CHAPTER 1

INTRODUCTION AND OVERVIEW

INTRODUCTION

This research was concerned with learning that takes place in structured environments in which an individual is expected to meet learning objectives as a conscious activity, such as in front of a teacher in a school classroom or in front of a computer using a learning program. It was specifically concerned with identifying individual intellectual ability patterns, providing instructional treatments to match, and assessing the effects on learning performance.

To date, aptitude-treatment interaction (ATI) research has not led to practical improvements in primary or secondary school classrooms. Certainly in Australian classrooms, during the last, say, fifty years, it is difficult to detect change that has resulted to instructional treatments such that more accommodation is made for individual learning differences. It appears that ATI studies have not presented sufficiently clear and compelling evidence as incentive for educators to translate findings into classroom contexts. On the other hand, however, there seems to be a growing concern that inadequate attention is being paid to tailoring delivery systems to cater for these acknowledged differences in underlying cognitive processes.

To some extent, the lack of practical application of previous research findings may be explained by the succession of relatively inconclusive ATI studies conducted during the 1960s and early 1970s, periods when such research was prevalent. A significant body of the early ATI research appeared to founder on difficulties experienced by the researchers in identifying a concise framework within which individual learning processes can be investigated. Numerous theoretical paradigms of cognition have been proposed to explain why individuals differ in their ability to meet set learning objectives. Multi-disciplinary research into the learning function has included neurophysiologists and neuropsychologists using direct-observational studies, psychometricians applying factor-analytic techniques to cognitive test data, and clinical neuroscientists utilising nontraumatic brain function imaging. Various models of intellectual ability and brain functioning have been selected by researchers as a basis for investigating ability pattern - instructional treatment interactions. Chapter 3 summarises the historical development of such models and provides a perspective on the cerebral organisation of human cognition and concomitant progress in the understanding of learning processes.

The model selected for aptitude measures used in this ATI research is based upon that proposed by the late Russian neuroscientist Aleksandr Luria (1966a, 1966b, 1976a, 1976b). His model was developed and refined during forty years of clinical observation of patients with brain damage. Luria's model views intelligence as a cognitive construct, proposing that simultaneous analysis / synthesis and successive analysis / synthesis are the two metaprocesses which include a variety of cognitive skills, and which underlie the acquisition of knowledge. The Luria model, as refined and operationalised by Das and his co-workers at the University of Alberta in Canada (Das, Kirby and Jarman, 1975; Das, Kirby and Jarman, 1979; Naglieri and Das, 1988) and Fitzgerald (1973, 1975, 1990) and his co-workers at the University of New

England in Australia proposes that individuals develop a preference for processing information in either the successive or simultaneous mode. This research has indicated that the Luria model has applicability for educational purposes across various grade and content areas, and has been demonstrated to have potential as the underlying learning paradigm upon which to base ATI studies. Given the complexity of mental functioning, Luria's model is extraordinarily parsimonious in that it identifies precursor abilities and focuses on the process of cognition in contrast to the content of cognition.

The major tenets of Luria's model of cognition have been confirmed by a wide body of research, including factor analyses of psychometric test data. More recently, Luria's systems approach and integrative view of major brain structure functioning have been substantially supported by findings from neuroanatomical research, in contrast to many of the models proposed prior to the emergence of recent brain imaging technologies. Chapter 4 provides a description of the Luria model, reviews related research and examines the characteristics of the two processing dimensions of the Luria model.

The main focus of this present research sought to explore learning as subjects undertook self-administered instruction in an unit designed to develop elementary reasoning skills. It has long been held that schools should enhance reasoning abilities in their students and this view was influential in the elementary reasoning topic being chosen for instruction. The content judged to be applicable for the primary subjects involved in the main study of this research included Set Theory and syllogistic reasoning, both of which have been traditional components of courses in elementary reasoning. Chapter 5 examines these aspects of reasoning, reviews the teaching of reasoning skills to young children and relates the discussion to the dimensions of the Luria model.

INDIVIDUAL DIFFERENCE MODELS AND ATI RESEARCH

Following a review of ATI studies and related research, it is suggested that the complexities of two fundamental issues appear to have contributed to a largely confusing collection of findings which have been of little educational significance. In order that appropriate foundations are established for the present ATI research, it was contended that, at the outset, it was of primary importance to establish (i) a rational approach to definitions, and (ii) a clear and concise approach to modelling mental function.

Approach to Definitions

A teacher may write on a report "An intelligent pupil. She has the ability but is not working to capacity". Although neurophysiologists can agree on names for discrete physical parts of the brain, there has been a history of confusion and disagreement amongst educators and psychologists on the definition of terms related to brain functioning such as intelligence, ability and capacity. The confusion extends throughout the literature and encompasses lack of specificity in the use of words applicable to intellectual behaviour generally. Problems are compounded when, for example, the word "aptitude" is replaced by "trait" or "characteristic", or the word "treatment" replaced by "instructional style" or "instructional method", without clarification.

The brain's functioning is now thought to comprise an unbroken process of chaotic, fractal activity, and it is perhaps not surprising that psychologists have yet to develop generally agreed definitions for many aspects of intelligence and cognitive abilities. Bohm (1983, p. 52) concludes that "intelligence is not deductible or explainable on the basis of any branch of knowledge ... its knowledge is deeper and more inward than any knowable order that could describe it".

Spearman (1927, p. 14) quotes J.S. Mill: "The tendency has always been strong to believe that whatever receives a name must have an entity of being, having an independent existence of its own." He suggested that the word intelligence, as an example, has become "a mere vocal sound, a word with so many meanings that finally it has none". Johnson et al (1984, p. 4) believes "that this term [intelligence] originated as a useful adjective but has been forced inappropriately into use as a noun". Even as an adjective, though, as in "that was an intelligent act", the circumstances pertaining at the time must be included in its understanding. In other circumstances, the very same act could well be "unintelligent".

In 1921 the first symposium was held to focus on intelligence. At the symposium in 1986, with the advantage of 65 years of additional work, Detterman (1986) reflected

> " ... with the study of intelligence nearly a century and a quarter old, and IQ tests in use for over 90 years ... though the definitions provided by this symposium may be more refined, substantial disagreement on a single definition still abounds."
> (Detterman, 1986, p. 164)

Guilford (1982, p. 49), following over thirty years of work on the structure of intellect, latterly defined intelligence as "a systematic collection of abilities or functions for the processing of information of different kinds in different ways". He suggests that cognitive psychology took an enormous step forward when it substituted the concept of "consciousness" with that of information processing.

E.G. Boring (1923) provided what appeared on the surface to be a cynical definition of intelligence, by stating that "... intelligence as a measurable capacity must at the start be defined as the capacity to do well in an intelligence test". In a similar vein, Keating (1988, p. 35) suggests: "Naming a parameter with a processing label no more guarantees it to be a description of actual cognitive activity than naming a test IQ makes it a real assessment of intellectual capacity." On one hand, these views could be taken as a refusal to face the definition problem - there are numerous intelligence tests and thus an equal number of definitions of intelligence. On the other hand, however, Jensen (1982, p. 258) quotes Miles' (1957) advice: "The important point is not whether what we measure can be labelled "intelligence", but whether we have discovered something worth measuring." Guilford (1967, p. 13) suggested that "Boring (1923) gave the proper cue, at least for psychometricians, when he went on to say that we should be able to gain insight into the nature of intelligence tests through the method of correlation". This is the essence of the approach taken to definitions of cognitive attributes in this study: understanding and agreement on definitions of abilities (for example, factor labels), then, is dependent upon and clarified by the construct validity of the tests from which they originated.

Approach to Modelling Mental Function

There is little doubt that the lack of a commonly accepted model that adequately and practically represents the structure of mental function has hampered research and the implementation of ATI research findings into the classroom. Gustafsson (1982), reviewing ATI studies, concludes:

> "It is obvious that the confusion concerning the structure of abilities is to a certain extent responsible for lack of [ATI research] success. Thus, researchers have selected and interpreted aptitude variables within different frames of reference, which in turn has caused great problems assembling and integrating the findings."
> (Gustafsson, 1982, p. 25)

Modelling human behaviour can be viewed as a vast multi-dimensional matrix of individuals, situations and times. Dynamic chaos is an ever-present phenomenon in biological systems, which exhibit a sensitivity to prevailing situations such that small differences in conditions result in individual behaviour and development of bewildering complications. Thus it is inevitable that modellers have had to reduce the dimensions of this complexity. The majority have taken one or more of the three rather audacious steps of (i) assuming that underlying temporal variability can be ignored, (ii) equating "real-life" with "controlled" situations, and (iii), presuming that individuals can be partitioned into groups for which averages adequately represent each member. An inevitable corollary of these assumptions is that a lively debate has been carried on in the literature resulting in proposals of disparate theories and models of mental function.

Beginning with Galton (1869), an ardent experimentalist and inventor of the correlational method, and Spearman (1904), the inventor of factor analysis and its application to cognitive test data, there has ensued a plethora of psychometrically-based models for representing human cognition. Added to these have been two other classes of model, namely the cognitive developmental paradigm, after Piaget (1964) and the information-processing paradigm after Luria (1966a - 1982). Each succeeding model within each of these paradigms has been a contender for recognition as an adequate representation of mental function. Numerous writers, both researchers and reviewers of research, have rationalised that many of the tenets of these diverse models are not essentially competitive, whether proposed by psychometricians, cognitive developmentalists, or clinical researchers, and suggest that they tend toward a holistic, integrative view of mental function. Das, Kirby and Jarman (1979) and Sternberg (1984a) see a successful integration of correlationally based structural theories and experimentally based processing theories in the offing. Others, such as Keating (1984, p. 33) contend "... that it is persuasive enough to argue that such an integration is unlikely if not impossible".

The Luria model selected for this study is, nevertheless, like any other model, a simplification designed to permit analysis and prediction. Assumptions and aggregations are unavoidable until medical science can tap into and read the essence and working efficiency of the individual's multiple facets of cognitive functioning. Aggregation is necessary for psychology to function as a science. Epstein and O'Brien (1985) suggest that:

> " ... science is not concerned with relationships between fragments of behaviour, but with establishing general relationships between variables, no matter how narrowly or broadly defined, which can then be put to use for different purposes, including predicting narrowly defined behaviours."
> (Epstein and O'Brien, 1985, p. 534)

Aggregation facilitates reproducibility, generalisability, the simplifying of relationships by synthesising redundancies and thus prediction. At what level of aggregation should a pragmatic model of mental function be concerned?

An individual can be said to be "good at mathematics", or "fair at algebra", or "poor at factorisation". Apart from the subjectivity of the adjectives, an important general question is implied: What are the differentiated skill groups in mathematics, or, more generally, at what levels in the various academic subjects can rational aggregations be made for sensible assessment of discrete abilities? Fortunately, for this research, this question can remain unanswered. This study involves an assessment of *precursor* abilities, *information processing* abilities, and is not concerned with previously acquired understandings or knowledge. This is a pivotal distinction. The aggregation of abilities in this study requires measurement of precursor abilities designated as cognitive processes "removed" from the curriculum domain of interest (mathematics, in the specific example given above) to explain and predict achieved performance in that domain.

This ATI research selected just two broad aptitudes that are potentially pervasive across the school curricula. By the measurement of the dual information processing abilities defined by the Luria model, students may be notionally partitioned into groups according to measures in each of the two dimensions. They may thus be individually classified as, for example, "high in simultaneous information processing - low in successive information processing", based upon component scores resulting from data analyses of performances on criterion tests. This is consistent with the advice of Cronbach and Snow (1977):

> " ... aptitude-outcome relations are to be described on a absolute scale rather than in terms of ranks or comparative standings. A particular treatment produces a good outcome for the person whose spatial skills have reached a certain level; *that* is the form a scientific finding and a causal explanation can reasonably expect to take." (Cronbach and Snow, 1977, p. 161)

The selection of relatively parsimonious high-order aptitudes, such as the simultaneous-successive aptitudes formulated by Luria, is supported by numerous researchers including Driscoll (1987), Jonassen (1982) and Gustafsson (1982). Some research now suggests that simultaneous and successive abilities can themselves be broken down into sub-dimensions of information processing, and the relevant argument are analysed in Chapter 4.

OUTLINE OF RESEARCH STUDIES

Study 1 - Simultaneous and Successive Information Processing Aptitudes in Senior Primary Students: Based upon the Luria model (1966a, 1966b, 1976a, 1976b), Study 1 involved the administration of criterion tests to identify simultaneous and successive information processing aptitudes in the Year 6 female subjects (N=296). Principal Component Analysis, one of the class of factor-analytic techniques, was used to extract two principal components (or factors) from the intercorrelations among raw data obtained from the administration of six tests. The explicit aim of Study 1 was to determine measures of individual aptitude for both simultaneous and successive information processing by generating individual scores on each of these two identified components. The subjects could then be assigned to one of nine aptitude groupings based upon their measure (nominally classified as high - medium - low) in each of the two domains. These groupings were designated for subsequent use in the aptitude-treatment interaction Study 2.

Study 2 - Aptitude-Treatment Interaction Study in Reasoning: The aim of Study 2 was to examine the interaction between the two orthogonal dimensions of information processing identified in Study 1 and two corresponding instructional treatments designed to maximise learning performance on introductory reasoning tasks. The instructional materials were designed specifically to develop students' knowledge, understanding and performance on elementary reasoning tasks related to Set Theory and syllogisms. More generally, the study investigated whether individual learning can be optimised by presenting a student with instructional material designed to capitalise on the profile of the individual's information processing abilities.

It was hypothesised that students with higher successive information processing aptitudes would learn more effectively from the instructional treatment nominally labelled "verbal" (designed to advantage students higher in successive analysis / synthesis) than they would from the "spatial" treatment (designed for students with higher simultaneous analysis / synthesis information processing aptitudes), and vice versa. It was anticipated that aptitude x treatment interactions were most likely to be evident when comparisons were made involving students in the high - low ability group (high in simultaneous - low in successive) with those in the low - high ability group. The major research hypothesis for Study 2 was that there would be a disordinal interaction between successive - simultaneous aptitude variables and treatment groups with regard to performance in each of three categories of learning in the Reasoning unit, namely understanding and knowledge of Set Theory, Set manipulation and syllogistic reasoning.

Study 3 - Aptitude-Treatment Interaction in Learning Elementary Set Theory: Study 3 was a follow-up suggested from an analysis of the findings of Study 2, which seemed to indicate that the demands placed upon the learner by the *content* appeared to be an influential variable affecting aptitude x treatment interactions. Study 3 was directed at meeting two major objectives: firstly, to examine further the proposition, as indicated by Study 2 results, that Set manipulation tasks (intersection, union, sub-set) predominantly call upon spatial information processing abilities; and secondly, to examine the influence, if any, of pictorial and diagrammatic supplements to a "verbal" instructional treatment of elementary Set Theory tasks involving knowledge acquisition and understanding and Set manipulations.

Study 3 was conducted in two phases. Phase 1 was the administration to a new group of female Year 6 subjects (N=251) of five of the six information processing aptitude tests used in Study 1, plus a new sixth potential criterion "Sets" test. The latter was developed and administered to determine the loading of Set manipulation tasks on the two dimensions of information processing defined by the Luria model and investigated in this research. Phase 2 of Study 3 then involved individual observation and a clinical interview with each member of two specific sub-groups of students as they undertook tasks and exercises prescribed in one of two instructional treatments (nominally called "spatial" and "verbal") specifically designed for Study 3. The two sub-groups of students (N=49) were those classified from a Principal Component Analysis of the aptitude test data (from Phase 1) as either "high in simultaneous - low in successive" or "low in simultaneous - high in successive" information processing. The intent of the individual observations was to investigate in some detail, via structured probes, collection of anecdotal evidence and some quantitative data analysis, an insight into the cognitive processes being employed as each student undertook the tasks and exercises required by the assigned set of instructional materials.

SUMMARY

Currently many questions regarding the kinds of cognitive processes and situational variables that involve children's learning in a classroom still remain unanswered. For example, there seems to have been little progress made toward a consensus on notions of intelligence. More particularly, there seems to be an increasing number of proposals purporting to model mental functioning rather than a tendency toward agreement on the efficacy of one model. It is suggested that partly as a consequence of a lack of general acceptance of a model that adequately represents goal-directed cognitive activity, and also because numerous aptitude-treatment interaction studies appear to have resulted in either unsupported hypotheses or been inconclusive, there has been little evidence of catering for individual learning preferences in Australian classrooms. The traditional teaching method of using the one set of instructional materials and the one delivery system for the total membership of a class of students is commonplace.

A fundamental consideration throughout this research, and one which influenced its objectives, design and methodology, was that outcomes should be of practical value to Australian educators. This clear perspective required that the model upon which the research was based should describe readily measurable aptitudes that were equally pervasive across age levels and curricula. The model of mental functioning selected for this aptitude-treatment study was proposed by Luria (1966-1982) and operationalised by Das (1975-1988) and Fitzgerald (1973-1990) and their colleagues. Although, like any model of human intelligence, Luria's model is inevitably a simplification of the multi-faceted dimensions of abilities changeable over time, there seems to be growing agreement that it has significance in education. Developed from a neuroanatomical base, this support for Luria's parsimonious cognitive constructs has come from a wide body of multidisciplined research, both neuropsychological and neurophysiological. Within the context of ATI research, an emerging body of strong evidence has demonstrated that Luria's model has practical applicability to the classroom.

CHAPTER 2

APTITUDE-TREATMENT INTERACTION

Cronbach and Snow (1977), following a substantive review of aptitude - treatment interaction (ATI) studies, conclude, in general:

> "Aptitude x Treatment interactions exist. To assert the opposite is to assert that whichever educational procedure is best for Johnny is best for everyone else in Johnny's school. Even the most commonplace adaption of instruction, such as choosing different books for more and less capable readers of a given age, rests on an assumption of ATI that it seems foolish to challenge."
> (Cronbach and Snow, 1977, p. 492)

Kleinfeld and Nelson (1988) support Cronbach and Snow's (1977) logical expectation that individual learning will be improved if instructional treatment is matched to individual learner aptitudes. In their ATI study (Kleinfeld and Nelson, 1988), they provide a concluding comment that is not easily forgotten:

> "In sum, both psychological research on Native Americans' cognitive ability patterns and ethnographic research on Native American' observational learning style lead to the hypothesis that Native American children would do better in school if instruction were not so verbally saturated and drew more upon visual and spatial abilities. This conclusion seems so straightforward, so logical, and so compelling that it is difficult to believe it is not valid."
> (Kleinfeld and Nelson, 1988, p. 7)

It would seem appropriate to view differing perspectives on ATI as not so much disputing the "compelling logic" of ATI, but more as commentaries on the difficulties in isolating the relationship between the treatment and aptitude variables being investigated from the profusion and complexities of other variables peripheral to the study. Further, even if the selected aptitude and treatment variables interact significantly at some stages of a study, such a phenomenon may be confused or obscured in accounting for outcome as other uncontrolled situational and personological conditions vary haphazardly. Predominantly for these reasons, it is suggested that ATI research has failed to realise its promise, a review of the literature indicating that the majority of studies have either resulted in unsubstantiated predictions, or have been inconclusive. Research that has reported significant ATI has frequently been found difficult to replicate. It is thus not surprising that, following the 1960's and 1970's during which numerous ATI investigations were conducted, the research area has been largely neglected.

The origins of ATI research are attributed to Cronbach (1957) who, following his review of studies of learning behaviour, suggested that researchers had inadequately accounted for interactions between learner aptitudes and instructional treatments. He claimed that "experimentalists" were only concerned with variations in instructional treatments and ignored individual aptitude differences, and that "correlationists" were only concerned with individual variations and ignored instructional treatments. He therefore suggested that "the greatest benefit will come ... if we can find for each individual the treatment to which he can most easily adapt" (Cronbach, 1957, p. 679). He encouraged educators to develop instructional treatments specifically tailored to suit students grouped according to individual aptitude patterns such that learning performances will be improved. For the following twenty years a succession of researchers embraced exhortations such as Cronbach's, but as summarised by Lamos (1984, p. 173), the "goal of ATI research to find generalisable relationships between a particular treatment and learning outcomes has not been fruitful". Numerous researchers also express general pessimism, Snow (1977) concluding that:

> "It has become clear that interaction, both among individual difference variables and between them and instructional conditions, can be so complex as to push generalisations beyond our grasp, practically speaking."
> (Snow, 1977, p. 15)

Kirby (1984, p. 117) finds that ATI was "a theoretical helpful reconciliation of the two traditions [predicting performance from either the personological domain or the situational domain], but practically speaking it has had minimal impact". Bracht (1970) evaluated 90 ATI studies and found only 5 gave adequate evidence of ATI. Glass (1970, pp. 210-211) declared "I don't know of another statement that has been confirmed so many times by so many people ... if these interactions exist [interactions of curriculum treatments and personological variables], they exist with respect to very narrow and specific variables, not to the general, factorially complex IQ's and abilities that we typically measure".

