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INTELLIGENCE, MODALITY MATCHING AND INFORMATION PROCESSING

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Intelligence, Modality Matching and Information Processing" submitted by Ronald Frederick Jarman in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

The present study examined some relationships between intelligence, modality matching, and types of information processing in Grade 4 boys. The primary purpose of the investigation was to answer two questions. The first of these dealt with the types of information processing that are characteristic of different intelligence groups, and the second question related these types of information processing to modality matching tasks.

A set of tests representing Luria's simultaneous and successive syntheses, and a further set of specially-designed modality matching tests was given to all participating subjects. The results were analyzed by multivariate analysis of variance and factor analytic techniques to reveal both the levels of performance and types of information processing that were characteristic of the groups.

It was found that simultaneous and successive syntheses are relatively invariant types of information processing across a large part of the standardized range of intelligence. Simultaneous synthesis tended to be slightly more stable than successive synthesis. It was also found that the levels of performance of the intelligence groups differed markedly in modality matching tests, dependent upon the modalities involved. These differences were attributed to the interactions between the types of information processing chosen by the groups and the demands of each of the tasks. A model of information representation was proposed to account for these results.

The major implication of the study is that future research on human intelligence should explore the cognitive processes leading to performance measures on cognitive tests, in order to assess the efficacy of these processes for school related tasks.

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CHAPTER I

INTRODUCTION

Of the many areas of inquiry that are currently in evidence in psychology, few areas have a more lengthy and active history than the study of human intelligence. As a topic of research which increased strongly in activity around the turn of the century, the question of the nature of man's mental abilities has established itself since as an enduring issue in psychology. Research on intelligence has been continued throughout the course of several major movements in the history of psychology (Hebb, 1960), most notably the brisk increase of interest in Behaviorism (e.g., Watson, 1913, 1920, 1930) and the recent upsurge of cognitive psychology (Moroz, 1972).

In the course of the development of current conceptions of human intelligence, there has been some disagreement on the usefulness and informative value of the type of research that has been conducted. It appears from the recent literature that criticisms of studies of intelligence are now becoming more explicit in terms of identifying past inadequacies and future goals for research. Statements by Quinn McNemar (1964), for instance, in his presidential address to the American Psychological Association, are examples of these criticisms. McNemar notes that theory and research in the past has concentrated on two types of inquiry aimed at explaining individual differences in intelligence. The first variety is the study of the structure of intellect and has generally taken the form of the intercorrelation of tests to form taxonomies of abilities. The second type is the study of the nontest correlates of test performance. Both of these techniques have generated a formidable collection of research results, but neither technique has been successful in its efforts to explain individual differences in cognitive abilities. This fact has its basis in a single shortcoming of the past endeavors:

> . . . these studies of individual differences never come to grips with the process or operation by which a given organism achieves an intellectual response. Indeed, it is difficult to see how the available individual difference data can be used even as a starting point for generating a theory as to the process nature of general intelligence or any other specified ability (McNemar, 1964, p. 881).

McNemar's call for an emphasis on the process nature of cognitive functioning has been echoed increasingly by other psychologists (e.g., Bouchard, 1968; Ferguson, 1965; Green, 1966). In the last several years some directions have begun to appear which reflect an orientation toward process models of cognition and intelligence.

One of the most significant contributions in establishing future directions for research has been made by Messick (1972, cf. 1973). The perspective adopted by Messick is theoretically very broad, and multivariate in methodology. Messick emphasizes the interactions between specific abilities, more general cognitive strategies, and beyond these, the relationships between cognitive styles and personality traits. He argues that psychologists must move beyond conceptions of abilities in a simplistic and absolute sense, and recognize the multitude of processes that may contribute to a single "ability" measure. He cites recent evidence (Frederiksen, 1969) that indicates that under different instructional conditions different strategies are used by subjects to perform the same task; thus, as a result of the effects of cognitive strategies functioning as higher order responses to the characteristics of a learning task, a mechanism is provided for transfer from abilities to learning performance. In the case of Frederiksen's study specifically, it was found that under different instructional conditions specific abilities were related to components of learning in different ways for each condition. Furthermore, it was found that subjects employed several distinctly different strategies in the course of learning. Messick notes that much of this information would ordinarily not be recorded or would be lost under traditional methodologies of the study of the structure of mental abilities:

> Frederiksen's (1969) study underscores the futility of attempts to relate ability measures to overall or average indices of learning performance. It also highlights the need to open up conceptualizations of complex learning processes to include not only components of information processing abilities, but also higher order information processing heuristics such as plans and strategies which in turn may implicate variables of personality and cognitive style . . . It seems clear at this point that the functional models of complex mental processes that we seek must themselves be very complex and be cast in process terms (p. 369).

By virtue of the breadth of his discussion, however, Messick does not supply specific suggestions for research in the future. A slightly more focussed discussion has been supplied subsequently, albeit completely independently, by Estes (1974). Through a series of examples drawn from well-known tests and research paradigms, Estes argues that the multiple processes in any task performance may be understood if analyzed in the light of current knowledge in learning theory:

> . . . in every type of intellectual task any given level of performance can arise in many different ways . . . The desired goal may be achieved if we can interpret the processes involved in test behavior in terms of concepts drawn from learning theory and utilize these interpretations as a basis for developing techniques to localize the sources of deficits in performance revealed by test scores (p. 749).

Estes suggests that many apparently simple tasks currently in use in omnibus intelligence tests may actually sample much more complex processes than are readily apparent, and the fact that these tasks discriminate intelligence groups effectively should warrant an in-depth study of their nature. In this respect, therefore, Estes' suggestions for future research are more specific than the overview given by Messick (1972). In most other respects, however, Estes is nonspecific. He does not recommend the adoption of a particular model in learning theory and, perhaps most importantly, while he appears to favor a task analysis approach to the study of performance, he gives no guidelines or conceptual framework for this approach.

These latter problems in the orientation adopted by Estes (1974) appear to have been anticipated by Carroll (1974). The direction suggested by Carroll shares some common features with Messick (1972) with regard to problem definition and use of multivariate methodology, especially factor analysis:

> What still seems needed is a general methodology and theory for interpreting psychometric tests as cognitive tasks, and for characterizing (but not necessarily classifying) factor analytic factors according to a model of cognitive processes . . . the cognitive tasks used in factor analytic studies are necessarily complex from an information-processing point of view and factors simply tend to feature or highlight certain aspects of information processing in which there are prominent individual differences (p. 6).

Carroll's approach to the problems inherent in Estes' (1974) suggestions is to adopt a model of information processing proposed by Hunt (1971), and analyze tasks on the basis of this model (cf. Hunt, Frost & Lunneborg, 1973). Using the components of the model, Carroll has developed a coding scheme for tests, using categories such as memory type, strategies and mode of response required, and then applied this scheme to the French (1963) cognitive test kit. The second phase of Carroll's development of a process conceptualization of cognitive tasks is the use of factor analysis to confirm the coding categories. Thus, the direction adopted by Carroll is the reverse of the classic cognitive abilities research; it is comprised of task analysis on the basis of a model of cognition, and then validation of this analysis by factor analytic methodology.

Carroll's use of factor analysis in its confirmatory role is particularly interesting and forms a parallel to recent work on cognitive processes by Das, Kirby and Jarman (1975). The approach taken by Das and his colleagues is to factor analytically confirm and extend information on processes in cognitive tests that has been proposed first on the basis of clinical research. The theory of cognitive processes adopted by Das et al. was developed by Luria (1966a, 1966b). This theory maintains that cognitive content is processed in one of two ways. It may be processed as a simultaneous synthesis, in which case the information is arranged in some type of unitary composite which is mainly spatial in character; alternatively, information may be processed in the form of a successive synthesis, in which case the information is arranged in a sequential and mainly temporal order.

The rationale for the development of Luria's theory involves the effects of different types of brain lesions on cognitive tests. He has found that lesions in the occipital-parietal area leads to disturbances of the simultaneous organization of stimuli, and lesions in the fronto-temporal area disturb successive processing. These two forms of information processing, then, have developed from examination of the common aspects of various tasks that are associated with lesions of specific varieties.

The validation and extension of Luria's clinical research through statistical methodology has supplied some information on cognitive processes in mentally retarded children (Das, 1972), culturally-diverse populations (Das, 1973a, 1973b, 1973c; Krywaniuk, 1974), and different age and socioeconomic groups (Das & Molloy, 1975). A question of particular interest, which has not as yet been answered in the research on simultaneous and successive syntheses, is how these styles of information processing may vary in their employment by groups of subjects at different intelligence levels as operationally defined by intelligence tests. Das (1972) has found differences in this respect between retarded and normal children, and notes that these differences may allow new interpretations of some of the causes of discrepancies in mental ability levels among intelligence groups. The two forms of synthesis are seen as major styles of processing information, or "higher order information processing heuristics" in Messick's (1972) terminology, and thus their appropriate employment in task situations can be seen as a determinant, in part, of a given measured level of ability. Different levels of intelligence, therefore, may be characterized by different uses of simultaneous and successive syntheses for particular tasks. Thus, one purpose of the proposed study is to identify the similarities and differences, if any, in the employment of simultaneous and successive syntheses by different intelligence groups.

A second and major purpose of this study is to examine in depth a particular task that has been used in many contexts, including Das' (1973c) factor analytic work. This task is known under various titles, as will be discussed, but is best designated as modality matching. It consists of the judgement of equality or inequality of two stimuli. each of which is presented in a sense modality. Modality matching may be cross-modal, an example of which would be matching visual stimuli with subsequent auditory stimuli; or it may be intra-modal, such as matching visual stimuli with subsequent visual stimuli.

It will be noted in the review of literature to follow that modality matching has been identified by several researchers as an extremely important task in reflecting basic processes in intellectual development. The evidence which justifies ascribing this importance to the task, however, is surprisingly diverse in interpretation and lacking in empirical support. In fact, it appears that a properly designed study which would test many of the current claims made about this task has yet to be performed.

This study will examine the modality matching task in two ways. First, the levels of performance of different intelligence groups will be established for both intra-modal and cross-modal auditory and visual matching. Second, the strategies which different intelligence groups use in performing these tasks will be determined in the context of simultaneous and successive syntheses.

In summary, this study has two purposes. The first is to determine how different intelligence groups use simultaneous and successive syntheses. The second is to determine the levels of performance and the types of strategies that may characterize modality matching by different intelligence groups. Thus, this study will shed some light upon the strategies that are characteristic of different intelligence groups, and the significance of modality matching as an indicator of intellectual development. The review of literature now to follow will develop the context of the study more explicitly.

CHAPTER II

REVIEW OF LITERATURE

In the present chapter, selective reviews will be found under three headings: intelligence, modality matching and information processing.

Intelligence is a wide area of research, even when it is operationally defined as the score on an intelligence test. There will be no attempt made in this review to deal exhaustively with the available research in this area. Instead, the review will restrict itself to brief remarks with respect to conceptions of intelligence as they are relevant to the present study.

Modality matching research, which is sometimes known under other titles, has a lengthy history of development. Most of the interest in this area, however, has been within the last decade, with a considerable increase in interest in the last several years. This review will be complete for the research which is germane to this study.

Information processing is a relatively new topic in psychology; consequently, the concept lacks clear definition. This discussion will be restricted to an overview of one model of processing information, followed by a review of some factor analytic studies which support this model.

A summary of these three sections is provided.

Intelligence

Metaphorically, the main focus of research on human intelligence has been the charting or mapping of the domain of man's mental abilities. The history of this endeavor with its primary movements, is well encompassed by Butcher (1970), Dockerell (1970), Jenkins and Paterson (1961), Tyler (1969), Wason and Johnson-Laird (1968) and Wiseman (1967).

The measurement of intelligence by omnibus intelligence tests may be seen in the context of research on mental abilities, as an attempt to sample those components of mental abilities that have been identified as broad, socially important criteria. One way in which intelligence has been defined over the years, then, is as some variation upon the "ability to carry on abstract thinking" (Terman, 1921), or alternatively, simply as "general cognitive ability" (Burt, 1972). In operational terms, these definitions describe some of the characteristics of tests of intelligence. As Jensen (1969) has pointed out, these tests utilize some items of a non-conceptual nature, such as rote memory, but for the most part the tests are directed at determining the level of competence of the individual in conceptual problem solving. In Jensen's (1969, 1970a, 1970b) terminology, mental abilities may be roughly divided into two varieties: Level I abilities, which are predominantly memory abilities, and Level II abilities, which are predominantly abstract reasoning abilities. Jensen has argued that intelligence tests are mainly measures of Level II abilities.

Conceptions of intelligence tests as exemplified by Jensen's statements are not often disputed among psychologists. There has been a history of protest over the use of intelligence tests in various institutions, most notably education, but these protests have been directed mainly at the inappropriateness of the use of the tests with various subgroups and some possible social implications of their usage (Brim, 1965; Cronbach, 1975; Gulliksen, 1974; Hoffman, 1962; McClelland, 1973). When employed with groups similar to those in which the tests were normed, somewhat less dispute has arisen over the technical efficacy of the tests as indicators of approximate levels of general intellectual functioning.

Unfortunately, however, as part of the acceptance of intelligence tests on this basis, misconceptions of the meaning of intelligence scores have developed (Lyman, 1963; Wechsler, 1975; Wesman, 1968). These misinterpretations have been labelled "conceptual ghosts" by Humphreys (1962a, cf. 1962b), who lists five major misconceptions that have contributed to the "mystery" of intelligence test scores.

The first misconception is that of capacity. Intelligence tests are often interpreted as indicating an individual's capacity to perform various intellectual tasks. As noted by Humphreys, we have no operational techniques for making these inferences. Intelligence scores give a sampling of current performance at a specified point in time. The fact that they may have some predictive validity for some tasks in the future is based upon probabilities with respect to an individual's placement in a group over time. This, in and of itself, does not validate inferences with respect to the individual's "capacity" to perform tasks in the future.

The second misconception is that of fixed intelligence. Humphreys notes that many important variables play implicit roles in the prediction of intelligence scores at later ages. Among these are the age of the examinee at the time of administration of the predictor test and the amount of time between test and retest. Thus, the breadth of experience of the examinee between tests, the age of experience and also the breadth of the tests themselves all contribute to changing relationships between test and retest scores. The stability of these relationships in some circumstances does not allow inferences regarding fixed intelligence.

The third conceptual "ghost" that Humphreys has identified is the notion of aptitude. He notes that because a predictor test correlates to some degree with a criterion test, this simply indicates that for any of a multitude of reasons individuals have retained some relative position with respect to a group over time; it does not indicate aptitude. A parallel example of this type of fallacy is physical growth. We do not claim that children have varying degrees of aptitude for growing, because we can predict to some extent the height to which they will grow.

The fourth misconception in the interpretation of intelligence scores is the difference between non-empirical definitions of intelligence and what intelligence tests actually measure. Humphreys notes that while intelligence is often spoken of in terms of "flexibility of adjustment" or "general learning ability", a simple analysis of tests reveals that the extent to which these conceptions of intelligence are reflected in test content is severely limited.

Finally, the fifth misconception that is prevalent with regard to intelligence tests is that they represent a pure measure of a central "force" which has often been called "g" in Spearman's (1904, 1927) terminology. Humphreys notes that the classical problems in charting mental abilities, which eventually led to Thurstone's (1938) formulation of seven or nine different aptitudes, and then later to Guilford's (1959, 1967) more numerous varieties, are manifest in conceptions of intelligence tests as measures of a unitary inner force. The resolution of the difficulties in determining the extent to which these models of mental abilities are appropriate is not in sight at the present time, and hence ascribing any single theory to intelligence tests is unwarranted.

The question of what a score on an intelligence test actually represents then, according to Humphreys, should be approached by a path not plagued by the five misconceptions that have been noted. There are some well-established empirical facts about intelligence tests that should be taken into account. It is generally accepted that intelligence scores are fairly reliable. These scores are also quite stable over time, with little change in rank ordering of individuals over periods as long as several years. It is generally found that intelligence test results are good predictors of academic grades and similar school-oriented tasks. Finally, while it is not uniquely determined where in a functional hierarchy of mental abilities an intelligence test may be placed, it is clear that most IQ tests are a broader measure than simply a composite of several specific ability tests.

Viewed in these terms, it becomes apparent how the misconceptions quoted by Humphreys, such as capacity and fixed intelligence, have evolved. Intelligence test scores appear to behave so lawfully as to beg an explanation in terms of relatively immutable and generic characteristics. But as Humphreys has intimated, this fact originates not only from the characteristics of individuals, but also from the composition of the tests. The content of intelligence tests is broader, both in terms of areas sampled and in terms of time periods sampled, than any other variety of test. These differences take three specific forms when intelligence tests are compared with other school tests.

First, intelligence tests contain items that require utilization of broad domains of knowledge. The internal consistency of IQ tests is generally only moderate, especially in the case of some of the omnibus tests such as the Stanford-Binet and the Wechsler Intelligence Scale for Children.

As a second point of difference, which is somewhat specific to the first, intelligence tests tap a wider range of experience than do other varieties of tests, such as achievement tests. IQ tests are not developed as evaluation criteria for courses of study that may be specific to particular school systems, nor are the items constructed in the usual school testing formats.

Finally, and perhaps most importantly, intelligence tests require the individual to draw upon old knowledge or skills that may be transferred to a new situation. In contrast, school tests tap knowledge which may be specific to a shorter period of time, for example, one year.

When reviewed in the light of these characteristics, it is hardly surprising that intelligence tests display the characteristics of reliability, stability, validity and factorial connections to several theories of mental abilities. Their breadth, both temporally and in terms of content, contributes significantly to these psychometric qualities. In Ferguson's (1954, 1956) terms, human abilities become differentiated in the course of development, with transfer of learning facilitating this differentiation. Intelligence tests generally span these abilities to a greater degree than other tests, dependent upon the age of the individual and the particular test concerned. The meaning of intelligence scores, then, must necessarily be interpreted in the perspective of the opportunity that the individual has had to develop the ability to complete the tasks in the test; that is, the opportunity to transfer prior learning and differentiate skills cumulatively.

Viewed in these terms, intelligence tests become complex empirically, and possibly even inappropriate in more cases than not, but the concept of intelligence itself should at least be free of some of its nebulous notions and mysterious entities. It is established that on the basis of these psychometric characteristics, intelligence test scores reflect the standing of an individual relative to a group on a number of criteria which have been found empirically to be important for school and occupational success. The term should be restricted to this purely descriptive as opposed to explanatory function (Liverant, 1960), and inferences regarding the meaning of the scores beyond this interpretation are invalid.

Modality Matching

It has been noted by several authors, among them Jensen (1971), that the nature of cross-modal transfer is not well understood. Undoubtedly one of the principal reasons for this lack of understanding is the rarity of common terminology use among the studies which have been performed in this area, as well as confusion with respect to the various types of tasks under consideration. These problems, in conjunction with the fact that most of the studies on this topic have been loosely designed and evaluated, have led to a disparity in opinion as to the etiology and psychological significance of cross-modal processes (Bryant, 1968). The first objective of this discussion, therefore, will be to clarify the terminology presently in use, and to establish the terminology that is to be employed in this study. Following this, several other major problems inherent in present research on cross-modal processes will be noted. This will establish a context for an examination of that portion of the literature which is specifically relevant to the present study. The discussion will begin in a cross-modal context, with intra-modal considerations as logical consequences.

This review will introduce first the term "cross-modal coding" (CMC) as generic terminology for the complete spectrum of tasks under consideration.[1] The possible modalities in which these tasks may be

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[1]Jensen (1971) appears to be using "cross-modal transfer" in this sense, as is the case with several other psychologists, but the inconsistency of the term's usage is profound elsewhere. The introduction of the terminology used here is unique to this study, with "transfer" used in its usual learning sense, rather than as a broad category.

presented are visual, auditory and haptic. Across these three modalities, three principal varieties of tasks appear to have been utilized: cross-modal transfer (CMT), cross-modal discrimination (CMD) and cross-modal matching (CMM). The distinction between CMT and CMD is slight, whereas CMM tasks form a clear demarcation with respect to the other two.

Cross-modal transfer involves the learning and utilization of a principle in one modality, and then the employment of that principle to aid in the learning of a task in a second modality; the tasks may or may not be identical for both modalities. The main distinction in CMT which sets it apart from CMD and CMM tasks is the principle to be learned. Often the principle is a stimulus dimension. An example of this type of research is a study by Semmes, Weinstein, Ghent and Teuber (1954). Brain damaged adults were requested to choose an object visually from a given set (e.g., powder puff, rubber ball, sponge, coin, pencil and nail) with the correctness of their response indicated after each selection. The principles to be discovered were stimulus dimensions, such as softness, length or metallic content. It was hypothesized that the learning of these dimensions would transfer to the same task performed haptically several months later. This hypothesis was supported, although the effects were scattered and weak.

Cross-modal discrimination, in contrast to CMT, is a more clearly defined type of cross-modal coding from the viewpoint of the subject, and in some respects it may be seen as a degenerate case of CMT. In CMD tasks, a stimulus dimension is generally made explicit to the subject. The task is to distinguish degrees of this dimension in one modality and to utilize this discrimination learning to perform the same task in a second modality. Smith and Tunick (1969), for example, used plastic forms of equal volume (cone, sphere, pyramid, cube, rectangular solid and cylinder) covered with four textured materials (smooth, foam rubber, buckshot and rough sandpaper) in a study of visual-tactual CMD in young retarded children. Subjects were informed of the relevant stimulus dimension before each set of tasks was presented and were reinforced for correct discrimination responses. The CMD effects were found to be significant for both dimensions. Gardner and Judisch (1965) conducted a study which is exemplary of this type of design for auditory and visual modalities.

The major distinctions to be drawn in this discussion are the differences between cross-modal matching tasks and CMT and CMD tasks, for it is the former to which this study is addressed. From the point of view of the subject, cross-modal matching is the most explicit task of the three types under discussion. CMM involves the presentation of a stimulus in one modality and then immediate identification of a corresponding stimulus pattern in a second modality. Summarily, CMM differs from CMT and CMD tasks in at least three ways (Ettlinger, 1967; O'Connor & Hermelin, 1971): (1) In a CMM task, the subject is aware of the relationships between the stimuli in the two modalities and that the expectation of the experimenter is for the subject to match the stimulus in the first modality with that of the second modality. In CMT and CMD tasks, it is not made explicit to the subject at any point in time that there is some relationship between the task performed in one modality and the later task performed in a second modality. (2) in CMT and CMD tasks, learning takes place in the course of trials in the first modality; the objective is to discover whether or not this learning is transferred to the later task in the second modality. In CMM tasks, learning takes place to a lesser extent, and its transference is therefore of lesser concern. (3) CMT and CMD tasks may utilize a time interval of days, weeks or even months between the trials in the first modality and those in the second modality. In CMM experiments, the time interval is very brief; the subject is presented with a stimulus in the first modality and then is asked immediately to match it with a stimulus in the second modality.

It is evident even from the brief foregoing discussion that a first consideration in the design of a cross-modal coding study should be the clarification of the coding type that is of interest. The distinctions between CMT, CMD and CMM are of major importance, with the demands made upon short and long term memory, for instance, varying considerably across the three types. Despite these differences, studies have been conducted utilizing one type of task, with the discussion of the results done in the context of another type. Rudel and Teuber (1964), for instance, used a visual-tactual CMM design to draw inferences about CMD abilities in young children.

A second complicating factor in many of the studies of cross-modal coding that are currently available is the lack of intra-modal controls (Bryant, 1968; Jones & Robinson, 1973; Rubinstein & Gruenberg, 1971; von Wright, 1970). Nearly all of the studies of cross-modal coding presently in the literature do not utilize a design which supplies information on intra-modal performance as well as cross-modal performance.

This shortcoming is especially critical when the studies are viewed developmentally, for there is strong evidence that as children grow older their ability to discriminate auditory, visual and tactual cues increases steadily (Gibson & Gibson, 1955; Gibson, Gibson, Pick & Osser, 1962) and cue preferences within modalities become more synonymous with those in other modalities (Pick, Pick & Gliner, 1967). Thus, when developmental changes in cross-modal coding scores are reported without intra-modal data, the effects of these increases in discrimination abilities are confounded with any actual developmental changes in cross-modal coding ability.

A third and final source of confusion in the literature on cross-modal coding is the choice of modalities which have been employed in relation to the objectives of the research studies. Most of the research presently available involves the visual and haptic modalities (for examples and reviews see Balter & Fogarty, 1971; Birch & Lefford, 1963, 1967; Hermelin & O'Connor, 1964; Krauthamer, 1959; O'Connor & Hermelin, 1965; Rudel & Teuber, 1964). While some of these studies have been concerned with specific aspects of psychomotor abilities, others have been concerned with more general aspects of intersensory development as it relates to mental abilities. In this latter respect, visual and auditory tasks would have been more appropriate (Bartlett, 1947).

A probable cause of these three problems in the cross-modal coding literature, as well as lesser problems which have not been noted here, is the paucity of thorough reviews of the complete area of modality coding. If analyses of the area were available, it is unlikely that this confusion would be present. Early reviews of American research on sensory processes have been supplied by Gilbert (1941) and Ryan (1940) and on Soviet research by London (1954). More recently, partial reviews cutting across some of the major problem areas that have been noted have begun to appear (Abravanel, 1968, 1971; Bryant, 1968; Chalfant & Scheffelin, 1969; Gibson, 1969; Gibson, 1966; Pick, Pick & Klein, 1967; von Wright, 1970; see also McGrady & Olson, 1970; Wohlwill, 1971). A recent discussion by Freides (1974) appears to be one of the more sophisticated reviews available. Nonetheless, a systematic discussion of the present concepts and research methodology in the area in terms of future needs and directions still remains to be done.

One of the best reviews with respect to approximating a complete discussion of these issues is supplied by Chalfant and Scheffelin (1969). These authors denote the basic human integrative systems as depicted in Figure 1.

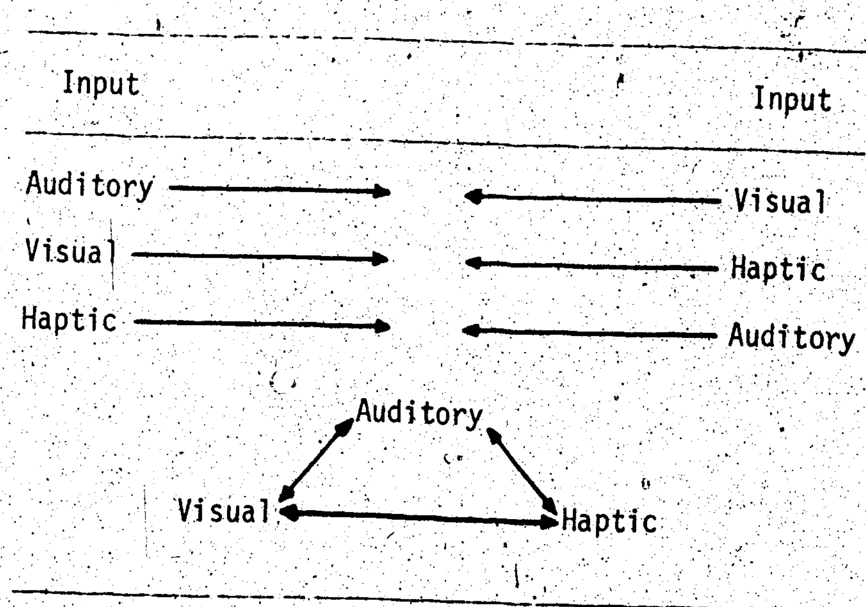

Figure 1. Intersensory integrative systems

Chalfant and Scheffelin (1969) supply a useful tabulation of the variables that should be taken into consideration in the design of research studies on cross-modal coding or, more generally, modality coding. These variables are listed in Table 1.

With several minor adjustments, the variables supplied by Chalfant and Scheffelin appear to be complete. Socioeconomic status (SES) of the subjects is one possible further variable that should be included for, given the well established relationship between SES and IQ, to the extent that cross-modal coding ability is a predictor of IQ (Hunt, 1969; Jensen, 1969), and hence possibly correlated with SES, differences in cross-modal coding ability could be expected to exist across SES groups. An examination of the SES variable may shed light upon the processes in modality matching (Jorgenson & Hyde, 1974). Birch and Belmont (1965b) and Walker and Birch (1970), among others, have reported SES information, but have not conducted statistical analyses using this variable. SES would in all probability be more significant as an independent variable in modality matching studies than would variables such as sex, for example, for which the results have been hazy (Jorgenson & Hyde, 1974; Kling, 1968; Muehl & Kremenak, 1966; Reilly, 1971).

The Chalfant and Scheffelin (1969) elaboration of critical variables serves the purpose at this point in this discussion of narrowing the focus of the remainder of this review and of placing the present study in context. The concern of this study is with auditory and visual modality matching, both cross-modal and intra-modal. Variables which are salient to the study will now be considered separately in the following sections, or discussed within the research design.

Table 1

Variables to be Considered in Modality Matching Research

Mode of Stimuli	Organism	Mode of Response
Intramodal	Sex	Intermodal
Intermodal	CA	Intramodal
Simultaneous presentation	MA	Symbolic
Successive presentation	IQ	a. motor
Symbolic stimuli	Organic involvement	b. vocal
Nonsymbolic stimuli	Prior experience or training	Nonsymbolic
Intensity		a. motor
Number of units		b. vocal
Rate		Production
Duration		a. latency of response
Interval		b. duration of response
Instructions		c. frequency of response
Order		d. intensity of response
Complexity		Imitative response
Distortion		Judgemental response
		a. same
		b. different
		c. recognition
		d. recall
		e. equivalence
		f. correspondence
		g. recoding to a rule

Spatial-temporal dimension

As is the case with visual-haptic cross-modal research and its reference to psychomotor abilities, studies in the specific area of modality matching for visual and auditory stimuli have received their impetus in large part from a theoretical link to a specific problem area: reading achievement. Indeed, many of the studies presently in the literature are not addressed to the question of visual and auditory matching processes per se, but instead are directed at the relationship between reading achievement and auditory-visual modality matching (Beery, 1967; Birch & Belmont, 1964b, 1965b; Blank & Bridger, 1966b, 1967; Blank, Weider & Bridger, 1968; Butters & Brody, 1968; Ford, 1967; Jorgenson & Hyde, 1974; Kahn & Birch, 1968; Kuhlman & Wolking, 1972; Muehl & Kremenak, 1966; Reilly, 1971; Rudnick, Sterritt & Flax, 1967; Silverston & Deichmann, 1975; Sterritt & Rudnick, 1966). It has been hypothesized that the significance of auditory-visual cross-modal matching to reading achievement lies in the prima facie parallel demands of the two tasks, that is, "preparatory to reading, the child must relate auditory patterns in speech, which are temporally ordered, to the spatially ordered visual patterns in print. To actually read, he must reverse the process by responding to the printed visual patterns with appropriate sound sequences (Muehl & Kremenak, 1966, p. 230)." This hypothesis appears to have been consistently supported. Virtually all of the present studies have found that auditory-visual matching ability significantly predicts reading achievement. Also, as would be expected if this hypothesis were correct, intra-modal matching of the same tasks does not predict reading achievement. Thus, it is apparently the intersensory integration aspect of modality matching that correlates highly with the components of reading.

Unfortunately, not all other aspects of modality matching studies have been as consistent as the relationship between reading and CMM (Goodnow, 1971b, cf. 1971a). One would expect, for instance, that because cross-modal integration apparently employs discrimination skills in two modalities, as well as some form of integrative mechanism, it would be more difficult than an equivalent intra-modal task. This has not been found to be true in general; cross-modal matching has been found to be more difficult than intra-modal matching (Caviness, 1964, cited in Goodnow, 1971b), but other studies indicate that it is easier than intra-modal matching (Muehl & Kremenak, 1966), and finally, some studies have found no differences between cross-modal and intra-modal matching (Hermelin & O'Connor, 1961). It is evident from a close inspection of the available studies that this lack of agreement in CMM research results could be due to subtle variations in stimulus type, response alternatives, instructional sets and a host of other variable conditions. More explicitly and more importantly, however, these inconsistencies could be the result of interactions between the principal mechanisms underlying the modality matching process and the situational variables. Because these mechanisms are as yet only tentative, the morphology of the process of modality matching remains somewhat problematic.

