\frac{13}{16}$ ins x $3\frac{1}{2}$ ins and there were four of each, making a pack of 16 cards.

The child was shown a long (26 ins), wide (17 ins), low (2 ins) cardboard box which the experimenter could partition into four equal rectangular sections using 2 ins high partitions of thick cardboard.

Quanitification of Class Inclusion. Four *sets* of six stimuli were each presented on cards $2\frac{3}{16}$ ins x 16 ins. On card A, four green squares and two green circles were presented in line. The individual figures had the same dimensions as for the Cross Classification item (this was true of all the remaining cards). The stimuli *within* each of the two classes on the card were separated by 3/4 ins and presented as a group. The separation between the two stimulus groups on the card was 2 ins. The organization and separation of stimuli on the remaining three cards were identical to the above. Card B contained four purple circles and two green circles: Card C, four orange circles and two orange squares; and Card D, four purple squares and two yellow squares.

Class Intersection. This item was given as three sub-items. For each sub-item there was a "column" and a "row" each of four stimuli presented on a long rectangular card ($3\frac{1}{2}$ ins x $11\frac{3}{4}$ ins). The stimuli were approximately equally spaced on these cards. In addition to the row and column cards, there was a set of nine recognition stimuli for each sub-item presented separately on 3 ins x 3 ins cards.

Sub-item 1. Starting from the top of the column card (i.e. the end furthest from the subject during testing) the stimuli were a segment of a circle, a triangle, an oval, and a square - all *orange*. Starting from the left of the row card (i.e. as the stimuli were seen by the subject) the stimuli were coloured, in turn, green, yellow, black and purple: all of these stimuli were *circles*. The recognition set was made up of the following stimuli: a green square, a yellow circle, a black circle segment, an orange square, a green circle, an orange oval, an orange triangle, a purple circle, and an orange circle. All stimuli used in the column card, row card, and the recognition set were approximately equal in area. This was also true of the other sub-items.

Sub-item 2. Taking the column card from the top, the stimuli were an orange square, a green square, a brown square, and a yellow square. From the left, the row stimuli were a purple half-circle, a purple rectangle, a purple circle, and a purple diamond. The recognition set was as follows: a purple square, a green circle, a purple half-circle, a yellow diamond, a purple circle, a green square, an orange square, a purple rectangle, and a yellow square.

Sub-item 3. The stimuli from the top of the column card were a green annulus, a green U shape, a green right angled cross, and a green X shape. From the left, the row stimuli were a yellow T, a purple T, a blue T and an orange T. The recognition stimuli were a purple T, an orange annulus, a green T, a green X, a green right angled cross, a green annulus, an orange T, a yellow T, and a blue U shape.

Paired Association Learning. The *stimuli* for the PAL.s were shapes (triangle or rectangle) cut from coloured gummed paper (blue or red) and centred on white $3^{3}/_{4}$ ins x $3^{3}/_{4}$ ins cards. The rectangles measured $1^{1}/_{2}$ ins x $2^{1}/_{2}$ ins while the (isosceles) triangles had a base $2^{7}/_{8}$ ins and a perpendicular height of $1^{7}/_{8}$ ins. Six sets of the four stimuli were produced, one for use during *presentation* trials. The remaining five sets were presented during test trials, each set having a different ordering of stimuli (see Appendix B).

The *response pictures for presentation* trials were line drawings (in black ink) of (a) a lizard, (b) a pig, (c) a bird and, (d) a fish - individually presented on 4 ins x 4 ins white cards. For test trials, four different spatial arrangements of the response pictures were produced, and each *arrangement* was presented on a single large (8 ins x 20 ins) white card. As previously described the surfaces of all cards were protected by an adhesive transparent plastic sheeting.

During both learning tasks, the experimenter used a very large cardboard box (with one side removed) placed on the table as a screen. A timer emitted a click, barely audible to the experimenter and subject, at 3 second intervals.

Procedure

Subjects were individually tested for a maximum of six sessions, the first test session (the administration of the CMMS) occurring from one to three weeks prior to the remaining sessions which occurred on successive (week) days. During the first of these remaining sessions, the experimenter administered the classification tests. In subsequent sessions the subject was given the two PAL.s.

Classification Items. These items were given to all subjects in the order given below. The full testing session usually took from 15 to 20 minutes but there was a reasonable degree of variability from child to child. During the classification items the child stood facing the table, while between items he was seated on a chair several feet from the table.

1. Re-sort. The stimulus cards were arranged in rows on the table without any systematic organization by shape, colour or size. The subject stood facing the array of cards while to the right and left of the cards were the two black boxes. The experimenter said, "Here are some cards. You can see that each card has a picture on it. Now I want you to put together the pictures that are alike - that go together - so that you make *two* piles. Put all of *one sort* of picture in here (gestures toward one black box) and all the *other* sort in there (indicating the other box)." The above instructions were repeated if the subject hesitated. After the subject had completed his first sort, the experimenter placed the wide shallow box (partitioned into *two* sections) between the black boxes and continued, "Good, now can you make two piles a *different* way? See if you can put the pictures together in a different way from last time. Put one new pile here, and the other new pile there (the experimenter indicated, in turn, the two parts of the shallow box)." If the subject resorted adequately but his first two criteria were not shape and colour - this happened infrequently - he was asked if he could think of yet *another* way to make two piles. If the subject failed to sort consistently by a second dimension, the experimenter returned the cards to the subjects original sort

(although placed in the two partitions of the shallow box) and said, "Now why did you put all these together (indicating one pile)? They're all . . .?" The question was repeated for the other pile of stimuli. With few exceptions the subject readily found labels for the two stimulus classes. The experimenter continued, "That's a good rule for making two piles: 'Put all the --- here, and all the --- there. Now can you think of a different rule for making two piles?"

2. Cross Classification. The stimuli were presented organized as described for the previous item. The experimenter gave the following instructions: "Put together those pictures that are alike - those that go together - so that you make four piles." After the subject had divided the cards into 4 piles (i.e. yellow circles, yellow squares, green circles, and green squares - no child failed to do this), the experimenter presented the subject with the shallow box partitioned into four sections. The experimenter continued, "You can see that this box has four parts. Now, I'm going to put one pile of cards in each part of this box". The experimenter then constructed a colour x shape matrix. One partition was then removed from the box, leaving the circles of both colours on one side of the remaining partition and the squares on the other. The experimenter gestured over the two groups of circles and asked the subject, "Can we put these with these? Why?" The same questions were then asked about the squares. The partition was replaced and the other partition removed, leaving yellow shapes on one side of the remaining partition and green shapes on the other (each group, of course, in two piles). The experimenter gestured over the two groups of yellow shapes and again asked the child,

"Can we put these (gesturing to yellow circles) with these (pointing to the yellow squares)? Why?" The questions were repeated for the two piles of green shapes.

3. Quantification of Class Inclusion. Each of the four cards was used in a separate sub-item. The cards were presented in the order A, B, C, D. As each card was presented, the experimenter asked the subject to point to all of the superordinate class items (e.g. for Card A the experimenter said, "Point to the green pictures on this card.") The experimenter then asked the child to point to items in each of the two sub-classes (for Card A the experimenter said, "Point to the circles" and, when this was done, "Point to the squares.") When the child had pointed to the figures as instructed (and no child had difficulty in doing this) the experimenter asked the question, from the list below, that was appropriate for the card used in the sub-item.

"Now look at the card and *listen very carefully*:

(A) On this card are there more squares or more green ones? Why?

(B) . . . . . are there more circles or more purple ones? Why?

(C) . . . . . are there more orange ones or more circles? Why?

(D) . . . . . are there more purple ones or more squares? Why?

4. Intersection. For each sub-item the column and row cards were presented at right angles on the table so that there was an empty space at their juncture large enough for one of the choice stimulus cards to complete the L shape. The experimenter gestured at the stimuli on the column card

and asked the following series of questions until he received a satisfactory response: "Why have all these pictures been put together? Are they alike in any way? Are they a little alike one another? They are all (pause)?" For sub-item 1, the subject replied "they're all orange". The experimenter then pointed to the stimuli on the row card and again asked the above questions until the subject gave a satisfactory reply: for sub-item 1 this was, "They're all circles".

The experimenter continued, "What *single* picture should I put here (indicating the space at the intersection of row and column cards) to go with all these (gesturing at the column stimuli) *and* all those (indicating the row stimuli). Tell me the picture that fits in with everything (sweeping gesture over both row and column stimuli)."

If the subject gave the correct answer he was asked the reason for his answer. If he answered incorrectly, the experimenter presented the appropriate set of recognition stimuli in a line and asked the subject, "Now I want you to look at all these pictures and find a picture that fits in with all these (column stimuli) and all those (row stimuli). Find one that will go there (indicating the intersection of row and column)."

If the subject picked the correct card, he was further asked if there were any other pictures that would do just as well. Irrespective of his answer to this last question the child was asked the reason for his initial choice.

The above procedure was repeated for the three sub-items.

Paired Associate Learning. The subject sat facing the experimenter across the table. On the table, to the experimenter's right, the large cardboard box screened from the subject's sight the four stimulus and four response pictures employed during presentation trials and the five sets of stimulus pictures for use during test trials. The four response selection cards were stacked face downward. At the rear of the laboratory, a timer emitted soft clicks at 3 second intervals.

The experimenter turned the top selecton-card face-up and said, "I'm going to show you four pairs of pictures, one pair at a time. Now, when I show you a pair of pictures, you'll see that one of them will be like the pictures that we had yesterday, and the other one will be one of these animals: the lizard, or the fish, or the bird. The game is that each picture has got a partner and you must learn which pictures go together.

This is how we play. First I show you four pairs of pictures; then I'll show you a picture on its own and you point to the animal that goes with it. Then I'll show you the next picture and you show me the animal that goes with that one. Do you think you know how to play the game? After I have tested you one time, I will show you the pairs of pictures again. We'll keep playing the game until you can point to the right animal for each picture every time". During the initial presentation trial the experimenter simply said, "Remember the pictures that go together".

As should be clear from the above, a PAL consisted of a series of presentation-test trials. During the presentation phase the experimenter held each pair of stimulus and response

pictures about $1\frac{1}{2}$ feet from the subject and at his eye level. The stimulus picture was an inch or so to the left of the response picture - from the subject's viewpoint. The experimenter timed the presentation rate from the clicks in the background. On any trial the subject viewed each of the four stimulus-response pairs for 6 seconds with a 3 second inter-pair interval. The test phase was unpaced. The experimenter showed a set of test stimulus pictures to the subject one at a time, turning over a different response-selection card for each test stimulus. The subject simply had to point to the animal that he thought went with each test stimulus that he was shown.

The five different orders of presenting the stimulus cards during the test phases have already been mentioned. In addition, there were four different orders for presenting the stimulus-response pairs during the presentation phases. Each subject was given the same combinations of presentation and test orders over a given number of presentation - test trials of a particular PAL (see Appendix B).

During the first PAL all subjects had to learn to associate the red triangle with the lizard, the blue triangle with the fish, the red rectangle with the bird, and the blue rectangle with the pig. The subject was given up to *10* presentation-test trials a day until he chose all response pictures correctly on two successive trials. When the latter event occurred testing for the day was terminated. The following day the experimenter told the subject that they would continue playing the same game, and a presentation-test trial appropriate for the first PAL was given. In all but two cases, subjects performed perfectly on this trial.

The two exceptions were given another presentation-test trial and performed perfectly on this trial. In any case, after the subject had demonstrated retention of the first PAL solution by correct choices on *one* trial, the second PAL was introduced without warning. The subject then had to associate the red triangle with the pig, the blue triangle with the bird, the red rectangle with the fish, and the blue rectangle with the lizard. Children were given up to 10 trials a day until they reached a criterion of all response pictures correctly chosen on 3 out of 4 presentation-test trials.

Two things should be noted concerning the above. Firstly, during the second PAL, a given response picture was associated with a stimulus picture that differed from the one with which it had been associated in the first PAL on *both* attributes. Secondly, it was theoretically possible for the subject to solve the second PAL *without error*. This was so because, although the epxerimenter introduced the new PAL without comment, the subject had viewed the correct new associations on a *presentation* trial before he was first tested on these new associations.

Results

Scoring of Classification Tests. The subject was only considered to have passed the *Re-sort* classification item if he completed the second without any of the experimenter's prompts. If the subject re-sorted *after prompting* he was considered partly correct.

The subject passed the *Cross Classification* item if he agreed that the four piles could be "collapsed" into both shape and colour dichotomies, and could give a satisfactory reason for his answer (e.g. "They're all yellow").

The subject passed *the Quantification of Class Inclusion* item if he answered *all* sub-items correctly and each time gave a satisfactory reason (e.g. "There are six green ones and only four squares.")

The child was judged fully correct on the *Class Intersection* item if he could *describe* the figure required at the intersect of column and row cards (i.e. he did not need the choice set), and could give an adequate reason (e.g. "It's orange to go with those and a circle to go with those") for his answer in *each* of the sub-items.

In terms of classificatory ability the final sample consisted of 15 High, 16 Transitional, and 17 Low children. The three groups did not differ significantly in IQ ($F(2,45) = 2.50$, $p > 0.05$).

PAL. One subject from the Low group failed to reach criterion on the first PAL within three sessions. She was arbitrarily assigned 39 trials to criterion (and the number of errors made during those trials) for the first PAL and, of course, was not given the second learning task. Another subject from the Transitional group solved the first PAL but could not be tested on the second PAL due to factors beyond the experimenter's control.

Compared with both the other groups the Hi group showed *less variability* in both errors and trials to criterion on the first PAL. A logarithmic transformation of both dependent variables provided a satisfactory correction for this heterogeneity of variance. Two dependent variables were analyzed (log (errors + 1); log (trials to criterion) and since analyses revealed no differences due to dependent variables, the data are reported in terms of trials to (and including) criterion.

The three groups of varying classifactory ability differed *significantly* in transformed trials to criterion on the initial PAL ($F(2, 45) = 11.69$, $p < 0.001$). As can be seen in Table 14, the effect of *Classification Level* on learning was due to the superiority of the High Children over the other two groups.