However Cronbach and Snow (1977, pp. 494-495), discount Bracht's pessimistic findings: "Bracht often worked from an abstract ... we only from full reports ... we reason differently from Bracht ... we take ordinal interactions seriously, whereas Bracht lumped 'ordinal or no interaction' together. Other researchers and reviewers are more hopeful that positive results will eventually flow from ATI research, including Cronbach and Snow, 1977; DeLeeuw, 1983; Driscoll, 1987; Gustafsson, 1988; and Jonassen, 1982.

What are the characteristics of a successful ATI study? Answers to this question are discussed below, and have been taken into account in the design of this research.

CONSIDERATIONS FOR APTITUDE-TREATMENT INTERACTION STUDIES

Temporal Consistency

Within the context of ATI research, selected aptitudes should be temporally enduring, such that their measure in each of the individuals does not alter for the duration of the study. They should be, most particularly, stable during the administration of the specifically designed instructional treatments and not influenced by the task demands of the content during instruction. Aptitudes that were subject to change or fluctuation over short time frames would make futile the interpretation or understanding of *any* interaction. The need for adequate temporal consistency of aptitudes used in ATI research was first highlighted and demonstrated by Fleishman and Bartlett (1969) and later by Cronbach and Snow (1977). The latter reviewed numerous ATI studies and concluded: "While one can be interested in momentary states, any theory of aptitude surely should be based on an organisation of more lasting traits" (Cronbach and Snow, 1977, p. 160). Epstein and O'Brien (1985, p. 534) comment that aggregation is essential in order to enhance "temporal reliability and generality of relationships".

An aptitude may be amenable to both conscious or unconscious change:

(a) as a result of a specific learning objective,
(b) simply by default as the individual works through a particular treatment or sets of instructional materials,
(c) due to its inherent instability in an individual. It may be a transient trait subject to fluctuation with mood, environment, or any one of a number of situational variables,
(d) with the content of the learning.

Fleishman and Bartlett (1969) were the first to warn of a potential cause of temporal inconsistency by suggesting a possible shift from one aptitude to another as a student works through a given treatment. Cronbach and Snow (1977, p. 23) also recognised this as a potential problem: "Sometimes the treatment "works back" upon the aptitude, so that after a time the person's aptitude has changed." Merrill (1975) also adopts a pessimistic stance regarding the value of ATI research in general which appears to be particularly related to his belief that no aptitude of adequate stability exists such that it would have permanence and pervasiveness during learning. He maintains that all individual aptitudes are dynamic, and thus challenges the validity and practicality of ATI research. He claims:

> "The search for the interaction of stable trait aptitudes and fixed treatments is never likely to be of instructional value. At the very moment one has identified such a relationship the aptitude configuration of the student has changed, never to be repeated. Hence the finding is descriptively interesting but prescriptively of little or no value."
> (Merrill, 1975, p. 221)

Epstein and O'Brien (1985) have a contrasting view and suggest, more optimistically, that:

> "If the same items of behaviour are sampled over many occasions, it is both possible and desirable to establish the reliability of individual items aggregated over occasions in an analogous manner to the usual procedure for establishing internal consistency reliability for responses aggregated over items."
> (Epstein and O'Brien, 1985, pp. 551-552)

In contrast to Kaufman (1979) who suggested that simultaneous and successive processing aptitude profiles are amenable to change by training, Leasak, Hunt and Randhawa (1982), exploring the potential of the Luria model as a basis for intervention programmes to assist slower learners, found the aptitudes of simultaneous and successive information processing to be stable habitual traits:

> "In the light of the results of the factor rotations, it would appear that the factor structure and hence the underlying cognitive processes are invariant."
> (Leasak, Hunt and Randhawa, 1982, p. 264)

This is the view most generally supported in the literature.

The question of temporal consistency is also necessarily related to the *duration* of an ATI study. Becker (1970) cautions that in order to generalise findings from ATI research, the effects must have time to become apparent, and studies based on tasks or units of work of short duration should be avoided. Cronbach and Snow (1977, p. 44) suggest "a period of habituation is probably necessary before the student is working with full effectiveness; this leads us to think that an experiment lasting any less than ten class periods will be uninformative. Yet there is no doubt a point of diminishing returns beyond which the AT regressions do not change". They further believe that "investigators of ATI ... should try to hold instructional time constant in their designs. How much a student learns, over ... a fixed number of hours of work, meaningfully indicates the effectiveness of the treatment" (Cronbach and Snow, 1977, p. 45). The duration of the main ATI study in the present research extended over 8 class periods.

Sources of Variance

In any ATI study, underlying concerns of researchers have been to positively attribute observed interactions to the selected aptitudes, or, more commonly, in the event of no apparent interaction, to determine if other more influential variables were interacting and masking the discovery of the hypothesised interaction. Cowart and McCallum (1988) caution that the Luria-Das model constructs would not be adequately robust relative to other sources of variance. The arguments and research reviewed in Chapter 4, however, suggest that the Luria model is a suitable choice for an ATI study incorporating as it does dimensions that have been shown to be relatively robust.

Model Constructs

Driscoll (1987) and Jonassen (1982) suggest that much of the ATI research has not fulfilled its promise because it has been largely atheoretical. Driscoll (1987, p. 4) maintains: "Empirically conceived without a supportive conceptual base, many [ATI] studies have resulted in a shotgun approach to identifying learner variables and instructional treatments."

The potential complexities inherent in using acquired ability models as a theoretical basis of ATI research was pointed out by Vernon (1969):

> "With more detailed testing ... major ability types can be readily broken down into more specialised ones ... . However, when considering the whole spectrum of abilities, these are relatively much less influential. We do not gain a great deal of additional

> information about most people by going to the trouble of measuring them accurately, though they may be particularly important in some cases ... "
> (Vernon, 1969, p. 22)

Clearly Vernon is correct when one considers the impracticality of an ATI study being established at the level of Guilford's 180 abilities. On the other hand, it is equally clear that any ATI study based upon *g*[1] would simply be analogous to the "streaming" in which "treatments" are varied "academically" according to the general ability level of the class. Walton (1983), in his review of the literature on aptitude-treatment interactions, concluded:

> "There was no evidence of the usefulness of such an [general] ability for differentiating between alternative treatments."
> (Walton, 1983, p. 66)

Jensen (1970, p. 122) also finds that "... gross aptitude measures generally show very little interaction with methods of instruction". He also makes the obvious point that IQ tests have been developed to actually minimise IQ's interaction with instructional variables.

Although Burt (1970) suggests that Guilford's model would be useful for establishing abilities that would be involved in fulfilling a particular learning task, Bracht (1970), Cronbach and Snow (1977), Gustafsson (1982), and Vernon (1970) argue for broader rather than narrower aptitudes. Bracht (1970) and Cronbach (1967) argue that when factorially simple personological variables are selected it is more likely that significant interactions between aptitudes and treatments will occur. Gustafsson (1982) now supports this approach, and found his ATI research

> " ... has not been productive of any strong and generalisable findings, which may be due to the fact that lower-order rather than higher-order factors have been concentrated upon."
> (Gustafsson, 1982, p. 25)

Relationship between Aptitude and Content

Cronbach and Snow (1969) highlight the need for substantial correlations between aptitude and learning processes within each of the matching treatments, and the desirability of minimal

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[1] *The concept of intelligence as a unitary general factor, g, proposed by Spearman (1904).*

correlation between the aptitudes themselves. The aptitudes simultaneous and successive information processing, chosen for this present ATI study, are orthogonal; and, as *processes*, are delineated from the *content* of treatments (Das, Kirby and Jarman, 1979). Suggestions in Naglieri and Das (1988) affirm that the "demands of the task", referring to the information processing demands, and are to be differentiated from "task content". They state "simultaneous and successive processing are involved with the acquisition, storage and retrieval of knowledge, according to the demands of the task rather than its modality, presentation or content" (Naglieri and Das, 1988, p. 37). However problems are accentuated when, within the framework of an ATI study, the alternate treatments, each designed to cater for the matching aptitude, necessarily require the individual to employ extensively both aptitudes. It has been suggested by Walton (1983) that this appears to be a problem of fundamental significance. Notwithstanding efforts during instructional design to restrict, ideally, each treatment to requiring exclusively the application of only one of the aptitudes under investigation, it appears that this requirement is difficult to satisfy.

Aptitude Measures

The usefulness of an ATI research study is enhanced from the point of view of its later implementation to classrooms if the aptitudes selected for the study occur, in typical student populations of classroom size, in a normal distribution from "high" to "low" on the selected aptitudes.

The preferred measures to characterise individual learners' aptitude profiles would be scores on aptitude measures that can be related to population values rather than rankings within the learner group (Cronbach and Snow, 1977). It is clear that the distribution of the scores across students from class to class could vary and may be biased, for example, by sex, culture, socio-economic status, prior learning or a host of environmental influences pertaining prior to the time of the ATI study or classroom implementation. If in a classroom the subjects' scores on the selected aptitude variables tended towards an exaggerated skew distribution the ranking approach to grouping would have limited value.

Prior Knowledge

One potential complication in aptitude-treatment studies is the extent to which the subjects may have prior knowledge of the learning tasks, as highlighted by Gagné (1985):

> "When educational programs are designed to be adaptive to individual differences, assessing the kind and extent of prior knowledge of students is the most important step to take at the beginning of each new unit of instruction."
> (Gagné, 1985, pp. 257-258)

This problem did not occur in the present study as the topic units were specifically selected to cover content that was entirely new to the subjects. The Reasoning unit administered to the Year 6 subjects involved Set Theory and syllogistic reasoning, both of which are not currently taught at the primary level in New South Wales schools. This lack of knowledge was also confirmed by pre-instruction testing in the trial studies.

Modifiable Aspects of Content

Cronbach (1957, p. 681) argues that it is best to "seek out aptitudes which correspond to (interact with) modifiable aspects of the treatment". An issue of consequence to this research is raised by the implications in Cronbach's phrase "modifiable aspects of the treatment". This study selected topic areas in which it was speculated that the *content was modifiable* to permit the development of alternative treatments to match two contrasting aptitudes patterns in the subjects. The nature of the content to be learned, and the consequent task demands, were such that it appeared the instruction materials could be presented in two alternative treatments designed to cater for different aptitude profiles.

Modifying content to advantage students with a high simultaneous information processing aptitude appears to be the most challenging aspect of instructional design. It appears from a review of studies, investigating ATI using "spatial" or "figural" aptitudes, that numerous researchers have concluded that the superficial addition of diagrams and pictures do not transform a "verbal" treatment into a "spatial" treatment. Gustafsson (1982) and Cronbach and Snow (1977) found that the mere addition of diagrams rarely result in significant ATI in such studies. In studies reviewed by Cronbach and Snow (1977, p. 505), they report: "Preponderately, spatial abilities have failed to interact with more / less emphasis on diagrams in the treatment ... ."

However, whereas the addition of diagrams or symbols does not necessarily call upon spatial aptitudes, the latter are required if the treatment requires the individual to actually *process* spatially presented material, or require spatial *reasoning*, such as visualising changes in shape under rotation or requiring reasoning about diagrams. Lyn Cooper (1980), a researcher who has investigated spatial information processing in laboratory studies, finds that spatial processing strategies are both differentiated and task-dependent. In one study she used pictures of a figure (example, square above a triangle) and asked subjects to confirm, after they had absorbed the figure, whether it matched a test figure. Cooper found subjects used "diverse and flexible strategies for processing spatial information" (Cooper, 1980, p. 174). She recommends further research on "the task-dependent nature of spatial information processing ... [to] help us to understand better which aspects of items on tests of spatial abilities are critical to eliciting one type of processing strategy or another" (Cooper, 1980, pp. 174-175). Cooper maintains that spatial information processing strategies are complex and that an individual subject may dynamically change strategies according to content.

There is a trend apparent in the literature to emphasise content as an initial focus for ATI research, and this has led to a proposal that content-treatment-interaction (CTI) may be superior to ATI. CTI, proposed by Jonassen (1982) as a concept of more value than ATI, places primary emphasis on the demands of content to be learned and the implications of those demands for the design of instruction. Then, rather than produce a series of instructional designs to match *individual* learner characteristics, Jonassen suggests that the "one best method" be progressively modified on the basis of information about learners to make it more effective. Driscoll (1987, p. 7) also views CTI, as opposed to ATI, as providing a "heuristic for researchers and designers", and suggests that "this approach, while perhaps not as attentive to differences in learner aptitudes, is more practical, cost-effective, and likely to be productive in terms of curriculum and product development than the ATI approach". It is suggested that CTI is another name for the progressive improvement of instructional materials and strategies that has been traditionally employed by educators. The objective of class teachers has always been to provide the best treatment of content for learning by their students, and Jonassen (1982) and Driscoll (1987) appear to be essentially suggesting a continuing focus on instructional design rather than catering for individual differences.

In summary, ATI researchers and potentially classroom teachers are required to make the choice between (a) an initial focus on *treatment*: identifying the nature of the content that suggests clearly separate treatments and then assessing the appropriate aptitudes in the subjects or students that would be advantaged by these alternative treatments, or (b) an initial focus on *aptitude*: identifying fundamentally important aptitudes, and then exploring the potential for the matching of alternative treatments that may or may not be possible according to the nature of the content. This study chose the latter approach, *and then* assessed what learning tasks in the curricula were "modifiable" to permit appropriate treatments to match the selected aptitude profiles.

Practicality

In the widest interpretation, individual learning aptitudes embody cognitive, motivational, and behavioural elements. They may reflect genetic structure, cognitive development or environmental influences. With the exception of the given genetic characteristics, many aptitudes are changeable at varying rates over varying time frames, either by maturation, by social and other environmental influences, or subject to conscious change and management by training. Readiness, incentive, style, rate of learning and preferred methodology all vary from person to person. ATI studies cannot practically be designed to incorporate vastly complex and changeable individual differences, due to the finite availability of teaching and supporting resources necessarily placing severe practical limits on variables that can be taken into account. In this respect, the cause of ATI will be advanced over time by the fuller use of the computer, with expert heuristic systems assisting the teacher with each stage of aptitude testing, treatment preparation and delivery of appropriately matched strategies.

The practicing teachers' view of ATI is probably echoed by Oakhurst and McCombs (1979):

> " ... for most of us, the time and expense involved in alternative module making is not worth taking unless the existing instructional treatment or module cause large or alarming student failure rates or excessive variations in the criterion variable."
> (Oakhurst and McCombs, 1979, p. 34)

For potentially wide applicability to the classroom, aptitudes selected for ATI should be factorially simple, parsimonious, practical and hold promise for cost-effective implementation. Those selected for this study meet these criteria, and are not subject to significant change by management or experience (as discussed in Chapter 4). When one takes into account the testing time, the design of matching treatments, the administration of these treatments, and the comparative evaluation of results, a teacher cannot be expected consistently to cope with catering for other than broad-band, robust aptitudes to be matched with treatments.

DEFINING INTERACTIONS

A prerequisite of research on aptitude-treatment interaction is the identification of the taxonomy of potential interactions that may occur between the nominated individual aptitude variables and alternative instructional treatments. The term ‘interaction’ requires interpretation, there being some disputation in the literature (see below). However, the most accepted understanding has been that advanced by Cronbach and Snow (1977, p. 3) who suggest, in general, that "interaction is said to be present when a situation has one effect on one kind of person and a different effect on another", and "an ATI exists whenever the regression of outcome from Treatment A, upon some kind of information about the person’s pre-treatment characteristics, differs in slope from regression of outcome from Treatment B on the same information" (Cronbach and Snow, 1977, p. 5).

Cronbach (1957, pp. 680-681) defines three possible results from an ATI study, namely, no interaction, ordinal interaction or disordinal interaction. These are illustrated graphically in Figures 2.1 to 2.3:

- *no interaction*, where the lines joining outcome scores for both treatments are parallel [Figure 2.1];
- *disordinal interaction*, where the lines joining outcome scores for both treatments intersect within the measured aptitude range [Figure 2.2];

and

- *ordinal interaction*, in which the lines joining outcome scores for both treatments are not parallel and do not intersect within the measured aptitude range [Figure 2.3].

In Figure 2.1, all students should be assigned to Treatment 2 regardless of their aptitude as there is *no interaction* and Treatment 2 produces superior learning for all aptitude levels. In Figure 2.2, depicting *disordinal interaction*, students with aptitudes above that for which the intersection occurs should be assigned to Treatment 2, and below to Treatment 1.

FIGURE 2.1 NO INTERACTION
(Cronbach, 1957, P. 680)

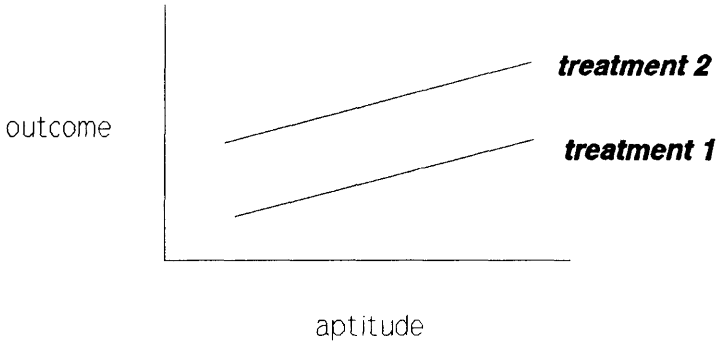


FIGURE 2.2 DISORDINAL INTERACTION
(Cronbach, 1957, P. 680)

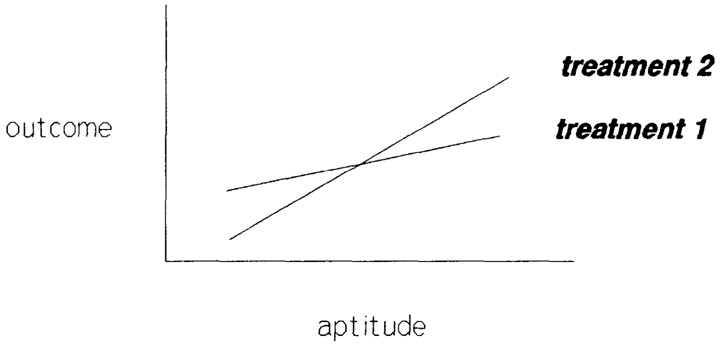


FIGURE 2.3 ORDINAL INTERACTION
(Berliner and Cahen, 1973, P. 60)

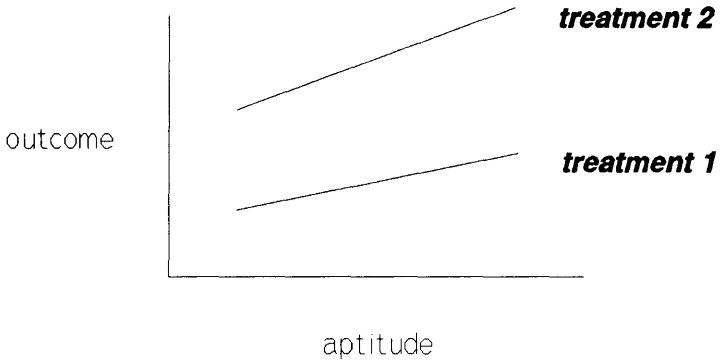


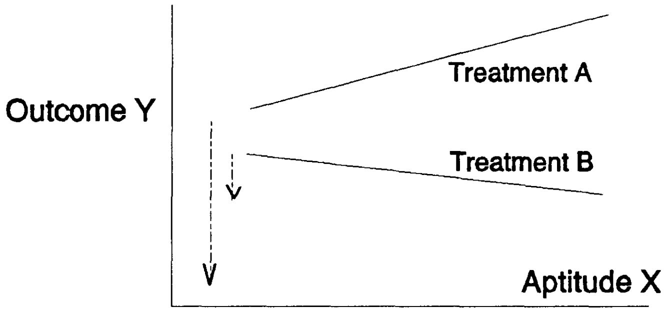
Figure 2.3, showing *ordinal interaction*, indicates that all students measured within the aptitude

range shown should be assigned to Treatment 2 regardless of their aptitude. The relationships depicted in these figures are linear. Non-linear relationships are of course also possible, Cronbach and Snow (1977, p. 31) finding that "data from the extremes of a scale often depart from a trend line in the middle range".

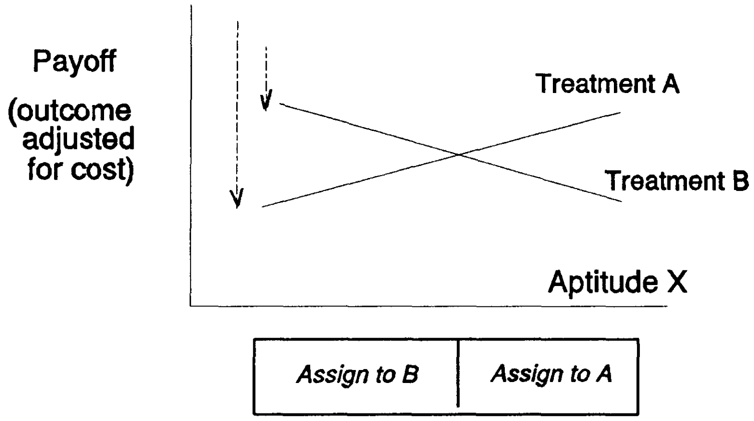
Bracht (1970) holds a more restrictive, conservative perspective of interaction than Cronbach (1957), maintaining that the aim of aptitude-treatment studies is to find "significant disordinal interactions between alternative treatments and personological variables" and discounts the value of finding ordinal interaction, a position adopted in the present research. Cronbach and Snow (1977) suggest that "a practicing psychologist" may extrapolate to individuals higher or lower in aptitude than those measured, although it is to be noted in the present study the number of subjects exceeded the advice of Cronbach and Snow (1977, p. 46): "We shall argue that an ATI study with Ss assigned at random to one of two treatments ought to employ something like 100 Ss per treatment."