Conjectures, of course, have been drawn as to the nature of modality matching processes. Simplistically, these conjectures have fallen roughly into two varieties and have become identified with two research teams presently studying this problem. One theory proposed is that of Herbert Birch and Lillian Belmont and co-workers, which hypothesizes that a process of integration at the perceptual level is responsible for modality matching skill. In brief, these authors argue that perception is a developmental product (Wohlwill, 1960) and that children are characterized by the development of increasing correspondence between stimulus cue and dimension usage across modalities. Based in part also on discussions by Sherrington (1951) and Munn (1965), who argue that intrasensory systems develop before intersensory systems due to the later establishment of an intersensory liaison, Birch and Belmont have pursued this theoretical stance energetically, extending their research over a considerable span of time and over various groups (Belmont, Birch & Belmont, 1968; Belmont, Birch & Karp, 1965; Birch, 1954; Birch & Belmont, 1964a, 1964b, 1965a, 1965b; Birch & Bitterman, 1949, 1951; Birch & Lefford, 1963, 1967; Kahn & Birch, 1968; Klapper & Birch, 1971; Walker & Birch, 1970).

The second point of view in accounting for the mechanisms involved in modality matching is exemplified by Marian Blank and Wagner Bridger. Blank and Bridger reject the perceptual hypotheses of Birch, Belmont et al., and propose that a mediational process--mainly verbal, but not necessarily so for all tasks--is responsible for the links between stimuli presented in two modalities (Blank, 1970; Blank & Bridger, 1964, 1966a, 1966b, 1967; Blank, Weider & Bridger, 1968). Thus, Blank and Bridger appear to favor the use of higher order processes rather than perceptual processes as explanatory constructs for the modality matching phenomenon (see Boernstein, 1970; Jensen, 1970b).

Until very recently, evidence that would shed light upon the relative tenability of either of these points of view, or of any combinations thereof, was unavailable. Due to a further major shortcoming of the design of visual-auditory CMM studies, a confounding effect has been present consistently in nearly all studies to date; this effect is the result of the usual link between visual stimuli and spatial distribution of the stimuli as opposed to auditory stimuli and temporal distribution of the stimuli. That is, in virtually all of the studies available, with the exception of two now to be discussed, visual stimuli effects have been confounded with spatial effects and auditory stimuli effects have been confounded with temporal effects. Research by Rudnick, Martin and Sterritt (1972) and Sterritt, Martin and Rudnick (1971) represents the first attempt to separate these factors and study their individual relationships to modality matching processes.

Sterritt, Martin and Rudnick (1971) generated all possible com[illegible] stimuli and response patterns by utilizing auditory-temp[illegible] visual-temporal (VT) and visual-spatial (VS) types of stimu[illegible]ory-spatial [AS] would be a simultaneous sound pattern from sp[illegible]ly distinct sources and would be non-discriminable). These three v[illegible]ties generate nine possible combinations of stimulus-response sets, wh[illegible] were created by the use of headphones, lamps and printed materia[illegible] AT-VS, VS-AT, AT-VT, VT-AT, VT-VS, VS-VT, AT-AT, VT-VT, VS-VS. Subjects in the study were 72 black children who had attended kindergarten and were living in an impoverished neighborhood. Results indicated that neither AV integration nor TS integration was more difficult than the respective intra-modal integrations. In ascending order of difficulty, the patterns were visual-spatial, visual-spatial with temporal (auditory or visual) patterns and then types involving only temporal patterns. Thus, the temporal-spatial dimension emerged as the significant individual differences variable, with the role of auditory and visual modalities seen as relatively insignificant. Also, the factor of "integration" was found to be of low importance, i.e., the difficulty level of tasks utilizing a match between temporal and spatial stimuli was equal to those matches utilizing just one or the other dimension. The later study by Rudnick, Martin and Sterritt (1972), utilizing 270 black first grade children, supported this set of results.

These studies by Rudnick, Martin and Sterritt do not, of course, strictly invalidate the research to date in the area of modality matching. Their research does open up many questions with respect to the processes involved in this type of task. It is possible to conjecture, for instance, that the spatial-temporal dimension is the individual differences variable operating in the majority of the previous studies, and not the visual-auditory aspects as commonly believed. Differences in results with respect to the relative difficulty of intra-modal matching as opposed to cross-modal matching could conceivably have been due to differences in demands made upon spatial-temporal integration abilities among some of these studies, with the possibility masked by the previous emphasis upon visual-auditory processes.

But there are still many questions to be answered. The Rudnick, Martin and Sterritt studies involved the use of young children from a disadvantaged neighborhood. Would the integrative aspects of these dimensions emerge as the most important variable in older children?

What is the role of short-term memory in this problem? What are the mediating variables, if any, in the various varieties of spatial and temporal tasks, and specifically, what is the role of language? What is the relationship between modality matching and intelligence? The remainder of this review on modality matching will concern itself with these questions, insofar as there are data available that will shed light upon them. Unfortunately, only conjectures can be made as to the relative contributions of spatial and temporal factors in some of the studies now to be cited.

Developmental trends

There has been a small amount of research done in the area of developmental trends in visual and auditory modality matching. Therefore, rather than attempt to generalize across studies which have used different techniques as applied to homogeneous age groups, this discussion will be restricted to those studies dealing specifically with a span of chronological age.

The first extensive developmental study of visual and auditory cross-modal matching was done by Birch and Belmont (1965b, cf. 1965a; see also Walker & Birch, 1970). This study utilized a 10 item, auditory-visual matching task, with three simultaneously presented alternatives per item. The subjects were 220 children, drawn from kindergarten through grade 6, with ages ranging from 5 years 3 months to 12 years 1 month. The data that were collected in the study are summarized in Table 2.

As is evident from the trend in the mean number of items correct,

Table 2

Number of Correct Equivalent Judgements
of Auditory-Visual Pattern by Grade

Grade	N	Mean Age (Yr ± Mo)	No. of Correct Equivalence Judgements M	SD	Range
K	30	5-8 ± 3.1 mo	4.1	1.4	1-7
1	30	6-6 ± 3.8 mo	5.6	2.2	1-9
2	30	7-7 ± 3.4 mo	7.9	1.6	5-10
3	30	8-6 ± 4.3 mo	8.5	1.9	3-10
4	35	9-7 ± 3.8 mo	8.7	1.2	6-10
5	35	10-7 ± 3.8 mo	9.6	0.8	7-10
6	30	11-6 ± 3.8 mo	9.5	0.8	8-10

there is a steady increase by grade in the ability of children to perform this task. However, while this information is useful for the lower grade levels, its informative value decreases sharply in the higher grades. This is due to a strong ceiling effect in the data resulting from the 10 item test. By grades 5 and 6, nearly all of the subjects attained a near-perfect score, and hence individual differences in the task virtually disappeared. Surprisingly, Birch and Belmont (1965b) conclude that this convergence of scores at these grade levels indicates that ability to perform this task reaches an asymptote at these levels:

> Growth in auditory-visual integration was most rapid in the interval encompassed between kindergarten and second grade. By the second grade mean accuracy in performance had reached an 80% level. In succeeding years improvement in auditory-visual integrative performance was slow and steady, with an average annual increase in accuracy of 5% until the fifth grade at which age the asymptote was reached (pp. 298-299).

In later research some of the inadequacies of this first study were rectified. Kahn and Birch (1968) used a 20 item test of the same design as noted previously to study the auditory-visual integrative abilities of 350 children from grades 2 through 6. The data that they obtained is summarized in Table 3.

Table 3

Distribution of Auditory-Visual Integration Scores and Age (Yr - Mo) by Grade (N = 70 per Grade)

Grade	Auditory-Visual Integration			Age		
	M	SD	Range	M	SD	Range
2	9.6	4.0	2-17	8-4	5.1 mo	7-7 to 9-5
3	13.5	3.8	5-20	9-3	4.1 mo	8-7 to 10-4
4	15.1	2.9	7-20	10-1	5.7 mo	9-5 to 11-6
5	15.8	3.5	6-20	11-2	6.0 mo	9-10 to 12-5
6	17.0	2.7	7-20	12-2	4.6 mo	11-5 to 13-3

The most significant point to be made about this data is that the asymptotic effect that Herbert Birch had found in the earlier study (Birch & Belmont, 1965b) is absent. Rather, the ability to match auditory stimuli with visual stimuli, as determined by the type of test used in this study at least, appears to continue to develop throughout the grade levels involved.

Recent research by Reilly (1971) supports the findings of Kahn and Birch (1968) in full, with additional information supplied on sex differences. Reilly also used a 20 item test, and administered it to

225 subjects from grades 1 to 4. The mean scores for boys in grades 1 2, 3 and 4 were 8.90, 12.65, 16.17 and 18.13, respectively. For girls, the grade level scores were 9.52, 13.39, 17.14 and 18.00. Statistical tests indicated that there were no significant differences due to sex at any grade level, but differences between grades were significant for all levels. Unfortunately, Reilly drew similar conclusions about asymptotic effects in modality matching ability. These conclusions are, once again, not valid due to noticeable ceiling effects in the instrument.

The information that may be drawn from these studies is relatively firm with respect to the developmental rate of cross-modal matching ability in the early school grades. As a function of the instruments that are presently being used to measure performance on this task, the ability of children to match auditory stimuli with visual stimuli increases steadily from kindergarten to grade 4. Beyond the fourth grade, the utility of the instruments to span all grade levels begins to decrease, with little information supplied on the developmental course of cross-modal matching ability.

The same questions may be asked of intra-modal matching performance. Does it increase at a steady rate also, and for which grades are there data presently available? A single study has been conducted on this problem involving 196 children from kindergarten through to grade 6 (Klapper & Birch, 1971). Unfortunately, the methodological inadequacies that had been present and later been corrected in some of Herbert Birch's earlier work, are once again in evidence in this study. A 10 item test with a "same-different" format[2] was used, resulting in fairly low reliability estimates. The data which are of interest to this discussion are reported in Table 4.

Table 4

Competence Levels in Judging Temporal Sequences at Different Ages

Age (Yr)	Auditory Patterns (M ± SD)	Visual Patterns (M ± SD)
4	4.3 ± 2.22	2.8 ± 2.34
5	6.1 ± 1.94	4.7 ± 2.20
6	7.2 ± 2.15	5.6 ± 2.35
7	8.3 ± 1.50	6.8 ± 2.10
8	8.9 ± 1.49	7.8 ± 1.90
9	9.5 ± 0.80	8.7 ± 1.44
10	9.9 ± 0.32	9.5 ± 0.84
11	9.6 ± 0.61	9.8 ± 0.56

The data for auditory and visual matching are characterized by a steady increase as a function of grade level, with visual pattern matching more difficult than auditory pattern matching at all but the final grades. Thus, the development of the ability to intra-modally match temporal sequences appears to follow a similar monotonically increasing path as is true for cross-modal matches. This discussion

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[2] See next section, "Memory effects", for a discussion of the structure of "same-different" items.

will return at a later point in this study in order to examine the discrepancy between the auditory and visual intra-modal matching performances noted in Table 4.

In summary, the developmental course of cross-modal and intra-modal matching performance in children appears to be fairly well established. Goodnow (1971a, 1971b) has noted that these trends are replicable when some variations on the usual tasks are used. The next problem, therefore, is to examine some of the possible mechanisms that may be responsible for these trends.

Memory effects

In order to assess the effects of individual differences in memory ability upon modality matching processes, it is possible to use information from two interrelated sources--the structure of the items that are employed in modality matching tests and any relationship variations that may occur concomitantly with those structures as a function of which modalities are involved.

Modality matching items generally have been constructed in two different ways. One type of item uses a "same-different" format; a stimulus is presented in the first modality and then removed, after which a single stimulus is presented in the second modality. The subject is asked if the two stimuli are the "same" or if they are "different". The other type of item uses a multiple choice format. A stimulus is presented in the first modality and then removed, after which a set of choices is presented to the subject, with instructions to "find the one that is the same" as the first stimulus. The choices may be presented simultaneously, as when visual pattern alternatives are listed on a single card, or successively, as when tone pattern alternatives are played one after another or visual pattern alternatives are exposed consecutively to the subject on separate cards. It is clear that memory requirements vary across these item types. The problem is to determine if this variation will indicate the role of memory in modality matching.

There is a small amount of data available which may answer this question. Birch and Belmont (1964), for instance, employed an auditory-visual (AV) cross-modal task, which involved the use of three simultaneous response alternatives, to divide children (ages 9-4 to 10-4 years) into high and low AV performers. The data indicates that these children did not differ significantly on the digit span subtest of the Wechsler Intelligence Scale for Children (WISC). Kahn and Birch (1968) correlated the digit span subtest of the WISC with the same AV modality matching task for children of grades 2 to 6. The Pearson product-moment correlation coefficients varied from .21 in the second grade to .14 in the sixth grade. Sabatino (1968) reports correlation data for the same tasks given to learning disabled children--WISC digit span and AV modality matching--which approximates zero.

In the case of an auditory stimulus pattern, with three response alternatives presented visually and simultaneously then, it is suggested that memory is not a significant factor in modality matching performance. Ford (1967) has supplied some data from a study of 121 fourth grade boys which extends this finding to four visual response choices presented successively. As in the previously noted studies, the WISC digit span subtest was correlated with AV modality matching results. Despite the apparent increase in memory use in this form of matching, the Pearsonian _r_ was insignificant at .03.

Although there is no specific data available for same-different item types, it is evident that in this case the significance of memory as a predictor of modality matching performance would be even less than is the case for the item types in the studies that have been cited. Ford's (1967) study used an item format which should maximize reliance on memory, and yet memory has not emerged as a significant variable in accounting for individual differences in modality matching performance. Thus, it is intimated from this correlational evidence, mapped over item types, that for visual and auditory modality matching, auditory short-term memory is not a predictor variable of individual differences in matching performance. Jorgenson and Hyde (1974) support this finding and extend it to visual short-term memory.

The nonsignificant role of short-term memory noted here is supported further by non-correlational evidence supplied by Goodnow (1971a, 1971b), who studied both memory and attentiveness in modality matching in 30 kindergartners. The subjects were asked to reproduce a "tapped-out" series in order to determine if their recall of the initial stimulus accounted for the individual variation in their modality matching performance. Almost without exception, the children were able to reproduce the series, leading Goodnow (1971a) to conclude that "widespread difficulty in matching cannot be accounted for by (a) inability to remember the original series immediately after presentation, or (b) by failure to attend to the presence of segments or intervals in the series (p. 1191)."

The second related possibility with respect to investigating the role that memory may play in cross-modal matching ability is to study differences in matching performance as a function of modalities. That is, one asks the question of whether or not memory plays a role in modality matching to differing degrees dependent upon the modalities concerned. Goodnow (1971b) has supplied some interesting evidence in this respect. She synthesized a series of studies on the basis of the number of item response alternatives utilized in various modalities and reached the firm conclusion that when vision is the second modality involved, the mean error rate does not increase as a function of the number of alternatives in the item. Thus, for auditory-visual (AV) and visual-visual (VV) modality matches, memory does not affect performance.

Goodnow (1971a, 1971b) does not discuss the role of memory in the case of the auditory mode being used as the second modality (AA and VA). Muehl and Kremenak (1966) supply some data that may be used for this purpose. These authors used a "same-different" item format for intra-modal (AA and VV) and cross-modal (AV and VA) tasks. Their data indicate that the VA match was of equal difficulty to the AV match, thus tentatively suggesting that for this item type, at least, memory plays no further role when the second modality is auditory.

Collectively, the evidence cited here indicates that the factor of individual differences in short-term memory plays no significant role in determining differences in auditory-visual matching processes. Apparently the role of memory in these processes is to act as a threshold which most, if not all, subjects are able to meet. The determinants of modality matching ability, therefore, are more likely to lie in the strategies which subjects use in completing the task. Language use and other mediatory techniques are a potential source of explanation for modality matching performance.

Verbal and nonverbal mediation

The role of language in intra-modal and cross-modal coding is one of the most enigmatic points of interest in this area of research. In terms of the distinctions that were drawn earlier in this discussion between modality transfer, modality discrimination and modality matching, the role of verbalization appears to be controversial, and therefore this discussion will return briefly to these distinctions.

For cross-modal transfer and discrimination, it has been proposed that language is a definite aid to imbeciles in terms of serving as a mechanism for heightening the saliency of some aspects of the task (O'Connor & Hermelin, 1963). In this sense, language is seen as acting as a "bridge" between modalities (Burton & Ettlinger, 1960). The role of language may vary from task to task considerably, however, for it has been shown that in some cross-modal transfer tasks, deaf subjects are no more handicapped than normal children (O'Connor & Hermelin, 1971). Ettlinger (1967) has noted that in these coding processes--modality transfer and modality discrimination--the necessity for verbal mediation is unclear and only conjectures can be drawn.

To a lesser extent, the same controversy appears to exist in the area to which this study is addressed--modality matching. Connors, Schuette and Goldman (1967) argue that the ability to match stimuli across modalities is facilitated by verbalization. Obliquely, Rodda (1968) appears to agree, by noting that children with language difficulties perform at lower levels than average children on auditory-visual matching tasks. Conversely, Blank and Bridger (1964) maintain that language is not an essential mediator for cross-modal matching. Geschwind (1965) also supports the latter view.

Part of this apparent disagreement is caused by the manner in which the problem is formulated; the question of the role of language in modality matching must be asked correctly. It is clear that language can be used in these tasks and, dependent upon the efficiency and ingenuity in the manner in which it is used (Goodnow, 1971a, 1971b), it can facilitate modality matching performance. To begin with, however, the question is whether or not language is actually necessary for competence in modality matching (von Wright, 1970). Indications are that it is not (Ettlinger, 1967; cf. Cole, Chorover & Ettlinger, 1961).

The natural way of determining the necessity of language to cross-modal matching ability is to study groups that vary in their access to language codes. Belmont, Birch and Belmont (1968), for instance, used this technique by studying brain-damaged patients with and without significant language disturbance. The subjects involved were 18 cerebrally damaged patients with aphasia, 18 cerebrally damaged patients without aphasia and 18 control subjects. A 20 item auditory-visual matching task, with three simultaneously presented alternatives per item, was administered to all subjects. The results indicated that although subjects in both of the brain-damaged groups performed at a lower level than the normal subjects, there were no differences between the aphasic patients and the non-aphasic patients. The authors concluded that "the findings of the present study provide no support for the view that the ability to integrate information presented in one sense modality with equivalent information in another modality is dependent upon verbal mediation (Belmont, Birch & Belmont, 1968, p. 568)."

If language is not a necessary component of modality matching, under what circumstances can it be seen to play a role in this task, and how might this role be a function of the age of the subject and the type of stimulus materials involved? A study by Klapper and Birch (1971) supplies some interesting clues in this respect. These authors studied developmental changes in the ability of children to judge the intra-modal equivalence of temporally distributed visual and auditory stimuli; the stimuli were a light flashed at a stationary point in space and clicks emanating from a stationary point. The subjects were 196 children distributed over ages 3 to 11. The results of the study indicated different development curves for matching ability in the two modalities, with intra-modal matching of auditory and visual stimuli merging at a point of equal difficulty between the ages of 10 and 11, and auditory matching scores higher for all ages less than 10 years. An inspection of the data reveals that the convergence of the auditory and visual curves at these ages was due, in part at least, to the severe ceiling effect in the Klapper and Birch instrument, but nevertheless at lower ages the curves were consistently disparate. Klapper and Birch (1971) conclude that:

> .... had the judgements been underlain by a common coding mechanism, verbal or non-verbal, one might have anticipated equivalence in age specific levels of ability in the two sense modes. In fact, children's abilities to judge temporal patterns when they were visual and auditory were

> not equally good, with accuracy of judgement clearly more advanced for auditory presentations at almost all ages (p. 552).

But thi[illegible]urious conclusion to reach, for it is possible to argue exact[illegible]ite point of view. Verbalization could conceivably have been i[illegible]oth tasks, but its effects may have been different [illegible]the [illegible]s. One would suspect that verbal codes such as numbe[illegible]and [illegible]m would be more likely to be spontaneously created and more ea[illegible]y u[illegible]ized for auditory stimuli than for a light flashing in space. [illegible] for the auditory stimuli, the actual generation of a coding sy[illegible]may not be necessary, but for the visual stimuli some creativity [illegible]ld have to be shown in coding the temporal patterns of flashes. H[illegible], the auditory stimuli should be easier to code for young children, w[illegible] this effect lessening as language facility and flexibility develop. This is precisely the pattern of Klapper and Birch's data.

Klapper and Birch's (1971) rejection of the effects of language as a facilitation[illegible]hanism in modality matching is consistent with the general theo[illegible]l orientation taken by Herbert Birch and his colleagues. As noted previously, they have tended to argue a non-mediational point of view, with the emphasis of explanation for modality matching processes placed on perceptual integration. But they have not held this point of view consistently, as exemplified by a study conducted by Kahn and Birch (1968). In this study 350 subjects from grades 2 through 6 were administered a 20 item auditory-visual matching test. By self-report technique, the subjects were studied with respect to the strategies they adopted in the course of responding to the items. The strategies fell into four categories: (1) variations in counting procedures--these included counting with appropriate pauses (e.g., I counted the taps like this . . . 1 (pause in S's voice), 2, 3 (pause in S's voice . . . etc.) and counting the number of taps that came together and thus coding the clusters of taps (e.g., I counted the taps, but I added up the ones that came together and then put them into groups, like this . . . 1, 1 + 1 = 2 and then 1, etc. . . .); (2) attempts to visualize the correct dot pattern; (3) use of a sense of body participation; (4) no knowledge of technique. Of special interest here are the first two techniques, counting and visualization. Kahn and Birch found that almost half of the subjects in each grade used a counting technique of some type. On the average, approximately 15% of the children used a visualization technique. The significant factor in this information is the different scores obtained by these two groups. The "visualization" group obtained consistently higher scores than the "counting" group for every grade level. An analysis of IQ revealed almost identical IQ distributions for the two groups. Thus, while Kahn and Birch (1968) do not propose that verbal-mediation is a factor in modality matching, they do implicitly support a mediational point of view with respect to imagery and spatial schema processes, a point of view which has been shown, of late, to account potentially for a good deal of the learning processes in children (Jarman, 1973).

Furthermore, the finding that spatial schema processes aid in cross-modal matching much more than do counting procedures, although Kahn and Birch do not appear to feel that this is a significant fact, is consistent with the views as the spatial and temporal aspects of the task that have been discussed earlier (Rudnick, Martin & Sterritt, 1972;

Sterritt, Martin & Rudnick, 1971). The children who visualized the auditory patterns purposefully transferred temporal stimuli to spatial stimuli. When shown the alternatives from which they were to choose the correct match, they had only to find the visual representation of a schema that they had already formed. On the other hand, the children who utilized counting procedures did not have a representation available that could be directly matched with the alternatives on the cards. They had to perform additional encoding and decoding in order to arrive at a decision and were more prone to error as a result. Thus, the children who visualized the auditory series had in effect already solved the item before the response alternatives were presented to them.

Goodnow (1971a, 1971b) has discussed some further aspects of verbal-mediation processes in modality matching and notes that, aside from counting (Lehman & Goodnow, 1972), children also sometimes use rhythm. The description given by Goodnow is that the children remember the auditory series "like a song" and "sing it in their heads". Goodnow alludes to the possible use of spatial schema and imagery, when she notes that this portion of the psychological literature has never been properly integrated with modality matching studies. The Kahn and Birch (1968) study demonstrates that verbal mediation should be accompanied by imaginal mediation in explaining modality matching processes. Indeed, it may be that imagery is the most powerful technique for auditory-visual cross-modal matching because it supplies the most congruent system of representation for comparison with the visual pattern alternatives. Verbal mediation, on the other hand, may be the best technique for visual-auditory cross-modal matching because of the temporal sequence that would be established for comparison to the auditory pattern alternatives. Thus, it is not a question of which mediation is used or is most effective for all tasks; it is a question of using the appropriate mediation system for the task at hand.

Having noted the use of verbal and imaginal mediation, however, is not to account entirely for the difficulties that some groups of children apparently experience in modality matching tasks. Why, for instance, are poor readers deficient in modality matching (Muehl & Kremenak, 1966)? Why do language-delayed children also have this problem (Holloway, 1971)? Ostensibly, poor readers could utilize these mediation devices as well as normal readers, and the language-delayed children should still have some access to imaginal processes. At this point only conjectures can be drawn, but a central theme in these questions appears to be the problem of order of events (see Elliott & Trahiotis, 1972; Kallan, 1972). An assumption in the cross-modal matching tasks is that the order of stimuli clusters can be "held" as the matching takes place. The significance of order in modality matching alternatives has been noted by Garner (1970), who supplies evidence showing that symmetric patterns are consistently found to be easier to match than asymmetric patterns. The relative ease of a symmetric pattern may be due to the fact that only one half of the order of the pattern must be grasped; the other half is simply a reflection of the first. The problem of order, then, could explain why language in poor readers does not appear to aid them in modality matching. For language-delayed children, their lower performance in modality matching tasks may be not so much a result of poor language development as it is a result of basic cortical problems in temporal ordering of events. This is a classic problem of cause and effect in correlational data. The possibility noted here is that reading difficulty, language difficulty and modality matching difficulty, for some particular groups, may be due to a common cause. Rather than being causes of others, a dysfunction in the serial order of behavior (Bryden, 1967; Lashley, 1951) may be the central cause of each problem.

In summary, this section has determined that verbal and imaginal mediation, as two particular cognitive strategies, play a significant role in modality matching performance. A final point to examine is how this performance relates to broad levels of intellectual functioning.

Relationships to intelligence

For purposes of the present study, intelligence has been defined operationally as the score obtained on a general intelligence test. The only indicators presently available of the relationship between intelligence as so defined, and modality matching ability, are correlational data from a variety of subject groups.

Birch and Belmont (1964), in their seminal paper on auditory-visual integration as related to reading achievement, note that WISC scores correlate slightly with auditory-visual modality matching in the manner shown in Table 5. Subjects were 150 low reading achievement children, for whom the mean IQ was 96.7 with a standard deviation of 10.3, and 50 normal readers for whom the mean IQ was 110.8 with a standard deviation of 11.6. The correlational data above are for the total group of 200 children; the magnitude of correlations for a normal group would be somewhat lower due to the pooling effect of disparate means.

Birch and Belmont studied these relationships again in later papers

Table 5

Product-Moment Coefficients of Correlation Between Auditory-Visual Score and WISC IQ for Normal and Retarded Readers

Tests	r
A-V vs. Full Scale IQ	.38
A-V vs. Verbal IQ	.27
A-V vs. Performance IQ	.30

(Birch & Belmont, 1965b; cf. 1965a) and obtained slightly higher results for the OTIS quick scoring test of intelligence and several other intelligence tests that they do not specify. A total of 220 children were involved in the study, with samples from grades K-6. Their 10 item A-V modality matching test was correlated with the IQ measure for each grade, with the results as noted in Table 6. An interesting pattern in this set of data is the relatively steady increase in the magnitude of the correlation coefficients up to grade 3. The decrease after that point is a result of Birch and Belmont's faulty design of the A-V instrument; at the higher grade levels there is a severe ceiling effect which reduced the variance by grade and thus lowered the magnitude of the correlations.

As noted, these studies by Birch and Belmont are methodologically slightly unsound. A study by Ford (1967) has been conducted in order to correct some of these faults. Ford used 121 grade 4 boys with an IQ range on the Henmon-Nelson intelligence test of 60 to 141 (mean = 106.17; standard deviation = 14.61). Ford also used a 20 item version of Birch

Table 6

Product-Moment Correlation Coefficients Between IQ and Auditory-Visual Pattern Test Score by Grade

Grade	N	r	p
K	30	-.11	N.S.
1	30	.56	<.01
2	29*	.42	<.05
3	30	.57	<.01
4	35	.41	<.02
5	35	.34	<.05
6	29*	.28	N.S.

*IQ score unavailable for one subject

and Belmont's test, with four response alternatives per item rather than three. The correlation between IQ and A-V performance was found to be .34.

Graham Sterritt and Mark Rudnick at the University of Colorado have also conducted several studies on A-V matching performance which improve on the methodological inadequacies of Birch and Belmont's research. Rudnick and Sterritt (1966) devised three tests, all of which employed the same three choice visual pattern response format. The first test, which was the standard Birch and Belmont test, was rhythms tapped out by a pencil (B-B); the second was tone patterns played via headphones (A); and the third was a light sequence flashed by a single bulb (V). Subjects were 36 boys in grade 4, all of whom were administered Form IIIA of the Lorge-Thorndike Intelligence Scale. The verbal (V), nonverbal (NV) and total (T) mental age scores intercorrelated with the three tests as shown in Table 7.

Table 7

Intercorrelation of Mental Age
and Perceptual Test Scores

	B-B	V	A
V	.53	.47	.45
NV	.46	.46	.50
T	.53	.49	.52

Rudnick, Sterritt and Flax (1967) repeated this design for a group of 30 boys in grade 3, with somewhat lower results (see Table 8).

Table 8

Intercorrelation of Mental Age
and Perceptual Test Scores

	B-B	V	A
V	.22	.32	.18
NV	.42	.41	.32
T	.40	.43	.31

It should be noted that the higher correlations obtained by Sterritt and Rudnick, as listed in Table 7, are a result of using mental age as a variable rather than IQ. This is a reflection of the developmental trends that have been discussed in a previous section of this review.

Birch and Belmont (1965a) note this fact in their data on 218 normal children. Chronological age and mental age correlated .73 and .79 respectively with A-V performance, but IQ correlated only .29 with A-V matching.

The conclusions that may be drawn from these studies must be tentative at best. It is indicated that auditory-visual matching processes account for only a small portion of the variance in omnibus intelligence tests (cf. Jorgenson & Hyde, 1974). This is hardly surprising, for the same would probably hold true for any rather homogeneous test of a similar nature to the modality matching task.

Yet Jensen (1969) states that modality matching-specifically cross-modal matching--is the key indicator of basic intellectual functioning:

> It seems evident that what we call general intelligence can be manifested in many different forms and thus permits measurement by a wide variety of techniques. The common feature of all such intercorrelated tests seems to be their requirement of some form of "reasoning" on the part of the subject--some active, but usually covert transformation or manipulation of the "input" (the problem) in order to arrive at the "output" (the answer). The conceptually most pure and simple instance of this key aspect of intelligence is displayed in the phenomenon known as cross-modal transfer. This occurs when a person to whom some particular stimulus is exposed in one sensory modality can then recognize the same stimulus (or its essential features) in a different sensory modality[3] . . . How does the child manage to show the cross-modal transfer? Some central symbolic or "cognitive" processing mechanism is involved, which can abstract and compare properties of "new" experiences with "old" experiences and thereby invest the "new" with meanings and relevance. Intelligence is essentially characterized by this process (pp. 10-11).

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[3] Note Jensen's confusion of terminology. By his description, this is cross-modal matching, not cross-modal transfer.

At this point the magnitude of the confusion with respect to the psychological significance of cross-modal matching ability is apparent. There is yet to be a study designed that explicitly explores the relationship between broad levels of intellectual competence and modality matching ability. The research cited in this section includes some information as a routine portion of data analyses intended to meet other objectives. Furthermore, simple correlational analysis has been used in all of these studies, which has resulted in very little information. Almost nothing is known about how different IQ groups may vary in their facility with modality matching tasks or, more importantly, how the strategies utilized to solve modality matching tasks may vary across IQ groups. (See Lucas [1970] for a very brief discussion of modality matching in mental retardates.) The important question is: Given that IQ is an omnibus assessment of the general level of a subject's intellectual functioning, when subjects are grouped by IQ levels, do the groups use the same or different strategies to solve modality matching tasks? Alternatively, does the notion of IQ assessment mask important differences among individuals with respect to their approach to modality matching and, if so, what is the theoretical significance of modality matching tasks that is currently lost in their nebulous relationship to IQ assessment techniques? The studies cited here hardly begin to answer these questions. Jensen's (1969) remarks, as curious as they are with respect to the fact that he musters no empirical support for his statements, supply some of the basic impetus to explore the issue further.