Table 14

Learning Performance on the First PAL as a Function of Classification Ability

Group	Mean Trials to Criterion	S.D.
Low	12.88	5.98
Transitional	11.75	4.31
High	6.33	2.09

The three possible a posteriori comparisons between pairs of means were made. With the F.s required to reach the quoted probability levels adjusted by the *Scheffé (1959)* method, it was found that the High group performed significantly better than either the Transitional ($F(1,45) = 16.08$, $p < 0.01$) or the Low group ($F(1,45) = 19.39$, $p < 0.01$). The latter two groups did not differ significantly ($F(1,45) = 0.12$).

In the *second* PAL, the variability of learning scores within the High group was again less than for the other two groups. Again the dependent variables underwent logarithmic transformation and, for the reason given above, only the results for the trials to criterion measure are reported.

Level of Classificatory Ability was significantly related to learning performance in the second PAL ($F(2,43) = 11.05$,

$p < 0.001$). As shown in Table 15, the relative performance of the three groups was similar to the pattern shown in the first PAL.

Table 15

Learning Performance on the Second PAL as a function of Classification Ability

Group	Mean Trials to Criterion	S.D.
Low	13.81	5.48
Transitional	16.2	7.42
High	7.33	3.61

Again, a posteriori comparisons were made with the critical F values adjusted by the Sheffé method. The High group performed better than either the Transitional ($F(1,43) = 18.98$, $p < 0.01$) or the Low group ($F(1,43) = 14.06$, $p < 0.05$). The latter two groups did not differ significantly ($F(1,43) = 0.46$).

Since *Classification Ability* was predicted to interact with *Learning Task* (First PAL; Second PAL) in affecting the child's performance, an analysis of variance was performed on the untransformed trials to criterion measure with *Level of Classificatory Ability* as a between subjects factor and *Learning Task* as a within subjects factor. The main effect of *Classificatory Level* was significant ($F(2,43) = 14.87$, $p < 0.001$) as was that of *Learning Task* ($F(1,43) = 8.49$, $p < 0.01$). The Classificatory Level x Learning Task interaction was *not* significant ($F(2,43) = 1.76$, $p > 0.10$). Clearly there was *negative* transfer from the first to the second PAL but the amount of transfer did not differ significantly for the High, Transitional and Low groups.

The learning data were subjected to further analyses of variance with subjects classified as having high, medium, or low IQ. Fifteen subjects were in the high IQ group (IQ.s $\geq$ 127), 16 subjects were in the medium group (104 < IQ.s < 127), and 17 subjects were in the low IQ groups (IQ $\leq$ 104).

Analysis of transformed trials to criterion indicated that IQ level had no significant effect on learning performance in either the first ($F(2,45) = 0.56$) or the second PAL ($F(2,43) = 1.63$, $p > 0.10$). Analysis of transformed error data yielded similar results ($F(2,45) = 1.06$, for the first PAL; and $F(2,43) = 1.91$, $p > 0.10$, for the second PAL).

Discussion

The results of the above analyses do not support the representation hypothesis. Although there was a strong relationship between classificatory level and learning performance in the second PAL, the relation between the two variables was equally strong in the first PAL. The predicted interaction between *Learning Task* and *Classification Level* in determining rate of learning was not found.

While it is of some interest that the ability to logically multiply stimulus classes (from the shape and colour dimensions) was strongly related to learning performance in PAL.s in which the stimuli were from intersects of such classes, it is more vital to the present thesis to determine (a) whether a two stage analysis of such PAL.s is valid; and (b) whether classification ability affects the stimulus selection stage of learning, the stimulus-response association stage, or both. In the absence of the predicted interaction the above statistical analyses are not useful in answering these questions. To illustrate this point, two quite different models which might deal with the reported results are presented.

First, it might be argued that there are indeed *two* types of learning involved in the PAL.s. The child is seen as having a variety of ways of encoding each of the four stimuli: he may encode their shape, their colour, or both of these. Learning in the PAL is the process of (a) selecting the correct code for the stimuli (representing them as cue compounds), and (b) associating the stimulus representations to the appropriate responses. It is postulated that it is the stimulus encoding habit, rather than stimulus-response learning, that is influenced by the child's classification level. In other words, the main (if not sole) difference between the High children and the others was that, in the PAL, the former group were likely to reject the incorrect codes based on single dimensions more quickly and thus produce the correct stimulus representations after fewer learning trials. This, of course, meant fewer trials to criterion in the PAL for that group. The equivalent effects of classification level on learning in the first and second PAL may be explained by the assumption that there was negative transfer between the PAL.s resulting from the "carry over" of inappropriate stimulus-response habits. This negative transfer, in turn, brought about the extinction of the appropriate stimulus encoding habits *for all classification ability groups* during a string of non-reinforcements at the beginning of the second PAL. The remaining learning in the second PAL then involved the re-learning of the appropriate stimulus encoding habit as well as the new stimulus-response associations. Classification level (as postulated above) would have affected the former learning process and to approximately the same extent that it did during the first PAL. Equivalent effects of classification level in the two PAL.s would therefore be expected.

In contrast to the above model, it might be assumed that the relevant stimuli of the PAL.s (i.e. the cue compounds) were both obvious to all subjects, and distinct - in the sense of being well differentiated by these subjects. The obviousness of the cue compounds as relevant stimuli could be expected on the basis of the one-to-one mapping of this stimulus code into the *four* responses. Simpler codes (based on, say, colour alone) would involve a one-to-two mapping of cues to responses and, since the instructions to subjects emphasized that each stimulus picture "had its own" response picture, these latter codes might be inhibited very early in learning. In the first PAL, therefore, learning would have involved a negligible stimulus encoding phase and a relatively extended stimulus-response learning phase. Classification level would be presumed to affect the *latter* type of learning. As in the first model, negative transfer between the two PAL.s would be expected on the basis of the "incorrect" stimulus-response habits developed during the first PAL. Assuming the amount of negative transfer to have been approximately the same for all levels of classification ability, the second PAL would have involved simply the learning of new stimulus-response associations after the intrusions from the first PAL had been inhibited. Classification level would affect the stimulus-response learning phase, and to the same extent as in the first PAL.

It can be seen that the results of Study 5 can be predicted by theories that assume *either* that classification level affected only the formation of a stimulus selection habit *or* that classification ability affected only stimulus-response learning. The first theory assumes (a) that there was a

significant amount of stimulus selection in the PAL, and (b) that this type of learning was rapid for High children and slower for Transitional and Low children. The second theory postulated (a) virtually no stimulus selection problem for subjects in the PAL and (b) that High children performed markedly better than the others on the learning of stimulus-response associations.

To discover which of the two theories provided a better fit to the data of Study 5, some sort of index of the extent of the stimulus encoding phase of learning in the PAL was clearly needed. The measure decided upon involved an analysis of the types of errors the subjects made during learning. Since the subject selected a response picture for every stimulus shown (i.e. there were no errors of omission) his errors could be exhaustively categorized as follows:

(1) the selection of the response picture associated with the stimulus picture of the same colour as the stimulus being tested - *colour errors*.

(2) the selection of the response picture associated with the stimulus of the same shape as the stimulus being tested - *shape errors*.

(3) the selection of the response picture associated with the stimulus differing in both shape and colour from the stimulus being tested - *unrelated errors*.

It is argued that if all the children are responding to obvious, distinct, well integrated cue compounds from the beginning of the PAL - as proposed in the second of the above theories - then the above three types of error should be equally probable. When presented with any given test stimulus, the subject either remembers the response picture

associated with the particular cue compound or he has forgotten it - at least temporarily. In the latter case he must guess, and errors consequently will be equally distributed over the three categories described above.

The situation should be somewhat different if there is a significant period of (stimulus selection) learning *before* the choice behaviour of the children is controlled by well integrated cue compounds. During such a learning period there may be a series of stimulus response presentations during which the subject selectively encodes the stimuli according to the attribute values on a single dimension. On the corresponding test phases of the learning trials, if the children had retained what had been learned, the only errors made would be colour or shape errors (depending on the dimension selected for encoding). An alternative (or additional) possibility in the stimulus selection period is that, during stimulus-response presentations, the children encode a stimulus as a cue compound (as well as encoding one of its components) but the memory trace of the compound is labile and only one of the components is an effective retrieval cue on the test phase of the learning trials. Again, any errors the child makes will be shape or colour errors. The point made here is that the partial learning that occurs during the stimulus selection period should produce a higher frequency of shape and colour errors relative to unrelated errors, and the degree of unevenness of spread of errors over the three categories should reflect the length of the stimulus selection period.

Each child's errors in the first PAL (two children in the High group were dropped from the analysis because they made

no errors in the first PAL) were classified as colour, shape, or unrelated errors and the children were classified according to classification level. The variability of error scores for High subjects was markedly less than that for the other two groups and a logarithmic transformation partially corrected for this heteroscedascity. An analysis of variance was performed on the transformed errors (log (errors + 1)) with *Error Type* as a within subjects factor and *Classification Level* as a between subjects factor. The main effect of *Classification Level* was significant ($F(2,43) = 6.63$, $p < 0.01$) as was the effect of *Error Type* ($F(2,86) = 16.90$, $p < 0.001$). The *Classification Level X Error Type* interaction did not approach significance ($F(4,86) = 0.58$). As can be seen from Table 16, colour errors were most common at all levels of classification ability, followed by shape errors, and finally unrelated errors. Further, while the High group differed substantially from both the other groups in overall errors to criterion, the differences between the number of colour errors and either the number of shape errors or the number of unrelated errors were of approximately equal magnitude for each of the three levels of classification ability.

Table 16

Geometric Means of (Errors + 1) and Arithmetic Means of Errors (in Parentheses) in the first PAL as a Function of Error Type and Classification Level of Subject

Classification Group	Error Type		
	Unrelated	Colour	Shape
High	1.75 (1.00)	4.39 (3.77)	2.30 (1.48)
Transitional	3.81 (4.63)	6.63 (7.44)	4.95 (4.88)
Low	3.87 (4.35)	7.12 (7.88)	5.14 (6.47)

The highly significant main effect of *Error Type* together with the fact that this factor did not interact with *Classification Level* may be plausibly interpreted as indicating a significant amount of stimulus selection learning in the first PAL for each of the three classification groups. If this conclusion is correct then the first rather than the second theory outlined in the discussion receives support. However, the lack of an *Error Type* x *Classification Level* interaction also appears to indicate that the High, Transitional, and Low groups exhibited no great (if any) differences in the length of the stimulus selection learning-period. This conclusion contradicts the assumption of the first theory that classification level affected learning performance in the stimulus selection learning rather than the stimulus-response association phase of the PAL. Clearly, the classification level must have affected the latter type of learning in line with the postulate of the second theory.

If the above argument is sound, then the question arises as to why the interaction of *Learning Task* (First PAL; Second PAL) and *Classification Level* in determining learning performance, predicted by the representation hypothesis, was not found. The basic preconditions for the effect seem to have been met:

(1) a significant stimulus selection phase of learning at all ability levels in the initial PAL - with no large differences in the rate at which such learning is accomplished by the groups of differing representation ability;

(2) a stimulus-response learning phase of PAL.s which was strongly related to level of representational skill

Why, then, was not the influence of representational skill on learning "magnified" in the second PAL as it should have been if the argument presented at the beginning of Chapter 14 was valid?

It may be recalled that the magnification effect depended on the differential extinction of the stimulus selection habit for groups of varying representational skill during the early stage of the test phase of the RS problem. The degree of extinction of the stimulus selection habit depended on the number of non-reinforced responses during the early trials of the second task which, in turn, depended on (a) the amount of negative transfer between the first and second tasks due to the "inappropriate" stimulus-response habits established during the first task, and (b) the speed with which the correct responses were substituted for those appropriate for the earlier problem. It was postulated that children of varying representational skill differed on the second factor. Children of low ability took longer to substitute the correct responses for the intrusions from the earlier problem, experienced more non-reinforced responses, and consequently were likely to reject the stimulus selection habit that was, in fact, appropriate for the second task.

The magnification effect depends, therefore, on a good deal of negative transfer between the training and test learning tasks. It is proposed that, in Study 5, the amount of pro-active inhibition from the first to the second PAL was insufficient to produce the magnification effect. One procedural detail of the study may account for this. Although one or two trials of the first PAL were given at the beginning of the test session in which the second PAL was introduced,

and although no warning of the introduction of the second PAL was given, it is true that the children reached criterion on the two PAL.s on two different (albeit successive) days. This procedure may have enabled the children to "tag" the first PAL as "yesterday's game" and the second PAL as a "new game". These distinctive tags might have enabled the subjects to keep the two sets of stimulus-response habits "separate" in memory rather more easily than would otherwise have been possible. This, in turn, would have meant few first PAL intrusions in the second PAL and thus fewer non-reinforced responses for subjects at all levels. The foregoing suggests that there was little negative transfer from first to second PAL and, consequently, little stimulus selection re-learning needed in that learning task. One way of checking this assertion is to analyze the error-type profile in the second PAL for each of the three levels of classificatory ability.

Again an analysis of variance was performed on the log (errors + 1) measure with *Error Type* as a within subjects factor and *Classification Level* as a between subjects factor. The main effect for *Classification Level* was significant ($F(2,43) = 7.88$, $p < 0.01$) but neither the main effect for *Error Type* ($F = 2.89$, $0.10 > p > 0.05$) nor the interaction of the two factors ($F(4,86) = 0.75$) was significant. Comparison of Tables 16 and 17 indicates that the lack of an effect for *Error Type* in the second PAL was due to an increase in the number of *unrelated* and *shape* errors - relative to colour errors - in comparison with the first PAL.