Another argument advanced to suggest that importance be attached to ordinal interaction is related to the scale selected for reporting outcome, suggesting that cost-benefit considerations may imply a transformation to a pay-off scale, as shown in Figure 2.4. In this figure, the outcome scale in the "adjusted" graph has been revised to show a value for the "per-person cost of treatment" and now indicates disordinal interaction with advantage to be gained by assigning students to Treatment B below the intersecting level of aptitude and to Treatment "A" above this point. However, in this present research the alternative treatments are of similar cost and ordinal interaction cannot be taken into account on the grounds of introducing the additional variable of cost. It is maintained that only disordinal interactions will be regarded as evidence for the existence of interaction suggesting improved potentials for learning performance, as recommended by Bracht (1970), Bracht and Glass (1968) and Glaser (1972).

FIGURE 2.4 CHANGE OF ORDINALITY WHEN COST IS INVOLVED
(Cronbach and Snow, 1977, P. 32)



(i) Unadjusted



(ii) Adjusted

APTITUDE-TREATMENT INTERACTION STUDIES

There have been numerous ATI studies relevant to this present research, namely, investigating alternative treatments for topic areas in mathematics, involving aptitudes depicted described as "spatial / verbal" or "simultaneous / successive", and involving subjects in the age range selected for this study. Those that bear specifically upon this research are reviewed below.

An ongoing debate in the mathematics literature, mostly of a qualitative nature, has concerned the traditional "prescriptive-didactic" methods of teaching compared with the "discovery" method, and some studies have linked this issue with the supposition that spatial ability is a specialised aptitude that would facilitate the meeting of learning objectives if instructional treatments were designed to capitalise on it. A number of researchers have undertaken studies to investigate both of these issues in ATI studies, examining, in the area of mathematics, the potential interactions between spatial abilities and instructional method. Osburn and Melton (1963) divided students into two groups at random, one learning algebra by the traditional "rules and demonstrations" method, the other learning by the more experimental "discovery" approach. Aptitudes were measured for spatial reasoning, mechanical reasoning, verbal reasoning, and numerical ability. The results indicated that students of high verbal aptitude derived most benefit from the traditional treatment, and those of high spatial aptitude from the discovery treatment ("the new maths approach somehow did capitalise on spatial ability"); whereas students of low verbal aptitude gained very little from the discovery approach and those of low spatial aptitude did not benefit from the traditional treatment. In studies on a similar theme, Becker (1967) used measures of verbal and mathematical abilities as the aptitudes, and "guided discovery" (examples-rule) and "meaningful didactic" (rule-examples) as the alternate treatments. Although findings from a pilot study apparently supported the hypothesis that those high on verbal tests and low on mathematical reasoning would do better in the "meaningful didactic" treatment, while low-verbal, high-quantitative students would do better with "guided discovery", in the main study no significant interactions were obtained. In the ensuing discussion, it was suggested that either the hour-long session of instruction may have been too short, or the test for mathematical aptitude included a substantial verbal component. It would seem likely that both of these aspects were deficiencies in the study (as suggested in the general discussion of ATI earlier in this chapter).

Behr (1967), in a study with over 200 subjects learning numerical operations in modulus-seven arithmetic, used a "figural-symbolic" mode and a "verbal-symbolic" mode for the two treatments and fourteen selected figural and semantic mental ability factors from Guilford's structure of intellect model. Behr hypothesised that:

> " ... factor tests of figural content would be better predictors of achievement of mathematical material presented in figural form than they would be of the same material presented in verbal form, and ... tests of semantic content would be better predictors of achievement of the material presented in verbal form than they would be of material presented in figural form."
> (Behr, 1967, p. 11)

Behr (1967, p. 40) found significant interactions between five of the fourteen selected factors and the two methods of instruction, and "interaction in four of the five cases was consistent with the expectations of figural factors being better predictors of learning and retention by figural presentation and semantic factors for semantic presentation". A subsequent revision of this study was undertaken by Behr and Eastman (1975) who rewrote the figural treatments so that they would rely more on "figural" abilities. Numerous figural illustrations were used in the figural treatment and any general rules or processes were discussed afterwards. The results of this second study revealed that there was no ATI between the aptitude measures and the treatments. The authors concluded that researchers might "divert their attention to other aptitude measures" and pointed to a search for "aptitudes unique to mathematical learning ... [based upon] a theory of mathematical aptitudes, which might be distinct from a general theory of intelligence" (Behr and Eastman, 1975, p. 157). It is suggested that Cronbach and Snow (1977) adequately identified two of the problems of the original Behr study. They suggested that the "figural symbolic" treatments used by Behr were not calling upon "spatial" processing aptitudes and the use of a relatively large number of aptitude measures produced "a breeding ground for chance relationships" (Cronbach and Snow, 1977, p. 286). It is clear that ATI researchers adopting aptitudes that relate to content are inevitably obliged to make assumptions and arbitrary divisions in an attempt to classify the subject matter of their studies.

An interesting series of ATI studies was conducted to investigate the teaching of quadratic inequalities, with subsequent researchers progressively modifying an original set of instructional materials. The interaction investigated was between the two aptitude variables spatial visualisation and general reasoning, and two treatments which were classified as "graphical" and "analytical". It was expected that subjects of high spatial aptitudes would be advantaged by using the graphical instructional material, but Carry (1967) found the interaction opposite to that hypothesised. He later pursued the hypotheses by supervising studies by Webb (1971), who modified the instructional material, but found no significant interactions, and Eastman (1972), who, using an inductive method with the figural treatment and a deductive method with the symbolic treatment, confirmed the original hypotheses. Webb and Carry (1975) then modified the analytical treatment in a way which they assumed would require students to encode the material in some verbal-analytical way, and the graphical treatment which hypothesised coding in a pictorial or visual manner, but found no interactions. Eastman and Carry (1975), using different measures for the spatial visualisation and general reasoning aptitudes, and changed treatments, found that general reasoning was a significant predictor of learning outcomes for the analytical treatment but not for the graphical treatment, and, on the other hand, spatial visualisation was shown to be a significant predictor for both graphical and the analytical treatments. Cronbach and Snow (1977, p. 283), although commending such large-scale follow-up research, reflect that the above series of studies "illustrate the difficulty of replicating and interpreting ATI". It is of particular relevance to this present study to note the major concerns that arose which caused successive revisions to be made to the treatment intended to advantage subjects with high "spatial visualisation". As indicated elsewhere in this thesis (including earlier in this chapter) the extent to which the design of treatments significantly advantage those subjects who test high on simultaneous processing aptitudes is perhaps the most critical component that predicates such hypotheses being supported.

Hancock (1975) undertook a study to investigate interaction between personological variables including measures of general ability as well as measures figural, semantic and symbolic aptitudes, and two treatment modes, one "verbal" and one "figural". The study presented the topic of linear order relations to ninth grade pupils but found no performance differences between the two treatment groups. Unexpectedly, he found disordinal interactions related to sex differences. Abkemeier and Bell (1976) classified subjects according to their stated preference for either a "figural" or a "symbolic" mode of instruction. The figural treatment definitions and examples were presented using arrow diagrams, and symbols and formulae were used in the symbolic treatment. The topic was mathematical functions. No significant interactions were found between instructional mode used and the mode preferred, but there was an ATI related to sex of subject, the results indicating that figural instructional materials were significantly better than symbolic instructional materials for males, but neither was superior for females.

Cronbach and Snow (1977) reviewed numerous ATI studies involving instruction using figures as one of the treatments modes. They concluded:

> "There was no evidence that spatial abilities interacted in this mass of work. ... It was found, with some frequency, that general ability had a weaker relation to outcome in partly figural instruction than in straight verbal instruction."
> (Cronbach and Snow, 1977, p. 287)

It is suggested that in many cases the "figural" treatments were deficient in design in that they did not advantage significantly those subjects classified as having a "high" aptitude for simultaneous *processing.* In many studies, the "figural" treatments would be more adequately described as "verbal with figural adjuncts", and thus not designed to capitalise on the inherent nature of the aptitude that was identified and measured in the criterion tests used.

In the topic area of probability, Walton (1983) investigated the interaction between simultaneous and successive information processing aptitude variables and two instructional matching treatments, one he classified as "verbal" and the other "spatial". The results indicated, although not always significant, that the verbal treatment was more effective for students with a high successive information processing ability and the spatial treatment was more effective for students with a high simultaneous information processing ability. Walton (1983), in acknowledging some of the deficiencies in the spatial instructional treatments suggested that:

> " ... more striking effects might have been obtained if the verbal component of the spatial treatment had been reduced to force the individual to rely on his ability to process information in a simultaneous manner, and without being able to translate visual representations into verbal forms."
> (Walton, 1983, p. 207)

Gustafsson (1982) investigated the ATI effects between a number of aptitude variables, including spatial abilities and *g*, and the treatment dimensions reading / listening and pictures / no pictures. The study dealt with the flow of blood in the body and was chosen because it was felt that "it would in part be of a spatial character and that visualisation processes thus would be helpful in acquiring it". Each treatment group comprised 100 subjects from Grade 5. Gustafsson (1982) found that in the treatments involving listening, *g* was found to be particularly predictive of achievement. Gustafsson suggests:

> "This may be because in these [reading / listening] treatments the proper sequencing and interrelating of processes is important: The incoming verbal information must be decoded, and the spatial type of content further dealt with ... "
> (Gustafsson, 1982, p. 30)

With regard to other results concerning significant interaction of spatial abilities with matching treatments, Gustafsson (1982, p. 31) was able to conclude positively that "this seems to be one of the few findings in support of the hypothesis that high-spatial pupils in particular profit from pictorials".

A number of researchers have proposed that information processing aptitudes should be used for the aptitude variables in ATI research. Salomon (1972) proposed the use of information processing capabilities in the design of instructional treatments. Fleishman and Bartlett (1969), perceiving information processing aptitudes as mediating processes which are consistent over tasks, also suggest they are suitable as aptitudes for ATI research. DiVesta (1975, p. 189) maintains that research in aptitude-treatment interaction studies "must consider the cognitive processes assumed to be correlated with traits and/or the processes induced by the treatments if such research is to be fruitful". The information processing construct being applied in aptitude-treatment interaction research has also been suggested by Clark (1975), Glaser (1972), Klich and Davidson (1980) and Molloy and Das (1979).

However, ATI studies generally fail to show that spatial abilities interact with more/less emphasis on diagrams in the treatment. As suggested above, the most likely explanation for these unsupported hypotheses is that treatments were not designed to require spatial reasoning. For example, Salomon (1972) referred to studies by Bracht (1970), Gagné and Gropper (1965) and King, Roberts and Kropp (1969) in which the assumption had been made that spatial ability implies that learning will be improved simply by the addition of diagrams to the verbal treatment. In these cases it was inappropriately assumed that spatial reasoning was then exclusively applied to the entire treatment by those subjects high on spatial abilities. Cronbach and Snow (1977) maintain that to label a treatment as spatial merely because it uses diagrams is "simple-minded".

SUMMARY

The logic of aptitude-treatment interaction is persuasive: individual learning will be optimised when students are considered as individuals with individual aptitudes for learning and are provided with instructional treatments to match their abilities, rather than being considered as a class and given instruction treated to suit the class average.

This chapter identified practical and theoretical considerations that potentially impact upon ATI research. Some useful insights into the characteristics of successful studies were considered, but clearly there were concerns underlying the discussion that served to highlight a network of difficulties facing the ATI researcher regarding design and methodology.

Theoretical perspectives reviewed served to identify the complex influences of situational and personological variables involved in an individual's conscious learning activity. When such activity occurs in an everyday school classroom the web of potentially relevant factors that affect learning increase the problem of experimental control by the ATI researcher.

It would therefore appear to be vital that the characteristics of the theoretical model chosen to underpin ATI research describes robust, readily measurable and pervasive learning aptitudes. Ideally, these variables should also be influential as predictors of learning across grade levels and curricula. Within the review of the major models of mental function in the following chapter, strong evidence emerges which points toward the characteristics of a model of mental function that provides a clear and relevant theory of individual differences suitable for ATI research.

CHAPTER 3

INTELLIGENCE, INTELLECTUAL ABILITIES AND CEREBRAL ORGANISATION

Since the first scientific anatomical and psychological work began in the late nineteenth century, psychologists have proposed cognitive constructs ranging from the monolithic to the multi-dimensional to describe intellect and mental functioning. The purpose of this chapter is to review significant theory and research in the psychology of intellectual functioning and the development of models of cognition applicable to learning in instructional settings. The chapter is organised within a historical framework, with the first section reviewing the development of theories of intelligence and intellectual abilities. The latter part of the chapter provides a brief review of recent neurophysiological research that is contributing to the understanding of the processes of cognition.

Clearly the major theme emerging from this chapter is the profusion of perspectives and resultant theoretical paradigms emanating from the now diverse multi-disciplined approach to the area of the exploration of intellectual abilities and processes. The review of the literature in these areas is useful because it provides a framework from which the theoretical underpinning of this present research was chosen. Although the review of the literature may appear to raise more questions than answers, concomitant with numerous essentially qualitative differences in approach, there is a theme describing cognitive functioning that appears to be central to a number of the major models. The identification of this theme is important because it provides the rationale for the selection of the Luria model for the present research.

MODELS OF INTELLIGENCE AND INTELLECTUAL ABILITIES

The first psychological study of mental ability was made by Galton (1869) in the 19th century who adopted an anthropometric focus in his early scientific assessments of individual differences. His measurements of sensory functions across families and family strains led him to view intelligence as an inherited general mental ability. Binet and Henri (1896) considered the mental ability tests of the Galton type as being too sensory, and Binet, using his two daughters as subjects, investigated various categories of the thinking process, including attention, reaction time, memory, abstraction, ideation, imagery and imageless thoughts. He later developed the popular 1905 and 1908 Binet scales for testing for mental deficiency and differentiating among normal children respectively.

Wechsler (1958) continued this psychometric focus and developed a competing range of tests, including the WISC-R scale (Wechsler Intelligence Scale for Children - Revised) used today in a number of Australian schools. Guilford (1967) expressed the view of such intelligence tests that is commonly held by many researchers today. He suggested that Wechsler was perhaps

> " ... so deeply rooted in the conception of unitary intelligence that he selected tests for his battery that correlated better with the composite score, for such tests were regarded as better measures of intelligence."
> (Guilford, 1967, p. 9)

Emerging in parallel with the above test-oriented developments which measured intelligence as a unitary construct were theories that viewed intelligence as being made up of a number of component intellectual abilities. Although Spearman (1904) is noted for his concept of intelligence as a unitary general factor *g*, he in fact proposed a two-level hierarchical theory of intelligence. Spearman, using his newly developed technique of factor analysis to analyse cognitive test data of British schoolchildren, extracted the general factor *g*, and proposed specific '*s*' factors to account for unexplained variance. Although *g* is now viewed as an oversimplified construct of mental ability. Nevertheless it is still a popular notion of intelligence with practicing educators, largely because it is a simple concept, and appears to be "measurable". They regard it as an index of the mental ability that manifests itself in virtually all performance contexts. However Das (1986) reflects, with an appropriately broad perspective:

> " ... there are other aspects of human behaviour which make a person outstanding, and I am not sure if these can be gauged within the constraints of a test. ... A short list of these qualities includes passion, pity, and curiosity. Fervent involvement in a cause or activity, compassion, and sustained curiosity may be easy to observe, but difficult to measure."
> (Das, 1986, p. 56)

There are other qualifications that clearly highlight the deficiencies of *g*. Humphreys (1985), and many others, point out that IQ is "not at all an invariant trait" and an individual's IQ can drift up and down over time. Perkins (1988, p. 16) stresses a further fundamental limitation in the value of *g*, stating that "as different individuals often display particular talents for different domains, *g*, being domain-neutral, does nothing as a precursor to reflect such early leanings".

Following Spearman, research by Kelley (1928), El Koussy (1936) and others showed the existence of more specific group factors such as verbal, spatial and other domains. Thurstone (1938) identified seven primary mental abilities: V verbal, S spatial, W word fluency, N numerical, P perceptual speed, M rote memory and I inductive reasoning. However the hierarchical theories of Spearman, Kelley, El Koussy and Thurstone, on close inspection, are not dissimilar and the perceived differences could be more related to the techniques and rigour of application of statistical analysis than to varying psychological paradigms. Sternberg (1984b, p. 142) views the main difference between the Spearman and Thurstone theories, for example, as being "in the emphases they placed on higher-order versus lower-order factors, Spearman emphasising the former, Thurstone the latter".

Vernon (1964, 1969) proposed two group levels between Spearman's general and specific levels - with *g* divided into two major groups *v:ed* (verbal-educational) and *k:m* (spatial-mechanical). Vernon divided each of these groups further into minor group factors - for example, *v:ed* into creative abilities, and reading, spelling, and linguistic abilities; and *k:m* into psychomotor and physical abilities and mechanical information. Vernon's cross-cultural studies led him to conclude that *v:ed* abilities, being affected by upbringing and schooling, are variable across cultures and have the greatest influence on academic achievement; whereas the *k:m* factor abilities, an "aggregate of all non-symbolic capacities", and are not affected by schooling and environment and are reasonably uniform across cultures.

A most influential addition to the theories of mental abilities was advanced by Cattell (1963, 1966, 1971) who proposed two components of general intelligence: fluid intelligence and crystallised intelligence. Cattell's model suggests that these are qualitatively different intellectual processes rather than innate abilities. Fluid intelligence (G_f) is displayed in the ability to use logic and perceive complex relationships. It is involved in the reasoning processes required for formulation of concepts, abstraction and adaption to new situations where prior learning is of no advantage. In contrast, Cattell proposed that Crystallised intelligence (G_c) is displayed in the ability to express judgments which have been previously taught and become "crystallised", evidenced in such culture bound primary abilities as verbal ability, numerical ability, and judgments that are the result of prior education and experience. G_c is thus more closely identified with the IQ tests referred to above. Cattell (1966), Horn (1968), Humphreys (1967) and Vernon (1969) all observed the similarities between the Vernon's *v:ed / k:m* model and Cattell's G_f / G_c model.

Believing that Spearman's single general factor *g* and Thurstone's seven primary mental factors were insufficiently rigorous or differentiated, J.P. Guilford (1956, 1967, 1988) proposed a morphological structure-of-intellect model which, at its last revision, suggested 180 possible permutations of first order abilities. Guilford's structure-of-intellect (SOI) model postulates three primary dimensions, each of which comprise a number of sub-classifications: six kinds of psychological operations (processes) - evaluation, convergent production, divergent production, memory retention, memory recording, cognition; five types of (stimulus) "content" related to the material - auditory, visual, symbolic, semantic or behavioural; and six forms of "product" (newly generated information serving as output arising from the application of a specified psychological operation upon given information) - units, classes, relations, systems, transformations and implications. The permutation of a given kind of operation with one type of content to generate one form of product describes a first order ability.

Cronbach and Snow (1977, p. 153) find Guilford's model too differentiated, reflecting that "one can describe any system in terms of minute particles or in terms of large unities". Horn (1973) concluded that there were broad general factors in Guilford's matrices, but that these factors were obscured by his analyses. Horn suggests that there are broad factors analogous to Thurstone's primary abilities underlying correlations of those postulated by Guilford, and that these in turn give rise to a factor of general intelligence equivalent in large measure to Spearman's *g*. In a similar vein, Eysenck (1979) suggests:

> " ... it is very doubtful if Guilford's tests really measure anything additional to

> Thurstone's factors, other than relatively specific content. Where he [Guilford] has gone wrong perhaps is in identifying dimensionality of test content with the dimensionality of human ability. Because we can construct tests lying along certain continua, it does not follow that the mind works along these same continua."
> (Eysenck, 1979, p. 181)

This view of Eysenck's is considered an appropriate perspective, particularly with regard to the complexities that inevitably arise when the dimension of content is inherent in a model of mental function. It is inevitable that resulting dimensions in such models may be perceived as being somewhat arbitrary.