As an overview, the problem to this point has been cast as one of determining the relationships and significance of modality matching ability to broad levels of intellectual functioning. The evidence appears to indicate that a significant portion of these differences may lie more in the manner in which a subject copes with the principal dimensions of space and time (that is, uses spatial schema and temporal sequencing in cognition) than in any specific ability measures as such. Stated another way, the problem appears to be one of cognitive style, for the strategies adopted by the subjects in approaching the task appear to predict their success better than any other known determinant.

The study of cognitive styles in psychology has been, of course, an eclectic endeavor (Kagan & Kogan, 1970). Indeed, one may turn to this area with some considerable trepidation. The principal notions of space and time, however, serve as limiting and directional cues in guiding a search for a set of theoretical constructs in which they may be, in turn, embedded. This review will now turn to a particular theory which appears to satisfy these requirements to a greater extent than others presently available. This theory is concerned with the manner in which information may be represented and processed and, as will be demonstrated, appears to be very closely linked with the etiology of modality matching tasks.

Information Processing

Simultaneous and successive syntheses

Any theory of mental abilities which concerns itself with the notion of information processing must necessarily hypothesize constructs which account for the arrangements and transformations made upon cognitive content. It is the case, of course, that these postulated mechanisms must be able to account equally well for the processing of content which is of highly complex forms as well as of elementary varieties.

Luria (1966a, 1966b) proposes that the processing of the cognitive content of the brain is accomplished via the employment of a series of exteroceptive, proprioceptive and interoceptive analyzers, which collectively synthesize input into various forms. As organisms of increasing order on the polygenetic scale are considered, it is found that the cortical placement of these analyzers tends to become distinct. In the human brain the analyzers are identifiable in terms of cortical localization and work in conjunction with one another by way of "overlapping zones". Through the functions of these zones, integration of content is accomplished. For purposes of this discussion, it is the forms that these integration processes take that are of importance. It is postulated that there are two basic forms of information processing: simultaneous and successive.

Simultaneous integration refers to the synthesis of separate elements into groups, these groups often taking on spatial overtones. It is hypothesized by Luria that these syntheses are of three varieties: (1) direct perception: the process of perception is such that the organism is selectively attentive to the stimulus field. Thus, those parts of the field which are salient for the subject are attended to first and with maximal attention. The result of this process is the formation of a synthesis of the stimulus input in the brain. According to Luria, this type of formation is primarily spatial, even in the case of the acoustic analyzer:

> Our hearing distinguishes not only timbre and pitch relationships, rhythms and accents, but also simultaneous associations of sounds, or chords; finally, our hearing always relates a sound to a certain point in space, or in other words, it incorporates the stimulus into a scheme of spatial relationships (1966a, p. 75).

In the case of simultaneous stimulus input in two or more modalities, the process is more complex, but the principle is said to remain the same. (2) mnestic processes: the organization of stimulus traces from earlier experience can take place in a simultaneous fashion. Examples of this type of integration are the construction of the gestalt of a visual image by the subject when portions of the image are shown consecutively, and the organization of consecutively-presented words into a group on the basis of a criterion. Further features of this variety of simultaneous integration which are implied by Luria are that the stimulus traces employed can be either short-term or long-term, and the integration of the traces is performed on the basis of criteria which may be specified by either the organism or an external source. (3) complex intellectual processes: in order for the human organism to grasp systems of relationships, it is necessary that the components of the systems be presented simultaneously. In this fashion, the relationships between components can be explored and determined. Luria notes that the use of spatial representation is an aid in this process, for when a unitary representation of components is formed, the system is readily "surveyable". An example of this process is the perception of language. As grammar is decoded by the organism, logical-grammatical relationships are established which interrelate syntactical events in order to reach conclusions. Finally, from this example it is evident that the three forms of synthesis which have been discussed--perceptual, mnestic and complex intellectual--are not independent. For the most part, the first two forms of synthesis can be viewed as the foundations of the third.

Successive information processing is identified by Luria primarily in terms of temporality. It can be construed heuristically as a "chain" which expresses the serial order of components and the "links" which connect the components. The important distinction between this type of information processing and simultaneous processing is that in this variety the system is not totally surveyable at any point in time. Rather, a system of cues consecutively activates the components. Similar to the case of simultaneous information processing, Luria identifies three varieties of successive processing: (1) sensorimotor: these are sequential acts which have become highly internalized and are generally known as habits or unconscious actions. Examples of this variety of successive synthesis are abundant, two of which are walking and writing. (2) mnestic: this type is best represented by the example of rhythmic or tonal melodies. Each note acts as a cue to identify the next, thus evoking a complete chain of mnemonic aids. (3) complex intellectual processes: the most obvious example of this variety of successive information processing is human speech. The structure of grammar is such that the processing of syntactical components is dependent upon their sequential relationships within sentence structure. This example of human speech also serves to point out the relationship between the three varieties of successive information processing--as in the case of simultaneous synthesis, the first two varieties play a major role in the third.

Factor analytic research

Luria's theory of simultaneous and successive syntheses appears to have existed almost unnoticed in North American psychology. Recently, the theory has been extended through factor analytic work by J. P. Das and his colleagues (Das, 1972, 1973a, 1973b, 1973c; Das, Kirby & Jarman, 1975; Das & Molloy, 1975). Some studies which are exemplary of this research will now be described.

Das (1973c) used a battery of eight tests in a study of 60 high and low SES grade 4 children of normal intelligence range, in order to examine information processing. These tests are described in the present discussion in Chapter IV. Das also included school record IQ scores and achievement scores for mathematics and reading. The data was intercorrelated and after principal components analysis was rotated by varimax. The factor matrix which was derived is in Table 9.

Several points are of interest with respect to these results. It is evident that Raven's Progressive Matrices, Figure copying and Memory for Designs load on the factor which Das has designated as simultaneous synthesis. Visual Short-term Memory, Serial recall and Free recall load on the successive factor. The speed factor is defined by the Word reading test and the school achievement factor is defined by the IQ and achievement scores.

Table 9

Rotated Factors (Varimax) for Cognitive and Achievement Tests: Edmonton High and Low SES Children (N = 60)[1]

Test	Factor I Successive	Factor II School Achievement	Factor III Simultaneous	Factor IV Speed
IQ (from school records)	347	793	204	045
Raven's Progressive Matrices	181	384	740	200
Figure copying	162	157	874	004
Memory for Designs	178	-055	-830	-162
Cross-modal coding	457	059	433	423
Visual Short-term Memory	760	034	124	462
Serial recall	896	355	042	013
Free recall	898	340	004	019
Word reading	-130	-320	045	-879
Reading achievement	184	851	100	266
Mathematics achievement	161	844	281	152
Variance	2.684	2.590	2.029	1.328

[1]Decimals omitted

Considering the simultaneous factor first, an interesting feature of the results is that the Memory for Designs test, which is a short-term memory test, loads together with Raven's Progressive Matrices, the latter of which is often regarded as the purest possible test of abstract reasoning. The previous review of Luria's research has intimated that simultaneous synthesis could be present in both reasoning and memory tasks, through the conceptual and mnestic varieties of these syntheses. This is demonstrated empirically in this factor. Despite the temptation to label Factor III as a reasoning factor, then, as would be traditionally done in view of the Raven's test acting as a marker test, the interpretation of simultaneous synthesis is more congruent with the nature of the tests. The factor describes the formation of spatial schema, with these schema being used for both reasoning and memory tasks.

The successive factor also demonstrates some interesting features. Visual Short-term Memory and auditory short-term memory (Serial recall and Free recall) both define a process which is apparently not modality-specific. The common characteristic in these three tests is sequential ordering of events. The nature of the stimuli vary considerably, but the strategy of processing is similar for all tasks.

The speed factor, which is identified by Word reading, appears to indicate that one's tempo of processing information is not a necessary defining feature of either simultaneous or successive synthesis. This factor has emerged fairly clearly as separate from these modes of processing and, as a consequence of the rotation procedure, is uncorrelated with them.

Of special interest is the school achievement factor. The IQ scores which were included in the data analysis were from the Lorge-Thorndike test of intelligence and thus the total score included performance scores and verbal scores. It might be expected from past factor analytic work that the IQ test would align itself with Factor III, in the event of this factor being interpreted as a reasoning factor. It was indicated in the discussion of intelligence early in the preceding review of literature that IQ tests are often thought to be tests of abstract reasoning or conceptual problem solving. And yet the IQ-school achievement factor has emerged as clearly defined and uncorrelated with simultaneous synthesis. Indeed, the factor is clearly differentiated from successive synthesis as well. One possible interpretation of this is that simultaneous and successive syntheses are information processing strategies which may be used by all individuals in a normal intelligence group irrespective of their placement in that group. This is only tentatively indicated, however, for the range of IQ scores used in this study was not wide, and this conclusion is limited to this range.

A test that has not been mentioned is cross-modal coding (cross-modal matching). In the study reported by Das (1973c), the Birch and Belmont (e.g., 1965b) version of this test was used, with the subjects required to find the correct visual pattern in a set of three alternatives following the presentation of an auditory stimulus. The review of literature on modality matching indicated that the principal dimension of individual differences in this type of task may be the spatial-temporal switching that is necessary in the cross-modal case. In Das' study, stimuli were presented temporally and had to be matched with their spatial counterparts. It has been stated that the generic feature of successive synthesis is temporal ordering of events. For simultaneous synthesis, it is the organization of spatial schema. One might expect, then, that if these two constructs were validly represented in the factor analysis reported by Das (1973c), and conversely, if the spatial-temporal dimension is the dominant dimension of individual differences in cross-modal matching, that the matching task would load almost entirely and equally on these two factors. That is, because the test involves temporal ordering of stimuli, followed by a switch to spatial composition of the stimuli for matching purposes, these two aspects should be reflected equally in the relationships of the test to the successive and simultaneous factors. Table 9 reveals that this is exactly what has occurred.

The constructs of simultaneous and successive synthesis, as described in the study by Das (1973c), have been verified in later research (Das & Molloy, 1975). The Digit span test from the Wechsler Intelligence Scale for Children was added to the set of tests used previously, to form a slightly expanded test battery for successive synthesis. The subjects were grade 4 boys defined by Lorge-Thorndike verbal IQ scores in the dull normal range.

The factor matrix from this study by Das and Molloy (1975) is given in Table 10. As noted in the table, the factors for simultaneous and successive syntheses and speed emerged clearly in this study, with Digit span loading on the successive factor as expected. Also, cross-modal coding loaded on the simultaneous and successive factors, although the loadings for this test were not as symmetric in relation to the two factors as had been found previously (Das, 1973c). Possible reasons for the changes in factor loadings for this test will be noted in subsequent

Table 10

Expanded Battery with Reading Achievement:
Rotated Factors for Grade 4 Children (N = 60)[1]

Test	Factor I Successive	Factor II Simultaneous	Factor III Reading	Factor IV Speed
Raven's Progressive Matrices	-023	864	177	043
Figure copying	-025	679	182	200
Memory for Designs	061	-729	185	139
Cross-modal coding	165	571	-003	294
Visual Short-term Memory	670	-095	282	-044
Word reading	-215	068	-050	689
Serial recall	921	-060	-123	-132
Free recall	895	-008	-067	-145
Digit span	809	067	107	155
Performance IQ	-251	644	-101	-433
Reading achievement				
Vocabulary	167	138	878	047
Comprehension	-136	-096	650	-539
Variance	2.941	2.659	1.414	1.168

[1] Decimals omitted

discussion.

It is evident that there are many possible ways of extending and viewing the constructs of simultaneous and successive syntheses. An interesting question to be asked, for instance, is the extent to which these modes of processing information may be taught or developed. That is, if the two types of syntheses represent a style of cognition, rather than a stabilized "ability" in accord with the traditional view of mental abilities, can they be developed by certain teaching techniques? Krywaniuk (1974) investigated this possibility in the context of a remediation research program for 40 Canadian Indian children. Pretests on the children indicated that they had high scores on the performance section of the Wechsler Intelligence Scale for Children (WISC) and the Raven's Progressive Matrices, suggesting that their spatial abilities were adequate. However, results on the WISC verbal and the Schonell and Serial Learning tests indicated difficulties in the verbal-sequential area. The children were then divided into experimental and control groups by matching them on the WISC scores, with the experimental group receiving instruction in verbal-sequential strategies. The instruction included the use of: (1) Sequence Story Boards, which use 12 pictures to be arranged in order to make up a story; (2) Parquetry Designs, which are geometric figures to be fitted together to make a design; (3) Serial recall, which was practice in the recall of a series of 12 objects after they had been removed from sight; (4) Coding, which was a system of hand and knee "claps" coded for dots and squares respectively, and presented in a fashion similar to cross-modal coding; (5) Matrix Serialization, which was specific practice in reading and recalling the order of presentation of the digits in the Visual Short-term Memory test, and (6) Filmstrips, which were a series of films on Visual Discrimination and Spatial Orientation, Visual-Motor Co-ordination, Visual Memory, Figure and Ground, and Visualization.

Prior to instruction, both groups had been given pretests on the battery of instruments that have been discussed previously. Following the remedial experience, which was approximately 15 hours for the experimental group and three hours for the control group, the battery of tests was given again. Pretest and posttest principal components analyses were done. Among the findings was the fact that the Progressive Matrices shifted its loadings more clearly to the simultaneous factor following intervention. The Visual Short-term Memory test, which had loaded on the speed and simultaneous factors in the pretest, shifted its loadings to the successive and simultaneous factors. These shifts were consistent with the nature of the intervention program and resulted in a factorial definition of simultaneous and successive syntheses which was comparable to that found in Caucasian children. The study, therefore, demonstrated the efficacy of teaching these basic strategies and encouraging their use.

Of particular interest to the present study is the nature of group differences as defined by IQ tests in the utilization of simultaneous and successive syntheses. Research inthis area is limited to a single study by Das (1972), in which 60 nonretarded children were compared with 60 retarded children on a subset of the battery of tests that has been used in the previously mentioned studies. The retarded children were matched on mental age (MA) with the nonretarded children;

the mean IQs of the groups were 67.08 and 91.56, respectively. In the results, t-tests between the groups indicated significant differences for all instruments. A principal components analysis was performed for both groups, the results of which are presented in Table 11.

The patterns of process differences between the two groups are similar in some tests but dissimilar for others. The tests which show differences are the Graham-Kendall Memory for Designs, Cross-modal coding and, to a lesser extent, Visual Short-term Memory. The main marker tests for simultaneous and successive syntheses have similar loadings for the retarded and nonretarded groups.

There are some curious trends in these patterns. Memory for Designs has been shown in nearly all other studies by Das to load strongly and negatively on the simultaneous factor. Its negative loading is to be expected, because the test is scored for errors, not correct responses. In the study discussed here, Memory for Designs has a strong positive loading on the simultaneous factor. A further anomaly is the Cross-modal coding test. For the nonretarded children this test had its principal loading only on the simultaneous factor. For the retarded children the test loaded approximately equally on the simultaneous and successive factors. One might have expected the reverse to be true for these two groups, given the earlier discussion regarding simultaneous and successive syntheses both entering into the cross-modal matching tasks. It should be recalled, however, that the nonretarded children still performed significantly better on the task than did the retardates.

This study by Das (1972) indicates that process differences of some type do exist between retarded and normal children. The nature of these

Table 11

Factor Analysis of Cognitive Test Scores of 60 Retarded and 60 Nonretarded Children: A Varimax Rotation[1]

Test	Nonretarded[a]		Retarded[b]	
	Factor I Simultaneous	Factor II Successive	Factor I Simultaneous	Factor II Successive
Raven's Progressive Matrices	792	161	786	007
Memory for Designs	269	579	830	-061
IQ score from school record	492	176	529	326
Cross-modal coding	742	-020	546	482
Visual Short-term Memory	693	294	533	481
Serial recall	154	683	048	855
Free recall	023	757	043	856
Variance	1.996	1.519	2.173	2.039

[1]Decimals omitted

[a]Grade 2 and 3 children

[b]Matched on mental age

differences, however, is not clear. The battery of tests used in this study was a reduced set and therefore some of the anomalies of the results are likely due to the fact that the factors could not emerge clearly. One purpose of the present study is to delineate the nature of these factors more explicitly for different IQ levels.

Model of information integration

The factor analytic extensions of Luria's (1966a, 1966b) clinical research that have been described briefly in the previous section have been summarized recently by Das, Kirby and Jarman (1975). As a method of synthesizing their research, as well as generalizing to other areas such as memory, imagery and language, Das et al. have proposed a model of information integration. This model is described here in completion of this discussion of information processing. Much of the following description is verbatim from Das, Kirby and Jarman (1975).

As demonstrated in Figure 2, the model of information integration contains four units: the input, the sensory register, the central processing unit, and the unit for output.

In the input unit, a stimulus may be presented to any one of the receptors, extero-, intero- or proprioceptors, and within the extero-ceptors to any one of the sense modalities. Further, the input can be presented in a parallel (simultaneous) or a serial (successive) manner. The stimulus is registered immediately by the sensory register and may be passed on for central processing.

In this process, the sensory register acts as a buffer, from which the central processor may receive information in one of two ways. When information is transmitted, the central processor may interrogate the

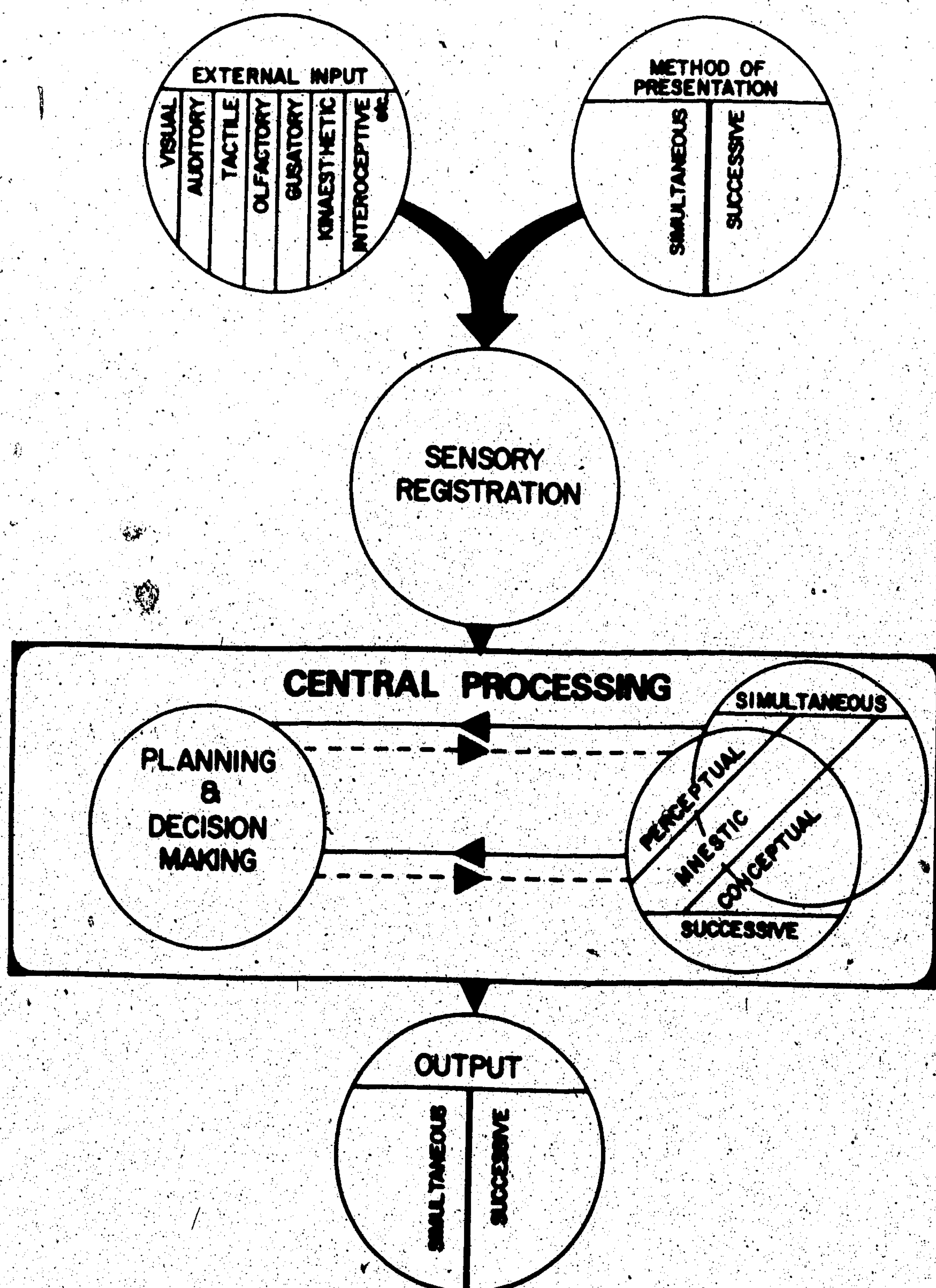

Figure 2. Model of information integration

buffer to see if anything is there, or alternatively, the buffer may interrupt the processor to force it to accept information. The latter would occur more frequently perhaps, because sensory information cannot be delayed.

Of particular interest is the form of information representation in the sensory register. There is a substantial body of evidence in North American literature on serial and parallel processing to suggest that the sensory register may not be limited to serial processing of information. Sperling (1960), for instance, has shown that a 3 x 4 visual array is not retained as a sequence, but rather as a simultaneous icon; thus, stimuli of a complex nature are also processed in the sensory register in parallel (Averbach & Coriell, 1961; Averbach & Sperling, 1961; Neisser, 1967; Sperling, 1960). They may then be "read out" serially into the central processing unit. Such an account is consistent with most modern theories of memory (e.g., Atkinson & Shiffrin, 1968).

The central processing unit has three major components: that which processes separate information into simultaneous groups, that which processes discrete information into temporally organized successive series, and the decision-making and planning component which uses the information so integrated by the two other components. The processing in these components is not affected by the form of the sensory input--visual information can be processed successively and auditory information can be processed simultaneously. It is suggested, following Luria (1966a), that these components can be identified with the functions of specific parts of the cortex--the occipital-parietal area has evolved to specialize in simultaneous synthesis; the successive is located in the anterior regions, particularly in the fronto-temporal area. Both of these are concerned with coding and storage of information; they do not plan, regulate, or control conscious behavior. That function is carried out by the frontal lobe as suggested by Luria on the basis of clinical observations.

The model assumes that the two modes of processing information are available to the individual. The selection of either or both modes depends on two conditions: (a) the individual's habitual mode of processing information as determined by social-cultural and genetic factors, and (b) the demands of the task.

The third component, which could be labeled thinking, uses coded information and determines the best possible plan for action. Perhaps it is also crucial for the emergence of causal thinking which Hess (1967) describes as "an integrative activity which brings simultaneous and successive patterns of nervous excitation into a subjectively meaningful frame of reference (p. 1283)". Both simultaneous and successive processing can be involved in all forms of responding. This is the case irrespective of the method of input presentation. Perhaps Lashley's (1951) work is relevant to the decoding or behavioral part in serial tasks. Serial ordering of behavior may not depend either on the manner in which information was coded or the motor aspects of the behavior itself. The output unit, then, determines and organizes performance in accordance with the requirements of the task. For example, in memory tasks a subject may be required to recall serially or recall the items in categories supplied by the experimenter; thus, appropriate output organization is necessary.

In summary of the model, therefore, information may be represented either simultaneously or successively in all four units with an interchange in the form of representation between units. Thus, the model subsumes the North American research on serial and parallel processes, incorporates the classical philosophical issues of space-time relationships, and perhaps most interestingly it addresses the question of selected types of cognition and brain localization. The central issue raised by the model in this latter area is the role of the brain hemispheres in simultaneous and successive processing. Luria's (1966a, 1966b) research is based on lesions of the left hemisphere only. In contrast, Ornstein (1973) has summarized a series of themes in philosophy and psychology related to left-right hemispheric differences, the essence of which is the theme for a growing body of research in psychology:

> The left hemisphere is predominantly involved with analytic thinking, especially language and logic. This hemisphere seems to process information sequentially, which is necessary for logical thought since logic depends on sequence and order. The right hemisphere, by contrast, appears to be primarily responsible for our orientation in space, artistic talents, body awareness and recognition of faces. It processes information more diffusely than the left hemisphere does, and integrates material in a simultaneous, rather than linear, fashion (p. 87).

The operational measures supplied by the current factor analytic work may be applied and integrated with some of the research quoted by Ornstein and others in the near future.

Summary and Conclusions

The preceding review of literature has dealt with three topics: intelligence, modality matching and information processing. The main points that have been noted will be stated briefly here.

Intelligence, as defined by IQ tests, is a sampling of general cognitive skills which is very broad in terms of developmental periods and test content. These tests sample levels of knowledge that have been transferred and refined from earlier and current developmental stages, and have been selected to have predictive validity for school-oriented behavior. A score on an IQ test does not indicate a fixed level of intelligence, capacity for learning, aptitude, a central force like "g" or a measure of behavior beyond the test content. The distinction between prediction and explanation points out the technical efficacy of intelligence tests which coexists with their explanatory weaknesses. That is, the tests have been shown to be strong empirically as predictive instruments. Masked in their classification of individuals, however, is the most important explanatory information on how the processes which have led to certain responses vary across individuals and groups. For the latter reason, intelligence tests alone supply little or no valuable psychological information. They may be used effectively, however, when their technical efficacy for the prediction of academic success is applied for the classification of groups, who are subsequently studied by other independent research methods.

Modality matching has been defined as the judgement of equivalence of stimuli presented in two modalities. It has been suggested by the literature that the main dimensions of matching in the auditory and visual modalities are time and space, and that individual differences exist on these dimensions, not in use of the modalities. The ability to integrate information in time and space increases ontogenetically at a steady rate in children, at least from kindergarten to grade 4. Individual differences in auditory and visual memory do not predict skill in these tasks. An area of disagreement in the literature is the strategies involved in modality matching, especially with respect to the possible use of imagery and language as forms of mediation. A further but related area of disagreement is the significance of cross-modal tasks as indicators of intellectual development; strong claims have been made to this effect, but empirically the evidence indicates these claims are unfounded. Further, the significance to intellectual development of competence in matching information intra-modally is unknown.

The model of information processing which is incorporated in this discussion is simultaneous and successive syntheses. Simultaneous synthesis is a processing strategy in which cognitive content is arranged in some type of unitary spatial composite. Successive synthesis is a strategy in which content is arranged in a sequential order. These two processing types are seen as cognitive strategies which are independent of modalities. That is, auditory and visual stimuli may be processed either simultaneously or successively. The usual nature of tasks, however, has tended to specialize successive processing for auditory and simultaneous processing for visual stimuli. Factor analysis has been used to define these strategies operationally, and to examine their use across several population parameters. From this research, a model of information integration has been developed which can be used as a conceptual framework for the generation of further research.

CHAPTER III

PROBLEM

Statement of the Problem

The general problem of this study is to determine the relationships among intelligence, intra-modal and cross-modal matching, and simultaneous and successive syntheses. This problem is composed of two specific questions:

1. What patterns of similarities and differences exist both in the use and effectiveness of simultaneous and successive syntheses by distinct intelligence groups?
2. What patterns of similarities and differences exist both in the levels of performance in modality matching tasks and the use of simultaneous and successive syntheses in modality matching tasks for distinct intelligence groups?

Rationale

The rationale for the problem is distinct for each of the two questions above.

Question 1

The first question examined in the study, concerning simultaneous and successive syntheses and intelligence, is an extension of research conducted by Das (1972). In this study, Das compared the patterns of simultaneous and successive syntheses in retarded and normal children. The subjects were matched on mental age (MA) with the mean IQs of the groups as 67.08 and 91.56, respectively, for the retardates and normals.

There are three specific aspects of Das' (1972) study that are modified here in order to clarify and generalize his results. First, an MA match procedure was utilized by Das. An alternative procedure is to match different intelligence groups on chronological age (CA) in the course of studying patterns of cognitive abilities (Ellis, 1969; Heal, 1970). For purposes of the present study, a CA match procedure is useful because it is the characteristics of varying levels of adaptation that is of interest in the study; IQ is viewed as a measure of this adaptation and therefore as an independent variable, with CA equal for subjects in all IQ groups.

Second, the use of two groups by Das derived its rationale from the fact that the study focused on mental retardation. It is possible to explore cognitive competence generally by using three groups from a major portion of the total IQ range, with a low intelligence group as one part of the design. Thus, in the sampling of a range of intelligence, further information is supplied on how patterns of cognitive strategies vary from below normal to normal IQ, and also beyond into the high IQ range, thus making the retardate-normal comparison more meaningful.

Third, the battery of tests which Das (1972) used in his study has since been refined and expanded (Das, 1973c; Das & Molloy, 1975). The battery is used in its expanded form here, across the three IQ groups.

In summary, these three extensions supplement the information now available on simultaneous and successive syntheses by:

1. Studying the characteristics of varying levels of adaptation as defined by IQ through matching on chronological age.

2. Generalizing the current information to a broader range of adaptation through the inclusion of a high IQ group.
3. Improving the methodology of the past research through the inclusion of a larger number of tests.

Question 2

The second question examined in the study concerns both the levels of performance and cognitive strategies which are characteristic of different intelligence groups on the modality matching tasks. In order to emphasize the distinction between level of performance and types of strategies, these two aspects of the question are given separate rationales.

The first aspect regarding level of modality matching performance and intelligence appears to be basic to any consideration of intellectual processes. Birch and Belmont (e.g., 1965b) in all their studies consider cross-modal tasks to be key indicators of intersensory development, which ostensibly would be the foundation for higher order thought processes. Blank and Bridger (e.g., 1964) take the view that cross-modal matching involves processes beyond the level of perceptual integration and argue that the task is an indicator of basic processes in conceptual development. Rudnick, Martin and Sterritt (1972) have stated that the critical dimensions of modality matching tasks are space and time, and that it is on these primary orientation dimensions that children vary in their facility with the tasks. Jensen (1969) has simply stated that cross-modal matching is the single most important indicator of intellectual development.

These statements regarding modality matching are unusually strong with respect to the relationship of modality matching to broad levels of intellectual competence. Yet, very few studies exist which examine cross-modal matching as related to intelligence. Intra-modal matching, which has been studied within only a single level of intellectual competence, has received even less attention in this context. Most importantly, not a single study exists which examines both cross-modal and intra-modal matching among intelligence groups. It has been emphasized in the preceding review of literature that inferences regarding the significance of modality matching tasks to intellectual development cannot be made unless both cross-modal and intra-modal tasks are included in the design of the research. It is only through the inclusion of all combinations of these tasks that the significance of the ability to process information within and between modalities can be assessed. This study includes both of these types of tasks in a battery of tests administered to three distinct intelligence groups. Together these groups make up the major portion of the range of intelligence in the general population.

Thus, the present study actually accomplishes two purposes in studying levels of performance in modality matching as related to intelligence. It examines the validity of the claims that have been made regarding cross-modal matching and intellectual development, and it explores the relative importance of intra-modal matching as compared with cross-modal matching in terms of intellectual development.

The second aspect of the question, which relates to the strategies that are used by different intelligence groups in modality matching tasks, derives its rationale from the possible isomorphic dimensions that enter into both modality matching and simultaneous and successive syntheses. That is, it has been noted that modality matching is a task which incorporates the primary dimensions of space and time. Integration of information on these two dimensions is the major source of individual differences on these tasks, since the role of modalities <u>per se</u> has been demonstrated to be negligible. In complement, it has also been noted that the primary characteristics of simultaneous and successive syntheses are spatial and temporal integration, respectively. These forms of integration have been defined operationally in the factor analytic studies that have been discussed.

On the basis of the research reviewed previously, it might be expected that temporal modality matching tasks (auditory-auditory) will load on the successive factor, spatial modality matching tasks (visual-visual) will load on the simultaneous factor, and combinations of these tasks (auditory-visual and visual-auditory) will load similarly on both the simultaneous and successive factors. These expected factor loadings are based on the common spatial and temporal dimensions in modality matching tasks and simultaneous and successive syntheses.