Table 17

Geometric means of (Errors + 1) in the Second PAL as a Function of Error Type and Classification Level of Subjects

Classification Group	Error Type		
	Unrelated	Colour	Shape
High	2.31	2.80	3.16
Transitional	6.27	7.68	6.67
Low	4.81	7.39	5.17

A non-significant effect for *Error Type* is consistent with the idea that there was little stimulus selection learning involved in the second PAL and, by inference, very limited negative transfer from first to second PAL. The result could thus be interpreted as supporting the above argument. Further the result confirms the conclusion, drawn from the analysis of the error-type profile in the first PAL, that classification level affected the rate of forming *stimulus-response associations* rather than stimulus selection learning. Clearly, a marked reduction in the amount of stimulus selection learning in the second PAL did not reduce the learning superiority of the High group over the Transitional and Low children. If the learning superiority of the High children was not sensitive to variations in the length of the stimulus selection phase of learning, it follows that the overall learning superiority reflected differences in the stimulus-response learning phase.

However, another interpretation of the results of the error analysis for the second PAL is possible. An increase in the number of unrelated errors relative to colour and shape

errors would be predicted merely on the basis of a significant number of intrusion errors in the second PAL. It will be recalled that in the second PAL, responses were allocated to stimuli that differed in both colour and shape from the stimuli with which they had been associated in the first PAL. Therefore, in the second PAL, intrusions from the first PAL would be classified as unrelated errors. While it seems probable that this last factor accounted for some of the reduction in the effect of *Error Type* for the second PAL, it certainly would not account for all of this reduction. As was mentioned above, the difference in the number of colour and unrelated errors, and the difference in number of colour and shape errors were *both* reduced in the second PAL. The latter reduction could not be due to intrusion errors.

If the post hoc explanation of the results of Study 5 offered above is valid then a comparatively minor procedural change should produce the expected *Classification Level* X *Learning Task* interaction i.e. confirm the prediction that level of representational skill would have a stronger effect on learning performance in the test phase of the RS problem than it did in the training phase. A significant number of learning trials (say six) of the second PAL should be given immediately after criterion is reached on the first PAL. This change should significantly increase the amount of negative transfer within the RS problem and consequently the amount of stimulus selection re-learning needed by the Low and Transitional children (relative to the High group). As a result, the magnification effect, previously discussed, should operate.

If the arguments presented in Chapter 12 were valid, the link between classification level and stimulus-response learning was largely mediated by a tendency for High children to rehearse a given stimulus-response association during *and after* the presentation of that particular pair of pictures. As suggested previously, one way to check the validity of this suggestion would be to vary the interval between presentation of successive stimulus-response pairs systematically. With longer inter-pair intervals (an interval of 3 seconds was employed in the present study), there should be more scope for the use of a mnemonic strategy dependent on representational skill - such as rehearsal - and the superiority of the High group in both PAL.s should be increased. Following the argument previously outlined the magnification effect and, therefore, the *Classification Level* X *Learning Task* interaction should also be increased.

Study 6

In order to test the interpretation of the results of Study 5 presented on pages 218 and 219 a further study was performed. The PAL.s were as in Study 5. However the presentation of Stimulus-response pairs on presentation trials (and stimulus items on test trials) was by slide projector controlled by a timer. Subjects viewed a rear projection screen. The automation of stimulus and response presentation meant considerable time savings, and enabled both PAL.s to be presented to a subject within a *single* test session of 45 minutes - thus eliminating the possibility of distinct memory tags for the first and second PAL.s.

Since rehearsal was thought to be one mechanism underlying the superior stimulus-response learning of high classification ability groups, it was considered that additional opportunities for rehearsal would increase the superiority of that group in both PAL.s - though rather more effectively in the second PAL. In the present study, therefore, half of the subject were given inter-item intervals of 6 seconds during presentation trials while the other half were given inter-item intervals of 2 seconds.

As in Study 5 classification ability was predicted to interact with learning phase (First PAL; Second PAL) in affecting the rate of learning. The increase in superiority of the high classification ability group in the second PAL was predicted to be greater in the group given a 6 second inter-item interval. That is, a second order interaction (classification ability X learning phase X inter-item interval) was predicted.

Method

Subjects. Subjects were 35 pupils from Grade Three of

Rehoboth Primary School, Wilson, W.A., and were 7½ to 8½ years of age at the time of testing. Initial testing resulted in 10 subjects passing at least 3 of the 4 classification items (High group). A Low ability group of 10 subjects scoring less than 3 items correct was randomly selected from the remaining subjects.

Stimulus materials and Apparatus. All subjects were tested in a vacant room at the school. The furniture of the room comprised a long table and two chairs. The room was darkened during the two PAL.s.

Stimulus materials for the classification tests were exactly as described in Study 5. The stimulus materials described in connection with the PAL.s in Study 5 were photographed (in the appropriate stimulus-response pairs for the presentation trials of the two PAL.s, and singly for the test trials) and the transparencies mounted on 35mm. slides for presentation by a Kodak Carousel Projector.

Stimulus-response pairs and test stimuli were rear projected through a ground glass screen with a viewing area 10 inches high and 15 inches wide. As projected on the screen the triangular stimuli (red and blue) had a perpendicular height of 3 inches and the rectangular stimuli a height of approximately 2½ inches. The subject viewed the screen from a distance of 3 feet while the experimenter sat 4 feet behind and to the left of the subject, controlling the projector through a timer and appropriate associated relay equipment. The timer enabled the experimenter to initiate an automatic four item presentation trial with each stimulus-response item exposed for 6 seconds and inter-item intervals (during which the screen was blank) of either 2 seconds or

6 seconds duration (depending on the treatment condition).

A single large card (8 inches X 20 inches) bearing the four response pictures was placed before the subject.

Procedure. The subjects were all individually tested in two sessions separated by approximately one week. In the first session the subjects were given the classification tasks as described for Study 5. At the beginning of the second session (which lasted for a maximum of 45 minutes) subjects from both High and Low ability groups were allotted (alternately) to either a 2 or 6 second inter-item interval. They were then briefly told about the projector and screen, and given the following instructions:

> I'm going to show you four pictures one at a time. These pictures are just like the ones I showed you last time. Each picture has an animal that goes with it. The game is to learn which animal goes with each picture. Each time I show you a picture, I'll show you the animal that goes with it. After I have shown you the pictures and their animals, I will show you the pictures on their own, and I want you to point to the animal that goes with each picture. The animals are on the big card. After that I'll show you the pictures with their animals again.

The experimenter then initiated the first automatic presentation of the four stimulus-response pairs and the interpolated blank intervals (the last item of a presentation trial was followed by a blank interval of the appropriate length). After the presentation trial the test stimuli were presented singly and at a rate determined by the subject's response speed. The subject simply pointed to the animal he thought went with the stimulus picture. The experimenter answered each time, either, "Good boy/girl, that's the one that goes with the lizard/fish/pig/bird", or, "No, that's not right". The complete procedure was then repeated.

The different orders for presenting items during presentation and test trials were as described for Study 5. The stimulus-response associations for the first and second PAL.s were as for the corresponding PAL.s of Study 5. Subjects were required to choose all response pictures correctly on two successive trials to reach criterion on a particular PAL, and when criterion was reached on the first PAL, the experimenter unobtrusively (and quickly) switched magazines on the projector and initiated the second PAL without warning (the experimenter had made a point of "repairing" the equipment during the first PAL so as not to alert the subject during the switch to the second PAL.)

Results

Two dependent variables were analyzed - errors and trials to criterion - and since analyses revealed no differences due to dependent variables the data are reported in terms of trials to (and including) criterion.

An analysis of variance was performed on the untransformed trials to criterion measure with *Level of Classificatory Ability* and *Inter-item Interval* as between subjects factors and *Learning Task* (First PAL; Second PAL) as a within subjects factor. The main effect of *Classificatory Level* was significant ($F(1, 16) = 9.38$, $p < 0.01$). None of the other main effects or interactions approached significance (all $Fs < 1$) *Table 17* gives mean of trials to criterion (and standard deviation) as a function of *Classification Level, Inter-item Interval and Learning Task.*

Table 17

Means and Standard Deviations of Trials to Criterion as a Function of Classification Level, Inter-item Interval, and Learning Task.

Classification Level	Inter-item Interval	First PAL		Second PAL	
		Mean	S.D.	Mean	S.D.
Low	2 sec.	8.0	7.0	8.8	3.0
	6 sec.	11.0	6.6	12.0	4.6
High	2 sec.	5.4	2.0	4.8	3.5
	6 sec.	4.0	2.0	5.8	4.0

Discussion

Clearly the predicted *Classification Level* x *Learning Task* interaction again did not appear. The procedural variation (i.e. both the PAL.s given in the one test session) did not produce significant negative transfer from first to second PAL (there was no significant main effect or interaction involving the Learning Task variable) for either the High or Low ability group. It seems that the memory tags explanation of the low interference between the two PAL.s in Study 5 cannot be valid.

Study 7

A final study was planned in an attempt to increase the interference from the first to the second learning task. It was considered possible that the *pictorial* presentation of both stimuli and *responses* in Studies 5 and 6 (and the fact that the responses were well differentiated units)

resulted in subjects encoding the stimulus-response associations as compound *visual images*. There is evidence that such a code is resistant to interference (Bugelski,1968).

In the present study the stimuli were as in Studies 5 and 6 but the responses were the names Bill, Ben, Bert and Brian. The PAL format (presentation trial - test trial) was replaced by a successive discrimination procedure with correction of errors. On any trial the subject was shown a stimulus, and gave verbally one of the four responses. If he was correct, this was confirmed and the subject was praised. If he was incorrect, the experimenter told him this and gave him the correct response for the picture.

The fact that the responses in both learning tasks were readily confusable and were given verbally meant that a visual code would be unlikely to be used in the encoding of the stimulus-response associations. Consequently an increase in the proactive inhibition within the RS paradigm could be expected. Following the argument given on pages 215 and 216 *Classification Level* was predicted to interact with *Learning Task* in affecting learning performance, with the superiority of the High ability group being increased in the test phase of the RS problem.

Method

Subjects. Subjects were 38 children from Grade Three of St. Joachim's Primary School, Victoria Park, W.A. Nine of these subjects passed at least three of the four Piagetian Classification tests. These constituted the High ability group. A Low ability group of nine subjects was randomly selected from the remaining subjects.

Stimulus materials and Apparatus. Subjects were tested in an office within the school. The room contained a large desk and two chairs.

Stimulus materials for the classification tests were as described for Study 5. The transparencies of the *individual stimuli* used in Study 6 were employed in the two learning tasks of the present study. The stimuli were presented by Carousel projector and rear projected through the screen described in Study 6. As projected on the screen the size of the stimuli was as described in Study 6. The subject viewed the screen from a distance of three feet while the experimenter sat 5 feet in front and to the right of the subject, controlling the projector through a standard remote control.

Procedure. The subjects were individually tested in two sessions separated by one to one and a half weeks. In the first session the classification tasks were given as in Study 5. At the beginning of the second session subjects were introduced to the apparatus as in Study 6 and given the following instructions:

> I'm going to show you *four* pictures one at a time. These pictures are just like the pictures I showed you last time. But this time *each picture has a name*. There are four pictures and four names. The names are: Bert, Bill, Ben and Brian. Do you think you can remember those names? What were the names again?....The game is to learn which picture is called *Bert*, which one is called *Ben*, which one is called *Brian*, and which one is called *Bill*.
>
> I will show you the pictures one at a time, and each time I want you to tell me the *name* of the picture. I will tell

you if you're right or wrong. We will keep playing the game until you're right all the time. You will have to guess the names to start with.

The experimenter then showed the subject the first stimulus and the subject responded with one of the four names. If he was correct this was confirmed. The experimenter said "Good boy/girl, that's Brian/Bert/Ben/Bill". If the subject was incorrect the experimenter said "No, that's Brian/Bert/Ben/Bill".

During the first learning task the subject was rewarded for calling the red triangle Brian, the blue rectangle Bill, the red rectangle Ben, and the blue triangle Bert. During the second learning task the subject was rewarded for calling the red triangle Bill, the blue rectangle Brian, the red rectangle Bert, and the blue triangle Ben. The order of stimulus presentation was as described in Appendix B for Study 3 (with 4 = triangle and 8 = rectangle). After 40 trials the stimuli were presented in reverse order (and so on). The inter-stimulus interval was the change-over time of the projector (about 2 seconds).

Criterion on the learning tasks was 11 successive correct responses and the reversal problem was introduced without warning. The second test session lasted for a maximum of 40 to 50 minutes with brief rest periods at 20 trial intervals.

Results

Two dependent variables were analyzed: errors and trials to criterion. Analyses of variance of both dependent variables was performed with *Classification Level* as a between subjects factor and *Learning Task* (training phase; test phase) as a within subjects factor. The analysis of

variance of the trials to criterion measure yielded a significant interaction of *Classification Level* and *Learning Task* ($F(1,16) = 6.75$ $p < 0.05$). Neither the main effect for *Classification Level* ($F(1,16) = 1.75$ N.S.) nor the main effect for *Learning Task* ($F(1,16) = 2.33$, N.S.) reached significance. From inspection of results (v. Table 18) it is clear that the new procedure succeeding in producing considerable negative transfer from first to second learning task. However, this interference was evident only in the *High* ability group!

Table 18

Means and Standard Deviations of Trials to Criterion as a Function of Classification Level and Learning Task

Classification Level	Training Task		Test Discrimination	
	Mean	S.D.	Mean	S.D.
Low	45.1	21.4	91.8	45.4
High	95.8	41.4	83.7	44.2

A similar pattern of results was found with errors to criterion as the dependent variable. The main effects for *Classification Level* and *Learning Task* were not significant ($F(1,16) = 1.96$, and $F(1,16) = 1.13$ respectively). The interaction of *Classification Level* and *Learning Task* *approached* significance ($F(1,16) = 3.14$, $.10 > p > .05$).

Discussion

The results are consistent with the idea that not only did the High ability group learn the initial stimulus-response associations more quickly than the Low ability group, but that these associations were more firmly established and therefore more persistent. By implication, the superior efficiency in stimulus-response learning of the High ability group was not matched by superior efficiency in extinguishing previously formed associations. Since this symmetry in learning and extinction rates was a key assumption of the representation hypothesis, the results of the study are very damaging to this theory.