Guttman and his co-workers (Alder and Guttman, 1982; Gratch, 1973; Guttman, 1965a, 1965b, 1969; Guttman and Levy, 1980) envisage a radex structure for intelligence, which can be depicted as a circle, in which complex tasks fall on the periphery and simple tasks toward the centre, the latter relevant to abilities more "central" to intelligence. Keating (1984) perceives the radex model and hierarchical factor models as

> " ... parallel, both mathematically and empirically; the radex turns out to be a scaling representation of the hierarchical factor model and the latter is a hierarchical factor representation of the radex."
> (Keating, 1984, p. 37)

If there has been a trend emerge in recent constructs of mental function, it would be in terms of emphasising the importance of domain-specific *competencies*. This is typified by Howard Gardner's (1983) proposals that individuals have seven domains of potential competence or cognitive abilities, which may be developed with the appropriate motivation relatively independently of one another. Gardner proposed that the seven competences are linguistic intelligence, musical intelligence, logical-mathematical intelligence, spatial intelligence, bodily-kinaesthetic intelligence, and two aspects of personal intelligence, intrapersonal and interpersonal. In an elaboration of his proposals, in an address to the College of Arts at the University of New South Wales in July 1991, he accepted that each of the seven competences can be further subdivided. Answering the challenge that his theory of domain-linked intelligences is culturally biased, Gardner responded that "my theory is less culturally biased than any other, but still very much culturally biased". Perkins (1988, p21) concluded that Gardner's theory of competences is consistent with the current consensus that "overwhelmingly that there are individual trajectories in different domains, strongly influenced by the structure of knowledge in the domains".

Piaget (1964), from a background of biology, proposed theories of cognitive development with a genetic-epistemological focus, quite distinct from those above, as a result of informal observations of younger children and questioning older children and adolescents in problem-solving situations. He ignored mainstream psychometric research techniques. Piaget's *methode clinique* involved asking questions and exploring in detail the reasons for answers given. Piaget proposed a staged development of an individual's cognitive abilities and claimed that cognitive operations of individuals are interrelated through cognitive structures, and that these structures change quantitatively with development. Piaget's theories of cognitive development are essentially concerned with achieved abilities, in contrast to theories that focus on precursor abilities. Cognitive developmental research over the last two decades has not supported Piagetian concepts as originally conceived (Brainerd, 1983; Carey, 1985; Case, 1985; Fischer, 1980). However, support for Piaget's theories is more readily found when the concept of ability "levels" reached through chronologically-based cognitive maturation is substituted for ability "stages".

Eysenck's (1979) structure-of-intellect model of intelligence is a cube like Guilford's, but with three modalities: (i) mental processes (reasoning, memory, perception), (ii) test material (verbal, numerical, spatial), and (iii), quality (mental speed, error testing, persistence). Eysenck's wide ranging work in the field of human intelligence has gained most notoriety, however, for its focus on genetic inheritance. He views the evidence as overwhelmingly in favour of a substantial genetic influence on intellectual ability, being particularly high for measured IQ, and somewhat less so for educational achievement. Eysenck (1979) found

> " ... 69% of variation [in intellectual ability] to be due to genetic influences and only 31% to environmental ones. Clearly, genetic factors outweigh environmental ones in causing the wide range of intellectual ability found in the human population."
> (Eysenck, 1979, p. 133)

He further found "a most striking and consistent finding" is the effect of combined features of home background and general social advantage. He equates this effect to 15 IQ points. It is of interest that recent research into elite athleticism, the biological potential of another human sub-system, is consistent with these findings with respect to the current conclusion that athletic genes contribute approximately 80% of ability, with training making up the balance. Perhaps, though, of even more interest for the present research, if there is merit in drawing the parallels between intellectual and athletic performance, is the finding that favourable genotypes may not only connote genes for elite performance, but also connote genes associated with a high response to the training regimen relevant to a specific sport. Recent neuro-physiological research using PET scanners has found, rather intriguingly, that disparate gains in IQ by cognitive task training (practicing a spatial exercise for several weeks) can be explained in terms of the *drop* in energy used by the brain to perform the task over the period. The report supports the construct of intelligence as fundamentally a function of neurological efficiency. It indicated that high IQ individuals achieved considerable gains in achievement with the brain working significantly less hard, whereas low IQ individuals did not experience the same degrees of reduction in brain activity: thus, the greater the subject's drop in brain energy the higher the IQ.

The historical development of "process models" of brain function have focused on the ways in which individuals process information, compared with the above models which principally focus their postulates, either wholly or partially, on culture-bound achieved abilities. Contributions to human information processing are coming from neurophysiology, computer science, cognitive psychology, epistemology, mathematical information theory, electronic modelling, genetics, and other branches of knowledge (Travers, 1984). Humans use mental processes to acquire all knowledge. Information processing models emphasise differences in individuals' preferences for the ways in which they decode, encode, process, store and retrieve information. These preferences are now conventionally referred to as making up an individual's "cognitive style". Apart from Luria's process model, covered in some detail in Chapter 4, the process models of Paivio, Jensen and Sternberg are outlined below.

An influential information processing model was proposed by Alan Paivio (1971, 1976). He suggested dual modes of information processing, which he called imaginal and verbal, with connections between the two. He theorised that visual events were processed and held in a different mental store from verbal events, and conceived of visual images being stored in the memory as mental images analogous to pictures replicating the sensory patterns. Paivio (1971) asserts that his two proposed symbolic processing systems do not normally function independently of each other nor in the one capacity only, with the relative involvement depending upon the nature of the task. Paivio (1971) suggests that visual imagery involves receiving, processing and transmitting information simultaneously in a spatial array, and conceives of verbal imagery as a sequential processing system. Support for Paivio's model comes from research by Kosslyn (1983), Kosslyn and Pomerantz (1977), Metzler and Shepherd (1974), and Shepard (1982) who found that mental imagery exists as a separate modality. On the other hand, Anderson and Bower (1973) and Pylyshyn (1973, 1981) are critical of the picture analogue theory. They see imagery as being encoded in a propositional format similar to the format used for verbal information.

Jensen (1973a, 1973b), viewing *g* simply as an indicator that reflects the processing efficiency of the neurological system, proposed an information processing model depicting two orthogonal dimensions of mental ability at two "levels": *level 1 abilities* for tasks which require little cognitive processing or transformation such as associative learning and serial memory, and *level 2 abilities* for tasks involving transformation of stimuli for reasoning and abstraction. There has been some discussion in the literature regarding the identification of memory with successive processing and reasoning with simultaneous processing. Das, Kirby and Jarman (1979, p. 139) conclude that "there is little overlap between simultaneous-successive processing and Level 1 and 2 abilities, because ... both simultaneous and successive processing occur in simple and complex cognitive tasks". Factor-analytic studies by Das and his colleagues (Das, 1973a; Das, Kirby and Jarman, 1975; Kirby and Das, 1978; and Das, Kirby and Jarman, 1979) suggest that Jensen's tests purporting to measure memory and reasoning cannot be viewed as simply equivalent to tests used for establishing simultaneous and successive processing factors. Vernon, Ryba and Lang (1978, p. 5), however, partially dispute these findings and suggest that the successive factor is "quite closely akin to Jensen's Level 1".

Robert Sternberg's (1983a, 1985) triarchic model of intelligence (contextual, experiential and componential) considers intelligence mostly in terms of original problem solving activity. Sternberg (1983) suggests:

> "Intelligence is not so much a person's ability to think within conceptual systems that the person has already become familiar with as it is his or her ability to learn to think within new conceptual systems."
> (Sternberg, 1983, p. 29)

His triarchic theory of intelligence proposes three mechanisms of intelligent functioning: (1) metacomponents, or executive processes, such as deciding on the nature of the problem and selecting a strategy for solving the problem; (2) performance components, or non-executive processes, used in actually executing a problem-solving strategy, and (3), knowledge-acquisition components, or the processes used to acquire new information. Neisser (1976) criticises Sternberg's model for its lack of parsimony, but also for its somewhat arbitrary division into components.

The disparate constructs of intellectual and mental function reviewed above do not appear to be historically converging to a commonly accepted model. The reasons clearly emanate from the inherent complexities of modelling the intellectual functioning of temporally inconsistent individuals interacting within chaotically influential environments. Sternberg (1984b), however, reasons that:

> "In sum ... psychometric, or differential, theories differ primarily in the number of factors they posit and the geometric arrangement of these factors. On their face, the theories **seem** quite different. At a deeper level, however, it is not clear that these differences are terribly consequential. Some of the differences appear, on closer examination, to be in emphasis rather than substance."
> (Sternberg, 1984b, p. 142)

In addition to innate cognitive ability, a learner's performance on a task is influenced by motivational, behavioural, and personality variables as well as the pervading characteristics of the immediate environment. A student's social-psychological experience in a classroom is subject to many influences, including the spirit and style of the class which may fluctuate with the teacher's moods, manner and strategies, and with interplay with the other students. For example, what model could predict that a student, who cannot remember a fact at one point in time can find that it suddenly comes to mind later; or that the strategy for solving a problem that previously was a mystery can become clear without any further instruction? Complexity of cognition is confirmed from examination of neurophysiological activity using recent non-invasive technologies which has highlighted numerous interdependent functional systems.

The latter part of this chapter reviews findings from neurophysiological research into the cerebral organisation of human cognition, which has been proceeding in parallel with the development of theories of intelligence and intellectual abilities.

CEREBRAL ORGANISATION OF HUMAN COGNITION

There has been a recurring perception in the neuropsychological literature for most of this century that there is an asymmetry of function in the brain's two mirror-image hemispheres, labels of abilities and roles for the hemispheres variously characterised as:

LEFT HEMISPHERE:	verbal, sequential, temporal, analytic, rational
RIGHT HEMISPHERE:	non-verbal, visuo-spatial, simultaneous, intuitive.

Recent research on the cerebral organisation of human cognition has resulted in many of these traditional theories being dismissed or substantially questioned by scientific evidence produced by the last two decade's technologies. New techniques for imaging brain function include electroencephalographic (EEG) recording of brain waves; computer-assisted tomography (CAT), which outlines underlying structural pathology; magnetic resonance imaging (MRI); positron emission topography (PET); and SQUID (superconducting quantum interference device) which senses minute changes in magnetic fields indicating electric neural activity, and provides the quantification and three-dimensional imaging at varying degrees of spatial and temporal resolution. These techniques are being directed at functionally mapping the numerous regions of the cortex responsible for distinct physiological variables such as feelings, language, hearing and the multi-faceted elements of cognition.

It is apparent that the more complex the task, the more whole-brained is the response. It is now clear that early broad claims on hemispheric specialisations have been overstated and oversimplified, and both hemispheres are used for complex tasks. Keefe (1987) concludes:

> "In general, hemispheric differences seem to be relative rather than absolute. Either hemisphere can probably function in either mode, depending partly upon the nature

> of the task and partly on the experience and preference of the learner."
> (Keefe, 1987, p. 30)

Pozner et al (1988) found, using PET,

> "Many [elementary] operations are involved in any cognitive task. A set of distributed brain areas must be orchestrated in the performance of even simple cognitive tasks. The task itself is not performed by any single area of the brain, but the operations that underlie the performance are strictly localised. This idea fits generally with many network theories in neuroscience and cognition."
> (Pozner et al, 1988, p. 1627)

Reddix and Dunn (1986) recorded EEG activity to study global aspects of cognitive processes and found that activity in the alpha bandwidth (8 - 13 Hz) is a reliable correlate of modal processing style. There is, Reddix and Dunn (1986, p. 9) report "an accumulating body of evidence indicating that people vary in brain organisation and that this differential organisation is related to differences in cognitive style (Dunn, 1983, 1985b; Languis and Kraft, 1985; Levy, 1980; Reddix and Dunn, 1984)". Kosslyn (1988) summarises his conclusions following an extended programme of research on mental imagery:

> "In short, both hemispheres can form images of the components, but the hemispheres apparently differ in their preferred way of arranging them. ... neither hemisphere can be said to be the seat of mental imagery: imagery is carried out by multiple processes, not all of which are implemented equally effectively in the same part of the brain."
> (Kosslyn, 1988, p. 1625)

Stacks (1989, p. 2) concurs with Gazzaniga (1989) in concluding that " ... a large body of clinical research demonstrates the integrative function of hemispheric cooperation."

Both the cost and complexity of neurophysiological and neurochemical technological research suggest it may be many years before they are used to investigate and potentially assist in the understanding of learning, and perhaps the modelling of individual learning styles for normally achieving students. Examples of the complexity are beginning to unfold: the brain hears loud sounds in a totally different location to quieter sounds, man-made objects are learnt and remembered in a different region to faces and that the region of the brain that processes proper nouns does not process common nouns. One of the perennial problems faced by psychologists is no doubt also of pervasive concern to the medical neuro-technologists who plan to map individual cognitive styles: the instability of the numerous personological variables, potentially even *during* testing periods, may recast the variables being investigated and thus question the enduring validity of the results.

SUMMARY

It is now generally accepted that profound qualitative reorganisation of psychological activities occurs during the process of human development and decay. The elementary functions available in very early childhood are progressively enhanced to become complex cognitive functioning systems. Due to this underlying process of change, coupled with the complexities of modelling human behaviour and appropriate levels of aggregations for representing mental functioning of the individual in a social context, it is not surprising that a commonly accepted construct of mental function has not emerged. It is clear, however, that for ATI research the choice of a model delineating "broader, more inclusive and more hardy" (Vernon, 1970) mental abilities would be desirable, with the chosen aptitudes being orthogonal and ideally task-independent. In the above review of models of mental function, there is a persistent thread of acknowledgment of "spatial" and "verbal" abilities and it is these that will be further reviewed in the next chapter for the promise they appear to offer for the ATI researcher.

One of the pivotal distinctions is between those models that view an individual's intelligence as a summation of acquired skills and abilities, and those that focus on how such knowledge is acquired, within the framework of maturation. In the latter category is the process model of A.R. Luria who postulated that simultaneous analysis / synthesis and successive analysis / synthesis underlie the gaining of all information and competences that are recognised as an individual's intelligence. Luria's model also encapsulates the recurring theme of spatial/verbal dichotomy that is identified within a number of the major models of intellectual function reviewed above. The next chapter analyses the Luria model and describes ATI research relevant to the present study.

CHAPTER 4

THE LURIA MODEL
AND SIMULTANEOUS AND SUCCESSIVE PROCESSING

Over the past decade a focus on information processing rather than intelligence has become a key perspective in psychological research investigating learning in instructional settings (Anderson, 1980; Elliott, 1990; Gardner, 1985). Information processing models characterise the learner in terms of underlying processes of cognition such as those of perception, input, transformation and output, rather than as a storehouse of data. Process models have been shown to be important tools for describing individual learner characteristics across grade levels and content areas.

Possibly the most influential work on information processing conducted to date has been by neurologist A.R. Luria (1966a, 1966b, 1976a, 1976b), Doctor of Education, Doctor of Medicine and Professor of Psychology at the USSR Academy of Medical Science in Moscow from 1945 - 1977. His stated lifelong goal was a satisfactory theory of higher human mental functions, which Luria (1966b, p. 32) defined as "... complex reflex processes, social in origin, mediate in structure, and conscious and voluntary in mode of function". Luria's primary data was derived from bedside tests on patients with brain lesions using very simple props such as pens, pencils and blocks. His model of brain function provides an explanation of the processes involved in conscious activity, in mental functions associated with a motive to meet an intellectual goal (as opposed to mental operations that occur unconsciously and automatically). He proposed that simultaneous analysis / synthesis and successive analysis / synthesis are two forms of information processing that underlie the acquisition of all knowledge. Luria's model has been used as the theoretical basis of research in a series of studies investigating learning and intellectual function in classroom settings, including recent studies by Angus (1985), Crawford (1986), Elliott (1990), Green (1977), Ransley (1981), Tulloch (1986) and Walton (1983). The neurophysiological basis of Luria's model has also received broad support from studies by neuroscientists researching brain function activity concomitant with cognitive processes in normal subjects (Couch-Shinn and Shaughnessy, 19894; Gazzaniga, 1989; Pozner at al, 1988; Reddix and Dunn, 1986; Stacks, 1989).

This chapter is organised in three sections. The first section describes the neurophysiological basis of Luria's work, with the second section elaborating the simultaneous and successive aptitudes depicted in his model. The final section reviews the confirmation of the neuropsychological constructs of Luria's model from researchers using multivariate statistical analyses of test data from large scale experimental studies.

THE LURIA MODEL OF INFORMATION PROCESSING

The essence of Luria's distinctive model is the notion of functional organisation of cognitive processes. Luria divides the brain into three dynamic interacting *functional* units whose participation is necessary for any type of mental activity. Luria (1973a) describes these three blocks or systems as units for (1) regulating tone or waking, (2) obtaining, processing and storing information, and (3) programming, regulating and verifying mental activity. Each unit is itself hierarchical in nature, consisting of at least three cortical zones built one above the other.

1. The First Unit - an arousal unit - for regulating cortical tone.

   > This unit is responsible for the waking state of the individual and has an activating and inhibitory function on arousal levels, and is important for orienting reflexes and adaption to new stimuli. Luria (1973a, p. 46) also suggests that this unit is "itself under cortical influence, being regulated and modified by changes taking place in the cortex and adapting itself readily to the environmental conditions ... ".

2. The Second Unit - an input / processing unit - for obtaining, processing and storing information from the external world.

   > The three hierarchically structured zones of this unit have distinct functions: The primary zones are responsible for the receiving the afferent sensory input. The secondary zones are responsible for analysing, synthesising, organising, coding and storing the input. The tertiary, or overlapping, zones are responsible for the integration of various sensory material which has already been coded. The tertiary zones are thus responsible for the higher cortical functions. The tertiary zones are supramodal, compared with the primary zones which possess maximum modal specificity, as proposed by Luria (1973a, p. 75) in his principle of "diminishing modal specificity and increasing functional lateralisation".

3. The Third Unit - an output / planning unit - for planning, programming, regulating and verifying mental activity for controlling behaviour.

   > This unit can be viewed as the master control of the brain, the supervisor of all conscious activity. The unit evaluates problem solving strategies. Luria (1966a, p. 67) describes the unit's processes as "the programming of human activity, collating the effect of action with the initial intention, and regulating and controlling mental processes".

In summary, when an individual attempts a learning assignment, the first unit of the brain is responsible for arousal to meet the demands of the task; the second unit for receiving the input, simultaneous and successive coding, processing and storing; and the third unit for planning the problem solving strategies to carry out and control the actions formulated. Naglieri and Das (1988, p. 39) place Luria's model within a temporal framework: "Luria's functional systems are dynamic in that they respond to the experiences of the individual, are subject to developmental changes, and form an interrelated system."

Localisation of Function and the Luria Model

Luria's physiological hypotheses on the localisation of his proposed functional systems to physical components of the brain has often been viewed as a "front-to-back" distinction, compared with the traditional concept of "left-right" roles for the hemispheres. Even though this present research is concerned only with the functional aspects of his model, this apparent contrast is worthy of comment, as it bears upon the debate regarding learner preferences and individual predispositions, and also aids in the fuller appreciation and understanding of labels applied to factors derived from statistical analyses.

Luria's "front-to-back" distinction submitted that successive processing takes place in the fronto-temporal regions of the brain and simultaneous processing in the parital / occipital lobes. This is to be compared with traditional literature which assigns labels of abilities and roles for the hemispheres such as "verbal - sequential" to the left hemisphere and "non-verbal - spatial" to the right hemisphere. Das, Kirby and Jarman (1979) consider that the laterality difference theories

> " ... superficially appear to resemble ours [Luria-Das] strongly. This is particularly true of the more recent formulations (Cohen, 1973; Nebes, 1974; Semmes, 1968) which have emphasised processing differences between hemispheres, the left (verbal) specialising in serial processing, and the right (non-verbal) in parallel processing."
> (Das, Kirby and Jarman, 1979, p. 148)

Das, Kirby and Jarman (1979) suggest that a possible resolution of the apparently contradictory theories would be to propose that the serial and parallel processing postulated by both paradigms exist. In that case, the temporal-parietal-occipital area of the right hemisphere would be "more" parallel than the corresponding area of the left hemisphere, and the fronto-temporal area of the left hemisphere "more" serial than that of the right" (Das, Kirby and Jarman, 1979, p. 148). Luria (1973a) found:

> "This principle of lateralisation of higher functions in the cerebral cortex begins to operate only with the transition to the secondary [zones] and, in particular, to the tertiary zones which are principally concerned with coding (or functional organisation) of information reaching the cortex ... . It is for this reason that the functions of the secondary and tertiary zone of the left (dominant) hemisphere start to differ radically from functions of the secondary and tertiary zones of the right (non-dominant) hemisphere."
> (Luria, 1973a, p. 78)

It is to be remembered that the dominance of one hemisphere is not always found and lateralisation is only relative in character. Luria (1973a, p. 105) gave "preference to the analysis of the functions of the dominant (left) hemisphere ... although definite predominance of the left hemisphere over the right is not found in every case but, according to Subirana (1969), in only 63.1% of cases".

Future ATI studies may well be advantaged by research into the cerebral organisation of human cognition related to cognitive style. This view is supported by Crouch-Shinn and Shaughnessy (1984), following an examination of some early research on hemispheric specialisation and brain function, who concluded that:

> "The major implication for education is that with more accurate assessment of a student's physiological and hemispheric functioning and learning strengths, a closer match could be derived between his or her learning styles and the appropriate methods of instruction to enhance and improve learning potential."
> (Couch-Shinn and Shaughnessy, 1984, pp. 11-12)

SIMULTANEOUS AND SUCCESSIVE PROCESSING

According to extensive American, British, Australian and Russian cognitive psychological research, some of which is reviewed later in this chapter, the successful completion of a task depends upon the integration of simultaneous and successive processing activities. Simultaneous and successive processing are involved with the acquisition, storage and retrieval of knowledge.