But the possible congruence noted here is tentative. It appears from the past factor analytic work that the simultaneous and successive factors are more stable than the mediation types that enter into modality matching tasks. Das (1972) found that these two factors emerged in factor analyses of a battery of tests for retardates and normals, but the loadings for cross-modal matching were different for the two groups. In fact, contrary to what may be expected, the retardates used both simultaneous and successive syntheses to perform the cross-modal tas[illegible] while the normals used a strategy that was mainly simultaneous.

Thus, simultaneous and successive syntheses are apparently more stable in factor analyses than are modality matching tasks. Stated in another way, the tests that have been used to identify these two types of syntheses encourage their use more strongly than the modality matching tasks encourage those strategies that would be expected on the basis of their spatial-temporal properties. It has been noted in the review of literature that modality matching tasks may be performed by various strategies, including a verbal (temporal) type of mediation or an imaginal (spatial) variety of mediation. It is apparently the case that these two types of mediation are used less systematically or less appropriately with respect to the type of modality matching task at hand than they are in the tasks which identify simultaneous and successive syntheses.

Rather than modality matching contributing to the operational definition of simultaneous and successive syntheses in factor analytic studies, therefore, these tasks are apparently performed by varying strategies. The factors of simultaneous and successive syntheses, on the other hand, are quite stable because the tasks used to identify these factors are consistently performed by the same strategies. While the strategies that are used for the modality matching tasks can be postulated a priori on the basis of the spatial and temporal aspects of the tasks as related to simultaneous and successive strategies, their actual empirical relationships are unknown. Modality matching is a task which may be performed by either of these two strategies; the question of interest is how the application of these strategies varies among intelligence groups in the course of completion of the tasks.

In summary, the use of all combinations of modality matching tasks for different intelligence groups supplies information on:

1. The validity of claims concerning cross-modal matching performance and intelligence;
2. The relative importance of intra-modal matching to intelligence;
3. The strategies used in intra-modal and cross-modal matching tasks, and the relationship of these strategies to intelligence.

CHAPTER IV

METHOD

The method of investigation consisted of sampling a population in order to define three IQ groups, selection and development of tests, and the utilization of appropriate testing procedures. Each of these steps are presented in the sections which follow.

Sampling

In selecting the subjects for the study, a number of criteria were taken into account. These criteria were determined by the parameters of the population from which the sample was drawn, as well as by the requirements of the design of the study.

The primary selection criteria for the subjects were verbal and nonverbal intelligence test scores. The use of IQ as a starting point for the investigation was as a gross measure of intellectual development, a point of view reflected by Ellis (1969): "IQ is nothing more than a sampling device for selecting populations which vary in level of adaptation (p. 565)." The test used for this criterion was the Lorge-Thorndike Intelligence test, which is administered annually in the Edmonton Public School System and has been noted to have the highest reliability of the IQ tests currently in use in Alberta (Ogston, 1973), high stability (Eagle, 1966), and high predictive validity using the Stanford Achievement test as a criterion (Proger, McGowan, Bayuk, Mann, Trevorrow, & Massa, 1971).

A consideration in the use of IQ as a selection criterion was an appropriate range of scores for each group. Beginning with the decision to utilize three groups in the study in order to be able to draw inferences on trends of cognitive processes across broad levels of adaptation, it was then necessary to compromise a number of factors in order to define the IQ ranges of these groups. It was first decided that verbal IQ should be a primary criterion because in previous factor analyses it tended to remain somewhat independent of simultaneous and successive processing; performance IQ on the other hand tends to load on a simultaneous factor (Das & Molloy, 1975). The limits of verbal IQ for the low IQ group were then set at 71-90. This range was chosen for several reasons, including the fact that it allowed sampling from normal classes only, thus avoiding any potential special class effects, but still supplied enough within-group variance in IQ to avoid unduly restricting the correlation of IQ scores with other measures. Also, use of this range for the low verbal IQ group allowed symmetric sampling of the balance of the IQ curve for the other two groups; the verbal IQ range for the normal and high IQ groups were then defined as 91-110 and 111-130, respectively. Together these three ranges were judged to be sufficiently broad for the study of cognitive competence at a general level, and yet still narrow enough to avoid severe floor and ceiling effects on the instruments, a problem which is common to this type of research (Baumeister, 1967). Finally, and most pragmatically, in the planning stages of the study the investigator conducted a complete survey of the distribution of IQ scores in the city of Edmonton, and found that by considering the total sampling criteria of the study the IQ ranges noted here were the only ranges within which the subjects could meet all criteria.

With verbal IQ as a primary selection criterion, it was then necessary to consider the implications of concurrent use of nonverbal or performance IQ as a secondary criterion. It is well-known that for subjects in the low intelligence range verbal skills are the predominant source of low intelligence scores. It was expected, therefore, that in a survey of the verbal and performance IQ distributions the subjects in the low IQ range would tend to have higher performance scores relative to their verbal scores than would the subjects in the normal and high IQ ranges. It was decided that an upper bound should be placed on this trend in performance scores in the low IQ range, in order to retain symmetry of sampling in both IQ scores. A survey of the IQ data suggested that ranges of 66-95, 86-115 and 106-135 were the most feasible ranges of performance IQ for the low, normal and high IQ groups, respectively, given all of the additional sampling considerations. The definition of the sample by IQ as discussed is summarized in Table 12.

Table 12

IQ Ranges for Sample Groups

	Verbal IQ	Performance IQ
Low IQ	71-90	66-95
Normal IQ	91-110	86-115
High IQ	111-130	106-135

These definitions of IQ ranges for use as sampling criteria, in turn, evolved from consideration of four additional criteria which were noted as necessary aspects of the sampling procedure. The first of these was sample size, which was set at 60 for each IQ group. The selection of a group size of 60 was based upon the requirement that there be a sufficiently large sample to perform within-group principal component and factor analyses. It is often preferred in factor analytic studies that a larger group size than 60 be used for this purpose. In studies which involve the use of individual tests, however, as was the case in this study, a smaller sample size must suffice. A sample size of 60 is considered to be minimal, because of error of measurement. The standard error of measurement for correlation coefficients (s_r) is estimated by (Magnusson, 1966):

$$s_r = \frac{1 - p^2}{N - 1},$$

where: p = coefficient of correlation in the population

N = sample size.

Thus, for the sample size to be used in this study, when s_r is at maximum ($p = 0$), the standard error of measurement would be equal to approximately 0.13. The size of this error may be larger than is preferable for research employing principal components analyses. However, Das (1973c) has summarized several studies on the topic of simultaneous and successive syntheses, all of which have involved comparable sample sizes to the present study, and notes that the stability of the factor structures in these studies is very high. This indicates that errors of the magnitude noted above are at least not critical in studies in this area.

Second, the sex of the subjects was restricted to males for all IQ groups. This choice was made in recognition of the difficulties in pooling groups with disparate means on the instruments for correlational analyses. It is likely that sex differences would be found in some of the tasks, and if each IQ group consisted of both sexes, within-group intercorrelations of the tests would be spuriously affected.

Third, grade level and chronological age were established as grade 4, with age equal across all three groups. Grade 4 was chosen in order to allow comparability with previous research on simultaneous and successive syntheses (Das & Molloy, 1975). The equalization of chronological age across the groups, or CA matching, is an additional interesting problem of grade level sampling in circumstances of varying ability levels. There are several alternative techniques for approaching this problem, the most common of which is to match as closely as possible by grade, and then consider additional statistical control (Hopkins, 1969; Stanley, 1967). Thus the subjects were selected solely from grade 4, and as expected a higher age range was found among the low IQ group.

Finally, socioeconomic status (SES) was considered in the sampling of the population. Although it has been noted in the discussion of modality matching that SES could conceivably be a significant predictor of performance on this task, this possibility is highly uncertain at the present time. A recent study of simultaneous and successive syntheses (Das & Molloy, 1975) indicates that SES differences in these factors tend to disappear by the time children have reached grade 4. The present study involves children of this grade level and therefore it is unlikely that SES would be found to differentiate children in the use of these strategies. Nonetheless, in order to reduce any possible effects, SES was random within a middle range, with avoidance of the selection of subjects from exclusively high or low SES population areas.

Using the IQ ranges and the additional criteria that have been discussed, a three phase procedure was used to identify the subjects. First, a list of approximately 400 grade 4 boys was made, with the boys distributed roughly equally in the three IQ groups. This list was drawn from the school system central office records, and schools in very high and very low SES areas were deleted. Next, the principals of the schools were interviewed regarding each potential subject for the study and asked if any children should be deleted for family or personal reasons. The teachers were also interviewed regarding any identified disabilities that would require deletion of a child. Finally, each child's cumulative record card was checked for any psychological or personal data that would require reconsideration of inclusion in the study.

By this process, 60 grade 4 boys in each of the IQ ranges were identified in 19 public schools, and approval was obtained for them to serve as subjects in the study.

Selection and Development of Tests

The tests used in this study were drawn from three sources and comprise a total of 17 measures. These sources include tests that have been used previously at the University of Alberta for related research, tests which were developed specifically for this study, and tests that have been used by the local public school system for [illegible]l classification purposes. In the following discussion, all of these [illegible]ts will be described in the order noted above, with a summary list supplied at the end of this section.

Selected tests

The first source of tests was the set that has been used by Das (1973c; Das & Molloy, 1975). A battery of six tests, comprised of the primary instruments that have been found to identify simultaneous and successive syntheses, were selected from this set. In addition, a test which measures speed of test taking responses was also adopted.

Raven's Progressive Matrices. This is a well-known test involving the matching of a colored visual matrix, on which there is a configuration of symbols, with its counterpart in a set of alternatives (Raven, 1965). The test is generally thought to be a relatively pure culture-reduced measure of reasoning. The total score on the test is the number of items correct, with a possible maximum of 36. A sample item from this test is included in Appendix B.

Figure copying. The figure copying test was developed by the Gesell Institute (Ilg & Ames, 1964), and has been used as a measure of intellectual ability. The test consists of 10 geometrical figures which are presented consecutively to the subject for reproduction while they are in full view. A maximum score of two is possible for each item, with a test total of 20. Copies of the 10 figures in the test and guidelines for administering and scoring the test are in Appendix C.

Graham-Kendall's Memory for Designs. This test was developed by Graham and Kendall (1960) to measure minimal brain damage. A set of 15 geometric figures, each on a separate card, are presented for five seconds to the subject. Following the presentation of each card, the subject is asked to reproduce the figure. The total score on the test is the number of errors made, as described in detail in the manual, with scores for each item varying from zero for a satisfactory reproduction to three for a reversed or rotated reproduction. The maximum score which would result from consistent errors is 45. A copy of the geometric figures is in Appendix D.

Serial recall. The serial recall task consists of a set of 24 word lists, with four words in each list. Of these lists, 12 contain words which are semantically similar to one another, and the other 12 contain four unrelated words. The two types of word lists are randomly ordered in the test. Each list is presented by the use of a cassette tape recording, following which the subject is asked to recall the list in the order given. The total score for each list is the number of words in the correct position, with a possible total of four per list, giving a maximum test score of 96. A list of the words used in the test is in Appendix E.

Free recall. The task is the same as the serial recall task noted above, but involves a different scoring procedure. In the free recall task all words correctly recalled are given one point, irrespective of order of recall. The maximum possible score is 96.

Visual Short-term Memory. This test was developed by E. Howarth and J. Brown of the University of Alberta. Each of the 20 items consists of a five-section grid which is presented to the subject for five seconds. Following presentation, a two second filler task of color naming is used to eliminate rehearsal. The stimuli are single digit numbers and the subject is asked to reproduce the digits on an empty grid following the filler task. Each digit in the correct location is scored as one mark, giving a possible score of five for each item and a possible test total of 100. A schematic representation of the timing of the presentation of each item and a list of the sets of digits used is included in Appendix F.

Word reading. This test is one of the Stroop (1935) charts of color names. The names of four primary colors (red, green, yellow and blue) are printed on a chart in block capital letters using black ink. The names are printed in eight sets, with five words in each set and the order of the sets randomized. The score on the test is the time obtained by a stopwatch for the subject to read the 40 words. A list of the words in the format in which they appear on the chart is in Appendix G.

Development of tests

The four tests which were developed specifically for this study are comprised of auditory and visual modality matching tasks.

Auditory-auditory matching. This task involves matching a stimulus pattern of 1000 cycle tones with a comparison pattern of tones. All tones are of 0.15 second duration with variation in patterns created by short pauses of 0.35 seconds and long pauses of 1.35 seconds. A score of one is given for each of the 30 items in the test. A copy of the items used in the test is in Appendix H1.

Auditory-visual matching. The items in this test utilize an auditory pattern as a stimulus as in the auditory-auditory test, but this is matched with a comparison visual display of dots. For a dot of 1 unit in diameter, a short gap is 0.80 units in length, and a long gap is of 7.17 units in length. Each of the 30 items in the test is scored as one mark. A copy of the test items is in Appendix H1.

Visual-auditory matching. This test is the converse of auditory-visual matching; the visual display is the stimulus portion of each item and the comparison section is a set of tones. This test is included in Appendix H1.

Visual-visual matching. This test is comprised of sets of visual patterns, where the first pattern of each set is compared to the second pattern, with a score of one given to each correct response for a test total of 30. A copy of the test items is included in Appendix H1. It should be noted that the items in the test are different from those used for the other three modality matching tests; the reasons for this difference will be discussed.

As stated, these four modality matching tests were developed by the investigator, in contrast to the first set which were selected from existing tests. In order to develop these tests such that both the particular needs of the study were taken into account, and the tests met desirable psychometric criteria, a design and pilot phase was undertaken prior to use of the tests in the main study. The course of development of the modality matching tests in this phase is described here in four parts as: (a) Design considerations; (b) Test construction; (c) Pilot testing; (d) Test revision.

Design considerations. A first consideration in the design of the modality matching tests was the item type to be used. The item format that was employed in these tests is the same-different variety. This item type requires a dichotomous decision on the part of the subject: the stimulus is presented in the first modality, and then removed or terminated, following which a stimulus designated as the comparison is presented in the second modality; the subject is asked if the comparison stimulus is the "same" or "different" from the first stimulus. As noted in the review of literature, this type of item format reduces reliance on short-term memory to a minimum (Goodnow, 1971a). Furthermore, it appears to be the most feasible item type for presentation of the second stimulus in the auditory modality. Multiple-choice items for matching tasks that involve the auditory modality in the presentation of the second stimulus are characterized by the creation of interference by each alternative for its previous member(s) in the set of alternatives. The effect of this interference is to make modality matching involving the auditory modality as the second modality more difficult than when this modality is visual, thus creating differences in the difficulties of these two tasks that are not directly due to the nature of the tasks themselves. In Campbell and Fiske's (1959) terminology, the method variance is then disproportional to the trait variance for visual-auditory matching. As a result of the problem, a "same-different" item format is preferred in studies involving all combinations of modalities.

A second consideration in the construction of these tests was commonality of stimulus patterns across modality combinations. Muehl and Kremenack (1966) studied all four combinations of auditory and visual modality matching but used different stimulus patterns in each of their four tests. The differences they found between performance levels across the four tests could not, therefore, be attributed only to the nature of the tasks, because task effects were confounded with the varying stimulus patterns among the tests. The investigator in this study used identical stimulus patterns for all four tests in the pilot versions, although as will be noted in the section on test revision, it was not possible to retain this criterion.

A third consideration in the design of the modality matching tests was the number of items to be used. In many circumstances of test construction a compromise must be reached between using a large number of items in order to increase reliability, and reducing the number of items in order to minimize test administration time (cf. Oosterhof & Glasnapp, 1974). As noted, each item developed for this study used a same-different format and therefore had a chance probability of correct response of 0.5, with the expected chance score of a test with k items of this type as k/2. The effects of these chance scores on test reliability through an examination of test length and number of alternatives per item has been discussed by Ebel (1969, 1972), who notes that in the case of items with two choices, a 50 item test might be expected to have a reliability of 0.48 by the Kuder-Richardson 21 formula and 0.59 by the Spearman Brown. In the case of the present study, 35 test items, five of which were practice items, was considered to be the maximum possible number to be used in view of the extensive total testing time required of each subject. It might be expected therefore that test reliability would be a concern in this circumstance, but as noted by Ebel (1969), higher reliabilities than the estimates he has supplied might be found in cases where:

1. The test items are unusually high in quality.
2. The test is unusually homogeneous in content.
3. The group tested is unusually variable in ability (p. 569).

In the present study all three of these conditions hold to a considerable extent and as will be discussed in the results, reliabilities were found to be well above the estimates supplied by Ebel.

The ordering of items in terms of difficulty indices was a fourth consideration in the design of the modality matching tests. In recent years some research has been conducted on the merits of various ordering criteria, but the results appear equivocal. Marso (1970) has noted that placing a few easy items at the beginning of a test is a well agreed practice, but the use of monotonically ascending difficulty in test items throughout the balance of a test may be no more effective than several alternate techniques. In view of the sample populations to be used in this study and the amount of testing time needed for the four modality matching tests, it was felt by the present investigator that maintenance of test motivation and attention would be critical factors. For this reason a "plateau" technique of item ordering was adopted, whereby items were placed in blocks of complexity. Item patterns containing the lowest number of components (designating a component as a single tone in the auditory case and a single dot in a display in the visual case) were placed first in each test to form the first block, with the difficulty of these in ascending order within the block. Item patterns containing increasing numbers of components were placed in subsequent blocks, with ascending difficulty within blocks. Thus the difficulty of the first item in each block was generally lower than the last item of the previous block.[1] It was hoped that the positive effects

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[1]The final versions of the modality matching tests are supplied in Appendix H1. The reader may check the test structure discussed here by referring to this Appendix. It should also be noted that for display purposes the dimensions of the items shown in the Appendix are reduced from those actually used; see Appendix H2 for technical specifications.

of these periodic slight regressions in the overall ascending order of difficulty of the items would be noticeable in the course of pilot testing, and this was noted subjectively by the investigator to be the case.

The final and perhaps most important consideration in the design of the modality matching tests was the development of the stimulus patterns to be used. In developing the patterns it was necessary to estimate first the needed spread in the number of components per item over the total test. A survey of the modality matching tests used in the studies quoted on developmental trends in the light of the age range used in this study, with some additional information from Orn's (1970) research at the University of Alberta, resulted in a decision to vary the item complexity from four components to seven components. The blocks of four, five, six and seven component items were proportioned as noted in Table 13 to make up 30 test items.

Table 13

Number of Components per Item
in Pilot Modality Matching Tests

No. of Components	No. of Items
4	8
5	8
6	8
7	6

The next decision with respect to the development of the item patterns to be used was the number and placement of items that contained stimulus patterns (i.e., the pattern presented in the first modality) that were the same as the comparison pattern (i.e., the pattern presented in the second modality). The number and placement of items was randomized through the flip of a coin, giving a desired correct answer of same or different to each of the thirty items to be constructed.

The final step in this procedure was then to design the item patterns using the number of components decided upon. Several guidelines were adopted in this procedure. First, the location of components was systematically varied in the item patterns across the total test. As noted previously, the patterns of the components varied from simple to complex in blocks defined by the number of components in each pattern. Second, for those items where the comparison pattern to be constructed was to be different from the stimulus pattern, this difference was always restricted to a relocation of one component in space or time in the comparison pattern, with no change in the number of components. Furthermore, the relocation of the single component was randomly varied in position from the start of the comparison pattern to the end of the comparison pattern. Thus any item having a correct answer of "different" could have a difference in the comparison pattern at the beginning of the pattern, as for example:[2]

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[2]Dimensions used in the following two examples are directly proportional to those used in the final versions of the tests.

Stimulus pattern

●   ● ● ● ●   ● ●

Comparison pattern

● ●   ● ● ●   ● ●

or a difference at any point throughout the pattern to the end, such as:

Stimulus pattern

●   ● ● ● ●   ● ●

Comparison pattern

●   ● ● ●   ● ● ●

On the basis of the five design considerations noted above, five example items and thirty test items were planned for construction.

It was decided that scoring of the items would be zero and one for an incorrect and correct response, respectively, with no correction for guessing (Aiken, 1968; Frary, 1969).

<u>Test construction</u>. Once a complete set of item patterns for the test had been designed, construction commenced on the pilot versions of the tests. A complete description of how the tests were constructed is included in Appendix H2, with the instructions and script for each test included separately in Appendix H3.

<u>Pilot testing</u>. The four modality matching tests were given a pilot trial in the year previous to the main study (see Appendix A).

The subjects selected for this purpose constituted a sample defined similarly to the sample used in the main study, with some reduction in size. A group of 60 boys in grade 3 in the Edmonton Public School System was identified on the basis of Canadian Lorge-Thorndike Intelligence Test scores. The sample was made up of 30 boys with verbal IQ scores between

70 and 90, and 30 boys with verbal IQ scores between 110 and 130.

All of the subjects were given the four modality matching tests, with the order of administration of the tests randomized.

The data which was collected from the testing was analyzed in terms of item difficulties for each group separately, and for the pooled groups. Ordinarily in construction of tests of the type used here, a second criterion that would be used in the selection of items would be tetrachoric correlations between item score and group membership. An important point in the rationale for this study, however, is that the objective of constructing the four modality matching tests was not to build instruments which will discriminate between intelligence groups. Rather, it was to construct tests by varying content systematically, and then note how this content is processed by different intelligence groups. It may be possible, using the latter rationale, that some items emerge as being of equal difficulty for all intelligence groups with no discriminating power. This of itself is an important finding and would be hidden by screening items at the pilot stage on the basis of the criterion of discrimination. Thus the only necessary statistical condition that the items had to meet once they had been constructed using other _a priori_ guidelines is that there was a suitable level of difficulty so that floor and ceiling effects could be reduced.

Test revision. On the basis of the pilot data (see Appendix H4), one of the tests was revised. The visual-visual matching test contained an excessive number of items that had difficulty levels in the range of .85 and above. Some of the items in this test were retained, and additional items were constructed. In order to increase the levels of difficulty, longer item patterns were used, employing a range of components from five to nine. The distribution of blocks of patterns in the thirty items was redesigned as shown in Table 14.

Table 14

Number of Components per Item in Revised Version of Visual-Visual Matching Test

No. of Components	No. of Items
5	2
6	4
7	6
8	8
9	10

Thus, as indicated in the final versions of the tests in Appendix H1, the visual-visual matching test was revised to a composition distinct from the other three unrevised tests for auditory-auditory, auditory-visual and visual-auditory matching.

School system tests

In addition to the 11 tests discussed previously, all of which were administered to the subjects by the investigator, six test scores from student records were included. All of these scores had been obtained through a regular school system testing program within six months previous to the date of commencement of this study. The tests are comprised of two intelligence measures and four achievement measures.

Verbal intelligence. This test is the Canadian Lorge-Thorndike Intelligence Test, Canadian Multi-Level Edition (1967). The test contains items involving synonyms, semantics, reasoning, concepts and functional relationships. A verbal IQ score is derived from norms.

Nonverbal intelligence. The Canadian Lorge-Thorndike also supplies a nonverbal IQ score. The items in this test include shape similarities, numerical seriation, functional relationships between objects, and shape analogies. A set of norms is used for this test to derive the IQ score.

Word meaning. This is a subtest of the Stanford Achievement Test, Form W (1965). The items involve choice of the correct word from a set of four alternatives, to form a complete sentence.

Paragraph meaning. This test is also a subtest of the Stanford Achievement test, and contains items made up of short paragraphs, several words of which are missing. The correct words are chosen from sets of four alternatives.

Word study skills. The third subtest of the Stanford Achievement test contains items on similarity in auditory and visual phonics.

Mathematics achievement. This test is produced by the Edmonton Public School System, and measures understanding of basic arithmetic operations including number lines, relationships, operations and geometric figures.

Summary list of tests

A list of the tests that have been discussed is given in Table 15. The order in which these tests are listed will be retained throughout all subsequent references to them.

Table 15

Tests Used in Study

1. Raven's Progressive Matrices
2. Figure copying
3. Memory for Designs
4. Serial recall
5. Free recall
6. Visual Short-term Memory
7. Word reading
8. Auditory-auditory matching
9. Auditory-visual matching
10. Visual-auditory matching
11. Visual-visual matching
12. Verbal intelligence
13. Nonverbal intelligence
14. Word meaning
15. Paragraph meaning
16. Word study skills
17. Mathematics achievement

Procedure

Of the seventeen tests on which data were collected in the study, eleven of these tests were administered by the investigator. The first set of seven tests, drawn from Das (1973c), were administered in random order.

The second set of four tests which were constructed by the investigator, were administered in a balanced design within each IQ group, in order to compensate for possible transfer effects from a given sequence of administration of these tests. This balancing was accomplished by using a simple four by four Latin square design (Cochran & Cox, 1957) and randomly assigning 15 subjects in each IQ group to each of four orders of test administration. Subject assignment and order of test administration is summarized in Figure 3.

Groups (N = 15 each)	Order of Test Administration			
1	A	B	C	D
2	B	C	D	A
3	D	A	B	C
4	C	D	A	B

A = Auditory-auditory matching
B = Auditory-visual matching
C = Visual-auditory matching
D = Visual-visual matching

Figure 3. Balanced design for order of administration of modality matching tests

In the administration of the tests, the commonly accepted procedures for establishing testing environments were recognized (Fiske & Butler, 1963). Central among these considerations was an attempt to establish a common orientation towards the tasks on the part of subjects in the three IQ groups. It was anticipated that attention and other factors that are part of the relationship between the test administrator and the subject would vary across the IQ groups. Therefore, in part as a result of this variation, and in part as a result of the requirements of the tasks themselves, the tests were administered individually, or in small groups of four to six subjects, with no large group testing.

A list of the 11 tests which were administered, with the order of test administration and the group sizes used, is given in Table 16.

Table 16

Order of Presentation and Group Sizes for Test Administration

Test	Order of Administration	Group Size
1. Raven's Progressive Matrices	random	small
2. Figure copying	random	small
3. Memory for Designs	random	small
4. Serial recall	random	individual
5. Free recall	random	individual
6. Visual Short-term Memory	random	two
7. Word reading	random	individual
8. Auditory-auditory matching	balanced	small
9. Auditory-visual matching	balanced	small
10. Visual-auditory matching	balanced	small
11. Visual-visual matching	balanced	small

CHAPTER V

RESULTS

The following discussion is divided into sections by type of analysis, with the substantive implications of the results of these analyses deferred for later examination. A descriptive overview of the age characteristics of the sample chosen and the data collected for the investigation is given first. This is followed by the results of the analyses performed on the data, which include analysis of variance, discriminant, and factor analyses.

Descriptive Statistics

As discussed previously, the design of the study included sampling from three ranges of the IQ distribution for grade 4, with matching among the groups on chronological age. It was expected that the mean chronological age (CA) of the subjects in the low IQ (LIQ) group would be higher than the mean CA for the normal IQ (NIQ) and high IQ (HIQ) groups. Table 17 demonstrates this discrepancy. The LIQ group was approximately six months older than the other two groups. Also, as expected, the standard deviation of the LIQ group was higher than that of the NIQ and HIQ groups. The difference between the LIQ group and each of the other two groups was found to be statistically significant (F [2, 177] = 32.60, $p \leq 0.0$), with no difference between the NIQ and HIQ groups. The implications of this CA difference will be discussed in terms of its effects on subsequent statistical analyses, for each analysis in turn.

Table 17

Means and Standard Deviations
of Chronological Age for the Sample Groups

LIQ		NIQ		HIQ	
M	SD	M	SD	M	SD
118.50	6.41	112.55	3.75	111.97	3.99

The data that was collected for the study incorporated 17 variables, as summarized in Table 15, for 60 subjects in each of the three IQ groups. The first 11 of these variables represent tests that were administered by the investigator, with the data for the remaining six tests drawn from school records. The means and standard deviations for each of the IQ groups on the 17 variables are given in Table 18.

There are three major aspects of the results in Table 18 that should be noted. First, verbal and performance IQ, which for most subsequent analyses will be treated as independent variables, have been included in the descriptive information as variables 12 and 13, respectively. These two variables acted as the major selection criteria for the subjects in the study with the LIQ, NIQ and HIQ subjects selected on the verbal scale from the ranges 71-90, 91-110, and 111-130. The performance scale ranges for selection of these three groups were set at 66-95, 86-115, and 106-135. Of particular interest is the symmetry of means and standard deviations for the three groups on these IQ measures. The Canadian Lorge-Thorndike has been normed with a population mean of 100 and the NIQ group in this study has a verbal IQ mean of 101.03.

Table 18

Means and Standard Deviations of Data for Sample Groups

Variable	Test	LIQ M	LIQ SD	NIQ M	NIQ SD	HIQ M	HIQ SD
1	Raven's Progressive Matrices	23.23	4.89	26.08	5.04	30.95	3.38
2	Figure copying	14.82	1.88	14.55	2.46	16.27	2.41
3	Memory for Designs	3.43	3.35	3.10	3.11	1.70	2.11
4	Serial recall	68.00	19.56	78.30	17.16	86.15	9.11
5	Free recall	81.90	10.57	88.60	6.58	91.22	4.97
6	Visual Short-term Memory	57.28	17.59	63.38	17.00	64.90	16.28
7	Word reading	24.23	4.70	22.21	3.61	21.18	3.25
8	Auditory-auditory matching	20.65	3.97	23.00	4.05	24.47	3.91
9	Auditory-visual matching	19.95	4.04	23.15	3.76	26.42	3.49
10	Visual-auditory matching	24.20	4.66	26.50	4.13	28.45	1.96
11	Visual-visual matching	25.63	3.09	27.33	2.43	28.15	2.09
12	Verbal IQ	81.70	4.99	101.03	5.21	119.57	5.54
13	Performance IQ	86.07	6.27	100.12	7.04	120.02	6.48
14	Word meaning	15.05	15.18	42.37	19.12	62.67	20.14
15	Paragraph meaning	12.88	11.97	32.20	19.65	63.02	21.38
16	Word study skills	12.92	10.30	37.92	18.78	54.83	21.53
17	Mathematics achievement	15.05	11.27	32.92	22.57	54.98	23.85

Furthermore, the LIQ group mean for verbal IQ is approximately 19 points below the population mean, and the HIQ group mean is approximately 19 points above the population mean, with standard deviations approximately equal for all groups. Thus, random sampling on the major criterion of verbal IQ resulted in the definition of three groups with almost precise symmetry relative to a normal IQ curve.

For performance IQ, however, the sampling resulted in an expected slight asymmetric definition of the groups. For the NIQ and HIQ groups, the means are extremely close to expectation, and to the means for verbal IQ, but for the LIQ group the performance IQ mean is slightly more than four points higher than the verbal IQ mean. This asymmetry results from the generally higher performance IQ scores of children defined by low verbal intelligence. Aside from this slight asymmetry in performance IQ, then, the first main point to be noted regarding the results in Table 18 is that the definition of the groups by IQ is surprisingly symmetric, in view of the random sampling of all IQ scores in grade 4 in the school system.

A second and more minor point in terms of the focus of this study is the increase in achievement scores represented by variables 14 to 17 as a function of IQ. While it is not the intention of the present study to examine achievement in depth, the positive and uniform increase in the reading and mathematics data by IQ classification is interesting, if not disconcerting. The predictive power of the Lorge-Thorndike Intelligence test for the Stanford Achievement test has been noted earlier (cf. Proger, McGowan, Bayuk, Mann, Trevorrow & Massa, 1971) and will not be confirmed formally here, but the variation in the groups is seen readily. This achievement data will be utilized in a minor way in subsequent discussion.

The third and major aspect of interest in the results that are reported in Table 18 is the variation as a function of IQ in the test scores for the tests that were administered. These tests are listed as variables 1 to 11, with the first seven tests drawn from previous simultaneous-successive processing research, and the last four constructed by the investigator. In order that the trends of these variations may be more readily discernible, the data for each of the variables was standardized by pooling the three IQ groups and then expressing the IQ group means for each test as a standard score relative to the grand mean. For variable 3, Memory for Designs, the inverse relationship that resulted from scoring errors rather than correct responses was transformed by the formula Y = 5.00 - X. Similarly, variable 7, Word reading, increased inversely in relation to IQ and was transformed also, utilizing Y = 50 - X. When standardized, the data from variables 1 to 11 in Table 18 becomes a clear profile for each group as shown in Table 19.