It seems that older children deal more effectively with more typical reversal shift problems *despite* the fact that they are more likely to establish more persistent cue-response associations in the training phase of the RS problem than do younger children. It seems likely that a *positive* relationship between age and proactive inhibition within the RS paradigm has not generally been evident because of the simple discrimination tasks typically employed in this paradigm. These tasks generally have only two relevant cues. Older children probably do not so much unlearn previous cue-response connections as integrate old habits and new habits into a super-ordinate structure using rules such as "Now I pick the opposite one from last time". This type of strategy probably more than counteracts the greater persistence of the stimulus-response habits from the training phase of the RS problem.

If the ability to represent cues does bring about the developmental trends in the RS problem then this is *not* through increased efficiency in extinguishing interfering

cue-response habits (the representation hypothesis). It may be because representation of the relevant cues causes the child to focus more attention on the relevant dimensions vis à vis the irrelevant dimensions during dimensions during discrimination learning (a version of the Kendlers' theory). Alternatively it may be because representation of the relevant cues causes the child to respond mainly on the basis of abstracted dimensions rather than to stimulus patterns or gestalts (a version of the Tighes' theory).

Summary

In Chapters 11 and 12, the writer formulated an explanation of developmental trends in speed of reversal shifting. This explanation depended on a number of interrelated proposition sets:

(a) In discrimination problems the child's ability to switch (learn and unlearn) *cue-response associations* improves more rapidly as a function of age than does his ability to switch *cue selection habits*.

(b) In older children the cue selection response is more likely than in younger children to involve the child thinking about or *representing* the relevant cues, (and possibly the relevant dimension) in discrimination tasks. In addition, with increasing age, such cue representations as the child does employ are more likely to be overlearned and *well integrated*. At any given age the probability that the child represents *the stimuli that control the cue selection response* in a discrimination task is markedly less than the probability that the cue selection response itself involves the cue and dimension *representations* mentioned above. The efficiency with which a child performs during the cue-response association stage of discrimination learning depends directly on the probability that he has represented the relevant stimuli during the cue selection stage and on the degree to which these representations are overlearned and well integrated.

(c) Given that a subject has represented lists of the relevant cues and responses in a discrimination task,

> he uses these lists of representations to *orient* himself to the task at hand; to *rehearse* the appropriate correspondences between stimuli and responses both during learning trials and inter-trial intervals; and to *infer* some stimulus-response correspondences on the basis of knowledge of other such correspondences. All these processes directly facilitate cue-response learning but do not directly influence cue selection learning. This is so since the cue representations involved in these processes are the *products* of a cue selection response, and obviously may not directly affect processes preceding them in time.

The above three sets of propositions are termed *the extinction rate theory*, the *representation hypothesis* and *representational processes* respectively. The extinction rate theory proposed age related changes in the relativity of learning rates for two types of learning. The representation hypothesis together with the representational processes outlined above were meant to provide a detailed description of the psychological mechanisms underlying these changes.

The aim of the research reported in Chapters 13, 14 and 15 was, naturally, to attempt to establish the validity or otherwise of the above theory. Two general strategies of validation were available. The first - and seemingly the most logical - was to determine whether or not the extinction rate theory itself was valid before assessing the validity of specific mechanisms proposed to explain how that theory worked. However, the direct test of extinction rate theory

proposed in Chapter 11 (pp. 107 - 110) was seen to be limited to the earlier range of the developmental trends predicted by the extinction rate theory. It was true that performance during the third phase of the Goodwin and Lawrence (1955) experimental paradigm would differentiate a group of subjects whose *cue selection habit* extinguished more quickly than *cue-response associations* from a group for whom *cue-response* associations extinguished more quickly than the *cue selection* habit. However, the extinction rate theory would predict that a group for whom the habits extinguished at the same rate would perform in the same fashion as the second of the above-mentioned groups. Further, groups that varied in the *degree* to which the cue-response associations extinguished more rapidly than cue selection habits would not be differentiated on performance measures in the third phase of the Goodwin and Lawrence paradigm. Since the extinction rate theory predicted that performance on RS-EDS comparisons and OS paradigms would be affected by the variation in relativity of extinction rates just described, it was apparent that the proposed direct test of the extinction rate theory would be insensitive to predicted developmental trends beyond the age of (approximately) six years.

The strategy adopted in the present investigation was to relate directly a child's representational ability (as measured by the stick figure recognition test in Study 4, and the set of classification tasks in Studies 5, 6, and 7) to his RS performance. More specifically it was predicted that children whose ability to represent a set of stimuli was high would outperform children of low representational ability in the test phase of an RS in which those stimuli were

relevant cues. Moreover that difference in performance would be greater than any difference found between the two ability groups on the training phase of the RS.

The above predictions were derived from the representation hypothesis (and therefore depended on the validity of the extinction rate theory) but they did not depend on the validity of the *representational processes* previously suggested (v. Chapter 14 pp. 160-161). If the predicted interaction between *Representational Ability* (High, Low) and *Phase of RS* (Training, Test) in determining learning performance had been found, the effect of representational ability need not have depended on the three mechanisms described under representational processes - although alternatives do not readily spring to mind. It was proposed, therefore, that if the predicted interaction was found, and the representation hypothesis were thus supported, further experiments would be performed in which variables predicted to affect the efficiency of the *representational processes* would be manipulated. If, for example, the degree of interaction between *Representational Ability* and *Phase of RS* had been found to be positively related to the inter-trial interval employed in the task, this finding would have supported the proposition that a rehearsal mechanism mediated this interaction (v. Chapter 12 pp. 129-131). Such an experiment would have provided support for all three levels of the general theory; the extinction rate theory, the representation hypothesis, and one of the representational processes. In fact the research programme became a series of attempts to establish the joint validity

of the *extinction rate theory* and the *representation hypothesis:* to find the expected *Representational Ability* X RS *Training Phase* interaction.

The results of Study 4 suggested that the stick figure recognition test measured the *rate* at which children formed representations of this class of stimuli and, consequently, their rate of forming *cue selection* habits in discrimination problems involving these figures as relevant cues. Studies 1 and 2 therefore, together with Study 4, indicated that, at least for certain classes of cues, the rate of learning cue selection habits increases markedly with increasing age. Of course, this conclusion did not conflict with the extinction rate theory so long as it was not shown that the age-related increase in cue selection learning rate equalled or exceeded any age-related increase in the rate of forming cue-response associations. However, if the representation hypothesis was to account for the findings of Study 4, it had to be assumed that the asymptotic strength of the stick figure representations (however measured), was at best, only moderately correlated with the rate of forming such representations (as measured by the recognition test) in the sample of children tested (v. Chapter 14 pp. 185-187). In addition it had to be concluded from Study 4 that only a subset of tests of representation ability (if any) would be related to RS performance in the manner predicted by the representation hypothesis.

Study 5 was (at least potentially) a most powerful and direct test of the representation hypothesis for one set of stimuli. This was so because the nature of the stimulus materials (colour-form compounds) and the tasks (PAL.s)

involved in the RS enabled independent, direct estimates to be made of the effects of representational ability (in this case Classification Level) on *cue selection learning* and *overall learning performance*. In turn, this enabled *two* independent tests of the representation hypothesis within the one experimental paradigm.

If the rationale behind the analysis of error type (shape confusions, colour confusions and "random" errors) was accepted (v. Chapter 15 pp. 211-214) it could be concluded that groups of children at different levels of classification ability did not differ significantly in cue selection learning while differing markedly in rate of forming cue-response associations. This was precisely the pattern of results expected by the representation hypothesis, and therefore this test supported the hypothesis. However, the second test offered by the study did not support the representation hypothesis: the predicted interaction of *Classification Ability* (Low, Transitional, High) and *Learning Task* (First PAL, Second PAL) in determining learning performance did not appear. It was pointed out that the predicted interaction of Representation Ability and Learning Task in affecting learning performance depended on a certain minimum amount of proactive interference from first to second learning task. It was argued that certain procedural details of Study 5 had resulted in this boundary condition for the prediction being violated (v. Chapter 15 pp. 215-218). Study 6 was an attempt to increase the level of interference between the two phases of the RS problem (by having the subjects complete the two learning tasks within the one test session). No increase in the level of interference resulted from this procedural variation Variation in the inter-item interval (hypothesized to affect

the opportunity for rehearsal and therefore to directly influence the superiority of the High ability group) did not significantly affect learning performance in this study. In Study 7 the modality of *response* presentation was changed (from pictorial to acoustic) and the responses themselves were made more confusable. These changes in the nature of the task (the relevant cues however remained the same as in Studies 5 and 6) did result in increased interference from training to test discrimination of the RS problem, but only for the *High* ability group. This result was in direct contrast to the expectation based on the *extinction rate theory* and the *representation hypothesis* (i.e. significantly less interference for the High ability group).

It would perhaps be appropriate at this stage to review the general implications of the reported studies. The significant relationships found between representation abilities and learning performances in Studies 4, 5, 6 and 7 (together with *age trends* demonstrated for these same abilities in Studies 1 and 2 and by other investigators - notably Inhelder and Piaget, 1964) do indicate that older children are more likely than younger children to effectively *represent* the relevant cues in discrimination tasks (a cue representation being defined as at the beginning of Chapter 14). This is at least partial confirmation of the *representation hypothesis*. Studies 4 and 5 indicate that this age related increment in the use of cue representation may (Study 4) or may not (Study 5) produce more efficient *cue selection* learning in the discrimination task. It rather seems to depend on how representation ability is assessed

and what stimulus class is being represented by the child. If the stimuli are novel and/or stimulus exposures during the representation test are brief then this test is likely to measure the *rate* at which the child can encode the particular stimuli employed in the test. In turn this *encoding rate* ability is likely to be reflected in the efficiency of the stimulus encoding phase (cue selection learning) of a discrimination problem in which exemplars of the stimulus class employed in representation test are the relevant cues. On the other hand, if the stimuli have been previously exposed to the subjects (either in the experimental situation or outside the laboratory) and no time limit is placed on stimulus exposures during the representation test, then scores on such a test are unlikely to reflect the *rate* of encoding stimuli. Consequently this second type of representation test will not be related to the stimulus encoding phase of a discrimination problem in which the relevant cues are drawn from the stimulus pool of the test. This latter type of representation test may well assess the child's ability to sustain the cue representations within a working short term memory. This ability should be related to the subjects' capacity to "operate" with the cues in solving problems - for example test performance should predict ability to rehearse a set of stimulus-response associations involving the cues. It follows that such a representation test should be strongly related to the *cue-response association* phase of a discrimination task involving the stimuli of that test. Study 5 seems to demonstrate just such a relationship.

As has been previously pointed out, none of these conclusions are particularly damaging to the representation bypothesis. This hypothesis (in conjunction with the

extinction rate theory) would, however, predict that for a particular class of stimuli a representation test of the *second* type would show a greater average increment in performance over a given age range than would a representation test of the *first* type. Such a prediction is clearly open to empirical test. A general conclusion is that rather more care must be taken in designing a test of representation ability than was originally anticipated - if the predictions of the representation hypothesis are to be fairly tested. Representational ability is clearly not uni-dimensional. At least two facets of this ability have been isolated in the present series of studies.

Assuming the validity of the analysis thus far, it must be admitted that the representation hypothesis cannot explain away the results of Study 7. There was evidence from the error-type analysis of Study 5 that the representation ability assessed by the Piagetian classification tests was strongly related to the *stimulus-response association* phase of learning tasks in which form-colour compounds were the relevant stimuli. There was evidence from the same source that the performance on the tests was *unrelated* to the *stimulus encoding phase* of such discrimination learning. The responses and procedures employed in both learning tasks of the RS problem of Study 7 were such as to ensure considerable proactive interference within the RS paradigm. It must be concluded that Study 7 satisfied all the boundary conditions under which the *Classification Level* x *Learning Task* interaction predicted by the representation hypothesis should occur. In fact, of course, the two factors did interact in affecting learning performance, but the direction of the effect was the

opposite to that predicted. Apparently the superior stimulus-response association learning of the High ability group (exhibited in the first learning task) was not matched by a superior capacity to *unlearn* the first task associations so established. As a consequence the stimulus-response habits of the High ability group, apparently not only acquired more quickly but *established more firmly* than the stimulus-response habits of the Low ability group, interfered more with this group's learning of the second task than the corresponding habits of the Low ability group interfered with the latter group's performance in the second task of the RS.

The apparent lack of symmetry between learning rate and extinction rate of cue-response habits revealed an unexpected flaw in the representation hypothesis. It had been assumed that the extinction of cue-response habits depended on much the same processes as were involved in the acquisition of these habits. If an increment in representation ability produced an improvement in cue-response learning then it was expected that the extinction process would also be facilitated. This assumption seemed plausible. The equivalence of learning and extinction rates was a simplifying assumption often made by theorists proposing two stage stochastic models of discrimination learning (e.g. Zeaman and House, 1963). Study 7 however indicated that learning and extinction must be considered as somewhat distinct processes, at least in the discrimination learning of 8 year old children.

The general implications of Study 7 are straightforward. If the extinction rate theory is correct, the developmental trends in relative extinction rates of cue selection habits and cue-response associations *cannot* be mediated by an

increasing likelihood of cue representation bringing about more efficient cue-response learning - as suggested by the representation hypothesis.

However it may yet be that cue representation is a precondition for rapid switching of cue-response associations within an RS problem. If it is, then the rapid switching of cue-response habits apparently does not involve the actual extinction of the initial stimulus-response associations. There is no evidence that representation ability is positively related to the *extinction* rate of cue-response associations - on the contrary with the four stimulus-response associations employed in Study 7 there was a significant negative relationship between representational ability and extinction rate of cue-response habits. As was previously argued, it is possible that rapid reversal shifting depends on a strategy of "doing the opposite of what was done last time". Possibly such a strategy demands that "what was done last time" be *represented* by children as a list of cue-response associations. If such an assumption is made then it follows that representation ability would be related to efficient RS performance. The results of Study 7 might be explained by assuming that the *strategy of doing the opposite* becomes unwieldy and therefore inapplicable if there are more than *two* relevant cues in the training and test discriminations of the RS problem (there were, of course, four relevant cues in Studies 5, 6 and 7). In other words subjects with an ability to represent the cues in discrimination tasks should only show efficient performance in the test phase of an RS problem if the strategy of *doing the opposite* doesn't impose too heavy a load on the subject's working short term memory.