The notion of two forms of information processing can be traced back to the Russian psychologist Sechenov (1878) who suggested that all afferent input has to be analysed and synthesised into spatial or temporal form. Immanuel Kant suggested that the mind codes external inputs and orders them in space and time before we can comprehend (Smith, 1933). Luria proposed that simultaneous analysis / synthesis and successive analysis / synthesis are two forms of information processing that take place at the perceptual, mnestic and intellectual levels (Luria, 1966a). His neurological studies suggested that certain regions of the brain are responsible for the integration of individual stimuli arriving consecutively into simultaneous surveyable groups; and that other regions are responsible for the organising of successive analysis / synthesis of incoming stimuli into temporally successive series.

Das, Kirby, and Jarman (1979) suggest that simultaneous and successive processing may be appropriately viewed as cognitive style. An individual's cognitive style can be conceived as individual differences in preferred (or habitual) ways of processing information. Naglieri and Das (1988) suggest that the individual's choice of one or other process depends upon:

- the demands of the task
- the person's habitual mode of solving that type of problem
- the person's competence in each type of process
- and his or her knowledge base.

These aspects interact and represent the individual's uniqueness.

In contrasting Luria's process model with the related coding paradigms outlined in Chapter 3, and in analysing the research based upon Luria's model, one of the issues that needs clarification is the distinction between **simultaneous - successive processing**, and **visual - verbal abilities**, the latter typically referred to in ability models of cognition. Throughout the literature there is evidence of researchers assuming equivalence of these dichotomies, leading to confusion of research findings when labels are carelessly applied to factors resulting from the factor-analysis of test results. Solan (1987, p. 239) is one of a large group of researchers who make this equation overtly, in stating "spatial perception has been equated with simultaneous processing and verbal skills with successive processing in this study ... ". Paivio (1975) has suggested that the imaginal ("synchronous") - verbal ("sequential") processing continuum in his model is equivalent to Luria's simultaneous and successive processing. Paivio's dual coding model is viewed by Das, Kirby and Jarman (1979) as more of an example of the verbal-nonverbal distinction. They maintain:

> " ... it is very difficult for verbal information to be synchronously organised, or for imaginal information to be sequentially organised. ... If one seeks to identify the simultaneous and successive processing dimensions with spatial (imaginal) and verbal processing, this can only be done by stretching the meaning of the terms *spatial* and *verbal* beyond their normal meanings."
> (Das, Kirby and Jarman, 1979, p. 152)

A number of researchers support the use of information processing models as the basis of aptitude measures in ATI studies, including Clark (1975), Fleishman and Bartlett (1969), Glaser (1972), Klich and Davidson (1980) and Salomon (1972), contending that the application of the individual's respective aptitudes for two modes of information processing are predominantly independent of content and the cultural properties of the tasks. Essentially, these researchers view information processing modes as "mediating processes" consistently used in various kinds of learning tasks. Das, Kirby and Jarman (1979, p50), however, suggest that the selection of either or both modes of processing identified in the Luria model *are* dependent upon "the demands of the task" (as well as the "individual's habitual mode of processing").

In this present study, distinctions are made between the *code content* (content of the learning assignment) and the *coding processes* required to input and process the stimuli. The labels *spatial* and *verbal* are more reasonably applied to code content, whereas *simultaneous* and *successive* are applied to coding processes. This issue is of fundamental importance to ATI studies using the precursor modes of information processing as the aptitudes for investigation.

Simultaneous Processing

Luria used numerous tests for the diagnosis of his individual patients, which included the following, classified by Luria as examples of simultaneous processing:

> locating a sound in space;
> recognising an object by touch;
> copying geometric figures;
> inverting a figure and re-drawing;
> using place value in arithmetic;
> showing time on clock face;
> comprehending inflective, prepositional
> or comparative grammatical structures.

Visual and spatial / kinaesthetic information, such as the identification of figure or an object by touch, does not present itself in a pre-organised fashion. The stimuli are presented spatially and it is necessary for analysis to take place, then synthesis. Simultaneous processing integrates the elements of experience without temporal ordering or stepwise relationships. Simultaneous surveyability of the coded information is the characteristic of this mode of processing, any portion being surveyable without reference to the whole. Schofield and Ashman (1987) summarise simultaneous processing as

> " ... the integration of information in a quasi-spatial, holistic manner so that the relationship between the elements can be immediately and clearly determined. It can involve both verbal and non-verbal tasks in spite of its quasi-spatial nature."
> (Schofield and Ashman, 1987, p. 10)

Luria (1966b) observed that disturbances of simultaneous processing abilities at the perceptual and mnestic levels invariably leads to difficulties with numerical and logico-grammatical relationships. Luria found that subjects with lesions in the occipital / parietal regions of the brain (in the dominant hemisphere) have difficulty in recognising objects or faces or letters, in processing visual or tactile information, and in performing arithmetical operations. The latter difficulty is experienced due to numerous arithmetic concepts and operations being organised spatially (see Arithmetic Ability below), such as in the significance of place value. Loss of simultaneous processing ability, as found by Luria in cases of damage in the occipital / parietal regions, resulted in individuals having difficulty with connecting elements into logical or grammatical constructions. For example, even though individual words or letters or figures can be processed, the patients had difficulty with "above", "to the right of", etc. in carrying out tasks such as

> " ... drawing a triangle below a circle and a triangle to the right of a cross" ... [and such as] ... "constructions [that] include those with an attributive genitive case (... the dog's master, or the master's dog). Before such expressions can be understood, the logical synthesis of the elements into an integral whole is required."
> (Luria, 1966b, pp. 156-157)

Luria (1975a, p. 71) found that such patients "are impaired in their ability to turn information received sequentially into synchronic quasi-spatial arrangements" and thus had difficultly in understanding comparative constructions as well as spatial prepositional constructions.

Naglieri and Das (1988) provided a detailed elaboration of simultaneous processing:

> "Simultaneous processing involves the integration of stimuli into groups (or the ability to see a number of elements as a single whole) that may take place during direct perception, during retention of information (memory), or at conceptual levels. For example, copying a design such as a cube is a simultaneous perceptual task, whereas reproduction of the same figure from memory requires memory as well as simultaneous processing. Solving matrices is an example of simultaneous conceptual task. An important aspect of simultaneous processing is that each element of the stimuli is interrelated to every other element (i.e., is surveyable). Simultaneous processing tasks are said to be surveyable because all the components included in the task are interrelated and accessible to inspection either through examination of the actual stimuli during the activity (as in the case of copying a design) or through memory of the stimuli (as in the case of reproduction of a design from memory). Luria (1966a) stressed the importance of surveyability by stating that "the grasping of any system of relationships, whether the grammatical system of language or a system of arithmetic concepts, is impossible without arrangement of the elements into a simultaneously surveyable scheme."
> (Naglieri and Das, 1988, p. 76)

Successive Processing

Luria classified these tasks as examples of successive processing:

repeating rhythm patterns;
reproducing sequences of words,
  numerals or pictures;

certain simple close processes;
recoding of internal speech for self expression;
following verbal instructions.

Individual stimuli, such as letters or digits in a series, are each processed as discrete events and then integrated into temporally organised successive series. Order of the coded information is the characteristic of this mode of processing. Information is available only in a linear fashion and meaning is only possible when the sequence is complete, because there is no intrinsic relationship readily apparent among the individual elements. Subjects that lose the capacity to reproduce such sequences are said to have lost mnestic capacity.

Luria (1966a) suggests that successive processing occurs at different levels of complexity, and at a higher order of intellectual activity successive synthesis functions to convert contracted schemas (such as internal speech) into expanded serially organised groups or elements, such as those discovered in narrative speech.

Damage to the brain in the frontal and fronto-temporal anterior regions cause disturbance to successive processing abilities, and not to simultaneous processing (Luria, 1966a). (The reverse is true regarding difficulties experienced in the occipital / parietal regions.) Such patients have difficulty with reproduction of sequences, whether they be sequences or words, numbers, symbols or rhythms.

Naglieri and Das (1988) summarise successive processing:

> "Successive processing involves the integration of stimuli into a specific sequential series, where each element is related only to the next. As with simultaneous processing, this may take place during direct perception, during retention of information (memory), and at conceptual levels. Following one line in a design of interwoven lines is an example of a perceptual successive task. Digit Span involves successive processing with memory, whereas appreciation of syntax (The house that Jack built was painted blue) involves successive processing at the conceptual level. During successive synthesis each stimulus is arranged in a specific series so that the

> elements form a specific chain-like progression. The relationship among stimuli in successive tasks is mainly an ordered one without surveyability. As with simultaneous processing, successive processing may be involved in tasks of various modalities (auditory, visual, kinaesthetic) and involve different type of stimuli (verbal and nonverbal)."
> (Naglieri and Das, 1988, p. 37)

Linguistic Abilities

The connections between simultaneous and successive processing and language is worthy of some analysis in this ATI study, in that instructional treatments in this present research necessitate that the subjects process language.

The considerable body of information processing research indicates that simultaneous processing is directly involved in the understanding of grammatical statements whereas the syntactic relationship among words entails successive processing (Jarman, 1980). Vocate (1987), following a review of numerous studies on neurolinguistics, concludes:

> "It is these two factors - the "paradigmatic" relation between individual lexical meanings that forms the concept and is the act of simultaneous synthesis of individual elements of information, and the "syntagmatic" combination of single words into verbal expressions, manifested as the "serial organisation of speech processes" - that are the two most general psychophysiological conditions essential for the conversion of thought into speech and for the expansion of verbal expression."
> (Vocate, 1987, p. 123)

Luria's findings from clinical studies that identified linguistic processing deficits in patients with specific brain lesions found that successive processing is involved in the processing of contextual grammatical structures and simultaneous processing is involved in the comprehension of logical-grammatical structures. These findings have been supported in a study by Das, Kirby and Jarman (1979) investigating the relationship between linguistic functioning and simultaneous and successive processing, which concluded:

> "Theoretically, the study appears to be important in that it considerably expands the scope of the successive processing dimension ... . One of the wider implications of these findings is that they support a "processing" rather than an "abilities"

> interpretation of cognitive functioning. ... The findings reinforce our contention that successive processing cannot be equated with simple rote memory."
> Das, Kirby and Jarman (1979, pp. 184-185)

Arithmetic Abilities

There are two basic approaches to arithmetic ability which parallel the information processing / acquired ability distinction in models of mental function generally. The former views an arithmetic test as a series of processing tasks, and the latter focus on the content that the test measures. This study, with its process orientation, involved students in Year 6, at which level school arithmetic involves a certain proportion of abilities requiring the reproduction of facts acquired by rote learning. Leont'ev (1981) uses the term *operation* to describe such unconscious operational responses, and *activity* to describe intellectual activity that is stimulated by a motive to meet a conscious goal. Most *operations* are performed as part of an *activity*. These distinctions are important conceptually when discussing arithmetic ability. Leont'ev contends that simple arithmetic operations such as "tables" calculations by children, although they began as activities at first meeting, are eventually transformed into subconscious automatic operations. Leont'ev (1981, p. 339) comments: "Adults process arithmetic tasks at the level of operations, whereas children perform such tasks at the level of actions." These views are consistent with Luria's (1966b), who suggested that the simple operations of multiplication and division, based on the multiplication table learned at school, "begin to acquire a verbal character". He contrasts this with the arithmetic skills such as addition and subtraction which are spatially oriented (the decimal system being erected on a "spatial grid").

Luria's process perspective of arithmetic ability is to be contrasted with researchers who contend that, either partially or wholly, abilities are domain specific and dependent upon a knowledge base in that domain. For example, Perkins and Simmons (1988) concluded, as have Grinder (1985) and Humphreys (1985), that cognitive development is predominantly the acquisition of various kinds of knowledge, much of it domain specific. Perkins and Simmons (1988) reviewed the cognitive structures and processes that mediate mathematical ability, and concluded that achieved ability included:

- a large knowledge base and understanding, domain specific
- flexible expertise
- a multilayered network of mental models to assist understanding key concepts and problem solving
- a repertoire of heuristic and problem management techniques
- problem finding ability.

Skemp (1971) analysed the extent to which "verbal" and "visual" representations occur in mathematics texts. He defines "verbal" as meaning the spoken and written word as well as numbers and algebraic symbols ("there is a tendency to read them sub-vocally"), and "visual" as diagrams, charts and figures of all kinds. Skemp suggests that a visual image or a pictorial representation of an object may be fairly described as a symbol. He contends that even when the detailed properties of an object are not visually coded and processed the individual can abstract at a higher level, while still representing the resulting concept visually. Skemp suggests visual representation as being "integrative and simultaneous" and verbal as "analytic and sequential". Skemp (1971) provides examples of "spatial symbolism" finding its way into every detail of the verbal-algebraic system:

- Position of a digit: 273
  shows 2 hundreds 7 tens 3 units

- Position shows which number is subtracted from which (15 - 9) or which is the divisor (12 ÷ 4)

- Position shows correspondence between sets, as in proportion:
  1 2 3 4 5
  4 8 12 16 20

- Spatial arrangement is an essential property of a matrix:
  a1 a2 a3 a4
  b1 b2 b3 b4
  c1 c2 c3 c4

In general accord with Skemp, Luria (1973a) suggests that arithmetical operations are

> " ... always dependent on the integrity of simultaneous syntheses with a similar structure to external spatial operations. This is reflected both in the columnar structure of multiple-digit numbers, in which the value of each number is determined by its place in the group as a whole, and also in the internal operations of arrangement of the columns necessary to understand the meaning of the number." (Luria, 1973a, p. 154)

Luria (1966b) found that patients who had lost simultaneous processing abilities, depending upon the severity of the lesions causing such disturbances, had difficulty with addition or subtraction involving greater than single digits, fractions, multiplication and division, and using mathematical symbols in expressions.

Other researchers such as Sultan (1962) and Vernon (1961) also suggested that spatial and mathematical abilities are associated, but more particularly at higher levels than suggested by Skemp, such as for abstract and conceptual thinking. Krutetskii (1976) states that "an ability for spatial concepts" is directly related to branches of mathematics such as geometry.

It appears that one thrust of current thinking is that domain-specific knowledge is a dominant factor for success in mathematics as tested in the classroom. Other researchers view the influence of precursor simultaneous and successive processing abilities, designated as cognitive processes "removed" from the domain of mathematical competences, as predictors and explainers of achieved mathematical ability. It is clear that both need be present in high degree for high achievement, and that if either is significantly deficient then low achievement is likely.

FURTHER RESEARCH USING THE LURIA MODEL

Cognisant of the influence of maturation on cognitive abilities, the focus of this section is to provide a review of relevant research using Luria's model as the theoretical base and conducted with normal students of senior primary school age, being the age range of subjects used in this study.

In recent years, researchers have augmented and extended Luria's work, particularly Das and his colleagues (for example: Das 1984a; Das, 1984b; Das and Dash, 1983; Das and Heemsbergen, 1983; Das, Kirby and Jarman, 1975; Das, Kirby and Jarman, 1979; Naglieri and Das, 1988); and Fitzgerald and his colleagues (for example: Crawford, 1986; Elliott, 1990; Green, 1977; Ransley, 1981; Try, 1984; Tullock, 1986; Walton, 1983). Other important relevant research was undertaken by Karnes and McCallum, 1983; McCallum and Merritt, 1983; Merritt and McCallum, 1983 and Wachs and Harris, 1986. This body of research work has resulted in detailed analyses of the simultaneous and successive information processing functions and additionally advanced the understanding of the planning and arousal components of the Luria model. Studies using the Luria model on normal school populations have consistently produced evidence of two factors that correspond to Luria's simultaneous and successive processing, with a series of studies elaborating the third factor, variously known as the "planning", "executive control" or "attention" function, embracing activity within Luria's third unit of the brain.

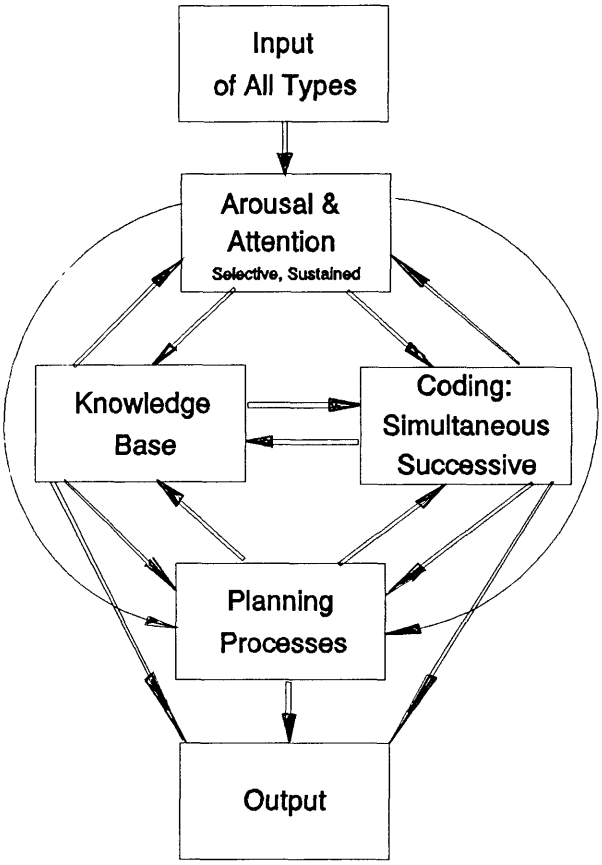
The majority of the above studies used factor-analytic techniques, whereas Luria's focus was neuroanatomical and neuropsychological, and he viewed factor analysis as only able to give "indirect indications of the concrete properties responsible for the interdependence of individual mental processes" (Luria, 1966a, p51). However, the factors identified by the researchers in the above studies were, of course, hypothetical constructs intended to describe the underlying sources of individual differences in simultaneous and successive processing that gave rise to observed individual differences in test scores. Thus the tests were specifically selected for validation of the simultaneous and successive processing model, in contrast to those psychometric researchers whose tests are developed by pure empiricism without supporting research paradigms.

It has been the continuing studies based on Luria's model, principally by Das and his co-workers in Canada and Fitzgerald and colleagues in Australia, that progressively refined and operationalised Luria's second unit function of simultaneous and successive processing. Das, Kirby and Jarman (1979, p. 187) identified a third factor, a third unit functional system, which controls the planning of processing, "thus emphasising a strategic component in cognition". This model is now referred to as the "Luria-Das" information processing model. The planning function, essentially a metafunction, was operationalised by Ashman and Das (1980). Hunt and Randhawa's (1983) psychometric study also confirmed the three factors: the successive and simultaneous processing factors, and a third factor they called "sustained attention". Further elaboration of the third (planning) factor was reported in Das, 1984c; Das and Dash, 1983; and Das and Heemsbergen, 1983.

The most recent summation of the above progression of research by Das and his co-workers is reported in Naglieri and Das (1988) and depicted as the PASS (Planning-Arousal-Simultaneous-Successive) model (see Figure 4.1).

One caution relative to ATI studies is issued in Cowart and McCallum (1988), following a series of studies by McCallum and co-researchers over a period during the 1980's . Their conclusion is that, following an assessment of convergent and discriminate validity of the simultaneous-successive-planning constructs of the Luria-Das model, aptitude-treatment interaction studies must be more than model-based and need to consider method. They suggested that Luria-Das model constructs are not as robust relative to other sources of

FIGURE 4.1 SCHEMATIC DIAGRAM OF THE PASS MODEL COMPONENTS
(Naglieri and Das, 1988, P. 39)



variance, and particularly method variance. This concern is believed to have substance and was discussed in the results section of this thesis.

There have been a number of studies using the Luria model as a basis for investigating information processing functions in relationships to academic performance in populations across abilities and from junior to senior primary school years.

In a small (20 children selected from each of Grades 3, 5 and 7) study, Dash and Mahapatra (1989) found the three factors - simultaneous, successive and planning processes - in all three grades - and further suggested that simultaneous processing and planning abilities developed with Grade more so than successive processing. They concluded that simultaneous and successive processing became progressively differentiated with age and educational experience.

Hunt, Randhawa and Fitzgerald (1976), in a study involving ten year old students, found that:

> " ... students who are high on the successive factor do better in rote and semantic short-term retention than those who are low, but the high successive synthesis factor, unless in combination with a high simultaneous factor, loses its importance where long-term comprehension is involved. This would suggest that simultaneous synthesis plays a major role in the organisation of information over a period of time."
> (Hunt, Randhawa and Fitzgerald, 1976, p. 6)

Schofield and Ashman (1987) tested 323 Grades 5 and 6 children divided into three ability groups based upon the WISC-R and, using the Luria-Das model of simultaneous-successive processing, found that:

(1) in the areas of successive processing and low level planning the gifted subjects (75 of the total sample) were not significantly better than their above average counterparts
(2) in the areas of high level planning and simultaneous processing significant differences were recorded.