The transformed means displayed in Table 19 show a uniform rank ordering of performance on the 11 tests as a function of IQ. This data is plotted in Figure 4, where this rank ordering is apparent; with the only exception of an inversion of means for Figure copying in the LIQ and NIQ groups, all of the group means increase as IQ increases. The tests that appear to indicate the greatest discrepancy in group performances are Raven's Progressive Matrices and Auditory-visual matching. The least discrepancy between the groups appears in Visual

Table 19

Standard Score Means for Sample Groups[1]

Variable	Test	LIQ	NIQ	HIQ
1	Raven's Progressive Matrices	-0.64	-0.12	0.76
2	Figure copying	-0.16	-0.28	0.44
3	Memory for Designs	-0.23	-0.12	0.35
4	Serial recall	-0.54	0.05	0.49
5	Free recall	-0.62	0.16	0.46
6	Visual Short-term Memory	-0.27	0.09	0.18
7	Word reading	-0.41	0.08	0.33
8	Auditory-auditory matching	-0.48	0.07	0.41
9	Auditory-visual matching	-0.70	0.00	0.70
10	Visual-auditory matching	-0.53	0.03	0.50
11	Visual-visual matching	-0.51	0.10	0.40

[1]Memory for Designs transformed by Y = 5.00 - X; Word reading transformed by Y = 50 - X.

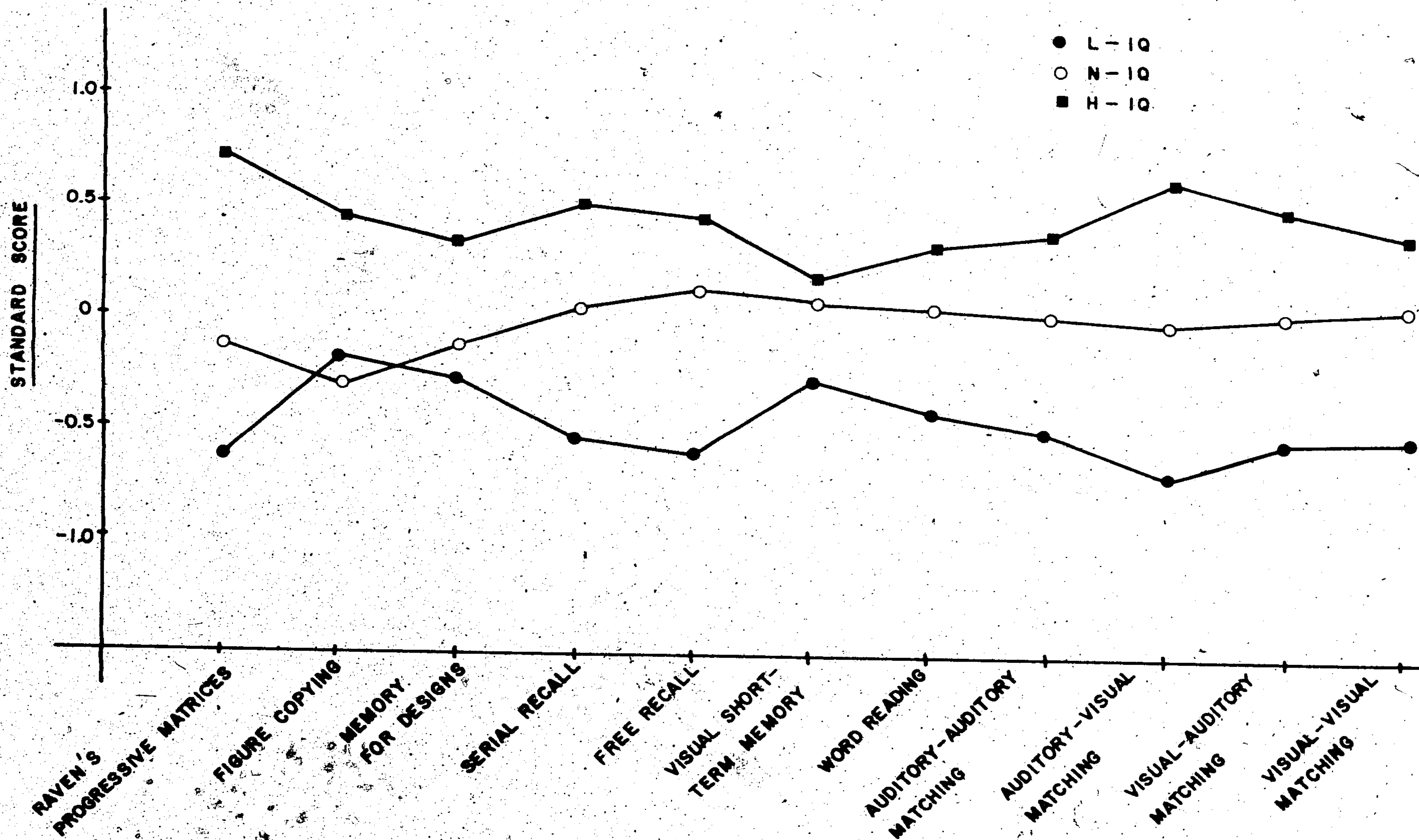

Figure 4. Standard score means for the sample groups

Short-term Memory. Analyses to be discussed subsequently will refine the initial visual impressions given here.

In supplement to the descriptive information supplied by the means and standard deviations, Tables 20, 21 and 22 give the intercorrelations of the tests for each of the IQ groups. Chronological age has been added in these tables as variable 18, in order that possible effects of unequal CA across the groups may be referred to in subsequent discussions.

The final descriptive information to be discussed is the reliabilities of the four modality matching tests constructed by the investigator. Kuder-Richardson 20 coefficients (K-R 20) were calculated within each IQ group for each of the tests. These coefficients are displayed in Table 23.

Table 23

Kuder-Richardson 20 Coefficients
for Modality Matching Tests for Sample Groups

	LIQ	NIQ	HIQ
Auditory-auditory matching	0.60	0.71	0.74
Auditory-visual matching	0.64	0.66	0.78
Visual-auditory matching	0.80	0.84	0.64
Visual-visual matching	0.73	0.63	0.64

The range of the K-R 20 coefficients shown in Table 23 is from 0.60 to 0.84. Kuder and Richardson (1937) have shown in their derivation of the K-R 20 that it is a conservative estimate of reliability, with underestimates given when assumptions of the formula are not fulfilled

Table 20

Intercorrelations of All Variables for the Low IQ Group[1]

Variable	Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Raven's Progressive Matrices	--	226	-293	-011	-056	-014	-046	-072	-095	-053	128	081	091	-065	054	026	034	043
2	Figure copying	226	--	-409	068	047	127	069	076	239	-075	215	-075	192	060	-008	228	141	075
3	Memory for Designs	-293	-409	--	-106	-077	-239	-144	064	-178	-041	-167	066	-026	-003	059	-066	-162	-196
4	Serial recall	-011	068	-106	--	888	214	-278	259	410	272	497	099	-168	193	069	169	082	152
5	Free recall	-056	047	-077	888	--	196	-317	256	354	211	432	-023	-128	229	115	149	087	133
6	Visual Short-term Memory	-014	127	-239	214	196	--	-353	332	258	342	305	-004	171	330	297	211	326	184
7	Word reading	-046	069	-144	-278	-317	-353	--	-225	-085	029	-074	-201	-054	-467	-432	-415	-234	-196
8	Auditory-auditory matching	-072	076	064	259	256	332	-225	--	174	230	-021	075	077	059	165	105	556	231
9	Auditory-visual matching	-095	239	-178	410	354	258	-085	174	--	553	485	099	-112	292	069	242	043	186
10	Visual-auditory matching	-053	-075	-041	272	211	342	029	230	553	--	378	-069	-007	073	079	249	092	219
11	Visual-visual matching	128	215	-167	497	432	305	-074	-021	485	378	--	139	037	117	078	139	-026	045
12	Verbal intelligence	081	-075	066	099	-023	-004	-201	075	099	-069	139	--	-058	267	348	187	039	-116
13	Nonverbal intelligence	091	192	-026	-168	-128	171	-054	077	-112	-007	037	-058	--	013	200	-007	163	066
14	Word meaning	-065	060	-003	193	229	330	-467	059	292	073	117	267	013	--	413	277	031	223
15	Paragraph meaning	054	-008	059	069	115	297	-432	165	069	079	078	348	200	413	--	421	428	221
16	Word study skills	026	228	-066	169	149	211	-415	105	242	249	139	187	-007	277	421	--	317	133
17	Mathematics achievement	034	141	-162	082	087	326	-234	556	043	092	-026	039	163	081	428	317	--	303
18	Chronological age	043	075	-196	152	133	184	-196	231	186	219	046	-116	066	223	221	133	303	--

[1] Decimals omitted

Table 21

Intercorrelations of All Variables for the Normal IQ Group[1]

Variable	Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Raven's Progressive Matrices	--	366	-366	161	258	180	040	302	400	425	404	079	421	-057	190	349	098	021
2	Figure copying	366	--	-410	197	303	223	-218	222	326	239	390	-052	288	-008	120	146	-039	249
3	Memory for Designs	-366	-410	--	-163	-275	-192	040	-275	-334	-422	-365	-014	-393	-020	-086	-154	-137	-082
4	Serial recall	161	197	-163	--	828	394	-354	306	097	297	248	172	231	237	194	030	-041	-069
5	Free recall	258	303	-275	828	--	524	-315	429	249	376	419	131	202	166	142	081	-088	-140
6	Visual Short-term Memory	180	223	-192	394	524	--	-313	319	242	412	340	118	-046	092	189	214	032	029
7	Word reading	040	-218	040	-354	-315	-313	--	-262	-010	-019	-143	-295	114	-217	-172	-173	042	053
8	Auditory-auditory matching	302	222	-275	306	429	319	-262	--	208	390	487	152	210	106	203	172	241	026
9	Auditory-visual matching	400	326	-334	097	249	242	-010	208	--	587	502	-189	174	-113	076	172	124	279
10	Visual-auditory matching	425	239	-422	297	376	412	-019	390	587	--	586	-106	281	-086	091	119	143	097
11	Visual-visual matching	404	390	-365	248	419	340	-143	487	502	586	--	-080	253	031	187	118	204	033
12	Verbal intelligence	079	-052	-014	172	131	118	-295	152	-189	-106	-080	--	-026	404	300	298	-058	-096
13	Nonverbal intelligence	421	288	-393	231	202	-046	114	210	174	281	253	-026	--	106	033	107	-038	-030
14	Word meaning	-057	-008	-020	237	166	092	-217	106	-113	-086	031	404	106	--	542	452	222	212
15	Paragraph meaning	190	120	-086	194	142	189	-172	203	076	091	187	300	033	542	--	374	456	268
16	Word study skills	349	146	-154	030	081	214	-173	172	172	119	118	298	107	452	374	--	224	326
17	Mathematics achievement	098	-039	-137	-041	-088	032	042	241	124	143	204	-058	-038	222	456	224	--	404
18	Chronological age	021	249	-082	-069	-140	029	053	026	279	097	033	-096	-030	212	268	326	404	--

[1]Decimals omitted

Table 22

Intercorrelations of All Variables for the High IQ Group[1]

Variable	Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Raven's Progressive Matrices	--	223	-299	-088	-081	-131	-052	028	031	275	077	-017	252	-014	065	136	068	077
2	Figure copying.	223	--	-244	-164	-118	-006	189	332	173	119	330	-043	148	214	219	297	335	261
3	Memory for Designs	-299	-244	--	-012	-173	-017	-007	-133	-103	141	124	050	-320	114	080	-188	015	-170
4	Serial recall	-088	-164	-012	--	863	304	-210	243	183	227	017	281	-085	220	248	125	227	030
5	Free recall	-081	-118	-173	863	--	-388	-198	218	120	116	027	184	-117	174	175	122	171	079
6	Visual Short-term Memory	-131	-006	-017	304	388	--	-104	181	157	098	207	-079	-145	105	-050	087	187	168
7	Word reading	-052	189	-007	-210	-198	-104	--	114	030	-064	137	-221	133	-246	-251	-248	-156	-114
8	Auditory-auditory matching	028	332	-133	243	218	181	114	--	492	355	383	-113	-190	-018	216	157	373	273
9	Auditory-visual matching	031	173	-103	183	120	157	030	492	--	495	355	-047	-070	011	052	218	356	273
10	Visual-auditory matching	275	119	141	227	116	098	-064	355	495	--	378	044	-172	158	201	130	388	164
11	Visual-visual matching	077	330	124	017	027	207	137	383	355	378	--	009	-068	158	015	221	295	067
12	Verbal intelligence	-017	-043	050	281	184	-079	-221	-113	-047	044	009	--	195	483	439	224	291	-242
13	Nonverbal intelligence	252	148	-320	-085	-117	-145	133	-190	-070	-172	-068	195	--	-049	-088	128	-073	-259
14	Word meaning	-014	214	114	220	174	105	-246	-018	011	158	158	483	-049	--	547	136	320	118
15	Paragraph meaning	065	219	080	248	175	-050	-251	216	052	201	015	439	-088	547	--	173	323	235
16	Word study skills	136	297	-188	125	122	087	-248	157	218	130	221	224	128	136	173	--	306	190
17	Mathematics achievement	068	335	015	227	171	187	-156	373	356	388	295	291	-073	320	323	306	--	349
18	Chronological age	077	261	-170	030	079	168	-114	273	273	164	067	-242	-259	118	235	190	349	--

[1]Decimals omitted

by the data (cf. Stanley, 1957). Thus, in terms of the earlier discussion on considerations in test construction, and projected reliability estimates for tests of this type as given by Ebel (1969), the expectation of good reliability in the case of the present study was supported. The coefficients noted above are not exceptionally high, but they are adequate.

Analysis of Variance

It has been suggested by the trends noted in the previous section that IQ group differences exist on most if not all of the 11 dependent variables in the study. In order to explore these trends, a three-group one-way fixed effects multivariate analysis of variance (MANOVA) was performed on the data from the 11 tests (Tatsuoka, 1971). The choice of this technique, rather than the use of 11 separate univariate analyses of variance, was made for two reasons: (1) the relatively large number of tests could result in significant differences being found on one or more univariate tests merely by chance; (2) it was possible, although not likely in this particular study, that no significant differences could be found on separate univariate tests, but with a general effect found when the tests are considered collectively.

The results of the MANOVA indicated significant differences between the groups, with a Wilk's Lambda of 0.44, and F (22, 334) = 7.70, ($p \leq 0.01$). As a point of interest, the 11 univariate analyses of variance were also performed, all of which resulted in probability values less than 0.05, with most estimated by computer at 0.0. Thus, in confirmation of the visual trends indicated in Figure 4, the three groups in the study represent samples from three distinct populations relative to the 11 dependent variables utilized.

Before leaving this discussion of the statistical significance of the differences between the IQ groups, an important point should be noted with respect to the original design of the study. It has been stated that conceptually the study is a CA match design with IQ as the independent variable. The effects of the significant 6 month difference in CA between the LIQ group and the other two groups therefore needs to be addressed. It can be observed in Table 20 that the correlations of CA with the 11 variables analyzed by the MANOVA are all low, with most obviously insignificant. Furthermore, the signs of these coefficients are all consistent with a direct developmental relationship between performance on the 11 tests and chronological age. On the basis of these correlations, it is possible to predict logically the effects of equalizing CA in the MANOVA through covariance, i.e., matching the groups statistically through using CA as a covariate (cf. Hopkins, 1969; Stanley, 1967). For all 11 variables, this would further increase the distance between the sample centroids, a distance which has already been shown to be significant. If the latter was not true, a Type II error would be possible in not covarying (Glass & Stanley, 1970). Thus it is not necessary to examine the suitability of the data for covariance (Elashoff, 1969; Glass, Peckham & Sanders, 1972), nor to broach the thorny issue of matching and ex post facto designs (Meehl, 1970; Stanley, 1965, 1966, 1967). The MANOVA results reported here indicate, in effect, lower bound estimates of the results of covariation, and the analysis of variance results may be referred to in the context of a CA match between the sample groups.

Discriminant Analyses

It was indicated in the results of the MANOVA that differences exist between the three sample centroids as defined by the simultaneous-successive tests and the modality matching tests. As a logical extension of the MANOVA procedure, a discriminant analysis was performed to articulate the nature of the differences on these 11 variables (Tatsuoka, 1970, 1971).

The vectors of weights for the discriminant functions utilizing variables 1 to 11 are presented in Table 24. It was found that the two functions derived accounted for 55% of the variance in the discriminant space, with Chi square = 139.57 ($p \leq 0.01$) for the first discriminant root and Chi square = 17.06 ($p \leq 0.07$) for the second root.

Several aspects of the results presented in Table 24 are informative. First, the very strong effect of Vector 1 relative to Vector 2 is evident both in the level of significance of the first eigenvalue, and the overwhelming amount of common variance accounted for by this vector. In comparison, Vector 2 is only of passing interest because its root does not have strong significance and the vector accounts for only 9% of the variance.

The test relationships to the two vectors found in the discriminant analysis are of course of primary importance. The first and major vector has its largest positive weights derived from Raven's Progressive Matrices and Auditory-visual matching. All other weights are considerably less significant relative to these two. The dominance of these two tests in discriminating between the IQ groups is confirmation of the trends displayed in Figure 4.

Table 24

Normalized Discriminant Function Weights for Simultaneous-Successive and Modality Matching Tests[1]

Variable	Test	Vector 1	Vector 2
1	Raven's Progressive Matrices	649	-084
2	Figure copying	-073	-812
3	Memory for Designs	142	064
4	Serial recall	021	-134
5	Free recall	130	319
6	Visual Short-term Memory	-027	008
7	Word reading	-024	-006
8	Auditory-auditory matching	128	126
9	Auditory-visual matching	697	-034
10	Visual-auditory matching	003	-036
11	Visual-visual matching	178	438
% Variance		90.91	9.09
Eigenvalues		1.056	0.106

[1]Decimals omitted from vector weights

The second vector found in the discriminant analysis has a large negative weight given by Figure copying and moderate positive weights given by Free recall and Visual-visual matching. It was noted in the descriptive statistics that the NIQ group had a lower mean than the LIQ on Figure copying, which could account for the curious trend of weights on this vector. No interpretation will be placed on this vector because of its low significance.

The results that were presented in Table 24 incorporated both the simultaneous-successive tests and the modality matching tests into a single discriminant analysis. Thus the relative contribution of each test in the context of the total 11 variables was determined. Additional discriminant analyses were performed for the two batteries of tests separately, in order that: (1) the possibility of a variable in one battery acting as a suppressor for a variable in the other battery could be precluded; (2) the relative importance of tests within batteries could be assessed. The results of the separate discriminant analyses are presented in Tables 25 and 26.

The trends noted in Tables 25 and 26 confirm and slightly magnify the results established by analyzing all of the tests collectively. Within the simultaneous-successive group of tests the IQ groups are maximally discriminated by Raven's Progressive Matrices. The Auditory-visual matching test is the strongest discriminator among the modality matching tests.

As an adjunct to the discriminant analysis on the simultaneous-successive and modality matching tests together, discriminant score means and standard deviations were calculated in order that the variance on each of the tests could be displayed by vector scale values.

Table 25

Normalized Discriminant Function Weights
for Simultaneous-Successive Tests[1].

Variable	Test	Vector 1	Vector 2
1	Raven's Progressive Matrices	944	-036
2	Figure copying	186	-859
3	Memory for Designs	090	115
4	Serial recall	048	-163
5	Free recall	249	469
6	Visual Short-term Memory	-009	030
7	Word reading	-030	-006
% Variance		89.57	10.43
Eigenvalues		0.745	0.087

[1]Decimals omitted from vector weights

Table 26

Normalized Discriminant Function Weights for Modality Matching Tests[1]

Variable	Test	Vector 1	Vector 2
8	Auditory-auditory matching	297	230
9	Auditory-visual matching	939	455
10	Visual-auditory matching	100	027
11	Visual-visual matching	142	860
% Variance		98.14	1.86
Eigenvalues		0.537	0.010

[1]Decimals omitted for vector weights

In addition the cross-products of the normalized weights were calculated to give the cosine of the angle between Vector 1 and Vector 2, which in turn indicated that the angle between these two vectors closely approximated orthogonality at $91^{\circ}\ 55'$. The means and standard deviations for the discriminant scores are given in Table 27. A plot of this data using orthogonal axes for display purposes is given in Figure 5; the length of each bar in this figure designates one standard deviation.

The effect that is displayed in Figure 5 is interesting in several respects. The tests which mainly comprise Vector 1 are demonstrated to differentiate the groups quite equally on this dimension. On Vector 2, however, an inverted relationship is evident, with the LIQ and HIQ groups approximately equal and the NIQ group slightly above both of these groups.

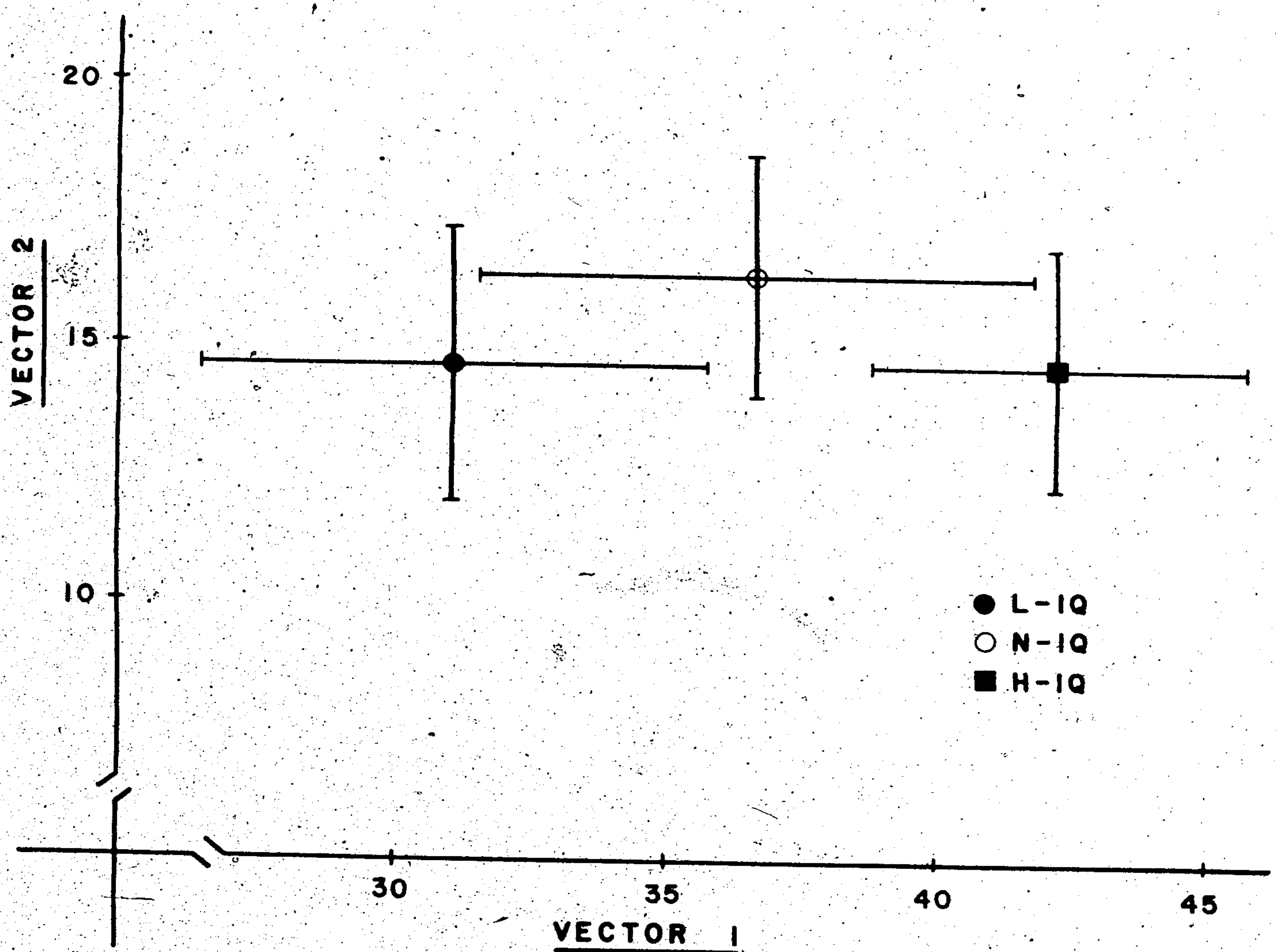

Figure 5. Discriminant score means and standard deviations for simultaneous-successive and modality matching tests

Table 27

Discriminant Score Means and Standard Deviations for Simultaneous-Successive and Modality Matching Tests[1]

	LIQ		NIQ		HIQ	
	M	SD	M	SD	M	SD
Vector 1	31.18		36.61		42.46	
		4.70		5.05		3.57
Vector 2	14.54		16.26		14.58	
		2.76		2.43		2.19

[1]Derived from Variables 1-11

The trend on Vector 2 appears to result in large part from the lower scores attained by the NIQ group on Figure copying.

In summary, the results of the discriminant analyses discussed indicate several trends in the data for the three IQ groups. First, as an extension of the MANOVA results it has been indicated that although the IQ groups differ in their levels of performance on all of the 11 tests administered in the study, there are variations in the degree of these differences on each test. The strongest group differences were found in Raven's Progressive Matrices from the simultaneous-successive tests, and Auditory-visual matching from the modality matching tests. Second, this differentiation was found to be predominantely unidimensional, that is, both of these tests contributed to a single vector, with this vector accounting for nearly all of the common variance in the discriminant space. Finally, group differentiation on this dimension was relatively uniform, with the IQ groups equidistant in discriminant space from each other.

Factor Analyses

All of the previous analyses have dealt with group differences in level of performance on the simultaneous-successive and modality matching tests. In contrast, the results to be discussed here deal with the interrelationships between individual performance on the tests, and subsequently through factor analysis, allow some tentative inferences to be drawn concerning process differences among the IQ groups.

As a prelude, several methodological considerations in the use of factor analysis will be noted here. The use of this technique has had a considerable history of controversy (Eysenck, 1953), some of which has centred on the levels of meaning that may be ascribed to factors (Coan, 1964; Royce, 1963), and some of which has dealt with the appropriateness of use of the technique under various circumstances. (See Gorsuch, 1974 for a flow chart of decision points in the use of factor analysis.) It is not the intention here to examine these issues in depth. Rather, three basic considerations in the use of factor analysis as they relate to this study will be noted briefly, followed by an examination of the results for each group.

A primary consideration in the application of factor analysis is the model to be utilized. For reasons of comparability to previous research (e.g., Das & Molloy, 1975), the principal components model with varimax rotation was employed (Mulaik, 1972).

Second, in the use of factor analysis, the suitability of the correlation matrix for analysis should be determined. An examination of the matrices in Tables 20, 21 and 22 reveals that the correlations between the first 11 variables are generally low, indicating the possibility of some variables acting randomly relative to others. Various techniques are available for testing the suitability of a correlation matrix for factor analysis (Dzuiban & Shirkey, 1974), but the most suitable technique still appears to be stability of factors under an alternate model (Dzuiban & Harris, 1973). In the factor results to follow, alpha factor analysis was employed as verification of non-random variates, and high correspondence was found between the alpha and principal components solutions; the alpha results will not be reported.

The third and possibly most difficult consideration in the use of factor analysis is the number of factors to be extracted. The hypotheses of this study imply a three factor solution, but exploratory analyses indicated that neither a three factor solution nor an eigenvalue greater than one criterion appeared appropriate in terms of interpretation. A compromise was established by plotting the eigenvalues according to the SCREE test, and selecting a point of clear demarcation for each group (Cattell, 1966).

Before interpreting the results of the principal components analyses, it was necessary to examine the effects of the significant differences in chronological age (CA) between the LIQ group and the other groups. The effects of this CA difference were found to be negligible as viewed from three interrelated perspectives: (1) For each group the correlations between CA and the first 11 variables, as displayed in Tables 20, 21 and 22, are highly similar; similar correlation profiles for each group suggest no differential effect of CA among the groups. (2) The squared multiple correlation of the 11 variables with CA was found to be highly similar among the groups. (3) As a corollary of (1) and (2), the CA variable behaved similarly for all groups when included in a factor analysis of the tests to be discussed.

In the selection of variables for factor analysis, Free recall was omitted from the 11 variables studied in the MANOVA procedure because it is the same test as Serial recall, with a variation in scoring procedure. Serial recall scores are a lower bound for Free recall scores and therefore the two measures are not independent. The deletion of this variable for the final step in the data analysis resulted in the use of ten variables in the principal components solutions. The solution for each IQ group will be examined in turn, followed by a summary of the three analyses.

The factor matrix for the low IQ group is presented in Table 28. Factor I has strong test loadings from Serial recall, Auditory-visual matching, Visual-auditory matching, and Visual-visual matching. An examina [illegible] other factors reveals that this factor appears to be unique [illegible] the hypothesized simultaneous-successive-speed factors and appar [illegible] resents a form of coding. It will be argued that this coding is [illegible] lly successive in nature, thus explaining the loading of the serial [illegible] l task on this factor, and it is the generation of the code that d [illegible] rentiates it from other successive tasks in factor analyses.

The se [illegible] d factor in Table 28 is clearly simultaneous synthesis. The tests which load on this factor are Raven's Progressive Matrices, Figure copying and Memory for Designs. The Memory for Designs loading is negative because the test is scored for errors.

Table 28

Principal Components with Varimax Rotation: Low IQ Group[1]

Test	Communalities	I	II	III	IV
Raven's Progressive Matrices	578	-081	600	-263	377
Figure copying	621	074	767	137	-086
Memory for Designs	672	-125	-798	-055	131
Serial recall	622	656	000	088	429
Visual Short-term Memory	612	294	206	652	240
Word reading	809	-028	138	-327	-826
Auditory-auditory matching	703	042	-043	831	089
Auditory-visual matching	702	792	110	214	-130
Visual-auditory matching	671	716	-115	298	-239
Visual-visual matching	760	800	216	-145	227
Component Variance	6.751	2.327	1.721	1.477	1.225
% Component Variance	100	34.47	25.49	21.88	18.15
% Total Variance	67.51	23.27	17.21	14.77	12.25
Eigenvalues		2.801	1.689	1.263	0.997

[1]Decimals omitted

Factor III apparently represents successive synthesis. Visual Short-term Memory is a task which involves the sequential recall of a set of digits, and as shown here the Auditory-auditory matching task is also performed by the LIQ subjects using a successive strategy. The sequences of tones in this task are apparently matched by recalling the sequence in its original temporal form, as opposed to coding the sequence as is done in the other three modality matching tests. The distinctiveness of the strategies used in the Auditory-auditory task relative to the other three modality matching tasks is particularly interesting and will form the basis later for some discussion and speculation.

Factor IV of the matrix for the LIQ group is the speed factor often found by Das (1973c). For the LIQ group it is apparent that speed aids serial recall, probably through cumulative rehearsal of the word lists as they are presented.

The results of the principal components analyses for the normal IQ group show some variation from those of the LIQ group, as demonstrated in Table 29. Most notably, the use of the SCREE test gave a three factor solution, rather than the four factors given for the LIQ group.

Factor I of the NIQ matrix appears to be a similar coding factor to the one found for the LIQ group. In contrast, however, Raven's Progressive Matrices and Memory for Designs, rather than Serial recall, have some relationship to this factor. Also, the Auditory-auditory matching test has a shared loading between this and the second factor.

The second factor of the matrix appears to be a combination of successive synthesis and speed. The two marker tests for successive synthesis, Serial recall and Visual Short-term Memory, have high loadings

Table 29

Principal Components with Varimax Rotation: Normal IQ Group[1]

Test	Communalities	I	II	III
Raven's Progressive Matrices	522	552	-018	466
Figure copying	790	112	191	861
Memory for Designs	550	-386	-051	-632
Serial recall	555	140	731	036
Visual Short-term Memory	574	350	672	-025
Word reading	714	272	-761	-246
Auditory-auditory matching	462	410	524	137
Auditory-visual matching	601	735	-001	248
Visual-auditory matching	782	848	239	073
Visual-visual matching	631	677	305	282
Component Variance	6.181	2.568	2.029	1.585
% Component Variance	100	41.55	32.83	25.64
% Total Variance	61.81	25.68	20.29	15.85
Eigenvalues		3.747	1.493	0.941

[1] Decimals omitted

on this factor, in conjunction with a high negative loading for Word reading and a moderate positive loading for Auditory-auditory matching.