One conclusion of this line of reasoning is, therefore, that developmental trends in the RS problem will be restricted to paradigms employing the usual "two cue" discrimination tasks (simultaneous or successive discriminations with two cues within the relevant dimension). Such a prediction might well be tested. A version of the OS paradigm employing successive discriminations with *four* cues within both the relevant and irrelevant dimensions should not show the usual age-related increase in proportion of optional reversal shifts.

In the above discussion a fine distinction was made between the *extinction* of a set of stimulus-response associations and the *switching* of these cue-response habits. *Switching* involves the child applying a symbolic transformation previously learned (the concept of doing things *the other way* around) to a learned list of stimulus-response associations. By its nature the transformation is only applicable if there are *two* ways of responding in the learning situation. The child employing the transformation does not so much unlearn previous stimulus-response habits. He rather adds a rider to a previously formed list of associations in such a way as to indicate how a second list of cue-response associations may be formed. In this way the cue-response learning of the training discrimination (as well as the cue selection learning of that phase) is integrated into the learning of the *test* discrimination and is therefore the basis of positive transfer.

If the extinction rate hypothesis is reformulated in terms of age-related increases in the rate of *switching* cue-response habits (relative to the rate of switching cue selection habits) - and it is understood that developments in switching rate will depend on task and subject parameters affecting the

utility of the strategy of doing the opposite - then a position similar to the one with which the writer commenced this series of studies remains tenable. Of course a rather different mechanism underlying rapid response substitution (switching) has now been proposed. To the reader a little disturbed by the apparent ability of the writer's theory to absorb apparently disastrous results it can only be pointed out that changes *have* been forced in the theory by the results of Study 7. Further, the *switching* hypothesis is testable in the manner outlined above. The experiment suggested in the above discussion tests the switching hypothesis without any auxiliary assumption being made about the role of representation ability in rapid switching. However the implication is clear that future attempts to relate representation ability to ease of reversal shifting should vary the number of relevant cues in the discrimination tasks. The present (modified) theory suggests that this is a critical parameter of the learning tasks.

Two theories that might deal with the present results have so far been briefly described. Firstly it is possible that the *extinction rate* theory as outlined earlier in the thesis is basically correct but that the age-related trends in extinction rates of cue-response associations and cue selection habits are *not* related to representation ability. The second possibility is that developmental trends in the RS problem reflect increasing use of the strategy of "doing the opposite". This strategy may or may not depend on representation ability. The present theory assumes that it does.

There are further possibilities. *If* the demonstrable

age-related increase in the efficiency of cue representation in discrimination problems *is* implicated in developmental trends in the RS paradigm cue representation may well have its effect in the more usual RS problem by focussing the child's attention more strongly on the relevant cues and inhibiting attention to the irrelevant cues in the discrimination task (a version of the Kendlers' theory). Alternatively cue representation may produce developmental trends in the RS problem by inhibiting attention to cue patterns or compounds (a version of the Tighes' theory). This second mechanism would only produce an effect if the usual type of discrimination tasks (i.e. relevant cues taken from a single dimension with at least one irrelevant dimension) were employed in the RS problem.

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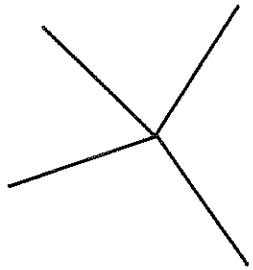
APPENDIX A

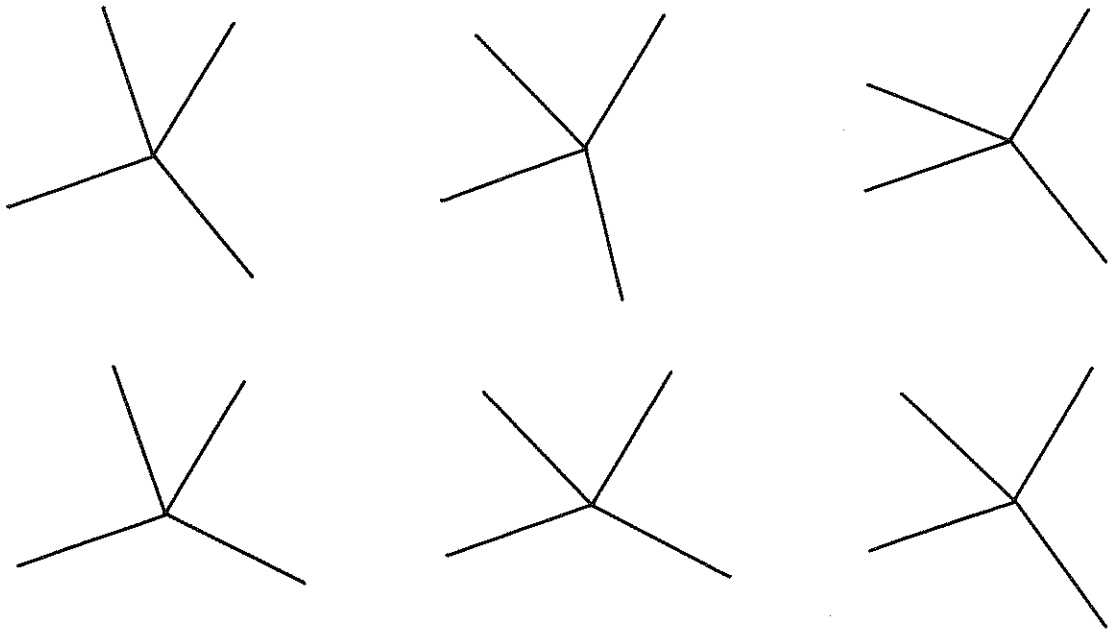
Stimulus	Angle between upper arms	Angle between upper right and lower right arms	Angle between upper right and lower left arms
1	100°	85°	140°
2	100°	110°	"
3	100°	135°	"
4	75°	85°	"
5	78°	113°	"
6	75°	135°	"
7	50°	85°	"
8	50°	110°	"
9	53°	135°	"

Items of the Recognition Test (Test stimuli placed above the corresponding recognition sets.)

ITEM 1

ITEM 2





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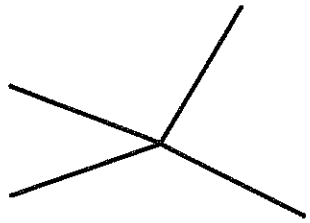

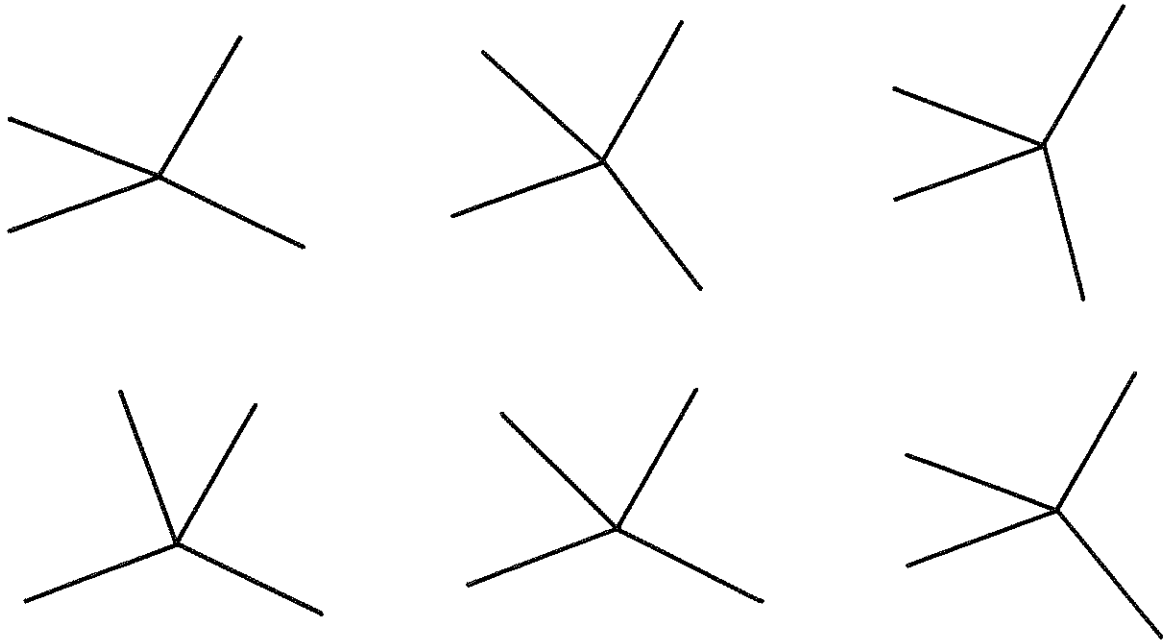

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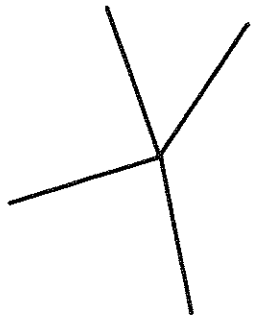

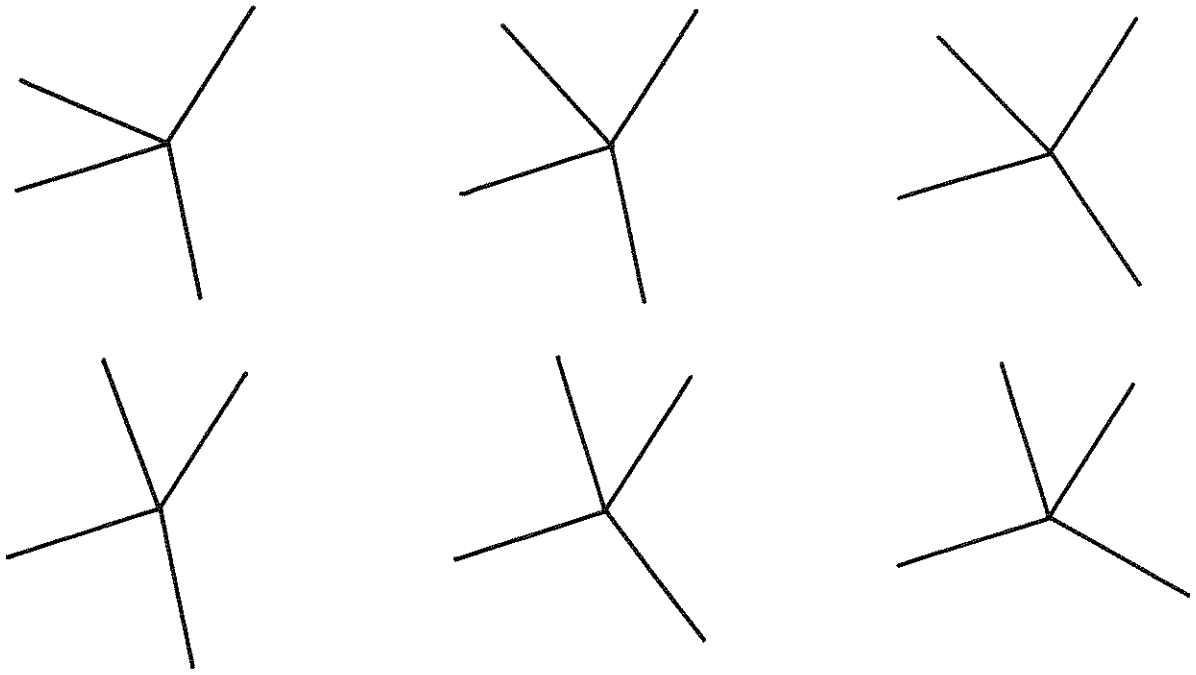

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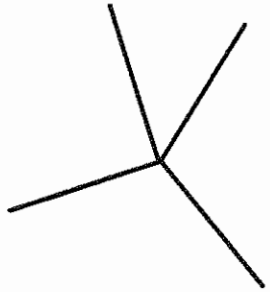

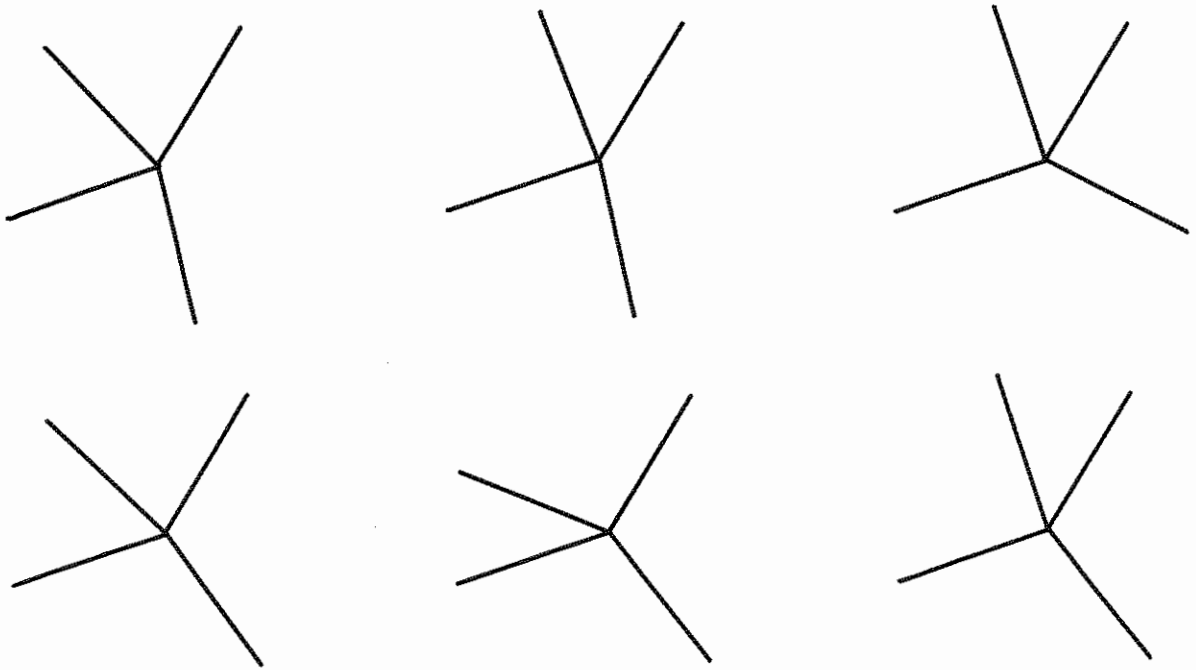

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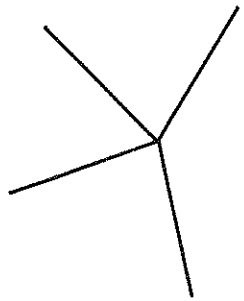