Kirby and Das (1977) compared simultaneous and successive processing with reading vocabulary and comprehension, using 104 Grade 4 "regular" classroom subjects, and found that in both measures of reading, proficiency in each form of processing is necessary. They concluded that neither by itself is sufficient for high achievement, and thus dysfunction in either should place a child at a disadvantage in learning to read. These findings are consistent with Solan's (1987) study with 14 Grade 4 and 24 Grade 5 children (mean IQ = 113) attending regular classes which found that both successive and simultaneous processing are necessary for good comprehension and good vocabulary skills. Hunt and Randhawa (1983) found, with 149 Grade 4 and Grade 5 subjects at an Armidale primary school, in Australia, that reasoning, reading, spelling and mathematics achievement factors were all significantly related to the sustained attention and simultaneous-successive factors. They found that in both measures of mathematics (basic understandings involved in the operations on counting numbers, and, underlying principles of rational numbers), those students who are high in both successive and simultaneous processing obtain the highest scores and those who are low in both are the lowest, irrespective of whether they have a high or low measure of sustained attention.

SUMMARY

Simultaneous analysis / synthesis integrates the elements of experience without temporal ordering or stepwise relationships, whereas successive analysis / synthesis processes the elements of experience as discrete events into temporally organised successive series. Simultaneous surveyability of the coded information is the characteristic of simultaneous processing, whereas order of the coded information is the characteristic of successive processing. Both modes of information processing are inherently required in most tasks necessitating conscious "activity". The extent to which either simultaneous or successive information processing may be used is dependent upon the individual's "cognitive style" or preferred mode of problem solving, the task demands placed upon the learner by the content, as well as his or her knowledge base.

The simultaneous and successive information processing modes defined by Luria are important precursor abilities that pervade the acquisition of knowledge in cognitive activity associated with motives to meet intellectual goals. This is in contrast to many of the psychometrically-based Western models of intelligence that tend to reflect the characteristics of the individuals' educational environment and culture, rather than the characteristics of the functional processing aptitudes of the individual. It is apparent that most of the bases of these models (for example: Cattell, 1971; Vernon, 1960) appear to assume that measures of verbal abilities are culture-fair whereas measures of spatial abilities are culture-free.

Luria's model is set within a framework of cognitive development, but not in the passive sense of Piaget's (1964) theory that suggests readiness for new intellectual ability achievement (e.g. "readiness for reading") is related to maturation. Luria suggests, more broadly, that higher mental processes are not only dependent upon changes in the elementary physiological functioning of their cortical base, but are at the same time dependent upon conscious social and environmental influences.

Whereas Jensen's (1973b) model of intellectual abilities proposes that a task can be placed along a continuum from simple to complex, implying quantitative differences in the amount of reasoning it requires, Luria views a task as requiring qualitative differences in terms of the information processing modes required for solution.

The Luria model was selected as the basis for this present research following a review of relevant evidence from clinical and psychometric research. Numerous researchers have found that the model identifies important individual differences in cognitive abilities and is a reliable predictive and explanatory tool in the context of classroom learning. Researchers have found the model provides a clear and concise basis for the identification and quantification of individual's strengths and weaknesses in the processing aptitudes.

In summary, the Luria model: (i) is soundly based on neuroanatomical and neurophysiological research; (ii) relative to other models of mental functioning, is a clear and concise paradigm for explaining individual differences in cognitive abilities; (iii) identifies two aptitude measures that can be generated as orthogonal variables, and, as coding *processes*, are distinguished from the content to be learnt; (iv) embodies aptitudes, of adequate temporal consistency, that are sufficiently dominant relative to other personological variables; and (v) is well supported by a large number of studies that have used the Luria model for the analysis of individual learning in a classroom context. The Luria model would seem to provide an eminently practical basis for this ATI research.

CHAPTER 5

REASONING

AND TEACHING YOUNG CHILDREN TO REASON

The curriculum area selected for the main ATI study in this research involved elementary tasks in the areas of Set Theory and linear syllogisms designed to enhance the students' general reasoning abilities. The selection of this subject matter was made for the following reasons:

1. The goals of augmenting students' thinking and reasoning ability are increasingly being recognised as important by researchers, and educators are investigating the manipulation of the school environment to maximise opportunities for children to learn to reason effectively. [See **Teaching students to reason** below]

2. It is likely that fundamental reasoning skills are transferable across some of the more traditional school curricula. [See **Are reasoning skills transferable across disciplines?**]

3. Tasks relating to Set Theory and syllogistic reasoning have conventionally played a central role in the teaching of logic and reasoning over many centuries. [See **Sets theory and syllogisms for logic training**]

4. The Reasoning unit tasks chosen for the present study allow the use of Venn diagrams for the spatial presentations, long held to be important tools for reasoning and understanding. [See **Venn diagrams**]

5. The progressive acquisition of the capacity to reason according to logical principles is generally considered to relate to cognitive maturation. It is suggested that children in the 10- to 12 years of age range of the subjects of this

study have attained the necessary reasoning skills for the solution of the tasks of the study. [See **Development of reasoning skills in young children**]

6. There is a manifest potential for representation of the syllogistic topic material in two distinct instructional treatments to capitalise on both simultaneous and successive information processing aptitudes. [See **Syllogisms and the Luria Model**]

REASONING AND LOGIC

Early philosophers, such as Aristotle, elevated human reasoning to the position of highest authority. The enhancement of the ability to think and reason effectively has been the goal of educators since the time of Plato, even though philosophers have only made halting progress in defining the concepts and psychologists have stumbled in their endeavours to understand the processes involved.

Although many early researchers concluded that reasoning can be taught, beginning with two classical studies by Glaser (1941) and Morgan and Morgan (1953), through to the optimism expressed in Segal et al. (1985), a more cautious view appears to be emerging. Writers such as Evans (1973), Johnson-Laird (1975), Nickerson (1986), Resnick (1987) and Staudenmayer (1975) view reasoning as interwoven with, and influenced by, personological and experiential variables. Nickerson (1986) summarises:

> "Reasoning ... encompasses many of the processes we use to form and evaluate beliefs - beliefs about the world, about people, about the truth or falsity of claims we encounter or make. It involves the production and evaluation of arguments, the making of inferences and the drawing of conclusions, the generation and testing of hypotheses. It requires both deduction and induction, both analysis and synthesis, and both criticality and creativity."
> (Nickerson, 1986, pp. 1-2)

Resnick (1987) suggests that higher order thinking skills can be characterised as *nonalgorithmic* (the path of action is not fully specified in advance) and *complex*, which yield *multiple solutions* involving *nuanced judgment*; and by the application of *multiple criteria*, *uncertainty*; *self-*

regulation of the thinking process, and the *imposition of meaning*, finding structure in apparent disorder.

In everyday discourse, when students face problem-solving situations, there is rarely a clearly articulated connection of ideas. It is more likely that they leap somewhat erratically from thought to thought, often without the necessary connections that make the difference between random and rational thinking. The reasoning demanded for problem solution by a child in school, and an adult in everyday life, involves a diversity of inputs for which much of the information used in the reasoning process must emanate from internalised collections of experiences and knowledge that can or cannot be chosen for recall. Moreover, there is too frequently no single correct or demonstrably optimum solution.

However, definitive progress has been made within the domain of logical reasoning - concerned with establishing criteria for valid arguments. This facet of reasoning was chosen as the topic area for Study 2 and is discussed below. Classical logicians' reasoning problems cited in their texts and papers on the topic of reasoning, or evidenced in their tests of reasoning ability, typically provide all the information needed to solve the problem; and each problem has one correct (valid, as opposed to truthful) solution. Within the facet of reasoning called logic, definitions of logical thinking thus tend to be less vague. Logicians generally provide a definition of logical thinking that refers to "correct or incorrect" thinking (Copi, 1978) or finding conclusions "on the basis of reason" (Angell, 1964). "What interests the logician is the correctness of the product of reasoning" (Kneller, 1966). "Logic is the science of the *form* of an argument, without respect to its content. In a very real sense, then, logic provides us with a normative model for reasoning behaviour ...." (Erickson, 1974, p. 305). Logic is normally narrowed to that aspect of reasoning that studies principles and methods of valid inference to arrive at patterns for valid solutions to specific classes of problems, concerning itself with structure and not content.

Of central importance is the question as to whether a knowledge of the work of logicians, and the resultant formalised rules of logic and regimen of patterns for tests of validity, would assist in everyday reasoning and problem solving? Nickerson's (1986) answer is in the affirmative and he concludes that a familiarity with the terms and rules of formal logic "can undoubtedly be helpful":

> "Unquestionably, an explicit understanding of some of the basic principles of logic is very useful; anyone who has such an understanding is likely to be able to reason more effectively than someone who does not."
> (Nickerson, 1986, p. 6)

He emphasises, however, that a complete understanding of the rules of formal logic in and of itself will not assure effective reasoning, and that it does not provide techniques for going beyond the information given, except that it makes explicit what has been given by implication.

ARE REASONING SKILLS TRANSFERABLE ACROSS DISCIPLINES?

Curricula tests of school children are, if not totally then very much predominately, related to content, to "what is taught". Nevertheless, in many of these subjects certain kinds of higher order thinking skills recur ... analysing given data, planning strategies, searching for consistencies and inconsistencies, reasoning by analogy, comparing with known situations, evaluating alternate solutions and checking consequences. These similarities have led to a renewed emphasis being placed upon the perennial question as to whether there might not be some instructional material in general thinking skills that would produce improved ability to reason in different curriculum areas. Such improved abilities, if able to be taught, would suggest that a relatively minor effort would lead to a broad educational return.

It is argued that critical thinking and logical reasoning underly the primary and secondary school curricula (Ennis, 1975; Hadar, 1975). Higher order thinking skills identified in cognitive simulation research and the metacognitive skills identified in developmental psychology are being accepted as worthwhile general courses in some Australian schools. In direct contrast to Resnick (1987), who suggests that "a fourth R - reasoning - might be considered a candidate for a new enabling discipline in the school curriculum" (Resnick, 1987, p. 49), Lipman contends that:

> "Reasoning is **not** .. "the fourth R". It is, instead, foundational, because it is fundamental to the development [of the other three]."
> (Lipman, 1983, p. 53).

There appears to be an enduring conviction that certain subjects taught in schools, such as Latin, "discipline the mind" and are thus taught for this purpose rather than the primary focus being on the value of the content. A more recent example is computer programming (Papert, 1980). However, Resnick (1987) offers a cautionary note to such contentions, observing that:

> "The view that we can expect strong transfer from learning in one area to improvements across the board has never been well supported empirically."
> (Resnick, 1987, p. 19)

In contrast to those enthusiasts for general reasoning programs, who view reasoning as a fundamental cross-discipline skill, other researchers and educators find more merit in incorporating the teaching of reasoning within at least a number of the traditional school subjects. Perhaps more for reasons of timetabling practicality ("the heavy content-orientation of traditional school curricula would barely allow room for such training in thinking skills" (Sternberg, 1983), and also politically (to retain the proprietary interests of established disciplinary departments) there is a body of opinion (e.g. Weinstein and Laufman, 1980) which suggests that reasoning skills are not sufficiently generalised, are not readily transferable, and do not warrant equal status with traditional school subjects.

> "Logic for children need not be a separate block of learning. It can easily be incorporated into the existing course of study."
> (Weinstein and Laufman, 1980, p. 190)

Resnick (1987) also noted that "each discipline has characteristic ways of reasoning". In the physical sciences, she identifies particular combinations of inductive and deductive reasoning; in the social sciences, more heavily influenced by traditions of rhetorical argument, he emphasises the skills of weighing alternatives, and of building a case for a proposed solution; and in mathematics, insistence is on formal proofs. Resnick (1987) contends that "each style of reasoning is worth learning" because

> "cognitive research yields repeated demonstrations that specific content area knowledge plays a central role in reasoning, thinking, and learning of all kinds".
> (Resnick, 1987, p. 18)

He concludes:

> "... prudent educational practice should seek to embed efforts to teach cognitive skills into one or another - preferably all - of the traditional school disciplines".
> (Resnick, 1987, p. 35)

Recommendations such as these should not be ignored by school educators with a disciplinary bias. They are consistent with the increasingly supported concept of domain-specific intelligences (see Chapter 3) rather than one general intelligence. Nevertheless, there has been research evidence to suggest that units of work or formalised programs (see below for a review) do produce educational benefit.

TEACHING STUDENTS TO REASON

Although relatively new, school programs that purport to enhance children's general reasoning abilities are multiplying in number. Kruse and Presseisen (1987) catalogue twenty-three programs to teach "thinking" to students. Analogous to the problems of tests of intelligence referred to in Chapters 1 and 2 (and which indeed frequently include a heavy component of formal logic questions), tests to measure the effectiveness of these programs have been subjected to sustained and substantial criticism. Nickerson (1986) clearly discounts the very concept of *measures* of reasoning abilities:

> "Any view of reasoning that overlooks the less formal and more creative aspects of the process [of reasoning] is an overly narrow view and is an inadequate foundation for programs to enhance reasoning."
> (Nickerson, 1986, p. 7)

However programs designed to teach young children to enhance their reasoning abilities have been commercially successful. A useful perspective is provided by a brief review of four of these programs, each with a diversity of goals and approaches:

Reuven Feuerstein's (1980) IE program aims at improving cognitive functioning related to the input, elaboration, and output of information. It consists of thirteen different types of exercises, which are repeated in cycles throughout the program, including, for example, orientation of dots, comparisons, categorisation, numerical progressions, representational stencil design and transitive relations. Sternberg (1983, p. 8) suggests that the IE program " ... appears effective in raising children's scores on ability tests". He does concede that most of the training exercises contain items similar or identical to those found in intelligence tests and multiple aptitude tests, and criticises the program for

> " ... the isolation of the problems from any working knowledge or discipline base (such as social studies or reading, for example)" ... thus raising the question of ... "transferability of the skills to academic and real-world intellectual tasks ..."
> (Sternberg, 1983, p. 9).

Matthew Lipman's (Lipman and Sharp, 1975) P4C program is about as different from Feuerstein's IE program as another program could be (Lipman, Sharp and Oscanyan, 1980).

Whereas the IE program minimises the role of experiential knowledge and discipline content, Lipman's program maximises such involvement. The content of philosophy as well as philosophical thinking are emphasised in the P4C program, promoting improvement of reasoning abilities (perceptual inferences, logical inferences and inferences from evidence). Lipman itemises thirty thinking skills that P4C is intended to foster, including concept development, generalisation, formulating cause-effect relationships, drawing syllogistic inferences, consistency and contradiction, identifying underlying assumptions, and working with analogies.

At the popular "games" level, Meirovitz (Meirovitz and Jacobs, 1984), capitalising on his invention of the well-known "Mastermind" game, has promoted Muscles of the Mind Program (MMP) - a program to improve thinking, used in the United Sates, France, Germany, Australia, England, Japan and Israel. It is claimed to help children and adults "fully utilise their natural intellectual potential ... develop skills of deductive logic, inductive logic, planning, remembering, creative thinking, problem solving, visualisation, and communication" (Meirovitz and Jacobs, 1984). MMP uses games, where thinking, not chance, make the difference. The goals of MMP appear to be all-embracing, and include increasing self-confidence, "making life easier for students" and "preparing people to face all school, home, and work situations more easily".

Another group of programs is more specifically aimed at teaching that facet of reasoning generally referred to as problem-solving, and is promoted as useful and applicable across disciplines and life situations. The CoRT Thinking Program (de Bono, 1976, 1985) represents a visible and useful example of this kind of program. In content free lessons, CoRT encourages the student to select objectives, consider multiple solutions and evaluate consequences. Resnick (1987) claims CoRT is probably the most widely used problem-solving skills program, having been translated into several languages and officially adopted for school use in several countries.

There appears to be a growing belief that acceleration of reasoning abilities is possible by direct strategy intervention, assuming that the cognitive structures are there to facilitate development. There does appear to be evidence to suggest that children who have not matured fully cognitively, and retarded individuals, are unable to meet the general goals of the programs, and more obviously unable to make transfers across disciplines and situations. "Essentially, ... while no one can teach another person "how to think", one can teach people how to think more effectively" (Hartman-Haas, 1980, p. 2).

SET THEORY AND SYLLOGISMS FOR LOGIC TRAINING: THE LEARNING TASKS

Evidence of the importance attached to classification and sorting activities can be found by examining mathematics primers for early grades. (Although, it is curious to note that the N.S.W. Department of School Education has moved formal Set Theory from the primary mathematics syllabus into the first year of high school.) Teachers for many years have introduced these activities to young children so that they may obtain a stable concept of number.

> "Classification and sorting activities are the beginning that helps children to perceive a variety of relationships that are interesting to them. This is how mathematical thinking begins. ... Slowly, the children perceive more, less or same amounts in sets. ... All mathematical thinking involves relationships of increasing complexity."
> (Leeb-Lundberg, 1985, pp. 17 & 20)

It is argued that any introductory unit aimed at enhancing reasoning skills should include instructional material on Set Theory. In this ATI study, such material was selected and presented in a form which presumed no prior knowledge - apart from the ability to read. It is of fundamental importance (see below for discussion) that the concepts and at least some specifics of a Reasoning unit can be dealt with in the abstract, even though parts of the learning materials and exercises may incorporate real names and objects. Thus, it is desirable, for example, that conceptual understandings and the majority of Set manipulations can be attained by the students independent of acquired knowledge and experience. The subjects in the present study were generally not required to draw upon similarities and analogies which may have deflected from the logical structure of the reasoning tasks. In introducing the reasoning unit's materials to the Year 6 primary students, for example, it was clearly reassuring for them to be told by their supervising class teachers: "The really good thing about these lessons is that it doesn't matter whether you have a good or a poor knowledge of school subjects. It doesn't matter what marks you have received in previous exams. It only matters that you try hard. You all are starting from the same point because previous knowledge will not count."

Similarly, the conceptual understanding and the majority of the syllogistic reasoning exercises in the instructional materials for this study focus the student only on the logical validation or otherwise of the syllogisms' conclusions. The validity or invalidity of a syllogism, deducible from its logical form, is independent of the specific content or subject matter. Thus many educators have valued the use of syllogisms for the teaching of introductory logic, focusing on the distinction between correct and incorrect reasoning as the central issue. The significance of syllogisms for the teaching of logic can readily be confirmed by reference to introductory texts on logic such as Copi, 1965, 1978; Halberstadt, 1960; Hughes and Cresswell, 1968; Michalos, 1970; Osherton, 1974; and Strawson, 1952. Strawson (1952, p. 158) claims that "the doctrine of the syllogism is the main achievement of traditional logic".

VENN DIAGRAMS

Venn diagrams, introduced by the English logician John Venn in the late 1800s, have been adopted in schools and colleges as traditional devices to enhance understanding and problem solving abilities in a variety of disciplines, particularly in many branches of school mathematics such as Boolean algebra and for the teaching of logic in philosophy courses in Universities. Venn diagrams have been found to facilitate students' understanding of the meanings of terms and the relations between concepts. Together with logical truth tables and decision trees, Venn diagrams have been widely accepted as generally facilitating logical reasoning (e.g. Mason, 1980). Copi (1978) suggests that Venn diagrams

> "... not only provide an exceptionally clear method of notation, but also are the basis of the simplest and most direct method of testing the validity of categorical syllogisms ..."
> (Copi, 1978, p. 197)

Venn diagrams can be concisely described as diagrams "representing pictorially relations among sets" (Sneddon, 1976, p. 606), or more generally, as "representations of the relations between particular classes of concepts" (White, 1986, p. 151).

The universal procedure of using Venn diagrams to test the validity of any standard form syllogism may be summarised in a series of steps, as depicted in Figure 5.1 for the syllogism

All monkeys are playful
<u>All monkeys are students</u>
Therefore all students are playful.

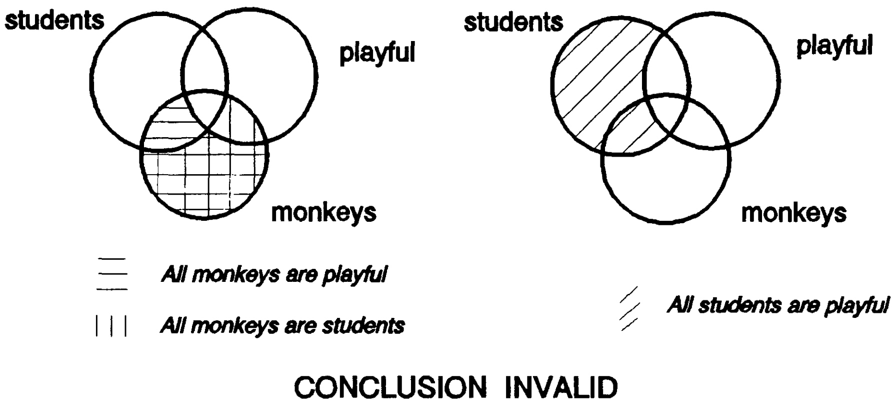
The steps are:

1. Label three circles with the syllogism's three terms (i.e. students, monkeys, playful).

2. Diagram both premises by shading those portions that have no elements. Add a letter *x* (or other marking) to indicate a region with at least one member element. [Diagram the universal premise first if there are one universal and one particular, and put an *x* on a line if the premises do not determine on which side of the line it should go.]

3. Inspect the diagram to see if the conclusion contains any information that is not present in the diagram of the premises. If it does, the conclusion is invalid, if not it is valid. In study 2, the young subjects were taught to draw a second diagram to depict the conclusion, and then inspect for differences in order to assess whether the conclusion can be validly inferred from the premises.