Factor III of the matrix for the NIQ group is clearly simultaneous synthesis, with a slightly reduced loading for Raven's Progressive Matrices. This is the only variation in this factor as it appeared for the LIQ group.

The final principal components solution, the matrix for the high IQ group, is presented in Table 30. As in the matrix for the LIQ group, four factors were derived.

Factor I of the matrix, which has been designated as a coding factor previously, is very interesting, because for this level of IQ the factor now is made up almost solely of the modality matching tests built by the investigator. These four tests have low to moderate loadings on the other factors, indicating clearly that they are performed by a common strategy in the high IQ group. Of specific interest is the three step transition of the Auditory-auditory matching test onto this factor. The test loaded completely on a successive factor in the LIQ group, split its loadings between the successive factor and the coding factor for the NIQ group, and loaded completely on the coding factor for the HIQ group.

The second factor of this matrix is simultaneous synthesis. The loading of Raven's Progressive Matrices is reduced slightly by the effect of the third factor, but the identification of Factor II remains clear nonetheless.

Factor III is apparently successive synthesis. The moderate negative loading from Raven's Progressive Matrices may indicate an increasing preference in subjects by IQ of one strategy or the other, but

Table 30

Principal Components with Varimax Rotation: High IQ Group[1]

Test	Communalities	I	II	III	IV
Raven's Progressive Matrices	766	275	519	-590	-271
Figure copying	618	368	483	-114	485
Memory for Designs	846	118	-909	-083	000
Serial recall	642	211	029	582	-508
Visual Short-term Memory	548	166	051	714	-093
Word reading	594	056	-021	-043	767
Auditory-auditory matching	641	645	251	355	188
Auditory-visual matching	566	714	109	210	-014
Visual-auditory matching	801	823	-108	-149	-299
Visual-visual matching	612	709	-111	057	306
Component Variance	6.633	2.407	1.431	1.413	1.382
% Component Variance	100	36.29	21.57	21.30	20.84
% Total Variance	66.33	24.07	14.31	14.13	13.82
Eigenvalues		2.568	1.660	1.288	1.118

[1]Decimals omitted

this is very tentative.

The fourth factor in the matrix is apparently bipolar to those found previously for the other two groups. The factor has a high loading associated with Word reading, but the loading is positive. Also, a moderate negative loading is found for Serial recall, and a moderate positive loading for Figure copying. High scores on this factor would indicate low speed, low scores in Serial recall and high Figure copying scores. Apparently in the HIQ group, low scores on speed, which could sample tempo of response generally, are indicative of slower and less complete rehearsal and therefore lower scores on Serial recall relative to the rest of the group; high speed may result in less accuracy in Figure copying, through less attention to the quality of production of the figures.

The results of the three analyses that have been discussed demonstrate some contrasts and some similarities between the strategies employed by subjects in the three IQ groups. These results are summarized now in terms of the constructs of interest.

Simultaneous synthesis was seen to emerge quite clearly in the factor analysis for each group. Only minor variations were found, where in the NIQ and HIQ groups the three tests shared loadings slightly with combinations of other factors.

Successive synthesis was not found to be quite as stable across IQ groups. For the LIQ group specifically, the factor was not defined as clearly as it was for the other groups. In the case of the NIQ group, there appeared to be sufficient variation in individuals in speed of processing that this in turn was incorporated into the successive factor.

The speed factor also did not appear as clearly as the simultaneous factor. For the LIQ group this factor was defined almost solely by its marker test, Word reading, but for the NIQ group it collapsed onto the successive factor. As a further variation, this factor became a latency factor, when the normally negative loading for Word reading changed to a high positive loading.

As a summary of the factor analyses of the simultaneous-successive tests, therefore, the three factor solution found by Das in previous research (Das, 1973c) was replicated generally in this study, although the variations found are notable in the circumstances of some tests for some IQ groups. The implications of these variations will be considered in a subsequent discussion.

The results of the factor analyses of the modality matching tests demonstrated some clear trends. In each of the IQ group factor analyses, none of the modality matching tests loaded on the simultaneous factor. Moreover, in each of the analyses the three modality matching tests which incorporate spatial information, Auditory-visual matching, Visual-auditory matching and Visual-visual matching, formed a separate factor which accounted for the most variance. The test which contained solely temporal information, Auditory-auditory matching, shifted its loading progressively by IQ group from a strong loading on successive synthesis in the low IQ group, to a shared loading on the coding factor and successive syntheses for the NIQ group, to a strong loading on the coding factor with the other modality matching tests for the HIQ group. Auditory-auditory matching was performed by varying strategies by different IQ groups, therefore, but the other three modality matching tests involved the same coding strategy for all groups.

CHAPTER VI

DISCUSSION

The results of this study are discussed here in five sections. As an introduction, some relationships between cognitive strategies and task performance are proposed first. Following this, the two main research questions of the study as stated in Chapter III will be considered. These questions are concerned with the relationships of (1) simultaneous and successive syntheses to intelligence, and (2) modality matching to intelligence. The final sections consist of some concluding remarks on the nature of intelligence and suggestions for future research.

Cognitive Strategies and Task Performance

The statistical analyses that have been conducted in this study have been of essentially two types. Through analysis techniques which assess mean levels of performance, the profiles for the groups on the tests have been compared. Second, correlational and factor analytic techniques have been used to describe cognitive strategies among the IQ groups.

As an introduction to a discussion of the information given from these two perspectives, it may be useful to note here in a very condensed form that logically the distinction between levels of performance and cognitive strategies can be shown by the simple two-fold relationship in Table 31. The interpretation of this table rests upon the notion that cognitive strategies interact with cognitive capacity to produce measured levels of performance (cf. Bortner & Birch, 1970)[1]. These levels of performance may be of interest in terms of individual differences within a group, or may be of interest in circumstances of group comparisons as is the case in this study.

Table 31

Cognitive Strategies and Task Performance

	Level of Performance	
Strategy Type	Similar	Different
Same	1	2
Different	3	4

For each of the numbers in Table 31 a particular set of relationships can be hypothesized for strategy type, level of performance, and cognitive capacity. In a Type 1 distinction, two groups using the same strategy attain a similar level of performance on a cognitive task; in this circumstance, we tacitly assume equal mean cognitive capacities for the groups and equal facility with the strategy. In contrast, in a Type 2 distinction the same strategies are accompanied by different levels of performance between two groups; we may infer that the origin of the difference is in cognitive capacity, in differential facility with the strategy by the groups, or both. In a Type 3 distinction, different strategies between two groups accompany similar levels of performance; logically, there may be or may not be differences in cognitive capacity between the two groups. In the fourth type, different group levels of performance are accompanied by different group strategies; as in the

[1] Capacity is defined as structural constraints (cf. Das, et.al., 1975).

third type, cognitive capacity may or may not be equal between the groups.

The relationship between strategies and task performance noted in Table 31 apparently has not been stated explicitly and in its two-fold form in the research literature. And yet, an overwhelming number of the current psychological and educational studies incorporate parts of this two-fold relationship as basic assumptions in their rationale and are directed at determining the types of strategies used by different groups and the relative efficacy of different strategies.

In the area of human memory, for instance, the classic paper by Miller (1956) describes how strategies of coding digits into "bits and chunks" may be used in the recall of digit sets that exceed the capacity of the short-term store. This type of research on serial learning has been extended and generalized recently to other types of content (e.g., Johnson, 1970; Restle, 1973; Restle & Brown, 1970), and has been joined by research on imaginal and verbal mediation in paired associate learning (e.g., Paivio, 1969, 1971, Pylyshyn, 1973).

This interest in the effects of cognitive strategies on human memory has had its counterpart in the study of reasoning tasks. A series of papers by Janleen Huttenlocher and Herbert Clark, for instance, have argued the dominance and effectiveness of spatial-visual as opposed to verbal-sequential strategies in representing the information in three-term syllogisms of the type: X is larger than Y; Z is smaller than Y; which is largest? (Clark, 1969a, 1969b, 1971, 1972; Huttenlocher, 1968; Huttenlocher & Higgins, 1972; Jones, 1970).

An additional perspective in which this strategy-performance distinction has been of interest is cultural variations in cognitive strategies and the effects of formal and informal schooling on strategy development (e.g., Cole & Bruner, 1971, 1972; Cole, Gay, Glick & Sharp, 1971; Scribner & Cole, 1973). In the context of educational research as well, the recent interest in the concept of aptitude-instruction interactions reflects an effort in part to combine different cognitive strategies with different instructional techniques, in order to raise task performance (Berliner & Cahen, 1973; Cronbach, 1967).

In the present research, this distinction between level of performance and cognitive strategies is of interest in two respects. First, in viewing the results on the simultaneous-successive tests, both group level of performance differences and differences in the strategies used in these tests are indicated in the data. Second, the identification of cognitive strategies allows interpretation of task behavior in the modality matching tests, in addition to the levels of performance characteristic of IQ groups in these tests.

Simultaneous and Successive Syntheses

The first question of this study concerned the patterns of similarities and differences in simultaneous and successive syntheses which are characteristic of different IQ groups.

The results of the study indicate some clear trends for the simultaneous and successive tests. The differences between the IQ groups in mean levels of performance were significant for all tests. Indeed, the profiles of the groups on these seven measures are quite symmetric, indicating uniform group differentiation.

With respect to the strategies in the groups, the results indicated that the simultaneous synthesis factor emerged consistently in the factor matrix for each group. Successive synthesis, however, was not as clearly defined in the results for the groups, nor was the speed factor. The latter two factors tended to coalesce partially in the low IQ group, totally in the normal IQ group, and were distinct in the high IQ group.

The first aspect of the results of the study that is of interest is the variation found for the groups in the speed and successive synthesis factors. This variation was likely due to an interaction between the nature of the successive tests and the speed capabilities of the IQ groups. In view of the fact that the successive tests are all timed tasks, as opposed to purely power tests as in the simultaneous set, it is understandable that speed played a role in successive synthesis. As speed of processing decreased with IQ, the role of speed became more important; the temporal limits of the successive tests taxed the speed of processing capabilities of the subjects more heavily, thus incorporating individual differences in speed into the successive factor.

The fact that speed varied uniformly with IQ, then, created the relationships found between successive synthesis and speed. It may be interesting to examine some possible sources of this variation in speed among the IQ groups in order to determine if it was an artifact of the testing situation. There appear to be two basic sources, as noted by Horn (1968), who distinguishes between speediness related to the development of central intellective functions and speed related to peripheral functions, such as motivation and incentive.

In the present study, an important question is the role of these two sources in contributing to the speed differences found between the IQ groups. Data on developmental trends in speed of information processing, as summarized by Wickens (1974), indicates both sources are significant. Wickens notes that, as determined in a number of experimental paradigms including reaction time experiments, tachistoscopic recognition tasks, search tasks and continuous tracking tasks, there are some clear indications that speed of central processing is a function of age or maturation, and also it covaries with a number of non-processing variables such as practice, motivation, incentive and attentiveness.

As a complement to Wickens' (1974) conclusions on developmental trends in speed of central processing, comparative data for IQ differences is supplied by Holden (1970). In a study of retarded and normal children, Holden determined that differences in speed between the groups was due to central processing differences and was not specific to any single modality.

When viewed collectively, therefore, Wickens' (1974) review of developmental trends, Holden's (1970) research on retarded and normal children, and the present study all indicate that speed of processing very likely covaries with IQ in terms of a central intellective function. In addition, other simultaneous-successive research is further evidence for this conclusion. In a study by Das and Molloy (1975) of simultaneous and successive syntheses in grade 1 children, it was found that the successive factor contained a speed component. When the results from the present study are viewed developmentally in terms of mental age, the coalescence found between speed and successive processing with lower mental age is a[illegible] toward the results found for the grade 1 children by Das[illegible]

In c[illegible]lusi[illegible]irst point in this discussion regarding the relations[illegible]etw[illegible]d and successive synthesis, the variations in the factor[illegible]ter[illegible]ere probably due to differences between the groups in central [illegible]nts of speed of information processing. Peripheral determinants [illegible]ed may also have played a role in group differences, although this [illegible]ess likely; as indicated in the discussion of the method of the [illegible]y, motivation and other test-situation variables were maintained as c[illegible]ant as possible for all groups and the groups were mixed in IQ leve[illegible] the testing procedure.

The conclusion above regarding the role of speed should not overshadow the major fo[illegible]s of this study. Beyond the variation in speed by IQ and its effect[illegible] successive factor, the results of the study indicate a clear [illegible]ltaneous factor for each IQ group, and a recognizable successive factor for each IQ group.

A second point of interest in the results of this study is a comparison with Das' (1972) research on normal and retarded children. As stated previously, Das' results indicated a clearer factor pattern for retarded children than for normal children, such that the simultaneous and successive factors were congruent with the present research only for the retarded children. It has been noted in the rationale for the present study that Das' results were likely indeterminate due to a low number of tests in the factor analysis and therefore the conclusions of the study were only tentative.

This study obtained results both similar and different in comparison with Das' (1972) research. As in Das' study, the groups involved in the present research differed in levels of performance on all of the tests. In contrast to his study, however, the variations in factor patterns for the IQ groups are not as major as those found for his retarded and normal groups. The present study, therefore, suggests more consistency in patterns of simultaneous and successive synthesis as a function of intelligence than the results reported by Das (1972).

There are several possible reasons for the different results in these two studies. It is very likely that the present study has demonstrated more stability in the factor patterns for the IQ groups because the test battery was expanded from Das' (1972) study. The larger number of tests used here, as noted in the rationale for the study, allowed clearer definition of the factor patterns characteristic of the groups.

A second source of difference between Das' (1972) study and the present research is that the former involved matching the groups on mental age (MA) and this study used a chronological age (CA) match procedure. Is it possible that if the low IQ group in the present study had been matched on MA with children of normal and above normal intelligence that the patterns of strategies would be different for the groups? This is very unlikely as indicated by the study conducted by Das and Molloy (1975), in which the factors for simultaneous and successive syntheses were found in grade 1 children of normal intelligence. The grade level that would be used for selecting normal and above normal IQ children for MA matching with the low IQ grade 4 children of the present study would be approximately grade 2. Given that Das and Molloy have demonstrated that the simultaneous and successive factors emerge in normal children at the grade 1 level, and the present study has found these factors at the grade 4 level, it is likely that they would be found in the intermediate grades. One would expect no major differences, therefore, between the factor patterns for grade 4 low IQ children and MA-matched normal and above normal IQ children.

In conclusion of the comparison with Das' (1972) study, the present research has demonstrated that the simultaneous-successive factors are more consistent across IQ than was found by Das. The larger number of tests used in this study contributed to this finding, and it is likely that an MA-match design would demonstrate similar results.

As a third and final point regarding the results of the analyses on simultaneous and successive syntheses, it can be noted that as a result of two aspects of the design of the study, the findings are especially significant. These two aspects of the design are the sample size and the limits on IQ used to define the three groups.

The sample size used for this study was 60 subjects for each IQ group. This was the maximum number possible due to the amount of individual and small group testing involved in the research. This sample size was fairly small, in view of the number of tests administered and the use of factor analysis as a data analytic technique.

Despite the possible error introduced by the relatively small sample size, the results are remarkably consistent with previous research. Earlier studies have used comparable sample sizes, and therefore potential error has been a consideration in the interpretation of results. The present research is further independent confirmation of the simultaneous and successive factor pattern, thus incrementing the degree of confidence that may be placed in the existence of these factors.

A second aspect of the design which potentially mitigated against finding the simultaneous and successive factors in each of the IQ groups was the limits placed on IQ in order to form the groups. The effect of restricting the range of IQ for each group was to limit the dispersion in the sample distributions. That is, to the extent that the tests used in the simultaneous and successive battery correlated with IQ in the complete grade 4 population, their variance was restricted by restricting IQ. The effect of this restriction could be a reduction of intercorrelation in these tests, and therefore an indeterminate pattern of results when the tests were factor analyzed.

But the restriction of range in IQ did not have this effect. The intercorrelations of the simultaneous-successive tests tend to be independent of verbal IQ, as noted in the review of literature. Further, the results of the present study demonstrate that individual differences on the simultaneous-successive tests are still strong enough within IQ groups as defined here for the factors to emerge.

In conclusion of the design aspects of the study, therefore, it is significant that both sample size and restriction of range in IQ were a possible source of error in the study, but the simultaneous-successive factors were found nonetheless. These two potential sources of error add further weight to the conclusion that simultaneous and successive syntheses are strategies which exist over a major portion of the spectrum of intelligence.

Modality Matching

The second question of this study concerns the patterns of similarities and differences which are characteristic of the IQ groups in the modality matching tasks. These patterns are of interest both in levels of performance and in the use of simultaneous and successive syntheses.

The results of the study indicate that in mean levels of performance the modality matching tests were ordered from easiest to the most difficult as: visual-visual (V-V), visual-auditory (V-A), auditory-visual (A-V), and auditory-auditory (A-A). This order of difficulty in the tests was identical for each of the IQ groups.

In terms of group discrimination, however, the tests were ordered differently. A-V matching demonstrated much stronger group differences than the other three tests, which were roughly equal in strength of discrimination. In fact, A-V matching was the major discriminator of all of the tests administered, including the simultaneous-successive tests. Only the Raven's Progressive Matrices, which itself has been used in some research as a test of intelligence, demonstrated comparable group discrimination.

The results of the factor analyses indicated some very clear patterns in the strategies used by the subjects in the modality matching tests. These patterns are particularly interesting when combined with the levels of performance on each test, and viewed in the light of the distinctions drawn in Table 31 regarding cognitive strategies and task performance.

A-A matching demonstrated less group differences than the other tests, but also differential strategies. For the low IQ group it was performed successively, for the normal IQ group a combination of successive synthesis and coding was used, and for the high IQ group the task was coded. Thus, it can be said that A-A matching in this study approximates the Type 3 distinction in Table 31 (similar performance, different strategies).

The A-V matching task demonstrated very strong group differences, but the same coding strategy was used by all of the groups. This task approximates a Type 2 distinction (different performance, same strategy).

The remaining two tasks, V-A matching and V-V matching, discriminated the groups less powerfully than the A-V task, but were completed by the subjects in all of the groups by the same coding strategy. The designation that may be made for these tasks is an approximation of Type 1 (similar performance, same strategy).

In drawing these distinctions for each of the modality matching tasks, information is slightly oversimplified. Technically, no two groups actually had the same mean level of performance on any test, and the statements above deal with magnitude of difference, where all differences are significant statistically. But nonetheless, the advantages of conceiving of task performance-cognitive strategy relationships as first proposed in Table 31 is also clear, because three of the possible four combinations of circumstances are approximated in the data for this study. Most importantly, the role of strategies in modality matching is highlighted.

As a first item of consideration regarding the modality matching results of the study, it is interesting to note that simply in mean levels of performance the data is consistent with some previous research in modality matching. The finding that the order of difficulty of modality matching is from visual intra-modal tasks to visual and auditory cross-modal tasks, to auditory intra-modal tasks is consistent with the results reported by Sterritt, Martin and Rudnick (1971) and Rudnick, Martin and Sterritt (1972). The replication of this order of difficulty for each IQ group in the present research generalizes the results reported in these two studies. Also, within the results for A-V matching and V-A matching, the finding that V-A matching was the easiest of the two tests for each of the IQ groups is consistent with research by Muehl and Kremenak (1966).

In terms of the strategies used by the groups, however, the results of the study did not demonstrate all of the relationships that were expected on the basis of the review of literature. Notably, none of the modality matching tests were performed by a simultaneous (spatial) strategy as operationally defined in the factor analyses of previous research (Das, 1973c). This finding is inconsistent with Kahn and Birch's (1968) study, for instance, in which by post-test report it was found that some subjects used a spatial-visualization technique for the A-V matching task. Thus, no conclusive information is supplied here regarding the role of simultaneous synthesis in modality matching. At a later point in the discussion some possible reasons for this result will be considered.

In contrast to the lack of relationship between simultaneous synthesis and the visual components of modality matching, the temporal aspects of successive synthesis and auditory modality matching are quite informative. Of specific interest are the relationships between the successive factor and the factor that has been labelled as coding.

An examination of the successive factor reveals that both of the tests represent the mnestic level in Luria's (1966a, 1966b) terminology. The Serial recall task and the Visual Short-term Memory task involve no perceptual or conceptual processes on the part of the subject. Rather, the tasks require that the subject simply recall a set of stimuli in their original form and sequence. It is the sequencing aspect of the tasks which defines the successive factor.

What is the distinction between this successive factor and the other major factor that would indicate a coding function in the latter? Three points of evidence support the coding designation. The first of these is the difference between two distinct strategy types as discussed by Kahn and Birch (1968). The first strategy noted by Kahn and Birch is the direct recall of tone sequences; in the present study this was demonstrated by the loading of A-A matching on the successive factor for the low IQ group. The second technique is numerical coding. Kahn and Birch note that in their study roughly half of their subjects reported this technique as a dominant strategy. In the present study, all of the tests which had a visual component were performed by the same strategy by all of the groups. It is very likely that visual displays encouraged the subjects in all of the groups to use a counting strategy because of the easier clustering and grouping that was possible in this type of presentation.

A second point of evidence for the main factor representing numerical coding is an exploratory factor analysis not reported previously. It was found that among the various achievement tests, only the arithmetic test loaded on the coding factor in a factor analysis of all variables. Some evidence for the effects of numerical facility may be inferred from this loading, albeit this is tentative.

The third reason for the designation of this factor as coding is perhaps the strongest of all, and is supported by the results for the A-A task. It is evident that the numerical coding of an auditory sequence involves a translation to a new form of cognitive representation (e.g., beep, beep, pause, beep, pause, beep . . . becomes 2, 1, 1, etc.) (Lehman & Goodnow, 1972). In contrast, recall of an auditory sequence in its original form is not a translation strategy. The reason that the A-A task for the low IQ group loaded on the successive factor, then, is that the subjects in this group attempted to recall the sequence literally. In contrast, the high IQ group performed the A-A task by the same strategy as the other tasks: they encoded all information, auditory and visual, to a common numerical code. Further, recall of this code did not become a successive task, and instead coding formed a separate factor, because it was the accuracy of encoding (Biggs, 1969) and ability to match the code with the comparison stimulus that differentiated individuals and created intercorrelations, not the storage and retrieval of the code. Thus, the emphasis in the coding factor is on the organization and representation of stimuli at the point of input.

Spitz (1973) has noted that mentally retarded children have difficulty in organizing and selectively scanning both auditory and visual material, and differences between normal and retarded children in memory are due in large part to this difficulty. Mentally retarded children may differ from normals in other aspects of memory also (Ellis, 1970), but the encoding stage may be the most important point of difference. In the present study, the ability to encode visual and auditory stimuli covaried with IQ. This finding generalizes the information noted above regarding retarded children, then, to a wide range of intellectual competence.

In conclusion of the first point of this discussion regarding consistencies with expected results, the mean difficulties of the modality matching tests were consistent in this research with earlier studies. The strategies involved in the tests, however, did not include simultaneous synthesis as expected, and instead involved successive synthesis and numerical coding.

It is interesting to note as a second point that these interpretations of the strategies used in the modality tests appear, in turn, to be consistent with the differential levels of performance by the IQ groups on each test. This is due to the interaction between the manner in which information is presented in each test, and the strategies adopted by the groups to match the stimulus information with the comparison information.

The A-A test was the most difficult of the four tests for all of the groups, because information was presented in time only, and bits of information had to be processed immediately with no opportunity for confirmation of accuracy. The reason that this test did not discriminate the groups as strongly as the A-V test, even though it was the most difficult of the four tests, may have been the differential effectiveness of the strategies used by the groups. The low IQ group attempted to recall the stimulus portion of the items literally, and therefore their main source of error was likely in the storage and rehearsal of the sequences. The high IQ group coded the information numerically, but then had to code the comparison section of the item also in order to judge the similarity of the two portions of each item. As a result of the need to correctly code two temporal sequences, the high IQ group may have been prone to error as a result of incorrect coding almost as much as the low IQ group was prone to incorrect recall. Thus, even though different strategies were used by the groups for the A-A test, the strategies were apparently not markedly more effective than each other.

In contrast, in the A-V test the ability to code information presented temporally strongly discriminated the groups. The groups all used the same strategy in this test, but because the information was presented in time in the stimulus portion of each item, the groups were differentially effective in coding it correctly. The accuracy of the subsequent match to a visual stimulus, therefore, was a function of the correct coding of the stimulus portion of the items.

For the V-A test, group differences were reduced. The groups tended to have more comparable ability in coding when the stimulus information was presented visually, because rehearsal and rechecking of the code was possible while the information was in view. With a correct code, individual differences in this test were more likely in the application of the code to the information presented in time in the comparison half of the items. Errors, and therefore group differences, were reduced as a result.

The last test, V-V matching, was easiest and discriminated the groups least, because coding the stimulus portion of the items was done from a visual display, thus allowing confirmation of the correct code before removal of the information, and then the code was easily applied to a second visual display.

In conclusion, then, the tests were differentially difficult because of interactions between the form of presentation of the information, and the strategies adopted by the groups to process the information. With respect to the studies cited earlier on the order of difficulty of modality matching tests, the present study indicates that differential difficulties of auditory and visual combinations of modality matching are not simply due to the modalities involved. Rather, they are due to the effectiveness of strategies to cope with information presented in time and space.

These conclusions, in turn, relate to two further points regarding aspects of modality matching that have appeared in the literature, both of which have been mentioned in the review for this study. The first of these is the relationship between modality matching and intelligence as postulated by Jensen (1969). Jensen specifically referred to cross-modal forms of modality matching when he stated that intelligence is characterized by a central symbolic or cognitive processing mechanism, and cross-modal matching is the purest example of a task in which use of this mechanism is essential.

This study has demonstrated that Jensen's (1969) statements have elements of validity, but are oversimplified. The A-V task was the most powerful discriminator of the IQ groups, but the V-A task was not as strong in IQ group discrimination. Thus, it is not simply that a task must be cross-modal in order to demonstrate intelligence, but rather intelligence is characterized in these tasks by the ability to use an effective strategy in accord with the form in which information is presented. Additional comments on the nature of intelligence will be included at the end of this discussion.

A further respect in which this study clarifies some relationships presently in the literature is in the role of memory in modality matching. It was noted that all studies (e.g., Ford, 1967; Jorgenson & Hyde, 1964; Kahn & Birch, 1968) have found low to zero correlations between modality matching and short-term memory. But short-term memory has been measured in these studies by the type of tasks represented in the successive factor. Often, for instance, Digit span has been used. The emphasis in these tasks is on the storage and retrieval aspects of memory; the information may not be recoded to a new form following sensory registration. In contrast, it is the coding aspect of modality matching that mainly differentiates subjects, because once coded, the information is within the short-term store capacity of most subjects. It is understandable that modality matching would not necessarily correlate strongly with short-term memory as measured by tests like Digit span.

A final aspect of the results of this study which cannot be explained easily is the lack of relationship between modality matching and simultaneous synthesis. It has been noted that in previous research (Das, 1973c) an auditory-visual matching task loaded to varying degrees in different studies on the simultaneous factor. The only difference between the auditory-visual task in the previous research and the modality matching tests used in the present study is that the former used a card with three alternatives for the comparison stimulus, and this study used a same-different item format. The groups in the present study may have used the numerical coding technique in lieu of a simultaneous strategy because this technique was more applicable to all four tests. The subjects were aware at the beginning of the testing period that they would be exposed to all four modality combinations, and possibly as a result they adopted different strategies than the subjects in previous research.

Thus, the possible use of simultaneous synthesis in some forms of modality matching tests is not precluded by the results of this study. As a concluding section to the discussion of the present modality matching research, it may be interesting to attempt to synthesize the various studies of modality matching into a model, relate the model to simultaneous and successive syntheses, and then briefly consider some recurring issues in research in modality matching.

Types of information representation: A model

On the basis of the modality matching results of this study, as well as other research that has been examined, it is possible to conclude that modality matching tasks are a particularly pure paradigm for studying the general problem of cognitive representation (Pylyshyn, 1972). That is, in these tasks information is presented in terms of the generic dimensions of space and time, and the major point of interest is the relationship between the manner in which the information is presented and the strategy that the subject adopts to represent the information cognitively in order to match it with a comparison stimulus. This study has demonstrated that alternate forms of representing the information in modality matching tasks are used by different IQ groups, and it may be conjectured, albeit it has not been demonstrated here, that these different forms of representation play differential roles in the accuracy of the match to the comparison stimulus.

It is proposed here that there are four major levels of cognitive representation possible in modality matching. These levels are designated in Figure 6 as Literal, Variant, Conversion and Numerical. Each of these levels takes a particular form, dependent upon whether the information is presented in an auditory-temporal mode or a visual-spatial mode. Also, the forms of presentation and representation noted in Figure 6 are specific instances of the general model of information integration proposed by Das, Kirby and Jarman (1975) and included in this study as Figure 2. As will be seen, each level in Figure 6 can be designated as either simultaneous or successive synthesis.

At the first level, which has been designated as Literal, auditory information is represented in its original form for subsequent matching to a comparison stimulus. This is rote memory of the auditory pattern and is a successive strategy. It is likely that this was the main type used by the low IQ subjects for auditory-auditory matching in the present study. The strategy for visual information represented at

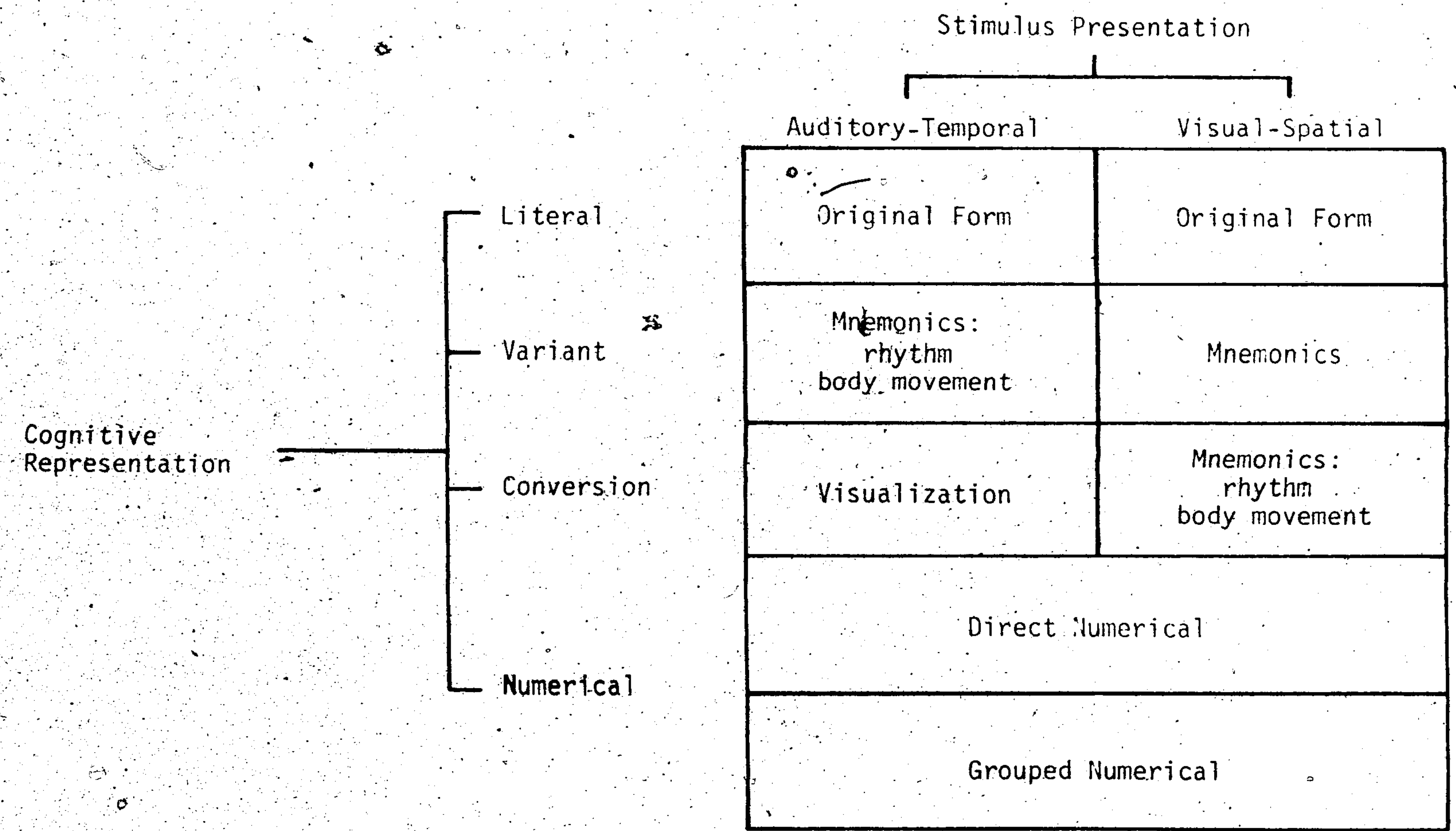

Figure 6. Presentation and representation types in modality matching

the literal level would be similar; it would constitute an attempt to continue to visualize the appearance of the array following removal of the stimulus, and would be simultaneous. The strategies in the literal level for auditory and visual presentations have been discussed, but not proposed in this form, by Kahn and Birch (1968).