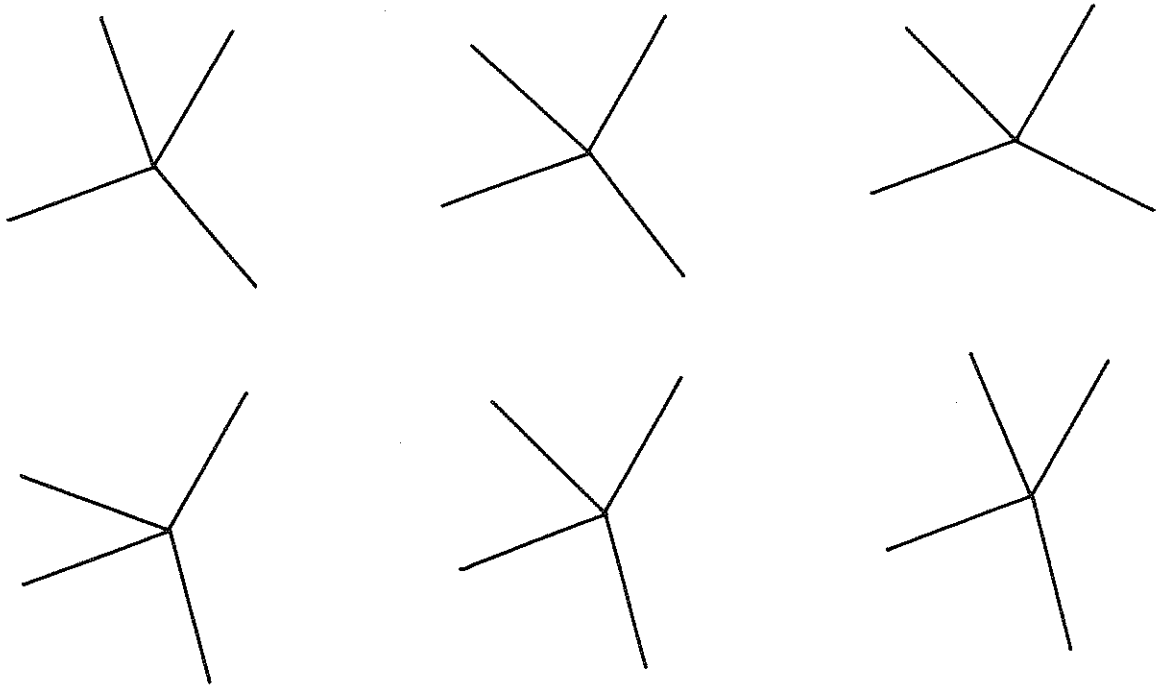

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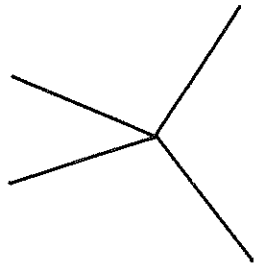

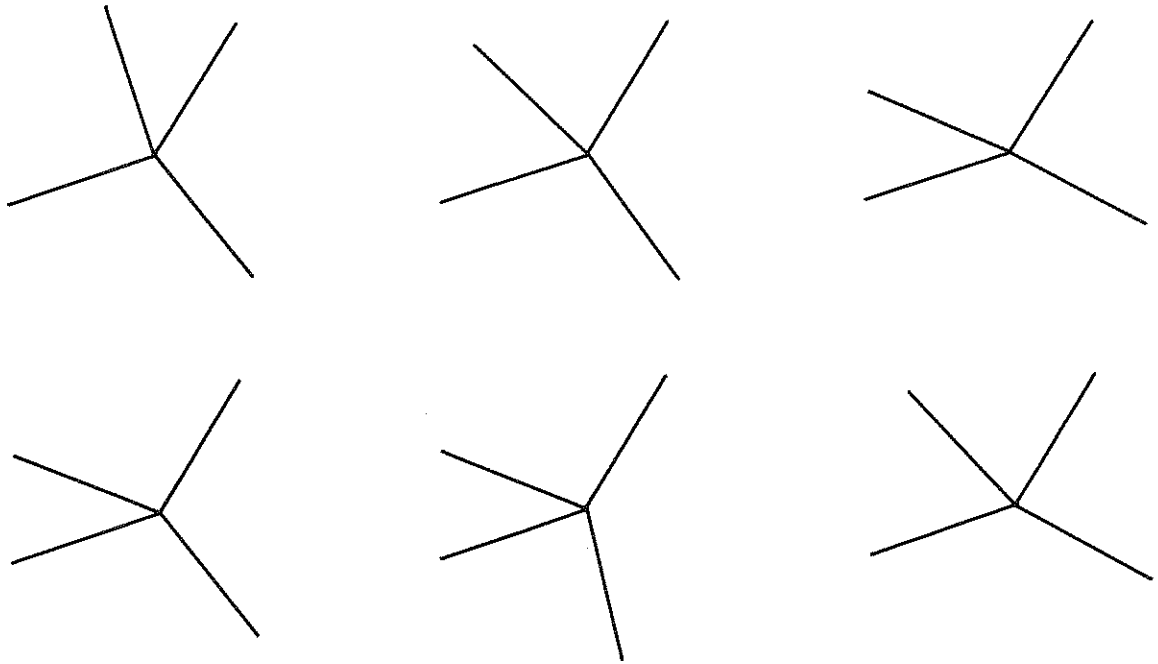

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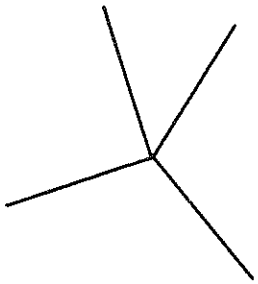

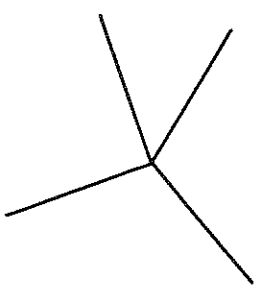

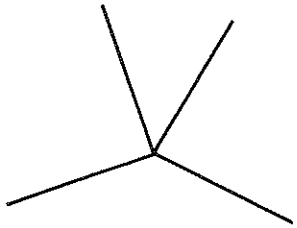

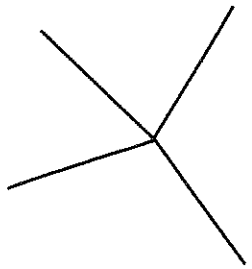

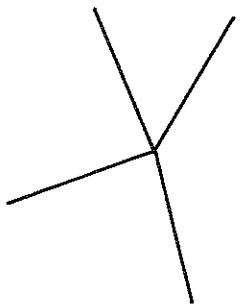

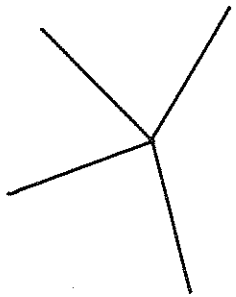

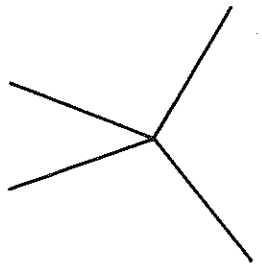

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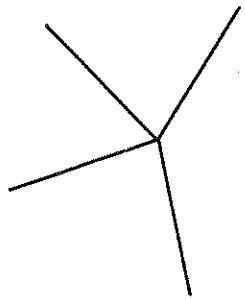

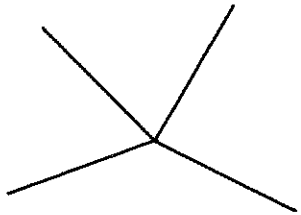

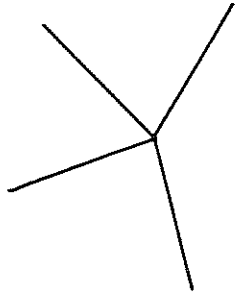

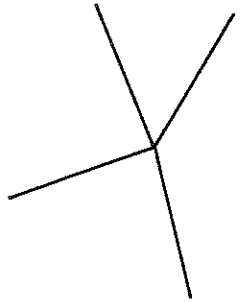

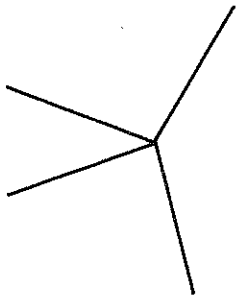

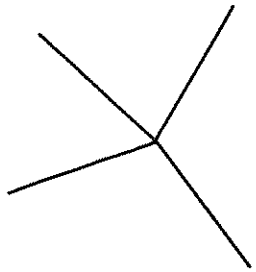

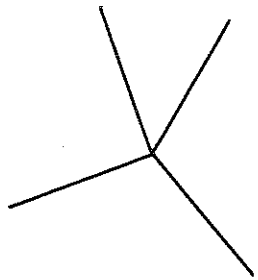

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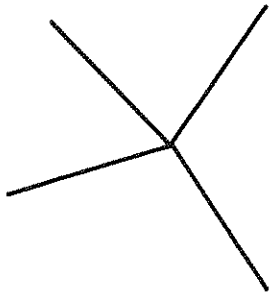

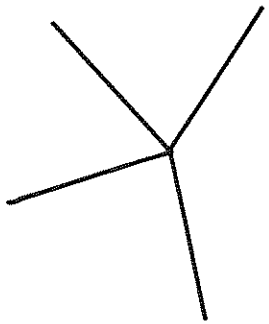

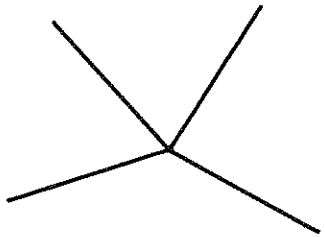

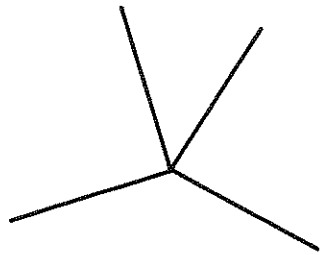

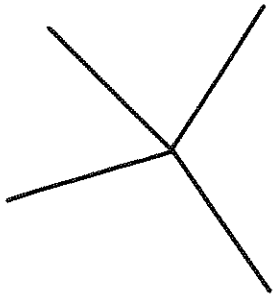

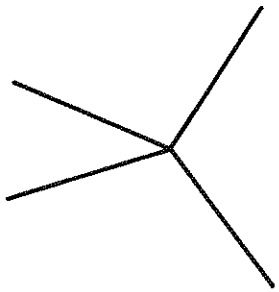

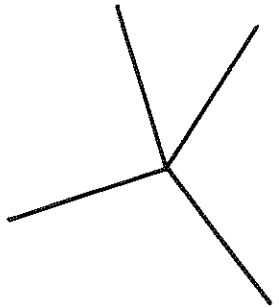

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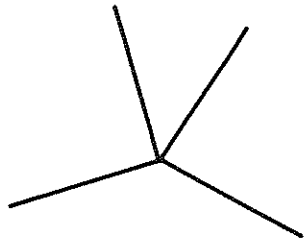

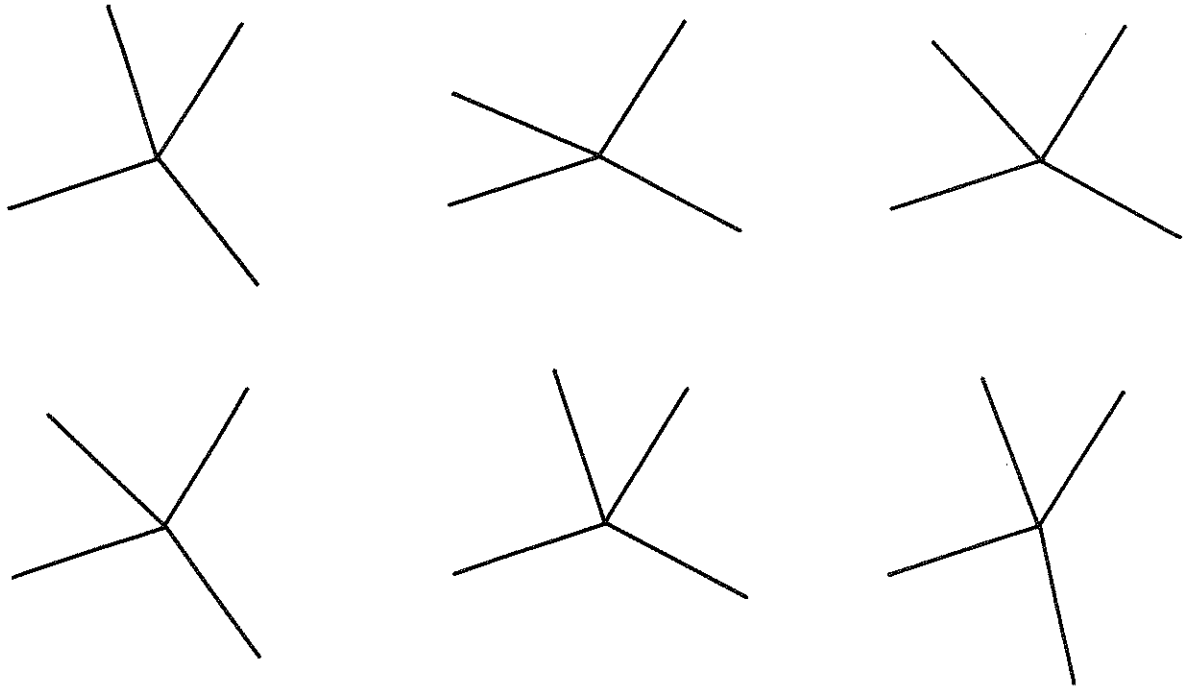

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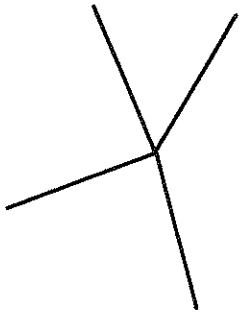