FIGURE 5.1 SOLVING SYLLOGISMS USING VENN DIAGRAMS



In Study 2, Venn diagrams facilitated the presentation of instructional material in the "spatial" treatment of lessons for a variety of tasks, including Set Theory concepts and manipulation as well as syllogistic reasoning, with the intention of allowing those subjects with high aptitudes for simultaneous information processing to capitalise on this ability.

LINEAR SYLLOGISMS

A *syllogism* is a deductive argument in which a conclusion is inferred from two premises. A *linear syllogism*, also referred to as a categorical syllogism, is a deductive argument consisting of three categorical propositions which contain exactly three terms, each of which occurs in exactly two of the constituent propositions.

An example of a linear syllogism is

All M are P (Major Premise)
Some S are M (Minor Premise)
and one of: Therefore: (Conclusion)
(a) All S are P
(b) No S are P
(c) Some S are P
(d) Some S are not P
(e) None of the above is proven.

The reasoner's task is to judge whether the conclusion given can be validly inferred from the premises.

Adopting Copi's (1978) terminology, there are four sentence types used in categorical syllogisms, conventionally labelled with the letters *A, E, I* or *O*:

A: a universal affirmative sentence (All M are P)
E: a universal negative sentence (No M are P)
I: a particular affirmative sentence (Some M are P)
and *O*: a particular negative sentence (Some M are not P)

While the conclusion of a syllogism is necessarily of the order S - P, the order of terms in the two premises can vary. The *mood* of a categorical syllogism is determined by the sentence type of the categorical propositions it contains. Referring to the letter identifications above, the mood of a syllogism, for example, would be designated *AIO*. The *form* of a syllogism may be completely described by its mood and figure, where the *figure* indicates the position of the middle term of the premises. There are four possible figures:

M - P	P - M	M - P	P - M
S - M	S - M	M - S	M - S
S - P	S - P	S - P	S - P
First Figure	Second Figure	Third Figure	Fourth Figure

Because each premise and the conclusion may be any one of the four permissible sentence types, and because there are four different syllogistic figures, there is a total of $4^4 = 256$ possible syllogisms. Of these, only 24, six within each figure, are valid. In this present study, sentence types were restricted to the use of quantifiers *some*, *all*, *all (understood)* and *every*. Thus the syllogisms in the study did not include the quantifiers *no* or *not* or *not one*. Categorical propositions were always affirmative and thus excluded universal negative or particular negative sentences. These restrictions were placed on the form of the syllogisms to simplify the reasoning required by the relatively young Term I Year 6 subjects.

Syllogistic Reasoning and Young Children

The prolific literature on strategies used by young children for solving linear syllogisms (e.g. Ceraso and Provitera, 1971; Chapman and Chapman, 1959; Clark, 1969a; DeSoto, London and Handel, 1965; Donaldson, 1979; Haars, 1981; Hadar, 1975; Hawkins et al., 1984; Henle, 1962; Hunter, 1957; Huttenlocher, 1968; Koopmans, 1987; Piper, 1981; Quinton and Fellows, 1975; Scribner, 1977; Sternberg, 1980) advance a number of possible solution strategies and related potential sources of error, and thus provided valuable background for Study 2.

Essentially, there are three major models suggested for the solution of linear syllogisms, with a fourth "mixed" model combining features of two of the major models. The first model proposes that subjects use visualisation and manipulation of problem elements into a spatial array as their reasoning strategy, as described in the spatial model suggested initially by DeSoto, London, and Handel (1965). Gavurin (1967) subsequently also found experimental evidence of a relationship between spatial visualisation and the manipulation of problem elements. Similar proposals were advanced by Handel, DeSoto and London (1968), and Huttenlocker (1968) who proposed that the visualisation and manipulation of problem elements may be a significant component in the specific reasoning strategies involved in solving linear syllogisms. The second model represents those subjects arriving at their solution using the inferences represented by the linguistic structures of the syllogism - a linguistic model identified by Clark (1969a, 1969b). The third model, an algorithmic model, involves the subjects using a more mechanical approach by applying a series of learned procedures, as suggested by Quinton and Fellows (1975). Latterly, Sternberg (1980) and Sternberg and Weil (1980) proposed a fourth "mixed" model of linear syllogistic reasoning "that combines the selected features of the spatial and linguistic models, and contains new features of its own" (Sternberg, 1980, p. 342). According to the mixed model of linear syllogistic reasoning, the terms of a linear syllogism are first decoded into linguistic deep-structural propositions and are then encoded into spatial arrays. Then the first pair of terms are "arranged", and the (common) pivot is found. "Once the pivot has been located, the person seriates the terms from the two-item spatial arrays into as single three-item array" (Sternberg, 1980).

Sternberg and Weil (1980) conducted an ATI study using alternate treatments of instruction for teaching syllogistic reasoning strategy, hypothesising that processing preferences would depend upon "subjects' patterns of verbal and spatial abilities". The instructions given to the subjects assigned to the spatial group were to "try to organise the statements into a spatial array" (Sternberg and Weil, 1980, p. 230), which suggests a rather cursory attempt to capitalise on spatial abilities. The hypothesis was unsupported and they concluded that "the correlations suggest that subjects may well have used a mixture of linguistic and spatial representations" and, further, that "visualisation training did not remove the effect of verbal ability" (Sternberg and Weil, 1980). In a latter phase to the same study, the researchers re-assigned subjects to spatial and verbal ability groups based upon a measure of the proportion of variance in the response-time data accounted for by the set of independent variables. This strategy confirmed an aptitude-strategy interaction in syllogistic reasoning. They concluded:

> "The effectiveness of a given strategy for solving linear syllogisms depends on one's pattern of abilities. The strategy represented by the mixed model seems to draw on both verbal and spatial abilities; the strategy represented by the linguistic model primarily to draw on linguistic ability; the strategy represented by the spatial model seems primarily to draw on spatial ability ..."
> (Sternberg and Weil, 1980, p. 234)

Apart from faulty logic, there are possibly four specific sources or conditions of potential error in the solution of linear syllogism by young children:

faulty understanding of the premises
  non acceptance
  misrepresentation
  reasoning experientially
  linguistic difficulties ...
    such as failure to comprehend the words in the syllogism, including the quantifiers
"atmosphere effect"
    guided simply by the global impression of quantifiers used in the syllogism such as "all" or "none"
tasks objectives unclear
    lack of agreement between experimenter and subject
cognitive immaturity
    subject either too young or physiologically unable to reason

Although Luria (1976) reported, from earlier studies on brain-damaged patients, that performance on syllogisms directly related to personal experience was substantially better than when the solution to the problem could only be reached on the basis of inference from the premises, most researchers (e.g. Begg and Denny, 1969; Bloom, 1981; Ceraso and Provitera, 1971; Scribner, 1977) deduce the contrary conclusion. Koopmans (1987) found:

> " ... errors in syllogistic reasoning have been extensively analysed, and they appear to be attributable to the fact that unschooled subjects tend to solve syllogisms by relying on their personal experiences rather than by recognising the premises in the syllogisms as the key to the right answer."
> (Koopmans, 1987, p. 2)

Scribner (1977) found that "empirical solutions were usually wrong", consistent with the main body of psychological opinion. Hawkins et al. (1984) also found this source of error repeatedly surfacing in numerous studies in which there was an apparent dichotomy between

> "reasoning ... in accord with formal logical procedures, without regard to the empirical truth of problem premises, and occasions when people reason practically or pragmatically".
> (Hawkins et al, 1984, p. 585)

Also in their own study using 4- and 5 year old children, Hawkins et al. (1984) found that "the relationship of the problem content to real-world knowledge affected the display of logical abilities." Hudson's (1983) review of syllogistic reasoning studies, involving children of very young ages such as in the Hawkins et al study (1984), identifies errors caused by experiential reasoning and also those caused by linguistic difficulties:

> " ... that the range of cognitive abilities elicited by cognitive assessment tasks can be significantly affected by the language employed by those tasks (Donaldson, 1979; Gelman & Gallistel, 1978; Siegel, 1978)".
> (Hudson, 1983, p. 85).

Begg and Denny (1969), Chapman and Chapman (1959), Henle (1962) and Ceraso and Provitera (1971) conducted studies demonstrating that syllogistic reasoning errors can be attributable to a faulty understanding of the premises. The latters' study concluded that:

> " ... Ss performing a reasoning task are not responding in a non-logical way, but are dealing with the logical structure of the material. When we eliminated a potential source of error, namely, premise misinterpretation, by presenting Ss with modified syllogisms whose premises were made quite explicit, we found a substantial improvement in their performance."
> (Ceraso and Provitera, 1971, p. 409)

For younger children to understand a syllogism task, according to Koopmans (1987):

> "It seems to be required that the counterfactual nature of the task is made clear to them by letting them solve a number of syllogisms in which they are prevented from applying their factual knowledge ..."
> (Koopmans, 1987, p. 17)

In the present study, the potential for empirical solutions by the subjects was restricted in the post and delayed tests by including only three items (of the ten in each test) on syllogisms incorporating terms that would have meaning for the subjects. In addition to a minority of examples of ordinary syllogisms, examples and exercises in the instructional materials emphasised nonsense categorical propositions - in which mythical beings and fantasy attributes were used to represent the terms of the syllogism - and abstract categorical propositions - in which letters were used for the terms of the syllogism. Test questions on syllogisms were divided into ordinary syllogisms, nonsense syllogisms and abstract syllogisms to permit analysis of potentially different levels of performance and identify sources of error.

A further source of error in the solution of linear syllogisms by young children was designated as an "atmosphere effect" by Woodworth and Sells (1935) and Sells (1936), in which the child's reasoning is influenced by the global impression of the words used in the syllogism. Markovits et al. (1989) suggests that the atmosphere affect intimates that "a *yes* response would be generated for syllogisms with positive premises, whereas those with negative premises would receive *no* responses." Begg and Denny (1969) postulated two basic principles to describe this effect:

(a) Whenever at least one premise is negative, the most frequently accepted conclusion will be negative; otherwise, it will be affirmative;

and (b) whenever at least one premise is particular, the most frequently accepted conclusion will be particular; otherwise, it will be universal.

Other studies have highlighted a further potential source of confusion which may lead to the forming of spurious conclusions, namely that of the task objectives of the researcher not being the same as those perceived by the subjects. In Haars' detailed interview-oriented study of young children, he was in a position to conclude that "the task received by the child and the one intended by the examiner are not necessarily isomorphic" (Haars, 1981, p. 10). The relevant part of the conclusions of Koopmans' (1987) study is consistent with this caution:

> "The necessity of understanding the counterfactual nature of the task in order to meet its demands to reason (see also Bloom, 1981) implies that more reasoning ability may have been displayed by the younger subjects in this sample if a fantasy condition had been included."
> (Koopmans, 1987, pp. 17-18)

Perhaps the most intensely researched issue on syllogistic reasoning by young children is related cognitive maturation, with a majority of study hypotheses, either directly or indirectly, resulting in a challenge to Piaget's (Inhelder and Piaget, 1958) view of intellectual development.

Piaget's stages of intellectual development can be summarised:

Sensori-Motor	the child's knowledge about objects comes from his actions upon them
Preoperational	the child learns to represent the world though symbols established by simple generalisations
Concrete Operations	manipulation of objects or symbols that represent things and relations in the child's mind
Formal Operations	the child can evaluate possible alternatives and deduce potential relationships.

According to Piaget's theory, transitive inferences are beyond children's logical capabilities until the concrete-operational stage of development, which usually begins at about 6- or 7 years of age, and it is not until the formal operations stage that a child is capable of syllogistic reasoning, around the ages of 11- or 12 years. Essentially, Piaget accepts the possibility of facilitating the acceleration of the development of reasoning, but places primary emphasis on the importance of the cognitive structures being there to permit such development.

Studies involving young children as subjects have challenged this developmental thesis of Piaget. In a study with children of 4- and 5 years of age, using verbal syllogism tasks, Hawkins et al. (1984) found that:

> " ... children reasoned in terms of logical form when the task was constrained in such a way as to most effectively eliminate the intrusion of practical world knowledge. There was no empirical truth value information that interfered with the use of logical reasoning".
> (Hawkins et al, 1984, p. 592)

Haars (1981, p. 10) also found that children of this same age range are capable of making deductive inferences required in solving syllogism problems and that "there is no doubt that preoperational or concrete operational children cannot do many things, but ... young children can and do more reasoning than is usually recognised".

Markovits et al. (1989) were critical of the Hawkins et al. (1984) study in which the high rate of correct *yes* or *no* conclusions for specific content using "fantasy" terms and the presence of referral to premises was taken to be evidence of deductive (syllogistic) reasoning. They reason that group administered paper-and-pencil studies are useful for testing large numbers of subjects, but do not offer an opportunity for the researcher to explore the reasoning processes or understandings of the subjects. In their own study, Markovits et al. (1989), using children in 6-, 8- and 11 year old groupings, chose a interview technique in order to obtain a clearer understanding of the children's reasoning, and categorised their responses to syllogistic tasks:

none	(I don't know)
premises	(reference to one or both premises)
conclusion	(repetition of conclusion)
empirical	(Zoboles have a nose to smell with)
authority	(daddy told me)
invention	(invented details added to link)
illogical	(explicit generation of lack of relation between premises e.g. "You didn't tell me if Plouques cry.")

Markovits et al. (1989, p. 792) found that the "older children can begin to subordinate empirical knowledge to their understanding of structural relations". Their results indicated that 11 year olds responded identically to logical and illogical syllogisms only 29% of the time (and 8 year olds 50% of the time). Their conclusion is of value to Study 3 of this research, as they highlighted and confirmed the distinction between a child's logical analysis and his or her ability to explain that analysis. They concluded:

> "Children can distinguish between logical and illogical syllogisms in terms of differential responses and justifications before they appear able to describe explicitly the nature of the distinction. This kind of metalogical understanding appears to develop after 11 years of age, in line with results obtained by Moshman and Franks (1986) on the development of the notion of logical necessity."
> (Markovits et al., 1989, p. 792)

In addition to Markovits et al. (1989), other researchers have concluded that children perform sophisticated reasoning tasks prior to their capacity to explain their strategies and procedures. In a criticism of a number of "paper-and-pencil" studies, Mason (1980) suggests:

> "One obvious conclusion might be that the judgment of the truth of a syllogism represents a different, and perhaps easier, task than the explanation of that judgment."
> (Mason, 1980, p. 66)

Johnson (1984, p. 14) also states, for this same reason, "it is not possible to determine the exact moment a child begins to reason, but it is obvious that children are making inferences prior to their use of language". On the basis of the body of evidence in the literature, this conclusion seems to be substantially corroborated.

Oscanyan (1978) asserts that children have already developed rather sophisticated reasoning skills prior to entering school, and understand the meaning of if-then logical forms, "though they may know nothing of the formal rules that govern these forms" as in the premise "if you touch that, you will get hurt". Further support comes from a study be Willatts and Duff (1989) from their work with very young children, and they contend that "awareness of the necessity of logical reasoning appears to develop very early, and its origins may be found in the preschool years." The findings from an interesting study of 160 gifted children (20 each from ages 4 to 11) undertaken by Shigaki and Wolf (1979) also challenged Piaget's contention that formal reasoning does not occur until around ages 11 or 12. Hadar (1975) found in his study, using experimental and control groups, each of over 100 students in the 10- to 11 years of age range, that the subjects could perform logical reasoning tasks, and further, that suitable instruction can improve specific aspects of their reasoning performance.

SYLLOGISMS AND THE LURIA MODEL

Luria (1966b) found that the inability of brain damaged patients to understand logico-grammatical relationships, which require "the arranging of their component elements into one simultaneous scheme" for understanding, was not solely related to parts of speech expressing spatial relationships but also to the understanding of comparative relationships. Luria (1966b, p. 86) found that although the subject continues to "perceive individual elements ... he cannot properly understand the conceptual relationships expressed". These comparative relations are to some extent all verbal expressions of spatial relationships (Luria, 1966b).

The syllogisms used by Luria were of the "spatial" type: "If John is shorter than Bill and John is taller than Dick, who is the tallest?". In an exploratory factor analytic study, Cummins (1973) used syllogisms of this type and found that they had a loading of 0.70 on what was labelled the simultaneous factor. However, in contrast, Walton (1983) used nonsense syllogisms from the Ekstrom et al. (1976) kit and found approximately equal loadings on both the successive and simultaneous information processing factors. He demonstrated that:

> " ... unfamiliar non-spatial syllogisms are not differentially related to the information processing factors of the Luria model ... This expected result was attributed to the unfamiliar nature of the syllogisms items which prevented the students from developing an information processing strategy to solve them."
> (Walton, 1983 p. 209-210)

In Study 2, non-spatial syllogisms were used and two instructional materials prepared. One was labelled a "spatial" treatment, a convenient nomenclature for use with the children. It was designed to facilitate learning for students with high simultaneous and low successive processing abilities. The other treatment, labelled "verbal" for convenience, was designed to cater for those subjects with low simultaneous and high successive processing abilities. Each of the two sets of instructional material incorporated lessons that taught strategies and procedures to solve syllogisms consistent with the bimodal information processing dimensions of the Luria model, in that each treatment taught syllogistic reasoning by the use of disparate "verbal" and "spatial" strategies. It has been argued (Sternberg, 1980) that the use of mechanical models for the solution of syllogisms that embody a series of learned procedures (see Quinton and Fellows, 1975) is a strategy that "seems almost to bypass the need for reasoning altogether". In direct contrast, a study by Erickson (1975, p. 315) observed that his results demonstrated that "subjects approach a syllogism judgment in a fairly consistent way no matter what kind of simple instructions are given". Erickson's study provided instruction to subjects in either formal verbal rules (of the type "no conclusion is possible from two negative premises", or in Venn diagrams. He suggests in a footnote to his findings that:

> "Additional research has shown that when subjects are run one at a time rather than in groups, and when instructions are more thorough, subjects given Venn diagram instructions perform best, and those given minimal instructions perform worst, with rule instructions intermediate."
> (Erickson, 1974, p. 315)

However, in the present study, the two treatments contained considerable detail and provided extensive exercises, designed to call respectively upon either simultaneous or successive aptitudes for both the learning *and* application of the respective disparate solution strategies, rules and procedures.

It has been suggested that use of Venn diagrams proposes a mechanical strategy for solution to syllogisms. An inspection of the spatial treatment's solution strategy may suggest that it can be applied mechanically, in that it instructs the learner to undertake a series of steps to assess each syllogism's validity. However, it is suggested that simultaneous processing abilities are inherently required *within* each of the steps. It is also evident that *learning* syllogistic reasoning with Study 2's spatial materials requires subjects to apply substantive spatial reasoning during the total learning process, involving "the ability to integrate the details into a single whole" (Luria, 1966b, p. 156).

SUMMARY

Educators over many centuries have aspired to achieve the goal of enhancing students' reasoning abilities, whether by specific courses in reasoning and logic or by incorporating appropriate instruction within traditional disciplines. In Australian schools, it appears that there has recently been a renewed interest in the teaching of reasoning and a number of stand-alone (some commercially available) programs have been implemented. This is particularly evident at the primary level where it appears that greater emphasis is formally being placed on enhancing general reasoning competencies (concomitant with a de-emphasis on content-based courses).

The present study investigated aptitude x treatment interaction over a range of reasoning tasks involving Set Theory and syllogistic reasoning, topics long held to be important components in a reasoning syllabus. Research on linear syllogisms, as reviewed above, has tended to concentrate on identifying the strategy or strategies subjects used, as a total study group, in solving the syllogisms. There has been limited attention paid to individual differences in terms of natural aptitudes for information processing.

Venn diagrams form the basis of the instructional treatment designed to advantage those subjects with high simultaneous aptitudes. They serve as a useful adjunct to verbal instruction and have traditionally been used to aid in the understanding of Set theory concepts. In the present study, Venn diagrams are also used as integral components of the "spatial" solution strategy for the solution of linear syllogisms.

Children's performances on syllogistic reasoning tasks have typically been viewed as an indicator of formal operations, particularly when the premises are "fantasy" or "abstract" in nature, as a correct solution to these tasks necessarily can only be achieved by inferring a solution from the propositions as they are given in the premises (Cole & Scribner, 1981; Orasanu & Scribner, 1982) (or by a guess). Most studies concerned with syllogistic reasoning seem to confirm that solution strategy and solution accuracy varies with age. It does appear that many very young children are capable of sophisticated reasoning, even those yet to enter school without knowledge of formal rules. At the 10- to 12 years age range of the subjects involved in the present study, a considerable body of evidence has demonstrated that such children, in the majority, are capable of understanding the purpose of syllogistic reasoning tasks and are capable of the logic required when the tasks are counterfactual.