The next level, designated as Variant, is a slight modification of the Literal level. Auditory information may be sequenced for recall more effectively through ~~rhy~~ rythm mnemonics, finger tapping, etc. As above, this strategy would still be successive, however. For visually-presented information, other types of mnemonics may be speçulated upon, but a simultaneous strategy may be retained. Goodnow (1971a, 1971b) has discussed the strategies associated with the auditory presentation of information; less is known about variations on representing visual information.

At the Conversion level, a substantial change in the form of representation of information takes place. Auditory information is converted to a visualization of its spatial counterpart (Kahn & Birch, 1968). Thus, successively-presented information is changed to a simultaneous representation in central processing, as discussed by Das, Kirby and Jarman (1975) in their model. In the case of visual information, this is converted through mnemonics to a successive form.

At the final level, designated as Numerical, information presented in an auditory or visual mode can be represented numerically in one of two sublevels. At the direct numerical level each tone or dot receives a number isomorphically, with time pauses or spaces designated by a pause in counting. Kahn and Birch (1968) describe this strategy as:

"I counted the taps like this . . . 1, pause in S's voice, 2, 3, pause in S's voice . . . etc. . . (p. 465)." This strategy involves a new representation of the information, but no information reduction. In contrast, the grouped numerical technique involves substantial reduction of information, as described by Kahn and Birch (1968): "I counted the taps but I added up the ones that come together and put them into groups, like this . . . 1, 1 + 1 = 2 and then 1, . . etc. . . (p. 465)." The high IQ group in the present study probably used the grouped numerical technique for all four of the tests. As noted previously, once the information is coded, it is processed successively, as would be the case for the direct numerical strategy.

It is important to note that the four levels that have been described deal with the stimulus presentation part of modality matching. The form of the comparison stimulus is not specified in Figure 6 and it may or may not be congruent with the level of representation chosen by a subject. For instance, in an auditory-visual matching task, the auditory sequence could be represented literally, in which case its form would not be directly comparable to the visual comparison stimulus. Alternatively, the auditory information could be represented at the Conversion level, that is visualized, in which case its form would be directly comparable to the comparison stimulus. Thus, different strategies may be differentially effective for different modality matching combinations, and also, changes in strategies to those more effective for high information loads may be necessary for tasks with large auditory or visual arrays.

As presented, the model of modality matching in Figure 6 is a specific section of the more general model proposed by Das, Kirby and Jarman (1975), as well as a composite of some of the more reliable research in the area of modality matching. As a final step in the discussion of modality matching and this model, four important issues in this area will now be touched upon very briefly and re-interpreted where possible.

The first issue to be considered is the role of language. It was noted in the review of literature for this study that a point of contention in modality matching research has been the role of language in facilitating task performance in modality matching. The extremity of the points of view adopted regarding language is notable in the case of some authors. Exemplary of the view that language is a necessary mediator for modality matching is a statement by Bridger (1970): "The temporal spatial matching test can only be solved by means of verbal coding of the temporal stimuli, suggesting that the deficit in the brain injured children might be cognitive rather than perceptual (underlining added; p. 258)."

In contrast, Birch and Belmont (1968) have argued that because aphasics and nonaphasics do not differ appreciably in modality matching performance, language use is not a necessary aspect of this task.

The point of view adopted in the present study is that language may often be involved in modality matching, but it is not an essential component of performance in this task. The model that has been proposed here includes language as one of several means of representing information, others of which could account for the lack of differences between aphasics and nonaphasics in modality matching. As noted in the review of literature for this study, to phrase statements on the role of language such that it is used as a total explanation, or alternatively, is excluded completely, is to overlook the other possible ways available in the human repertoire for representing information.

A second issue in the modality matching literature is the use of this task in understanding reading deficits. Despite all of the differences in theoretical viewpoints regarding modality matching, one fact has remained unchanged: modality matching predicts reading achievement. A substantial problem, however, is that no one has been able to provide a satisfactory reason for this relationship.

This lack of explanation, of course, is due as much to the complexities of the reading process as to differences in modality matching theories. It is highly likely that reading retardation is an omnibus category within which many specific varieties of disability exist. With refined definition of the types of reading difficulty, it is quite possible that modality matching will predict difficulties more strongly for some types than is the case now for the general reading deficit population, and not predict other types of reading difficulty at all.

It appears that the area of modality matching has reached an asymptote in its contribution to the understanding of reading difficulties. What is required now is the development of measures for subdividing types of reading difficulties, which can then be studied intensively by "content-pure" types of tasks like modality matching.

A third issue is the notion of modality dominance. In recent years there has been a good deal of interest in the hypothesis that children may develop a preference for processing information in a particular modality as a result of cultural-environmental influences (Bissell, White & Zivin, 1971; Lilly & Kelleher, 1973; Silverston & Deichmann, 1975). The orientation taken in much of this research appears to involve the implicit assumption that there is a direct isomorphism between information presentation and information representation. Children are often referred to as "verbalizers" or "visualizers" and this in turn is related to the respective modalities.

This point of view does not appear to include in its assumptions the proposition that temporal information may be represented spatially, and spatial information may be represented temporally. Both of these possibilities are built into the model proposed here, and are supported by some of the studies reviewed.

The notion of preferential modes should not, however, be dismissed because of this shortcoming. It may well be that as a result of cultural-environmental influences children develop a preferred strategy of processing information (Das, Kirby & Jarman 1975); it is simply unlikely that these strategies correspond directly and solely to a single sensory modality.

The fourth and final issue considered here regarding modality matching and the model proposed is closely related to the previous issue of modality preferences. It has been noted in the review of literature for this study that essentially two theoretical viewpoints exist regarding differences among sensory modalities. As exemplified by the work of Herbert Birch and his colleagues, the modal-specific point of view emphasizes the sensory modalities as separate units, which are able to exchange information only through the gradual ontogenetic emergence of intersensory integration mechanisms. The contrasting point of view, as represented to a certain extent by Marion Blank and her colleagues, and more explicitly by Gibson (1969) is essentially amodal. The information extraction properties of the sensory systems are emphasized in the amodal view, with commonalities between sensory systems established through sharing of information.

Freides (1974) has noted that neither view in its most extreme form is able to account for all of the results currently available in modality matching research. Some form of semi-specialization in information processing appears to be characteristic of the modalities, but also, this appears to exist at different levels in order that integration of varied forms may take place.

The multi-level conception of modality matching that has been proposed here is a semi-specialization point of view. This is best summarized perhaps by Luria (1971) in his description of the second block of the brain:

> It is well-known that the systems of this block are highly modality-specific: the occipital lobe, being a central device for visual analysis, does not take part in the de-coding of acoustic signals, while the temporal lobe participates only in a limited and specific form in the organization of visual information. It is well-known that each system entering this block has a hierarchical structure, and that the work of each primary (or extrinsic) zone is organized by a superimposed secondary (intrinsic) zone with highly developed upper levels of "associative" neurons . . . only a small part of the neurons of these zones are of the non-specific type of "attention units" while the greater part play a highly specific function firing to isolated cues of different modalities. The specificity of these areas decreases with the transition to the "tertiary zones" of the cortex or to the "areas of overlapping" which include units reacting to different modalities . . . (pp. 10-11).

Thus, the semi-specialized point of view supported by Freides (1974) in his extensive review of the correlational and experimental literature, has been proposed independently by Luria (1971; cf. 1970) on the basis of his clinical observations, and coincides with the conclusions of the present study.

Intelligence

This study has explored the relationships of simultaneous and successive syntheses and modality matching to intelligence. The study of individual competence in these two areas as a function of intelligence, in turn, supplies some interesting information on the nature of intelligence itself.

As noted in the introduction to this study, in recent years there has been a discernible trend in research on intelligence toward the study of the constituent processes involved in task competency. This stands in some contrast to research previous to the last decade which was dominated by the technology of IQ tests (Tyler, 1972).

As part of this change of emphasis in research, new definitions of intelligence have begun to appear. Some of these definitions are so general that they serve little functional purpose in research paradigms. Wechsler (1975), for instance, defines intelligence as "the capacity of an individual to understand the world about him and his resourcefulness to cope with its challenges (p. 139)".

Other recent definitions, however, appear to have some functional value and yet still avoid purely psychometric terminology. The major variety which seems to be emerging is what may be termed a means-ends definition of intelligence. In this view, the appropriateness and effectiveness of the individual's methods in attaining goals are said to characterize intellectual competence. Fischer (1969), for example, defines intelligence as "the effectiveness, relative to age peers, of the individual's approaches to situations in which competence is highly regarded by the culture (p. 669)". In a parallel fashion, Das (1973) has defined intelligence as "the ability to plan and structure one's behavior with an end in view (p. 27)". More recently, Das, Kirby and Jarman (1975), in a discussion of the relationships of simultaneous and successive syntheses to intelligence, have stated that intelligence does not ". . . evidence itself by a facility in using simultaneous rather than successive processes. It is the use of information obtained through these transformational procedures in order to plan and structure behavior effectively for goal attainment (p. 98)."

As an extension of the definition offered by Das, Kirby and Jarman (1975), it is proposed here that intellectual competence or intelligence may actually be a function of three factors.

As noted in the definition, the major aspect of intelligence is the ability to plan behavior effectively and utilize information in decision making. This corresponds mainly to the planning and decision-making component of the model of information integration proposed by Das, Kirby and Jarman, and included here as Figure 2. This function would be comparable to the executive component of some recent computer models of human cognition (e.g., Newell & Simon, 1972; cf. Anderson, 1975) and may be related to the plans of behavior discussed by Miller, Galanter and Pribram (1960).

Luria (1966a) postulates that planning and decision-making is distinct from simultaneous and successive syntheses by virtue of different cortical location in addition to different functions. With respect to the functional distinction, the planning and decision-making aspect of information integration cannot be viewed as simply a more general set of cognitive strategies than simultaneous and successive syntheses, but rather is qualitatively different from these by virtue of its role in the control of behavior.

In turn, simultaneous and successive syntheses may be seen to interact with capacity limits of the individual, to produce performance on a task. In the case of the modality matching tasks, capacity differences would lie primarily in the limits of the short term store in memory. Individuals may vary in both facility with simultaneous and successive syntheses and capacity, but because these two are confounded in measurement, degrees of differences in each of them cannot be assessed. Thus, strategies and capacity are intertwined, but together they may be distinguished from planning and decision-making.

The present study demonstrates these distinctions. This research was a study of task behavior in intelligence groups in "naturalistic" or uninstructed environments. That is, a series of tests were presented to the subjects with no guidelines or suggestions on how to complete each task. While the desired goal was clear to all of the subjects, the decision on the most appropriate and effective means for reaching this goal was left to each individual.

The study has demonstrated that IQ groups differ in their planning and decisions regarding an appropriate strategy for cognitive tasks. The low IQ group chose to use a rote-memory successive strategy for the auditory-auditory matching task, and a numerical coding strategy for the other modality matching tasks. In contrast, the high IQ group chose to use a common strategy for all modality matching tasks. These differences in the choice of strategies between the groups indicates the operation of an executive function.

The effectiveness of strategies and capacity differences are demonstrated in the results from the other three modality matching tests: auditory-visual, visual-auditory, and visual-visual. In these tasks, despite the choice of the same strategy by subjects of all IQ levels, strong group differences still were found. Thus, sources other than the executive function also contributed to a discrepancy in performance between the groups. These sources appeared to incorporate facility in the formation of a numerical code for temporally-presented information, which is a combination of facility in successive synthesis and capacity.

The present study has demonstrated, therefore, that IQ groups differ in their performance on tests in at least two fundamental ways. First, they differ in the manner in which they respond to task demands; that is, in their decisions regarding adoption of a particular strategy for a particular task. Second, they differ in their facility with strategies, specifically simultaneous and successive syntheses. Collectively, these two points indicate differences in the functioning of the central processing unit in the model of information integration proposed by Das, Kirby and Jarman (1975).

Future Research

There are many directions that research related to the present study could take, three of which will be suggested here in very general terms:

The first direction is related to the subtleties in the distinction between abilities and cognitive strategies. As noted previously, the use of the concept of abilities in research appears to have resulted in a view of immutable mental characteristics, and indeed has approximated a return to faculty psychology in some circumstances. In contrast, the notion of strategies incorporates assumptions regarding the adaption of man to varying task situations, and a nonpassive role in acting on the environment.

Much of the locus for this distinction lies in the postulation in various cognitive models of an executive function, or specifically in the model by Das, Kirby and Jarman (1975), a planning and decision-making unit. At the present time in psychology we have a great deal of data on how different groups and cultures perform on a multitude of tasks. We know very little, however, about the origins of decisions regarding the use of one strategy as opposed to another. Research in this direction could well implicate personality variables, as suggested by Messick (1972) and noted in the introduction to this study, as well as many other sociocultural and genetic factors.

A second and slightly more specific direction in which research is needed is the clarification of the factorial structure of simultaneous and successive syntheses. Luria (1966a, 1966b) has postulated three forms of each of these syntheses: simultaneous synthesis takes the form of perceptual, mnestic and complex intellectual processes; successive synthesis is found in sensorimotor, mnestic and complex intellectual processes. The present factorial representation of these appears to be a blend of some of these forms for each of simultaneous and successive syntheses.

An important direction in terms of both supplying further construct validity to the present factor analytic work, as well as opening other research possibilities, would be to define factorially the three forms of each of the syntheses. In order to accomplish this, Carroll's (1974) task-analytic research paradigm, as described in the introduction to this study, could be used.

A third direction for future research is the area developed in the present study: modality matching. These tasks represent an excellent technique for studying how information is processed when presented in the generic dimensions of space and time. In the future the suggestions made in the model proposed in the present study regarding information representation could be explored systematically. Origins of the tendency of different groups to use different strategies in these tasks would be a very interesting topic of research, as would the effects of instructions to perform the tasks by different strategies.

Together, these three suggested directions encapsulate much of the flavor of future needs in research on human intelligence.

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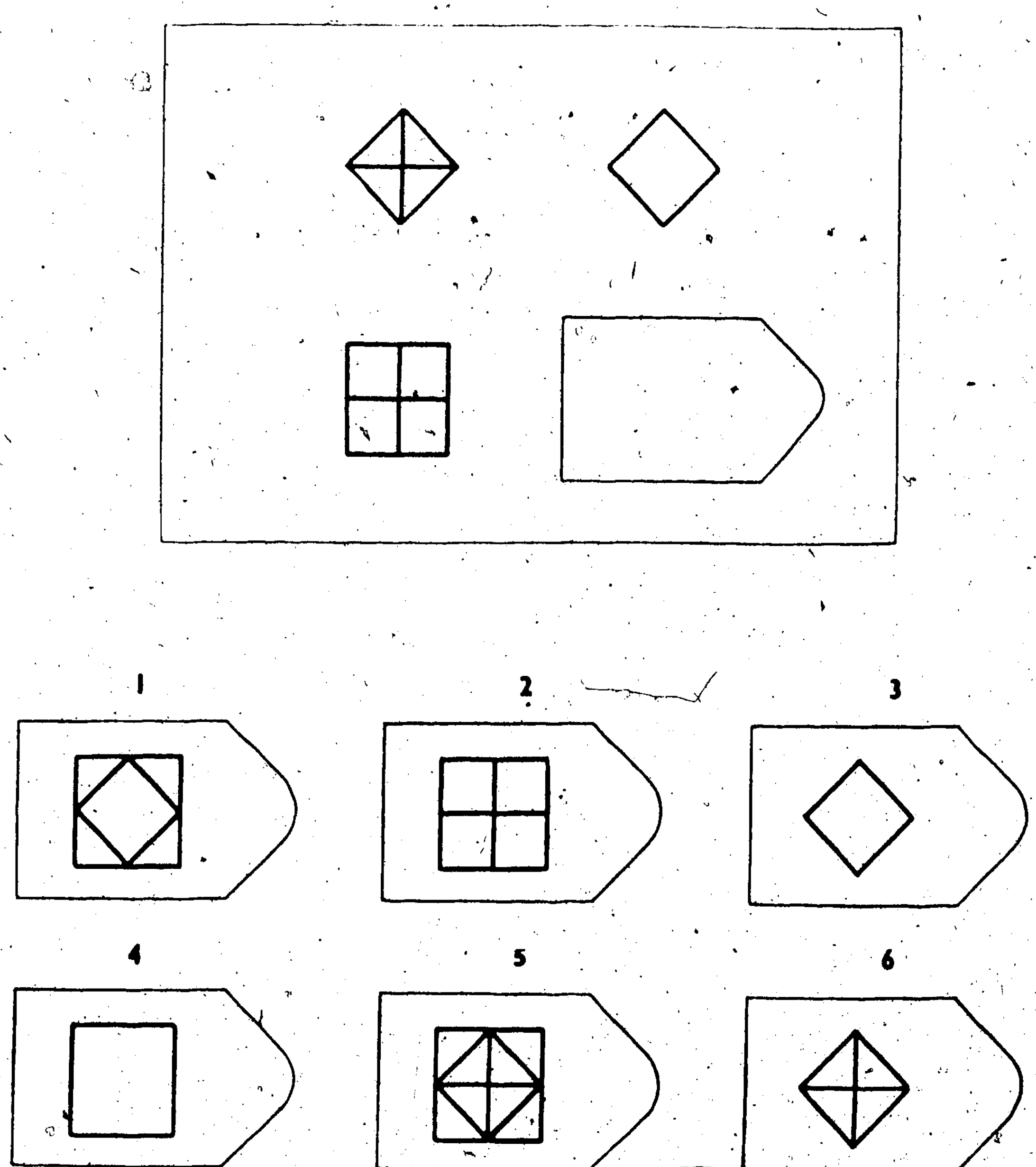
APPENDIX A

Schedule for Completion of Study

1. January, 1973-July, 1973	Literature review, problem definition and formulation of proposal
2. December, 1973-March, 1974	Construction of modality matching instrument
3. April, 1974-October, 1974	Pilot testing of modality matching instrument, test revision and development of final versions; definition of main study sample
4. November, 1974-February, 1975	Data collection
5. March, 1975-April, 1975	Data analysis
6. April, 1975-August, 1975	Report results

APPENDIX B

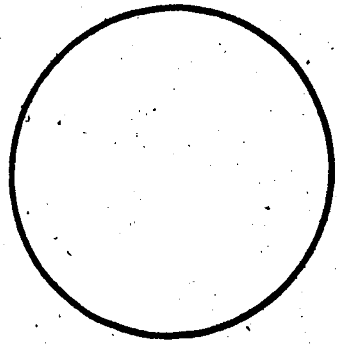
Sample Item from Raven's Progressive Matrices



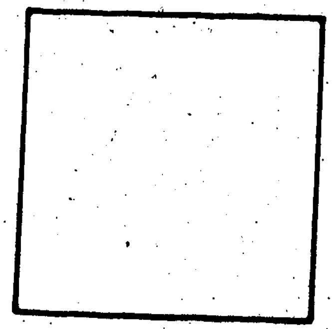
APPENDIX C

Figure Copying Test

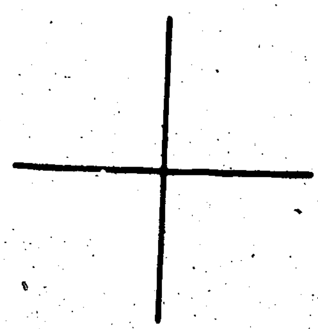
1.



2.



3.



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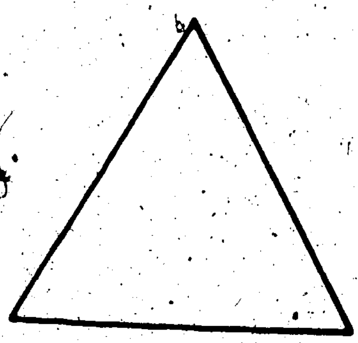

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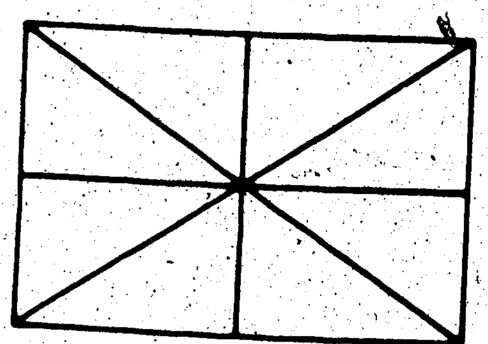

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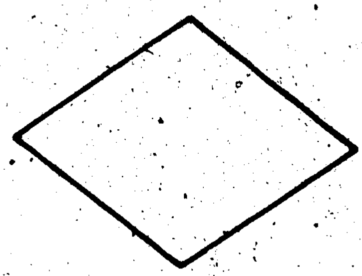

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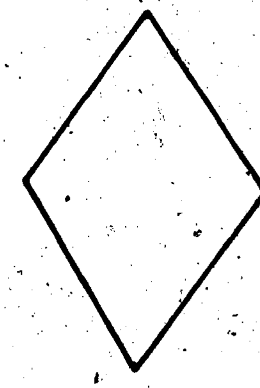

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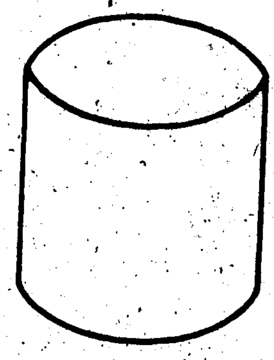
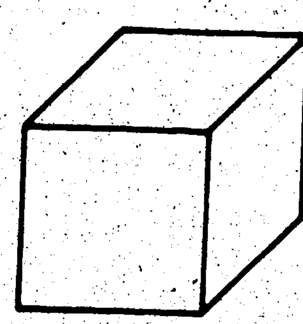
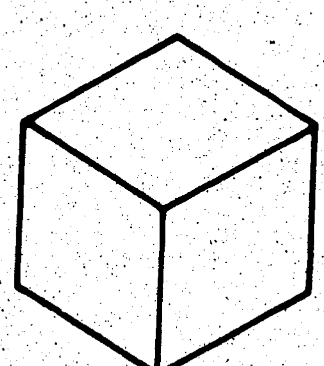


9.



10.



Guidelines for Administering and Scoring the Figure Copying Test[1]

The child is asked to make an exact, free-hand copy of ten shapes: a circle, a square, a cross, a triangle, a rectangle with intersecting diagonals and midlines, a diamond in which length is 1.7 times height, a diamond in which height is 1.7 times length, a cylinder and two cuboids in different perspectives. No time limit is given. Each drawing is scored as 0, 1 or 2 according to the degree of correctness of the production. The total score is the sum of the scores for the individual drawings with a range from 0 to 20. The scoring criterion is one of exactitude of shape and not the absolute size of the drawing. These scoring principles apply:

General principles for all drawings

1. The drawing must have the correct general shape and look like that which it is supposed to be.
2. The drawing should be approximately symmetrical.
3. Angles should not be rounded.
4. The drawing should not be rotated
5. Angles must be approximately opposite each other (except for the triangle).
6. Slight bowing or irregularity of lines is allowed.
7. Lines should meet approximately, but as long as other criteria are met small gaps at junctions are acceptable.

---

[1] From Leong (1974).

8. Slight crossing and overlapping of lines is permitted.

9. If two attempts are made in a single drawing score for the worst one.

10. Provided other criteria are met, neatness is not important.

Scoring principles specific to each drawing

1. Circle

(a) No diameter of the circle may be as much as 1 1/2 times as long as any other.

(b) The drawing must not be angled.

(c) Overlapping of curved lines is permitted.

2. Square

(a) The angle must be approximately 90^{o}.

(b) The drawing must be symmetrical.

(c) No side may be as much as 1 1/2 times the length of any other side.

3. Cross

(a) The drawing must be approximately 90^{o}.

(b) No side may be as much as 1 1/2 times the length of any other side.

4. Triangle

(a) No side may be as much as 1 1/2 times as long as any other side.

(b) There must be three well-defined angles.

5. Rectangle with intersecting diagonals and midlines

(a) The drawing must be rectangular with angles approximately 90^o.

(b) The diagonals must run from one corner to the opposite one.

(c) The midlines, both horizontal and vertical, must run approximately in the middle of the drawing.

(d) The diagonals and midlines should intersect one another at approximately the "midpoint" of the drawing.

6, 7. Diamonds

(a) There must be four well-defined angles.

(b) The drawing must be more diamond-shaped than square or kite-shaped.

(c) The pairs of angles must be approximately opposite.

(d) For drawing no. 6, the length of the diamond should be approximately from 1 1/2 to 2 times the height. For drawing no. 7 this is reversed.

8. Cylinder

(a) The diameters of the base and the top should be approximately equal and these in turn should be approximately the same as the height.

(b) The base and the top lines should be curved.

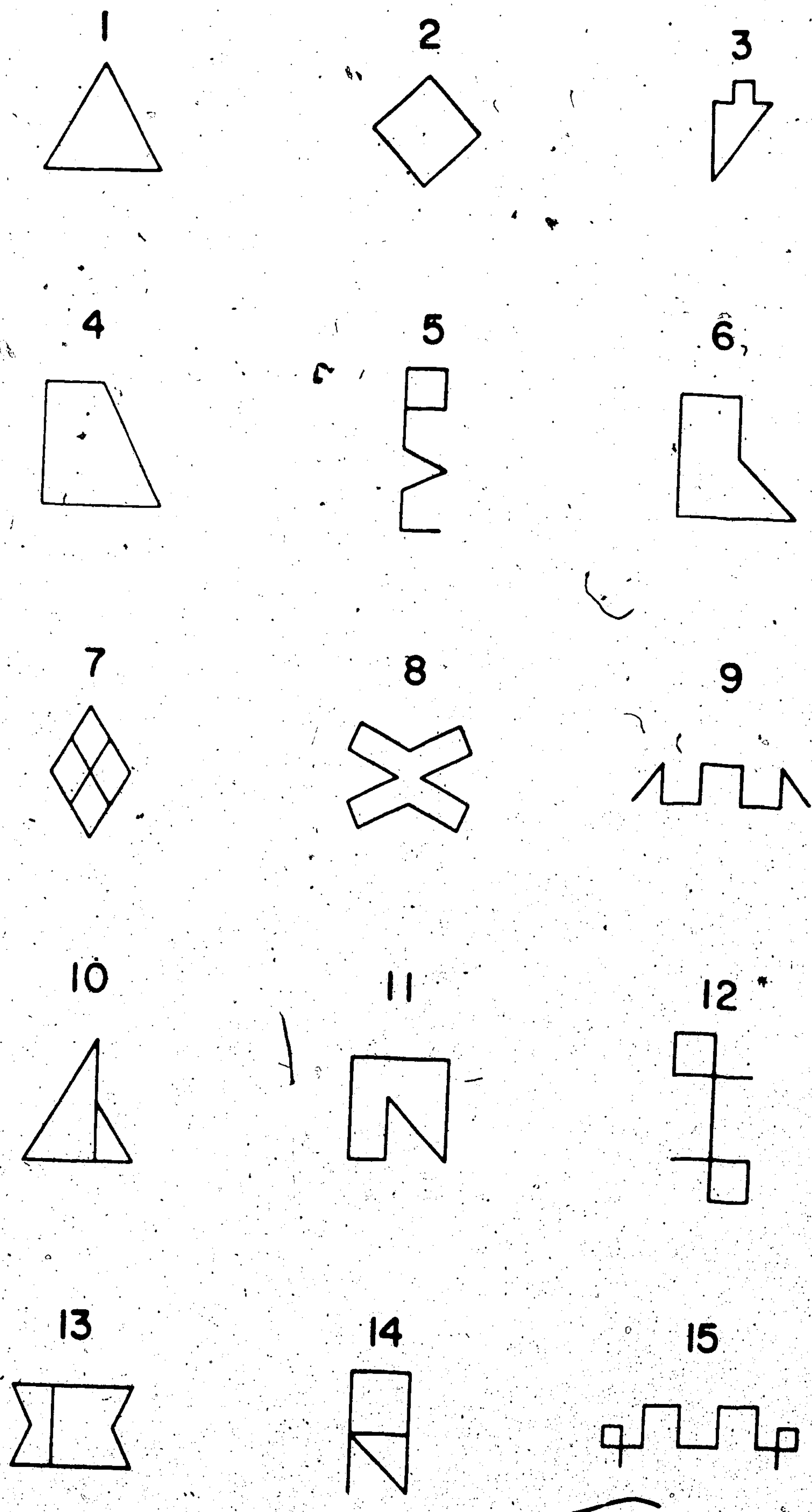
9, 10. Cuboids in different perspectives

(a) Proper perspective must be preserved as in the specimens.

(b) Lengths, widths and heights should be approximately equal.