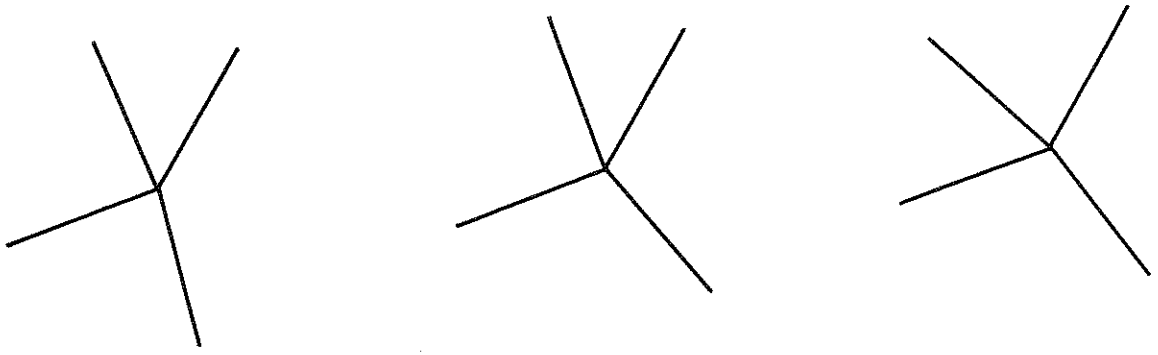

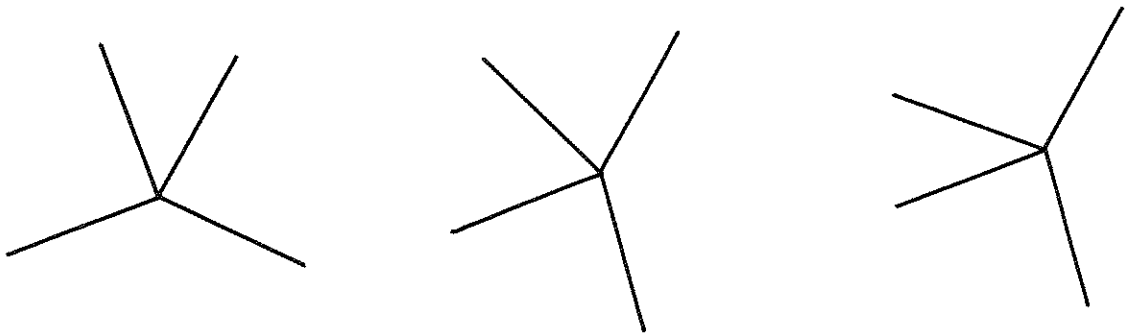

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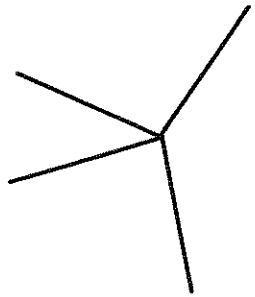
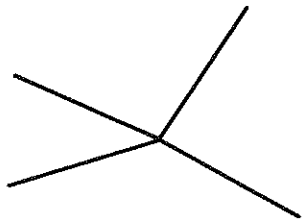
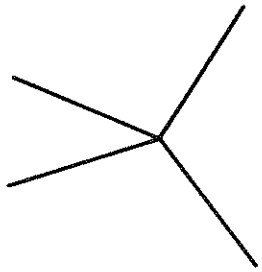
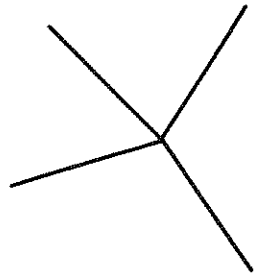
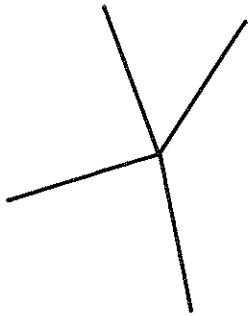
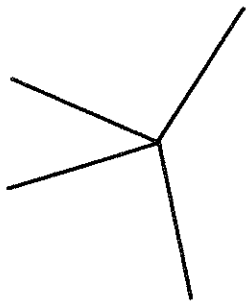


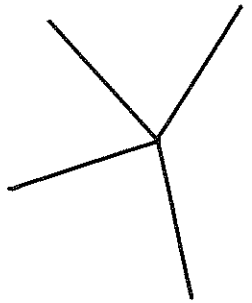




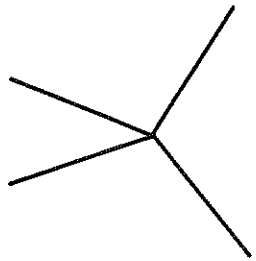


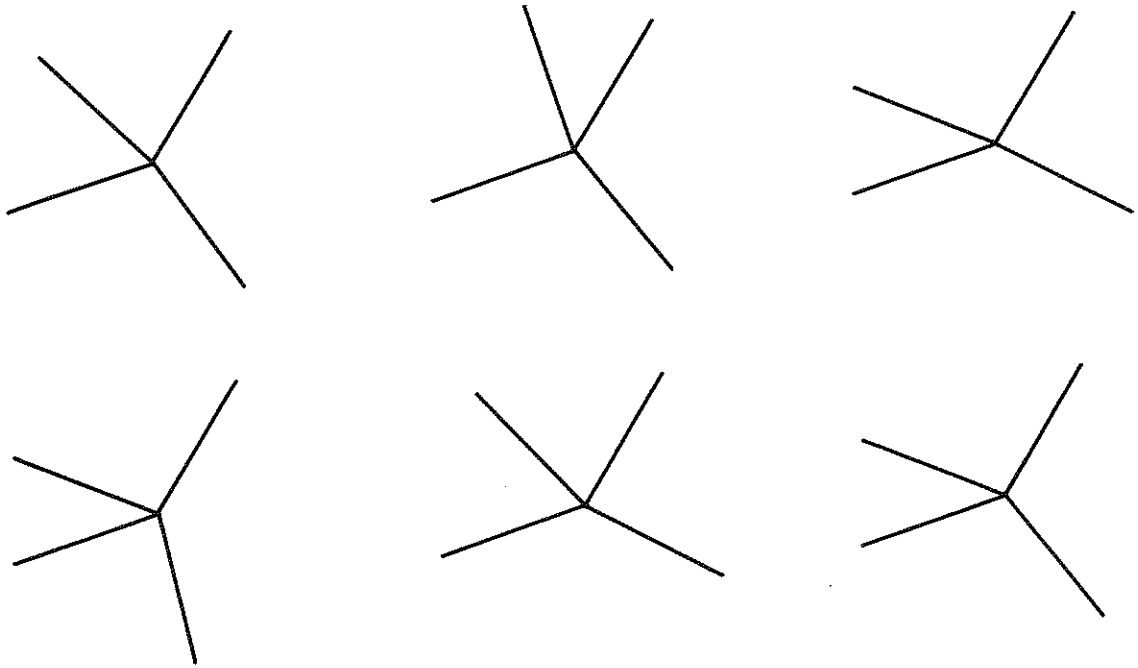






ITEM 18





APPENDIX B

Study 3. Order of presentation of discriminanda (the numbers refer to the shape of the stimuli as in Figure 1; the subscript R indicates a red stimulus while the subscript B indicates a blue stimulus):

4_R 8_B 8_R 4_R 8_B 4_B 4_B 8_R 8_B 8_R

4_R 8_R 4_B 4_B 8_B 4_R 4_R 4_B 8_R 8_B

4_B 4_R 8_R 8_R 4_B 8_B 4_R 8_B 8_R 4_B

4_B 4_R 8_B 4_B 4_R 8_R 8_R 8_B 4_R 8_B

Study 4. Order of presentation of discriminanda (the numbers refer to stimuli from Figure 1):

4 7 8 8 4 4 7 8 7 7 4 8 7 4 8 8 7 8 4 7

7 4 8 7 7 4 7 7 8 4 8 7 4 7 8 8 7 4 4 8.

Study 5. Orders of presentation of the 4 stimulus-response pairs in first *and* second PAL (each pair is indicated by its stimulus:

BT = blue triangle, BR = blue rectangle, RT = red triangle, and RR = red rectangle. When the five orders had been employed once as presented below, the order series (1 to 4) was recycled.)

1. RR, BT, RT, BR
2. RT, BR, BT, RR
3. BR, RR, BT, RT
4. RR, RT, BR, BT

The orders of presenting test stimuli in Study 5 were as follows:

1. RT, BT, BR, RR
2. RR, BR, RT, BT
3. BR, BT, RR, RT
4. BR, RT, BT, RR
5. BT, RR, BR, RT

After the 5 orders of testing stimuli were presented as above, they were repeated in the sequence: 2, 3, 4, 1, 5. The two sets of presentation orders were then repeated in the above sequence.

APPENDIX C

Raw Data

Study 1.

C.A. (Mths)	I.Q.	Recognition Test Score	Proportion 2s errors of Total Errors.	Proportion 2c errors of Total Errors	Proportion 2s errors of Type 2 Errors
62	111	2	.44	.19	.7
79	104	2	.3	.12	.7
81	117	3	.2	.13	.6
71	87	3	.26	.13	.66
66	109	3	.13	.13	.5
70	99	3	.13	0	1.0
69	106	4	.14	0	1.0
72	92	4	.28	.14	.66
71	124	4	.43	0	1.0
65	120	4	.07	.14	.33
64	108	4	.21	.21	.5
72	106	4	.28	.21	.56
76	121	4	.07	.14	.33
117	118	4	0	.14	0
114	110	4	.14	.14	.5
70	100	5	.23	.31	.42
61	113	5	.08	.16	.33
69	106	5	.23	.16	.6
75	112	5	0	.07	0
78	100	5	.23	.08	.75
81	114	5	.16	.08	.66
86	105	5	.08	.16	.33
94	103	5	.08	.23	.25

Study 1. (Continued.)

C.A. (Mths.)	I.Q.	Recognition Test Score	Proportion 2s errors of Total Errors.	Proportion 2c errors of total Errors.	Proportion 2s errors of Type 2 Errors
120	85	5	0	.16	0
100	102	5	.15	.08	.66
105	114	5	.08	0	1.00
70	91	6	.42	.17	.71
84	96	6	.08	.08	.5
77	109	6	0	.17	0
77	99	6	.08	.17	.33
80	96	6	0	.25	0
78	94	6	.17	0	1.0
94	112	6	0	.25	0
86	107	6	0	0	
104	93	6	0	.17	0
101	124	6	.08	.17	.33
67	103	7	.09	0	1.0
70	91	7	0	.18	0
81	117	7	.18	.18	.5
82	110	7	.09	.27	.25
94	109	7	.27	0	1.0
80	119	7	.09	.27	.25
95	126	7	0	0	
93	87	7	0	.09	0
104	112	7	.09	.27	.25
72	101	8	0	.3	0
103	94	8	.1	0	1.0
78	105	8	.2	.3	.4

Study 1 (Continued.)

C.A. (Mths)	I.Q.	Recognition Test Score.	Proportion 2s errors of Total Errors	Proportion 2c errors of Total Errors	Proportion 2s errors of Type 2 Errors
90	102	8	.1	0	1.0
88	114	8	.1	.2	.33
93	88	8	.2	.1	.66
90	117	8	.1	.1	.5
94	109	8	0	.3	0
93	99	8	0	0	
118	95	8	.1	.1	.5
113	111	8	0	0	
115	104	8	0	.5	0
117	93	8	0	0	
112	104	8	.1	.1	.5
116	86	8	.2	0	1.0
105	107	8	.1	.1	.5
103	99	8	.1	0	1.0
70	116	9	0	.33	0
80	93	9	0	0	
80	119	9	0	.22	0
82	106	9	.11	.11	.5
82	88	9	.11	.22	.33
80	86	9	.11	0	1.0
93	117	9	.11	.22	.33
89	98	9	.11	0	1.0
101	119	9	0	0	
104	108	9	.11	.11	.5

Study 1. (Continued).

C.A. (Mths)	I.Q.	Recognition Test Score	Proportion 2s errors of Total Errors	Proportion 2c errors of Total Errors	Proportion 2s errors of Type 2 Errors
119	94	9	0	0	
115	97	9	0	0	
105	100	9	0	.22	0
108	111	9	.44	0	1.0
80	105	10	.13	.13	.5
91	123	10	.13	0	1.0
95	91	10	0	.13	0
101	108	10	.13	0	1.0
108	111	10	0	0	
116	119	10	.13	0	1.0
113	122	10	.13	0	1.0
104	98	11	0	0	
119	105	11	0	.29	0
116	111	11	.29	0	1.0
95	97	12	0	0	
117	121	12	.17	0	1.0
104	120	12	0	.17	0
100	100	12	.17	0	1.0
120	108	13	.2	0	1.0
115	104	16	0	0	

Study 2.