CHAPTER 6

STUDY 1 - SIMULTANEOUS AND SUCCESSIVE INFORMATION PROCESSING APTITUDES IN SENIOR PRIMARY STUDENTS

INTRODUCTION

The model of cognitive processing abilities used in this study, based upon the research of Luria (1966a, 1966b, 1976a, 1976b), views an individual's aptitudes for simultaneous analysis / synthesis and successive analysis / synthesis as subsuming a diversity of cognitive skills which underlie the acquisition of knowledge. Previous studies have shown the existence of these two information processing abilities in primary school students (Angus, 1984; Crawford, 1986; Das, 1973; Das, Kirby, and Jarman, 1975; Das and Molloy, 1975; Elliott, 1990; Green, 1977; Hunt and Randhawa, 1983; Ransley, 1981; Try, 1984; Tulloch, 1986).

This chapter describes the research design and methodology of the initial study, presents the research hypotheses, and provides an analysis of data obtained from the administration of the criterion tests designed to quantify the simultaneous and successive information processing aptitudes of the subjects. Component scores were then available for use in Study 2, for which the same group of subjects were employed. Based on the component scores, individuals could then be assigned to aptitude groupings (classified as high - medium - low) in each of the two domains. Principal Component Analysis with Varimax rotation was adopted as the primary data analysis procedure for Study 1. Principal component analysis makes use of all the test variance in producing factor scores to characterise the data in terms of principal underlying dimensions. The criticism that Principal Components Analysis does not involve significance tests and thus risks the extraction of an inappropriate number of components has little relevance when analysing data from series of tests used in a coherent programme of research where the structure of the data is well known. There has also been criticism of studies of intellectual function employing batteries of tests developed without prior assumptions, which are then subsequently analysed, labels created for the resultant factors and theories or models of structure consequently defined. However the body of research based upon the Luria model, partially cited above, has confirmed the validity of the tests used in this study, both with regard reliability and criterion validity through relationships with external criteria.

Aim of Study 1

The aim of Study 1 was to determine the relative levels of aptitude of each of the Year 6 female primary school students (N=296) for both simultaneous and successive processing by identifying the principal underlying dimensions using factor analytic techniques to derive component scores. The expectation of findings consistent with this body of previous research was addressed through testing the following hypotheses for Study 1 of the present research.

Research Hypothesis for Study 1

Hypothesis 1: Principal Component Analysis of data obtained from the six tests administered will produce two independent components which may be labelled as a successive processing component and a simultaneous processing component, which together will account for the major proportion of the variance in the data.

Hypothesis 1.1: The successive processing component will be predominantly defined by the three span tests Number Span, Letter Span and Word Span.

Hypothesis 1.2: The simultaneous processing component will be predominantly defined by the three tests Shapes, Paper Folding and Matrix A.

The Subjects

The subjects selected for Study 1 were the total population of students in the ten Year 6 classes at three independent girls' schools located in the northern suburbs of Sydney. The schools draw their pupils from an area considered to be middle class. Table 6.1 gives the number of students in each of the classes from the three schools who commenced the study, and the number of subjects who completed all six criterion tests.

TABLE 6.1 DISTRIBUTION OF SUBJECTS - STUDY 1

SCHOOL (CLASS-NO. STUDENTS)	STUDENTS STARTED	STUDENTS COMPLETED
ABBOTSLEIGH (6D-30, 6H-29, 6L-30)	89	89
PLC (6B-29, 6C-30, 6H-30, 6L-29, 6P-30)	148	147
RAVENSWOOD (6B-30, 6G-30)	60	60
TOTALS	**297**	**296**

Test Materials

A range of tests that measure simultaneous and successive processing abilities, stemming from the research of Luria with brain-damaged patients, have been progressively developed and refined for use with normal subjects during the last two decades by Fitzgerald (1973 - 1990) and his colleagues at the University of New England. In this study, successive processing aptitude was determined by tests involving the reproduction of a series of numbers, letters and words, and simultaneous processing aptitude by tests involving the manipulation of shapes and figures.

The battery of tests used in this study were:

1. Auditory Number Span Test
2. Auditory Letter Span Test
3. Auditory Word Span Test
4. Shapes Test
5. Paper Folding Test
6. Matrix Test

Tests 1, 2 and 3 were expected to load on successive processing, and Tests 4, 5 and 6 were expected to load on simultaneous processing. Each of these tests is outlined below. The detailed administrative instructions and test items, with answers / marking keys are presented in Appendix A, pp. 225-230 for Tests 1, 2 and 3, and in Appendix B, pp. 232-241 for Tests 4, 5 and 6.

TESTS FOR SUCCESSIVE PROCESSING APTITUDE

Auditory Number Span Test

Auditory Number Span tests have been used as indicators of successive processing aptitude by Crawford (1986), Das and Molloy (1975), Green (1977), Kenny (1979) and Walton (1983). Das, Kirby and Jarman (1979) include a Digit Span Forward Test in a manual for tests of successive processing. The Auditory Number Span Test used in this study was principally based upon that used by Green (1977) with minor modifications to account for marginally more senior students than the Grade 5 primary subjects of Green's study. It consisted of sequences of numbers of varying length from a minimum of 4 numbers to a maximum of 11 numbers. Only the nine digits 1, 2, ... 9 were used, zero being excluded. The examiner would say: "Heads up. Ready. First Sequence. 4 5 2 8 6. Begin", reading the numbers at one per second. In her trial study using this test, Crawford (1986) found it difficult to deter students from copying numbers as they were read. In this study, the trial indicated that as long as the examiner ensured that the subjects had "heads up", this was not a problem. Additionally, the discipline and ethos in the independent schools, plus peer pressure, would mitigate against cheating that would be immediately obvious to an adjacent classmate. The students had from 10 to 20 seconds to recall and record each sequence depending upon its length. The students were instructed to place a cross in the space(s) for each number they could not remember. Sixteen sequences were used. Each number correctly recalled in the proper sequence was scored as one, with zero for wrong numbers or numbers in an incorrect position in the sequence. The administrative instructions and test items are presented in Appendix A, pp. 225-226.

Auditory Letter Span Test

This test was based upon that used by Walton (1983) with minor modifications to account for subjects approximately five years junior to those in the Walton study. Sixteen sequences of between 3 and 11 letters were chosen using only the letters C, F, G, H, K, L, P, R, S, W and Y. The test procedure, timings and basis of scoring were the same as for the Auditory Number Span Test described above. The administrative instructions and test items and presented in Appendix A, pp. 227-228.

Auditory Word Span Test

This test was based upon the Word Span Test developed by Green (1977). Twelve sequences of between 2 and 8 words were selected using largely monosyllabic words that would be very familiar to the students and easily spelt by the majority, such as "pen", "body", and "string". The test procedure and timings were the same as for the Auditory Number Span Test and Auditory Letter Span Test described above. Each word correctly recorded in sequence was scored as one, with no mark awarded for a word in an incorrect position (see also Scoring Span Tests below). Allowance was made for misspelling of words when the student clearly had recalled a word in the correct position but had misspelt it (eg. "leter" and "lettor" were accepted as "letter"). The administrative instructions and test items and included in Appendix A, pp. 229-230.

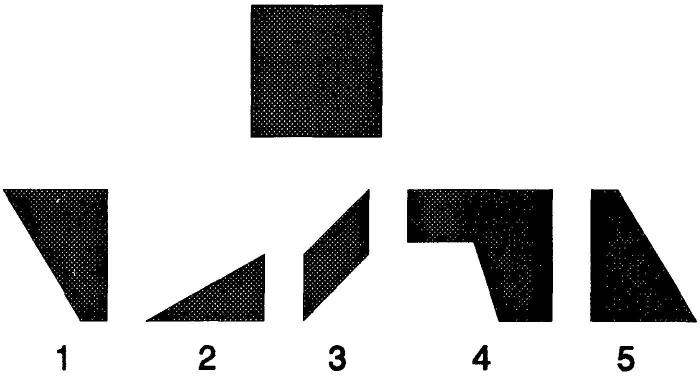
Green (1977) found the Word and Number Span Tests to be reliable indicators of successive processing aptitudes in Year 5 children. Walton (1983), using Year 11 pupils as subjects, and more difficult but conceptually similar tests to those used in this study, found the Digit Span and Letter Span Tests useful predictors of successive processing aptitudes.

TESTS FOR SIMULTANEOUS PROCESSING APTITUDE

Shapes Test

This test was modelled after the Paper Form Board Tests (Ekstrom et al., 1976) and Green's (1977) Shapes Test. The tests were stated as being suitable for Grades 9 to 16, and thus the test items were made marginally more simple, after Green (1977), who used a similar criterion test with Year 5 students. Comparable test items have been used for identifying simultaneous processing aptitudes to those employed by Hattie and Fitzgerald (1982) and Kenny (1979).

Each item in a Shape Test requires the subject to select which plane geometric pieces can be fitted together to make an identical shape of the same size as a nominated figure. Each figure is divided into between two and five pieces which are arranged at random underneath the nominated figure. When the correct answer to a test item was less than five, distracter pieces were included to provide a choice of five pieces for each test item. The test consisted of 12 items. A piece could be rotated and displaced to any position but none of the pieces could be turned over as a reflection. In this example,

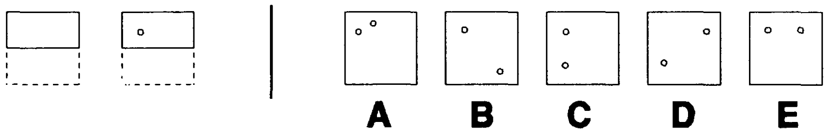


the pieces 1 and 5 make the square figure of the same size shown. Students were allowed 7 minutes to complete the test. Each item was marked correct if the pieces required to make the nominated figure had been selected and the distracter pieces had not been selected. Each correct answer received a mark of one and other answers were marked as zero. The administrative instructions, test items and answers are presented in Appendix B, pp. 232-236.

Paper Folding Test

This test was similar to the Paper Folding Test VZ-2 of Ekstrom et al (1970), and also to Cummins (1973) and Walton (1983). Although stipulated for Grades 9 - 16, the trial studies demonstrated that the specific items designed for this study were suitable for use with Grade 6. The test used consisted of 7 items. In each item, a square sheet paper is depicted as being folded either once or twice as indicated by drawings, after which a hole is then shown to be punched through the folded paper. The subject is then asked to select which of five figures would represent the paper when unfolded. The subject is involved in spatial manipulation and spatial configuration in determining where the holes would be located once the square sheet of paper is unfolded.

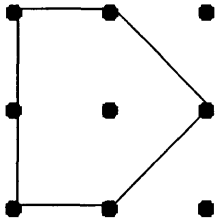
In this example, the paper folds are indicated on the left of the vertical line

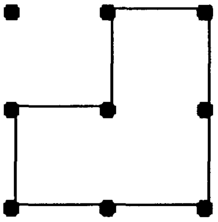


and Figure C represents the paper when unfolded. Students were allowed 5 minutes to complete the Paper Folding Test, and were assigned one mark for a selecting the correct solution, else zero. The administrative instructions, test items and marking key are included in Appendix B, pp. 237-239.

Matrix A Test

The Matrix A Test used in this study was based upon the original tests designed by Fitzgerald (1971), as modified by Green (1977) and later by Walton (1983) and Crawford (1986). Each of the items in the test consisted of the outline of plane figures constructed by joining specific dots on a nine dot matrix. The subjects were shown each figure for 5 seconds and then given ten seconds to reproduce it on an answer sheet exactly as displayed, without rotation or inversion. Eighteen items were used. The test items were of the type:





Each answer was given a score of 1 if correctly reproduced and 0 otherwise. No marks were given for partly correct answers. The administrative instructions and test items are given in Appendix B, pp. 240-241.

Green (1977) found the Shapes and Matrix A Tests to be good indicators of simultaneous processing aptitudes in Year 5 children. Walton (1983), using Year 11 children as subjects and slightly more difficult test items to those used in this study, found all three tests (Shapes, Paper Folding and Matrix A) to be useful predictors of simultaneous processing aptitudes.

TRIAL ADMINISTRATION OF TESTS

The numerous studies using similarly designed tests to those presented above provide substantive evidence for their use as indicators of the two information processing dimensions requiring to be identified. As a pilot study, the six tests were administered to a group of six primary students with the singular aim of establishing timings for the main study. The findings from the trial administration of the tests related to timings were:

1.	Number Span Test	7 minutes
2.	Letter Span Test	7 minutes
3.	Word Span Test	7 minutes
4.	Shapes Test	6 minutes
5.	Paper Folding Test	5 minutes
6.	Matrix Test	5 minutes
	Total time	37 minutes

Allowing for administrative activity such as distributing papers, reading instructions and collecting papers, an allowance of 65 minutes was made for the administration of these tests in the main study.

RESULTS OF STUDY 1

The observed means and standard deviations of scores of the six tests for the population (N=296) and for each of the three participating schools are presented in Appendix C, p. 244, and the correlation matrix for the six test variables in Appendix C, p. 245. The data were analysed using Principal Component Analysed with Varimax rotation. The loadings (given in Table 6.2 below) of the tests on each of two major components accounted for 70.9% of the total variance.

The results of principal component analysis of the test data identify two orthogonal information processing abilities, described as successive processing and simultaneous processing. These are nominated as Component 1 and Component 2 respectively in Table 6.2. The component loadings are comparable to those obtained in those studies employing similar tests by Fitzgerald and his colleagues at the University of New England (e.g. Crawford, 1986; Green, 1977; Walton, 1983).

TABLE 6.2 VARIMAX COMPONENT LOADINGS OF THE SIX VARIABLES NUMBER SPAN, LETTER SPAN, WORD SPAN, SHAPES, PAPER FOLDING,MATRIX A ON THE TWO COMPONENTS OBTAINED FROM THE PRINCIPAL COMPONENT ANALYSIS OF RAW SCORE DATA (N=296)

	COMPONENT 1	COMPONENT 2
NUMBER SPAN	.89	.06
LETTER SPAN	.90	.07
WORD SPAN	.83	.16
SHAPES	.06	.84
PAPER FOLDING	.04	.80
MATRIX A	.18	.74

A report (Appendix C, p. 246) was provided to each of the participating class teachers which indicated the information processing aptitudes of their students. This feedback to the schools proved of considerable interest and it was suggested by a number of the teachers that the results would prove useful in the way they perceived the ability of individuals in their classes.

For the purpose of the aptitude-treatment experiment to be conducted as Study 2, students were assigned to one of nine aptitude groups, by dividing each of the component scores, representing the two dimensions of information processing defined in the Luria model, into three equal frequency bands. These bands were "high" successive, "medium" successive, low "successive" and "high" simultaneous, "medium" simultaneous, low "simultaneous" respectively. (See Figure 6.1.) The groups were named, for the purpose of easy identification and discussion, by both number and letter: e.g. GROUP1-HH (High simultaneous-High successive), GROUP2-HM (High simultaneous-Medium successive).

ALLOCATION OF GROUP NUMBERS

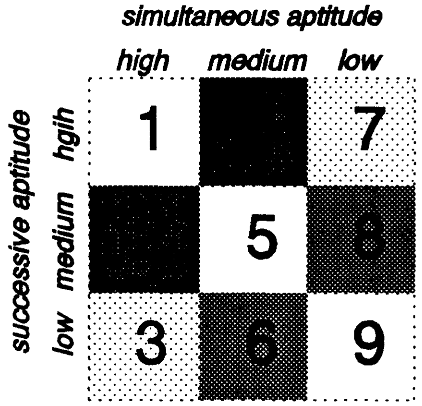


FIGURE 6.1

In all GROUP names in this research the first identifying letter represents the *simultaneous* aptitude level and the second the *successive* aptitude level. The resulting 3x3 matrix of cells each contained an approximately equal number of students, as shown in Table 6.3.

TABLE 6.3 DISTRIBUTION OF SUBJECTS INTO NINE APTITUDE GROUPS BASED UPON SIMULTANEOUS AND SUCCESSIVE COMPONENT SCORES

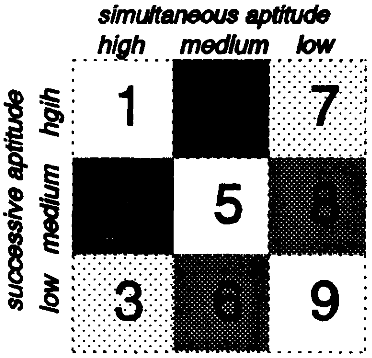
GROUP	NO. OF SUBJECTS	% OF TOTAL
GROUP1-HH	31	10
GROUP2-HM	28	9
GROUP3-HL	40	14
GROUP4-MH	33	11
GROUP5-MM	31	10
GROUP6-ML	33	11
GROUP7-LH	33	11
GROUP8-LM	35	12
GROUP9-LL	32	11
TOTALS	296	100

This 3x3 partitioning of the students into 9 groups permitted the following contrast vectors of interest in Study 2:

V1 GROUP3-HL contrasted with GROUP7-LH (Figure 6.2)
V2 GROUP6-ML contrasted with GROUP8-LM (Figure 6.2)
and V3 GROUP2-HM contrasted with GROUP4-MH (Figure 6.2).

Figure 6.3 below depicts a supplementary analysis of the data which has interesting implications for use in classrooms. Although not part of the main design, the broader groupings of students are potentially more practical from the viewpoint of teacher management. The contrast shown partitions those students in each of the cells with a higher simultaneous aptitude than successive aptitude (Groups 2,3 & 6) with those students in each of the cells with a higher successive aptitude than simultaneous aptitude (Groups 4,7 & 8).

APTITUDE CONTRAST VECTORS

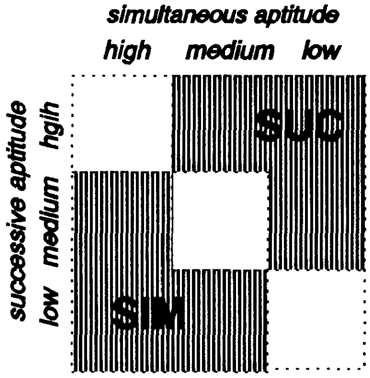


V1 GROUP3-HL : GROUP7-LH

V2 GROUP6-ML : GROUP8-LM

V3 GROUP2-HM : GROUP4-MH

FIGURE 6.2



SIM : SUC

FIGURE 6.3

DISCUSSION

The hypothesis that Principal Component Analysis of data obtained from the tests administered will produce two distinct orthogonal components that could reasonably be labelled a successive processing component and a simultaneous processing component was supported, consistent with numerous comparable research studies.

It is clear that the three span tests, namely Number Span, Letter Span and Word Span, loaded on the component that could be identified as successive aptitude (.89, .90 and .83 respectively), thus supporting Hypothesis 1.1. The three tests Shapes, Paper Folding and Matrix A loaded on the second component that could be identified as simultaneous aptitude (.84, .80 and .74 respectively), in support of Hypothesis 1.2. The Matrix A Test appeared to be particularly easy, as administered, for the majority of students (mean score 81.4%, compared with 54.9% and 53.8% for the other two tests loading on the simultaneous component) and thus not as effective at discriminating simultaneous processing ability as the other two. The results for Matrix A could have been improved if less that the five seconds have been given to the students for inspection of each figure, and/or if a greater number of more complex, and particularly non-symmetrical, figures had been used within the test.

The results of Study 1 are consistent with the repeated confirmation that an individual's information processing can be viewed as comprising two distinct orthogonal abilities, namely successive synthesis / analysis and simultaneous synthesis / analysis. The study is consistent with other research identifying these abilities in children of primary school age (Crawford, 1986; Green, 1977; Hunt and Randhawa, 1983; and Ransley, 1981) confirming that relative strengths and weaknesses in the two information processing variables result in measurable, robust individual differences in cognitive abilities.

Observation of the subjects' responses during testing, and subsequent close inspection of individuals' series of item responses, and overall item analyses, suggest that the exercise of each of these processes is clearly inter-related with other cognitive attributes and subject to influence by other personological variables. "I didn't remember a single one of the long strings of numbers", "I didn't get that paper folding one at all", "I lost heart in my ability to remember", were three post-testing reactions. It is highly probably that numerous and complex brain functions are, perhaps frequently *chaotically*, employed with the everyday utilisation of the two processing aptitudes. Nevertheless, it is to be emphasised that the results confirm the serviceability of the six tests used in this study as effective indicators of two measures of information processing, with simultaneous and successive labels, within the level of difficulties and item ranges used, for students in the senior primary school.

As with any attempt at measuring dimensions in the cognitive domain, the results can often be adversely influenced by extraneous "noise" - other factors operating concurrently with those that are the focus; and also by environmental surroundings which adversely affect subjects' motivation and concentration. From the general strength of the component loadings in this study relative to other similar studies (Crawford, 1986; Das, 1973; Das, Kirby, and Jarman, 1975; Das and Molloy, 1975; Green, 1977; Hunt and Randhawa, 1983; Ransley, 1981; Walton, 1983), it appears that senior primary female students in independent schools, given appropriate pre-test motivation and introduction, can produce test results that are dependable measures of the cognitive abilities under study. Further evidence is provided to support this conclusion when the results of this present study are considered in conjunction with the results from the administration of the same tests (number of test item marginally reduced) to an additional 251 subjects of similar profile as part of Study 3 in this research.

This preliminary study identified a two component structure comprising simultaneous and successive aptitudes, allowing component scores to be generated for each individual for subsequent analysis in relation to learning performance data from the same group of subjects who undertook one of two alternate instructional treatments of a unit designed to enhance elementary reasoning skills.