APPENDIX D

Memory for Designs Test



APPENDIX E

Examples: A. big long great tall

B. cow day key few

C. man mad map pan

key hot cow pen

wide large big high

day cow wall bar

long big fat great

pen wall book key

book bar wall hot

key few hot book

high fat huge wide

huge great fat large

key day cow bar

wide tall large huge

bar pen few day

40 second rest

wide long big great

great high tall long

few pen hot wall

day cow bar wall

tall fat large high

long big great fat

few day cow book

tall long big huge

key book day hot

wide huge long large

high tall fat big

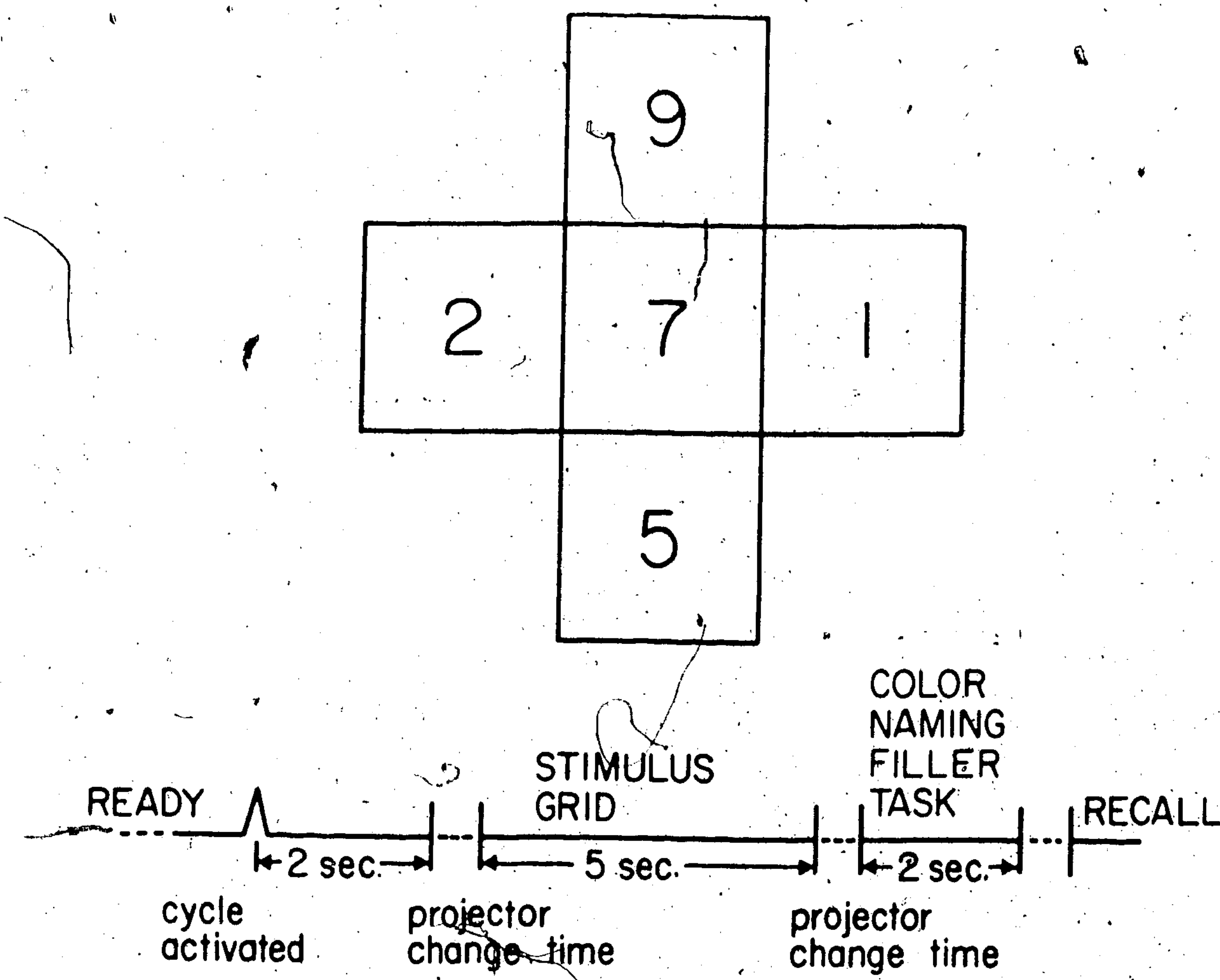
pen few wall cow

APPENDIX F

VISUAL SHORT-TERM MEMORY TASK

Example	Read as	Example	Read as
9 8 4 5 1	8 4 5 9 1	9 6 3 1 5	6 3 1 9 5

(1)	2 4 9 7 1	(2)	7 2 3 9 6	(3)	7 5 2 9 4	(4)	4 8 9 3 1
(5)	5 4 8 1 6	(6)	9 7 5 3 1	(7)	3 5 6 1 8	(8)	7 3 9 8 4
(9)	3 8 6 9 4	(10)	5 3 6 1 9	(11)	6 3 2 9 5	(12)	2 3 5 9 6
(13)	8 1 6 5 3	(14)	1 3 5 8 9	(15)	2 4 5 8 1	(16)	8 3 6 5 1
(17)	1 5 6 3 8	(18)	5 9 2 3 6	(19)	4 5 9 2 7	(20)	6 9 2 4 5


9
2
7
1
5
READY
STIMULUS
GRID
COLOR
NAMING
FILLER
TASK
RECALL
2 sec.
5 sec.
2 sec.
cycle
activated
projector
change time
projector
change time

APPENDIX G

Word Reading

RED	BLUE	YELLOW	BLUE	GREEN
RED	GREEN	RED	YELLOW	BLUE
BLUE	GREEN	YELLOW	RED	YELLOW
GREEN	YELLOW	RED	GREEN	BLUE
RED	GREEN	BLUE	YELLOW	GREEN
YELLOW	BLUE	RED	BLUE	GREEN
BLUE	GREEN	YELLOW	RED	YELLOW
BLUE	RED	YELLOW	GREEN	RED

APPENDIX H1

ITEM NUMBER	STIMULUS	COMPARISON	SAME (S)/ DIFFERENT (D)
EXAMPLES			
1	●●●	● ●●	D
2	●●●	●●●	S
3	●● ●	● ●●	D
4	● ● ●	● ● ●	S
5	● ● ●	● ●●	D
TEST ITEMS			
6	●●●●	●●●●	S
7	●●●●	● ●●●	D
8	● ●●●	●● ●●	D
9	●●● ●	●●● ●	S
10	● ● ●●	● ●● ●	D
11	● ●● ●	● ●● ●	S
12	●● ● ●	●● ● ●	S
13	● ● ●●	● ● ● ●	D
14	● ●●●●	● ●●●●	S
15	●● ●●●	●● ●●●	S
	REST	REST	
16	● ●●●●	● ●●● ●	D
17	●●● ●●	●●●● ●	D
18	●● ●● ●	●● ●● ●	S
19	● ● ● ●●	● ● ●● ●	D
20	● ●● ● ●	● ●● ● ●	S

ITEM NUMBER	STIMULUS	COMPARISON	SAME (S)/ DIFFERENT(D)
EXAMPLES			
21	●● ● ● ●	● ●● ● ●	D
22	●● ●●●●	●●● ●●●	D
23	●●●● ● ●	●●●● ● ●	S
24	● ●● ●●●	● ●●● ●●	D
25	●● ● ●●●	●● ●● ●●	D
	REST	REST	
26	● ● ● ●●●	● ● ●● ●●	D
27	●● ● ● ●●	●● ● ●● ●	D
28	● ● ●● ● ●	● ●● ● ● ●	D
29	●● ● ● ● ●	●● ● ● ● ●	S
30	●●●● ●●●	●●●● ●●●	S
31	●●● ●● ●●	●●● ●●● ●	D
32	● ●●●● ●●	●● ●●● ●●	D
33	● ●●● ● ●●	● ●● ●● ●●	D
34	●● ● ●● ● ●	● ●● ●● ● ●	D
35	● ● ●● ● ● ●	● ● ●● ● ● ●	S

ITEM NUMBER	STIMULUS	COMPARISON	SAME (S) / DIFFERENT (D)
EXAMPLES			
1	●●●	● ●●	D
2	●●●	●●●	S
3	●● ●	● ●●	D
4	● ● ●	● ● ●	S
5	● ● ●●	● ●● ●	D
TEST ITEMS			
6	●● ●●●	●● ●●●	S
7	● ● ● ●●	● ● ●● ●	D
8	●● ● ● ● ●	●● ● ● ● ●	S
9	● ● ●● ● ●	● ●● ● ● ●	D
10	● ● ● ●●●	● ● ●● ●●	D
11	●● ● ● ●●	●● ● ●● ●	D
12	●●● ●● ●●	●●● ●●● ●	D
13	● ●●● ● ●●	● ●● ●● ●●	D
14	●● ● ●● ● ●	●● ● ●● ● ●	S
15	● ● ● ● ●● ●	● ● ● ● ●● ●	S
	REST	REST	
16	●● ●●● ● ●	●● ●● ● ● ●	D
17	● ●● ● ● ● ●	● ● ●● ● ● ●	D
18	● ●●● ●● ● ●	● ●●● ●● ● ●	S
19	● ●● ●●● ● ●	● ●● ●●● ● ●	S
20	●●● ● ● ●● ●	●● ●● ● ●● ●	D

ITEM NUMBER	STIMULUS	COMPARISON	SAME (S)/ DIFFERENT (D)
EXAMPLES			
21	●● ● ●●● ● ●	●● ● ● ●●● ●	D
22	● ● ●● ● ●● ●	● ● ●● ● ●● ●	S
23	● ●● ● ●●● ●	● ● ●● ●●● ●	D
24	● ● ●● ●●● ●	● ● ●● ●●● ●	S
25	● ●● ● ●● ● ●	● ●● ● ● ●● ●	D
	REST	REST	
26	●●● ●● ● ●● ●	●●● ● ●● ●● ●	D
27	●● ● ●●● ● ●●	●● ● ●●● ● ●●	S
28	● ●●● ● ●● ● ●	● ●●● ●● ● ● ●	D
29	●● ● ●●● ● ●●	●● ● ●●● ● ●●	S
30	●● ● ●● ● ● ●●	●● ● ● ●● ● ●●	D
31	● ●● ●● ● ● ●●	●● ● ●● ● ● ●●	D
32	● ● ●● ● ● ●● ●	● ● ●● ● ●● ● ●	D
33	●● ● ●● ● ● ●●	●● ● ●● ● ● ●●	S
34	● ●● ● ●● ● ● ●	● ●● ●● ● ● ● ●	D
35	● ● ● ●● ●● ● ●	● ● ● ●● ●● ● ●	S

APPENDIX H2

Procedures for Construction of Modality Matching Tests

The construction of the pilot versions of the four modality matching tests was completed in two stages. All of the auditory portions of the tests were built first, followed by the visual portions.

Test construction: Auditory

In the construction of the auditory portions of the tests, the following equipment was used:

1. Heathkit Audio Generator Model 1G-72
2. Akai reel-to-reel Tape Recorder Model GX 365D
3. Akai Cassette Tape Recorder Model GXC 38D (with Dolby hiss reduction)
4. Stoelting Universal Timing Module; Timer Model SA600, Power Unit Model SA590.

The specifications for the auditory portions of the tests were adopted from Orn (1970). These specifications are as follows:

1. Frequency of tones: 1000 cycles per second
2. Length of tones: 0.15 seconds
3. Length of short pauses: 0.35 seconds
4. Length of long pauses: 1.35 seconds.

An initial consideration in the construction of the auditory patterns was the problem of how to operate manually all of the electrical equipment noted above to create the stimulus patterns when the tone and pause intervals are as short as specified by Orn (1970). This problem was alleviated considerably by the use of the knowledge that a 1000 cycle per second tone can be created by recording a 250 cycle tone at a tape speed of 1 7/8 inches per second and then playing the tape at a speed of 7 1/2 inches per second. Using this factor, it was possible to quadruple all of the times used in recording through the use of the slower tape speed, thus making it feasible, albeit demanding in terms of manual co-ordination, to record all of the item patterns consecutively. A conversion of Orn's (1970) specifications for a tape speed of 1 7/8 inches per second results in the following specifications:

1. Frequency of tones: 250 cycles per second
2. Length of tones: 0.60 seconds
3. Length of short pauses: 1.40 seconds
4. Length of long pauses: 5.40 seconds.

A further consideration in creating the auditory patterns once the time allowances for manually operating the equipment were quadrupled, was how to utilize the timer to create an open circuit of 1.40 seconds for a short pause in time in an item pattern, and an open circuit of 5.40 seconds for a long pause in an item pattern.

This problem was solved through using bank one of the timer for the closed circuit timing, and then wiring banks two and three for open circuit timing such that the lesser of the two times that were specified on these banks would be chosen automatically by the timer for use as the open circuit period. Thus, if bank two was set at 1.40 seconds and bank three was set at 5.40 seconds, bank two would be chosen. However, if bank two was increased by a factor of 10, giving a setting of 14.00 seconds, as could be accomplished easily by a manual switch on the timer, bank three would be chosen by the timer for the open circuit.

The task of constructing the tapes began by setting the reel-to-reel tape recorder at a speed of 1 7/8 inches per second with recording on track one only. The audio generator was set for a constant tone of 250 cycles per second and the timing module was placed between the recorder and the audio generator as a circuit switcher, utilizing the settings:

Bank one	0.60 seconds
Bank two	1.40 seconds
Bank three	5.40 seconds

For each item in turn the following sequence took place. During the 1.40 second interval immediately prior to the point at which the first tone of the stimulus portion of the item was to be recorded, the volume of the audio generator was turned up to moderate. Unless otherwise changed, recording commenced of tones of 0.60 seconds with pauses of 1.40 seconds. If at some point in the stimulus pattern a long pause was specified in the item design, then during the 0.60 seconds of tone recording immediately previous to the pause, the timing setting of bank two was increased manually by a factor of 10, giving bank two a setting of 14.00. The result of this was selection of bank three by the timer for an open circuit, giving a pause period of 5.40 seconds following the tone. By switching the rating on bank two manually in this fashion, pauses of 1.40 seconds and 5.40 seconds were generated according to the item patterns that had been designed.

In order to create an interval between the stimulus and comparison sections of each item, the audio generator was re-set with a volume of zero at the end of the recording of the last tone in the stimulus section of the item, and this volume was left off while the timer completed six cycles with the circuit closed for 0.60 seconds and open for 1.40 seconds. The comparison portion of the item was then commenced by re-setting the volume of the audio generator at moderate during the last open circuit period of the six cycles. The same procedure was used following recording of the comparison portion of the item in order to create a subject response interval on the tapes; the audio generator volume was set to zero while 16 cycles of open and closed circuits were completed.

Using the technique noted above, a continuous recording was made of the complete Auditory-auditory matching test item patterns as specified in Appendix H1. The next task was to record a script and directions for each item such that it would mesh with the recorded tone patterns. To accomplish this a sound-on-sound procedure was used; the reel-to-reel recorder was set at a speed of 7 1/2 inches per second, with track one set for listening and track two set for recording. The script for Auditory-auditory matching as supplied in Appendix H3 was recorded on track two of the tape and then, while listening to the tones of each item in turn, a number designation for the item was recorded, followed by the cue word "Ready". After the stimulus tones the word "and" was recorded to designate the separation between the stimulus and comparison patterns. Using this timing, each item structure was established as shown in Figure 7.

Once the complete Auditory-auditory matching tape was recorded on both tracks, these tracks were played simultaneously and the recording was switched to a single track on a cassette tape using the Akai portable recorder.

Using the master Auditory-auditory tape, the tapes for Auditory-visual, Visual-auditory, and Visual-visual matching were then constructed. The scripts for each of these tests as supplied in Appendix H3 were recorded on separate tapes and then portions of the Auditory-auditory

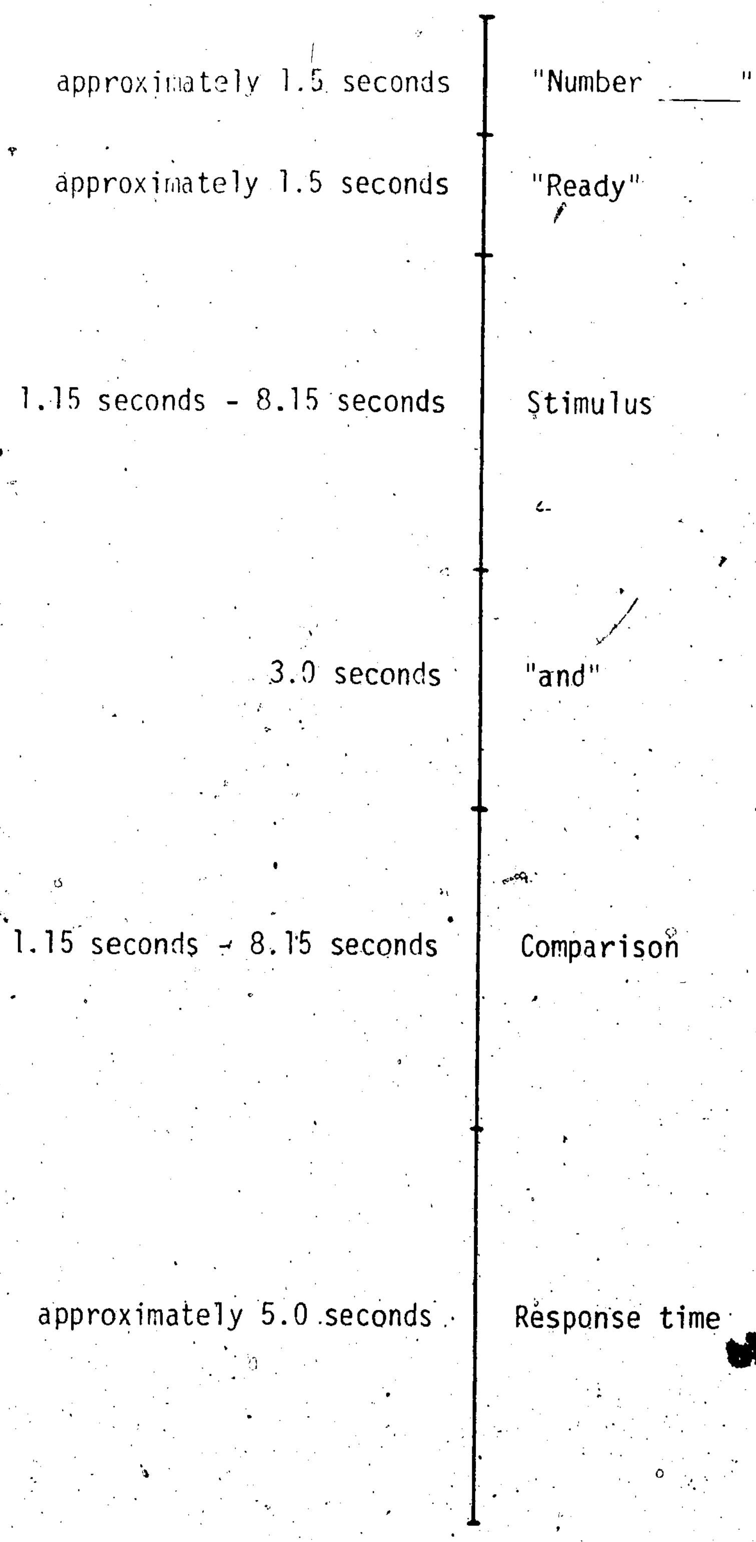


Figure 7. Structure of modality matching items

tape were transferred to new tapes, dependent upon which section of the item in a test was to be visual. In recording the Auditory-visual matching tape, for example, the Auditory-auditory matching tape was recorded with deletion of the comparison section of the items, thus creating a timed blank section on the tape during which the visual portion of the item could be shown. By this process, the remaining three tapes were constructed, thus completing all of the auditory portions of the modality matching tests.

Test construction: Visual

The equipment used in the construction of the visual portions of the modality matching instruments is as follows:

1. Nikon F 35 mm camera with electric motor drive
2. Large tripod
3. Kodak High Contrast Copy film and Ortho-Copy film
4. 32" x 40" sheet of flat white paper
5. Nine buttons of 11.00 mm diameter.

Similar to the construction of the auditory portions of the modality matching tests, the visual portions of the tests to be constructed used dimensions supplied by Orn (1970). These specifications are:

1. Diameter of dot: 2.5 mm
2. Length of short gap: 2.0 mm
3. Length of large gap: 18.0 mm

Orn's version of the cross-modal matching task was presented on 3" x 5" cards. In order to create slides for small group administration of the test, a procedure of photographing buttons placed on a large white card was used. Black nonreflective buttons of diameter 11.0 mm were selected and then Orn's specifications were scaled by a factor of 11.0 mm/2.5 mm to give:

1. Diameter of dot: 11.0 mm
2. Length of short gap: 8.8 mm
3. Length of long gap: 79.2 mm.

To create the slides the buttons were placed in the specified patterns on the sheet of paper and photographed from a point directly above the paper. All patterns were created using spacers and a horizontal guide, both of which were removed before each photograph was taken. The film used in the camera was high-contrast copy film. This film in turn was printed on Ortho-Copy film sheets, which were dyed a light blue color to reduce glare when shown in a slide projector. The sheets were then cut and mounted as slides. Additionally, an inexpensive black and white film was uniformly and partially exposed to create blank slides for exposure in the slide projector during the test administration periods when the stimulus or comparison section of an item was not displayed.

APPENDIX H3

Scripts for Modality Matching Tests

Auditory-auditory matching

Hello. Today we are going to listen to some patterns of sounds. All of these sounds will be little beeps. We are going to play a game with these beeps. We will see if some of them are the same as others, and see if some of them are different than others.

Let's listen carefully to some beeps.

[Stimulus part of Example 1 is heard.]

Now, let's listen to some more beeps.

[Comparison part of Example 1 is heard.]

Did you notice that the last beeps were not the same as the first beeps? Let's listen to both of them again. Ready for the first beeps?

[Stimulus part of Example-1 is heard.]

and now the second beeps.

[Comparison part of Example 1 is heard.]

The first beeps were not the same as the second beeps, were they? They were different from each other. Let's listen to some beeps that are the same as each other.

Ready?

[Stimulus part of Example 2 is heard.]

and

[Comparison part of Example 2 is heard.]

Those were the same as each other, weren't they? How can we write on paper that they were the same as each other? On the paper in front of you, the words same and different are written down for each group of beeps that we will hear. Let's listen to some more beeps and see how we would write the answer.

Ready?

[Stimulus part of Example 2 is heard.]

and

[Comparison part of Example 2 is heard.]

They were the same, weren't they? If we look at number 1 on the page, a circle is drawn around the word same to show that they were the same.

Let's listen to the beeps for number 2.

Ready?

[Stimulus part of Example 1 is heard.]

and

[Comparison part of Example 1 is heard.]

Those were different, weren't they? If we look at number 2 on the page, a circle is drawn around the word different to show that they were different.

Let's listen to the beeps for number 3.

Ready?

[Stimulus part of Example 3 is heard.]

and

[Comparison part of Example 3 is heard.]

Those beeps were different so a circle has been drawn around the word different for number 3. Now, would you like to try some? Use the pencil that you have in front of you to circle the right word after you have heard the beeps.

Let's do number 4.

Ready?

[Stimulus part of Example 4 is heard.]

and

[Comparison part of Example 4 is heard.]

[Pause for 15 seconds.]

Did you circle the word same for number 4? That is the right answer.

Let's try another one. We will do number 5.

Ready?

[Stimulus part of Example 5 is heard.]

and

[Comparison part of Example 5 is heard.]

[Pause for 15 seconds.]

Did you circle the word different for number 5? That is the right answer.

Let's do some more of these. After each group of beeps that you hear, circle the right answer on your paper, to show if they were the same or if they were different.

Number 6.

Ready?

. . . . . .

Auditory-visual matching

Hello. Today we are going to listen to some patterns of sounds. We are also going to look at some pictures. All of the sounds will be little beeps. All of the pictures will have dots in them. We are going to play a game with these sounds and pictures. We will see if some of the sounds are the same as some of the pictures. We will also see if some of the sounds are different than some of the pictures.

Let's listen carefully to some beeps.

[Stimulus part of Example 1 is heard.]

Now, let's look at the dots in this picture.

[Comparison part of Example 1 is seen.]

Did you notice that the beeps were not the same as the dots in the picture? Let's compare them again. Ready for the beeps?

[Stimulus part of Example 1 is heard.]

and now the dots.

[Comparison part of Example 1 is seen.]

The beeps were not the same as the dots in the picture, were they? They were different from each other. Let's compare some beeps and dots that are the same as each other.

Ready?

[Stimulus part of Example 2 is heard.]

and

[Comparison part of Example 2 is seen.]

Those were the same as each other, weren't they? How can we write on paper that they were the same as each other? On the paper in front of you, the words same and different are written down for each set of beeps and dots that we will compare. Let's compare some more beeps and dots and see how we would write down the answer.

Ready?

[Stimulus part of Example 2 is heard.]

and

[Comparison part of Example 2 is seen.]

They were the same, weren't they? If we look at number 1 on the page, a circle is drawn around the word same, to show that they were the same.

Let's listen to the beeps and look at the dots for number 2.

Ready?

[Stimulus part of Example 1 is heard.]

and

[Comparison part of Example 1 is seen.]

The beeps were different from the dots, weren't they? If we look at number 2 on the page, a circle is drawn around the word different to show that they were different.

Let's listen to the beeps and look at the dots for number 3.

Ready?

[Stimulus part of Example 3 is heard.]

and

[Comparison part of Example 3 is seen.]

The beeps were different from the dots, so a circle has been drawn around the word different for number 3. Now, would you like to try some? Use the pencil that you have in front of you to circle the right word after you have heard the beeps and seen the dots.

Let's do number 4 now.

Ready?

[Stimulus part of Example 4 is heard.]

and

[Comparison part of Example 4 is seen.]

[Pause for 15 seconds.]

Did you circle the word same for number 4? That is the right answer.

Let's try another one. We will do number 5.

Ready?

[Stimulus part of Example 5 is heard.]

and

[Comparison part of Example 5 is seen.]

[Pause for 15 seconds.]

Did you circle the word different for number 5? That is the right answer.

Let's do some more of these. After you hear the beeps and see the dots, circle the right answer on your page to show if they were the same or if they were different.

Number 6.

Ready?

Visual-auditory matching

Hello. Today we are going to look at some pictures. We are also going to listen to some patterns of sounds. All of the pictures will have dots in them. All of the sounds will be little beeps. We are going to play a game with these pictures and sounds. We will see if some of the pictures are the same as some of the sounds. We will also see if some of the pictures are different from some of the sounds.

Let's look carefully at the dots in this picture.

[Stimulus part of Example 1 is seen.]

Now let's listen to some beeps.

[Comparison part of Example 1 is heard.]

Did you notice that the dots in the picture were not the same as the beeps? Let's compare them again. Ready for the dots?

[Stimulus part of Example 1 is seen.]

and now the beeps.

[Comparison part of Example 1 is heard.]

The dots in the picture were not the same as the beeps, were they? They were different from each other. Let's compare some dots and beeps that are the same as each other.

Ready?

[Stimulus part of Example 2 is seen.]

and

[Comparison part of Example 2 is heard.]

Those were the same as each other, weren't they? How can we write on paper that they were the same as each other? On the paper in front of you the words same and different are written down for each set of dots and beeps that we will compare. Let's compare some more dots and beeps and see how we would write down the answer.

Ready?

[Stimulus part of Example 2 is seen.]

and

[Comparison part of Example 2 is heard.]

They were the same, weren't they? If we look at number 1 on the page, a circle is drawn around the word same, to show that they were the same.

Let's look at the dots and listen to the beeps for number 2.

Ready?

[Stimulus part of Example 1 is seen.]

and

[Comparison part of Example 1 is heard.]

The dots were different from the beeps, weren't they? If we look at number 2 on the page, a circle is drawn around the word different to show that they were different.

Let's look at the dots and listen to the beeps for number 3.

Ready?

[Stimulus part of Example 3 is seen.]

and

[Comparison part of Example 3 is heard.]

The do[illegible]ferent from the beeps, so a circle has been drawn around the [illegible]t for number 3. Now, would you like to try some? Use [illegible]ou have in front of you to circle the right word after you hav[illegible]e dots and heard the beeps.

Let's do [illegible] 4.

Ready?

[Sti[illegible]s part of Example 4 is seen.]

and

[Comparison part of Example 4 is heard.]

[Pause for 15 seconds.]

Did you circle the word same for number 4? That is the right answer.

Let's try another one. We will do number 5.

Ready?

[Stimulus part of Example 5 is seen.]

and

[Comparison part of Example 5 is heard.]

[Pause for 15 seconds.]

Did you circle the word different for number 5? That is the right answer.

Let's do some more of these. After you see the dots and hear the beeps, circle the right answer on your page to show if they were the same or if they were different.

Number 6.

Ready?

. . . . . .

Visual-visual matching

Hello. Today we are going to look at some pictures. All of these pictures will have little dots in them. We are going to play a game with these pictures. We will see if some of them are the same as others and see if some of them are different than others.

Let's look carefully at this picture.

[Stimulus part of Example 1 is seen.]

Now, let's look at this picture.

[Comparison part of Example 1 is seen.]

Did you notice that the first picture was not the same as the last picture? Let's look at both of them again.

Ready for the first picture?

[Stimulus part of Example 1 is seen.]

And now, the second picture.

[Comparison part of Example 1 is seen.]

The first picture was not the same as the second picture, was it? They were different from each other. Let's look at some pictures that are the same as each other.

Ready?

[Stimulus part of Example 2 is seen.]

and

[Comparison part of Example 2 is seen.]

Those were the same as each other, weren't they? How can we write on paper that they were the same as each other? On the paper in front of you, the words same and different are written down for each pair of pictures that you will see. Let's look at some more pictures and see how we would write the answer.

Ready?

[Stimulus part of Example 2 is seen.]

and

[Comparison part of Example 2 is seen.]

They were the same, weren't they? If we look at number 1 on the page, a circle is drawn around the word same to show that they were the same. Let's look at the pictures for number 2.

Ready?

[Stimulus part of Example 1 is seen.]

and

[Comparison part of Example 1 is seen.]

Those were different, weren't they? If we look at number 2 on the page, a circle is drawn around the word different to show that they were different. Let's look at the pictures for number 3.

Ready?

[Stimulus part of Example 3 is seen.]

and

[Comparison part of Example 3 is seen.]

Those pictures were different, so a circle has been drawn around the word different for number 3. Now, would you like to try some? Use the pencil that you have in front of you to circle the right word after you have seen the pictures.

Let's do number 4.

Ready?

[Stimulus part of Example 4 is seen.]

and

[Comparison part of Example 4 is seen.]

[Pause for 15 seconds.]

Did you circle the word same for number 4? That is the right answer.

Let's try another one. We will do number 5.

Ready?

[Stimulus part of Example 5 is seen.]

and

[Comparison part of Example 5 is seen.]

[Pause for 15 seconds.]

Did you circle the word different for number 5? That is the right answer. Let's do some more of these. After each pair of pictures that you see, circle the right answer on your page to show if they were the same or if they were different.

Number 6.

Ready?

APPENDIX H4

Item Difficulties for Pilot Administration of Modality Matching Tests: Low IQ (P_L), High IQ (P_H) and Pooled Groups (P_T)

Item	Auditory-auditory matching			Auditory-visual matchng			Visual-auditory matching			Visual-visual matching		
	P_L	P_H	P_T	P_L	P_H	P_T	P_L	P_H	P_T	P_L	P_H	P_T
6	.93	.93	.93	.90	.97	.93	.83	.93	.88	.97	.97	.97
7	.83	.93	.88	.90	.97	.93	.70	.83	.77	.83	.90	.87
8	.67	.90	.78	.73	.93	.83	.73	.93	.83	.93	1.00	.97
9	.57	.77	.67	.63	.97	.80	.67	.73	.70	.83	.97	.90
10	.50	.87	.68	.69	.90	.75	.63	.83	.73	.97	1.00	.98
11	.77	.80	.78	.50	.73	.62	.83	.80	.82	.93	.93	.93
12	.60	.60	.60	.67	.77	.72	.57	.80	.68	1.00	.97	.98
13	.67	.87	.77	.67	.83	.75	.70	.93	.82	.97	.97	.97
14	.90	.83	.87	.63	.80	.72	.77	.83	.80	.90	.90	.90
15	.57	.80	.68	.57	.83	.70	.77	.93	.85	.97	.87	.92
16	.50	.63	.57	.73	.83	.78	.77	.93	.85	.93	.93	.93
17	.73	.87	.80	.60	.80	.70	.87	.97	.92	.93	.93	.93
18	.73	.80	.77	.50	.80	.65	.83	.83	.83	.70	.93	.82
19	.70	.63	.67	.63	.57	.60	.77	.77	.77	.87	.90	.88
20	.53	.53	.53	.57	.70	.63	.77	.83	.80	.87	1.00	.93
21	.53	.63	.58	.73	.70	.72	.73	.90	.82	.90	.93	.92
22	.47	.63	.55	.40	.50	.45	.63	.87	.75	.93	.93	.93
23	.53	.57	.55	.57	.77	.67	.77	.80	.78	.60	.80	.70
24	.50	.60	.55	.43	.40	.42	.80	.77	.78	.93	.90	.92
25	.50	.63	.57	.60	.83	.72	.73	.90	.82	.93	1.00	.97
26	.50	.57	.53	.63	.73	.68	.53	.73	.63	.83	.87	.85
27	.37	.47	.42	.43	.67	.55	.70	.67	.68	.83	.93	.88
28	.67	.63	.65	.60	.60	.60	.57	.70	.63	.40	.80	.60
29	.63	.57	.60	.43	.63	.53	.63	.83	.73	.80	.83	.82
30	.80	.90	.85	.63	.87	.75	.80	.83	.82	.57	.80	.68
31	.60	.70	.65	.70	.77	.73	.70	.87	.78	.63	.67	.65
32	.43	.57	.50	.37	.43	.40	.80	.93	.87	.83	.87	.85
33	.43	.60	.52	.57	.57	.57	.77	.90	.83	.60	.90	.75
34	.57	.40	.48	.43	.43	.43	.60	.83	.72	.53	.37	.45
35	.63	.30	.47	.73	.80	.77	.70	.73	.72	.60	.80	.70