Grade	Chronological Age (mths)	Mental Age (mths)	Recognition Test Score	Matching Test Score	Recognition Test First.
1	79	81	2	2	
1	72	73	1	1	
1	72	66	1	2	Yes
1	74	112	1	1	
1	82	78	3	1	
1	82	95	2	5	Yes
1	76	109	1	1	Yes
1	82	80	1	3	Yes
1	76	73	3	4	Yes
1	83	90	3	3	
1	78	109	3	4	Yes
1	82	95	1	3	
1	79	90	3	4	
1	81	85	4	1	
1	77	80	0	4	Yes
1	73	85	2	1	Yes
1	76	97	1	1	Yes
1	72	66	2	2	
1	80	84	0	3	Yes
1	79	75	4	3	
2	94	77	2	2	Yes
2	94	95	3	5	Yes
2	95	82	3	4	Yes
2	95	77	2	2	
2	93	105	3	6	Yes

Study 2 (Continued).

Grade	Chronological Age (mths)	Mental Age (mths)	Recognition Test Score.	Matching Test Score	Recognition Test First.
2	93	80	4	3	
2	85	120	4	5	
2	84	72	2	3	
2	91	78	1	5	
2	91	100	2	3	
2	84	75	3	4	Yes
2	88	88	2	5	
2	91	92	3	6	Yes
2	86	84	2	0	Yes
2	84	74	1	1	
2	85	78	1	5	Yes
2	89	112	2	4	
2	86	85	4	4	
2	86	85	1	3	Yes
2	94	84	0	3	Yes
2	92	78	4	4	
3	105	88	1	6	Yes
3	98	112	3	5	
3	104	97	3	5	
3	107	87	2	5	Yes
3	106	84	5	6	
3	99	85	5	5	Yes
3	102	92	5	5	Yes
3	107	120	3	6	
3	107	105	3	4	

Study 2 (Continued)

Grade	Chrono-logical Age (Mths)	Mental Age (mths)	Recognition Test Score.	Matching Test Score	Recognition Test First.
3	107	100	3	6	Yes
3	99	142	3	4	
3	104	147	6	6	
3	105	105	4	5	
3	102	125	5	6	Yes
3	99	88	3	4	
3	104	74	2	4	Yes
3	97	125	1	2	Yes
3	102	109	2	0	Yes
4	118	133	4	6	Yes
4	115	92	4	4	
4	119	90	4	6	Yes
4	116	97	5	3	
4	116	125	1	6	Yes
4	113	125	4	6	
4	116	80	1	5	Yes
4	116	102	3	5	
4	110	112	2	4	
4	117	116	3	4	
4	116	90	2	5	
4	113	112	4	6	Yes
4	115	129	2	5	Yes
4	116	97	1	4	Yes
4	115	129	5	4	
4	113	116	2	5	Yes

Study 3.

C.A. (Mths)	I.Q.	Recognition Test Score.	Original Learning		Reversal	
			Errors	Trials to Criterion	Errors	Trials Criteri
88	100	8	77	160		
95	97	7	7	15	1	1
84	96	4	16	30	3	5
82	100	6	17	51	3	3
88	92	7	8	22	3	8
84	98	8	30	51	14	22
89	91	8	7	10	0	0
91	96	8	29	61	0	0
92	100	8	1	3	2	2
90	97	7	37	76	0	0
78	94	2	27	60	5	26
86	90	5	5	10	27	55
90	98	5	8	20	25	37
90	98	6	10	43	11	31
89	98	5	79	147	0	0
88	95	9	3	7	3	11
84	96	9	15	29	2	2
83	96	10	26	55	2	4
79	99	9	29	71	26	55
88	92	9	23	48	9	17
90	94	9	32	69	3	10
100	97	13	31	60	14	31
86	101	7	4	13	1	6
84	101	7	18	31	3	3
101	101	4	16	27	3	8
89	101	12	14	28	1	1
89	101	9	13	20	8	25

Study 3 (Continued).

C.A. (Mths)	I.Q.	Recognition Test Score.	Original Learning		Reversal	
			Errors	Trials to Criterion	Errors	Trials Criteri
87	101	8	1	3	13	41
84	115	5	1	3	17	37
79	103	6	2	7	4	7
85	112	7	1	3	5	19
84	104	6	16	41	5	7
82	112	5	2	6	9	21
92	118	7	11	29	1	1
101	128	6	19	44	5	11
82	116	5	7	19	6	43
82	116	6	37	63	0	0
83	105	7	49	108	39	77
90	102	12	9	20	1	9
92	111	11	1	3	2	2
85	106	9	1	3	1	1
89	122	11	17	28	2	2
88	110	9	4	17	0	0
82	102	9	4	17	6	8
98	104	12	6	18	1	7
91	110	9	1	3	14	59
84	104	10	51	108	3	10
85	106	9	52	119	25	44
85	110	8	3	9	3	6
98	111	8	11	30	1	1
98	102	8	27	58	6	23
89	115	8	42	136	13	33
95	111	5	10	34	2	2

Study 4.

C.A. (Mths)	I.Q.	Recognition Score			Original Learning		Reversal	
		Total	Stimuli 7 4 8	6 3 2	Errors	Trials to Criterion	Errors	Trials to Criterion
88	107	10	4	2	11	35	6	12
85	100	10	4	3	15	51	8	31
92	105	10	4	3	49	105	4	21
84	130	10	5	2	7	24	26	64
84	119	11	4	4	34	82	6	27
83	99	11	3	2	6	24	8	30
90	104	11	3	3	49	100	25	75
84	105	11	5	2	7	43	15	25
87	111	11	5	2	38	114	4	20
89	96	11	5	3	19	51	8	39
91	123	12	4	3	8	56	6	33
90	100	12	5	3	18	59	7	26
91	117	12	4	4	15	57	3	17
89	107	12	5	3	26	72	3	22
82	110	13	5	2	42	91	9	39
89	90	14	5	3	14	49	10	40
86	119	15	5	4	9	30	6	29
85	100	13	5	3	13	36	7	26
82	102	9	2	3	61	147	44	149
95	93	9	4	4	65	130	4	30
85	114	9	4	2	23	70	6	22
90	85	9	3	3	39	96	9	36
83	106	9	4	2	12	40	12	30
83	114	7	2	2	38	137	6	33
95	107	8	3	1	46	130	3	29
90	120	5	2	2	25	75	16	68
91	123	8	3	1	6	30	7	35
91	110	7	4	2	18	73	9	47
86	116	7	3	3	10	35	6	24
92	103	7	3	4	23	62	7	35
81	111	7	1	3	24	91	17	63
82	91	6	3	2	34	80	6	30

Study 4 (Continued)

C.A. (Mths)	I.Q.	Recognition Score			Original Learning		Reversal	
			Stimuli		Errors	Trials to Criterion	Errors	Trials to Criterion
		Total	7 4 8	6 3 2				
86	116	8	4	0	54	139	57	142
91	101	5	1	3	18	63	17	43
84	93	4	0	2	25	68	14	47
91	97	8	4	1	29	104	9	43
98	92	5	1	4	34	96	10	48
85	89	8	4	2	53	122	9	38
83	98	7	3	1	30	97	12	67
83	98	7	3	2	21	88	4	32
84	86	7	4	2	40	128	3	18
87	103	4	2	1	68	162		
81	104	6	3	1	46	138	8	35
Control Group								
85	115	8	4	0				
89	95	9	2	3				
83	120	5	2	2				
86	90	6	3	2				
93	106	10	5	2				
84	113	6	3	1				
91	122	9	3	4				
88	101	5	1	0				
85	104	7	1	3				
87	117	5	1	3				

Study 5.

C.A. (mths)	I.Q.	Classification N = Fail C=Correct PC=Partly Correct				PAL 1.				PAL 2			
							Errors				Errors		
		Resort	Cross Class.	Quant. Inclu.	Class Inter-sect	Trials to Criterion	Colour	Shape	Random	Trials to Criterion	Colour	Shape	Random
92	100	N	N	N	N	11	2	8	3	18	4	6	12
93	99	N	N	N	N	30	32	30	17				
96	87	N	N	N	N	15	17	1	0	11	4	3	1
94	106	N	N	N	N	9	8	2	3	21	19	7	7
87	133	N	N	N	N	14	4	8	9	16	8	13	14
86	91	N	N	N	N	16	6	16	10	12	2	6	6
90	100	N	N	N	N	4	0	1	0	13	12	7	7
96	94	N	N	N	N	15	10	5	4	10	8	1	1
87	103	N	N	N	N	11	5	2	2	17	12	4	6
93	134	N	N	N	N	9	4	4	6	12	2	2	6
95	102	N	N	N	N	17	17	4	4	8	3	1	2
95	140	N	N	N	N	14	7	6	3	11	4	8	1
88	110	N	N	N	N	5	3	1	1	13	8	4	1
91	115	N	N	N	N	8	7	0	0	7	10	1	1
96	81	N	N	N	N	8	5	1	2	5	3	0	3
83	120	N	N	N	N	13	5	8	2	21	8	12	2
98	150	N	N	N	N	20	9	20	8	26	19	20	10
96	91	N	N	PC	N	20	31	8	17				
81	102	C	C	PC	N	15	11	5	2	19	20	7	12
94	93	N	N	PC	N	9	4	3	3	9	4	8	3
96	101	C	N	C	PC	10	6	2	4	18	5	10	10

Study 5. (Continued).

C.A. (mths)	I.Q.	Classification N = Fail C=Correct PC=Partly Correct				PAL 1.				PAL 2			
							Errors				Errors		
		Resort	Cross Class.	Quant. Inclu.	Class Inter-sect	Trials to Criterion	Colour	Shape	Random	Trials to Criterion	Colour	Shape	Random
98	89	N	N	C	N	8	5	4	1	11	5	4	4
92	122	N	C	PC	PC	8	6	0	1	27	39	3	6
89	126	N	N	PC	N	14	5	6	7	20	10	12	11
92	105	C	N	N	N	5	2	2	0	15	6	7	11
95	122	N	N	PC	N	13	6	3	5	30	18	12	24
95	111	N	N	PC	PC	8	8	2	1	7	2	1	0
92	150	N	N	C	C	21	9	16	12	19	2	13	6
91	155	N	N	C	C	13	8	5	6	13	5	7	1
87	121	N	N	PC	N	13	8	7	9	22	12	17	13
83	111	C	N	N	N	13	8	7	0	5	5	0	0
81	114	N	C	PC	N	11	0	5	5	6	0	4	2
98	135	C	N	PC	N	7	2	3	1	23	15	10	19
87	115	C	C	C	PC	8	6	0	0	8	2	5	2
88	119	C	C	C	N	8	7	0	2	17	8	12	8
87	111	C	C	C	N	9	5	4	2	11	7	4	5
92	126	C	N	C	C	6	3	2	0	11	5	8	2
88	97	PC	C	C	C	8	1	5	2	4	0	1	0
86	88	C	C	C	N	4	2	1	0	9	4	0	1
92	152	C	C	C	C	7	3	3	2	10	7	8	2
82	139	C	C	C	PC	5	3	2	2	4	0	1	0
86	132	C	C	C	N	10	7	2	1	7	5	2	1
88	103	C	C	C	C	3	0	0	0	4	1	1	1

Study 5. (Continued).

C.A. (mths)	I.Q.	Classification N = Fail C=Correct PC=Partly Correct				PAL 1.				PAL 2			
		Resort	Cross Class.	Quant. Inclu.	Class Inter-sect	Trials to Criterion	Errors: Colour	Shape	Random	Trials to Criterion	Errors: Colour	Shape	Random
90	145	C	C	C	N	6	3	1	0	5	0	0	2
85	149	C	N	C	C	5	2	2	2	4	0	1	0
98	137	C	N	C	C	5	2	0	0	6	1	6	1
96	134	C	C	C	C	3	0	0	0	6	1	2	3
97	133	C	C	C	C	8	5	1	0	4	1	0	0

Study 6.

C.A. (mths)	Classification				PAL 1.		PAL 2.		Inter-trial Interval (Sec.)
	Re-sort	Cross Class	Quant Inclu.	Class Inter-Sect	Trials to Crit.	Err-ors	Trials to Crit.	Err-ors	
	(N = Fail C = Correct)								
97	C	C	C	C	2	0	3	2	2
92	N	C	C	C	6	9	3	1	2
105	N	C	C	C	7	14	11	24	2
93	C	C	C	C	6	10	4	5	2
91	C	C	C	C	6	3	3	2	2
99	N	C	C	C	7	8	11	18	6
94	C	C	C	C	2	0	4	2	6
99	C	C	C	N	3	3	9	11	6
90	C	C	C	C	3	2	2	0	6
97	C	C	C	C	5	6	3	1	6
93	N	N	N	N	4	5	9	5	2
96	C	N	N	N	8	5	7	6	2
105	N	N	C	N	3	4	13	21	2
92	N	N	C	N	5	7	5	6	2
103	N	N	N	N	20	30	10	12	2
93	N	N	N	N	6	6	7	15	6
103	N	N	C	N	4	5	13	21	6
101	N	N	N	N	10	20	11	24	6
96	C	N	N	N	20	35	18	31	6
93	C	N	N	N	15	17	9	6	6

Study 7.

C.A. (Mths)	Classification				Original Learning		Reversal	
	Re-sort	Cross Class.	Quant. Inclu.	Class Inter-sect.	Trials to Crit.	Err-ors	Trials to Crit.	Err-ors.
	(N = Fail C = Correct)							
99	C	C	C	C	41	18	100	32
96	C	C	C	C	57	22	70	25
92	C	C	C	N	60	30	157	61
92	C	C	C	C	13	2	40	11
97	C	C	C	C	17	2	20	7
93	C	C	C	N	31	7	125	42
93	C	C	C	C	84	32	131	40
101	C	N	C	C	59	19	51	20
99	C	C	C	N	44	10	132	40
106	N	N	N	N	71	25	42	11
95	N	N	N	N	73	27	131	58
100	N	N	N	N	103	39	48	18
104	N	N	N	N	106	27	120	54
98	N	N	C	N	53	15	68	23
92	N	N	N	N	97	34	93	33
90	N	N	N	N	155	49	168	54
91	N	N	N	N	168	76	37	9
94	N	N	C	N	36	13	46	11