CHAPTER 7

STUDY 2: AN APTITUDE-TREATMENT INTERACTION STUDY IN REASONING

INTRODUCTION

Review of Study 1

Analyses of the data from the series of six tests administered to Year 6 subjects in Study 1 adequately demonstrated the presence of two orthogonal components that reflect the two modes of information processing in the model of cognitive functioning proposed by Luria. The six model variables were analysed using Principal Component Analysis with Varimax rotation. A clear, simple structure emerged with the Number Span Test loading 0.89, the Letter Span Test loading 0.90 and the Word Span Test loading 0.83, defining a successive component. A simultaneous factor component was also well defined with the Shapes Test loading 0.84, the Paper Folding Test loading 0.80 and the Matrix A Test loading 0.74. Luria delineated these two modes of processing as successive synthesis / analysis and simultaneous synthesis / analysis. Individual component scores were generated on each subject for each of these dimensions and used in Study 2 to reflect individual differences in cognitive abilities. The raw scores for each component were divided into three approximately equal frequency bands, named "high", "medium" and "low", such that individuals could be notionally assigned into one of the nine resultant aptitude groupings.

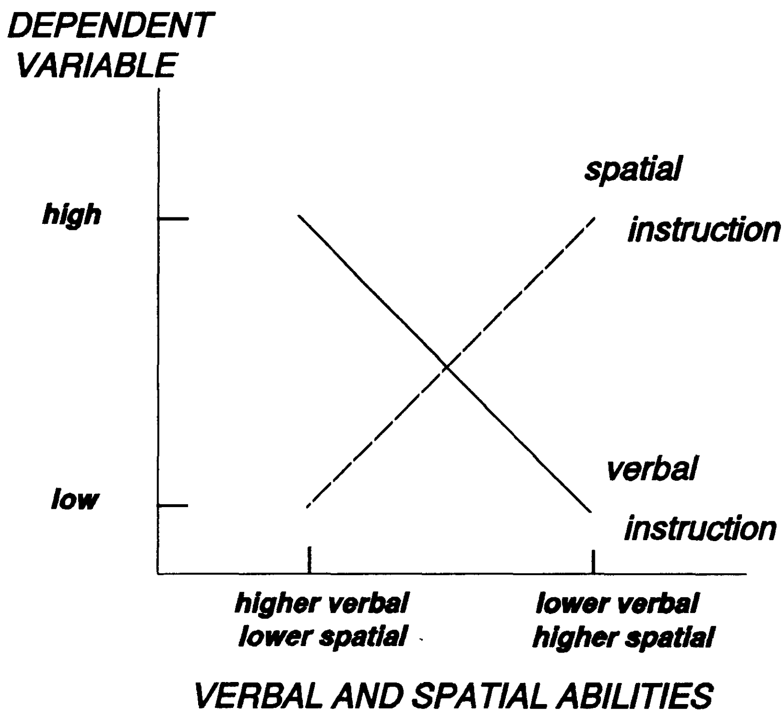
Aim of Study 2

Using these dimensions of individual differences in successive and simultaneous processing, the aim of Study 2 was to examine the interaction between aptitudes and two instructional treatments designed to maximise learning performance on elementary reasoning tasks. The aim of the self-administered instructional materials was to teach introductory reasoning topics, specifically by developing students' knowledge, understanding and performance on elementary tasks related to Set Theory and syllogisms. More generally, the study investigated whether learning can be optimised by presenting students with instructional material designed to capitalise on individual differences in information processing abilities.

Rationale

It was anticipated that students with higher successive processing aptitudes would learn more effectively from the instructional treatment designed to capitalise on successive processing aptitudes (for convenience, labelled a "verbal" treatment) than they would from the treatment designed to advantage those individuals with higher simultaneous processing aptitudes (labelled a "spatial" treatment), and that the latter group would experience improved learning from the "spatially" oriented instructional treatment compared with the "verbally" oriented instructional treatment. The major research hypothesis for Study 2 was a prediction of a disordinal interaction between successive - simultaneous aptitude variables and treatment groups in regard to performance in each of three categories of learning, namely 'understanding and knowledge of Sets and syllogisms', 'Set manipulation' and 'syllogistic reasoning'.

FIGURE 7.1 DISORDINAL APTITUDE-TREATMENT INTERACTION



It was anticipated that disordinal aptitude x treatment interactions were likely to be most pronounced when the treatment effect on learning performance was evaluated for students in the "high - low" ability group contrasted with those in the "low - high" ability group[1]. These expectations were addressed through testing the following research and statistical hypotheses.

Research and Statistical Hypotheses for Study 2

Study 2 investigated the interaction between information processing aptitudes and instructional treatments designed to match these individual aptitudes, using criteria of performance measured on three distinct categories of learning in the general topic area of Set Theory and syllogistic reasoning.

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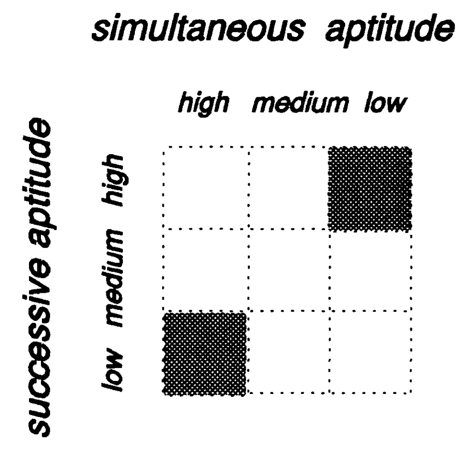
1 *In describing aptitude profiles, the convention used throughout this thesis is to name the simultaneous aptitude first, and the successive last. Thus "high - low" indicates high simultaneous - low successive.*

Research Hypothesis

There will be a disordinal interaction between simultaneous - successive aptitude variables and treatments groups in regard to learning performance in each of the three categories of learning, 'understanding and knowledge' of Sets and syllogisms, 'Set manipulation' and 'syllogistic reasoning'.

Statistical Hypothesis 1

There will be a significant disordinal interaction between the learning performance of the high simultaneous - low successive and low simultaneous - high successive processing aptitude groups (depicted below) under the verbal and spatial instructional methods.



Sub-Hypothesis 1A

In the performance on tasks classified as understanding and knowledge of elementary Set Theory and syllogisms, there will be a significant disordinal interaction between the learning performance of the high simultaneous - low successive and low simultaneous - high successive processing aptitude groups under the verbal and spatial instructional methods.

Sub-Hypothesis 1B

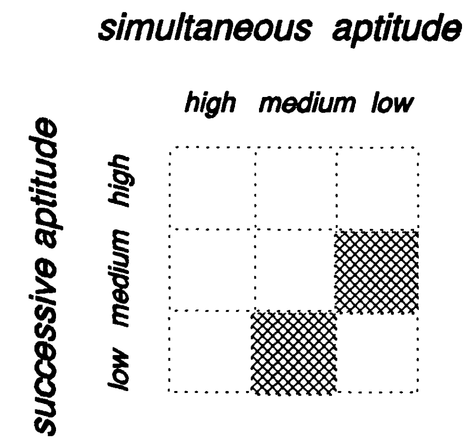
In the performance on tasks classified as manipulation of sets, there will be a significant disordinal interaction between the learning performance of the high simultaneous - low successive and low simultaneous - high successive processing aptitude groups under the verbal and spatial instructional methods.

Sub-Hypothesis 1C

In the performance on tasks classified as syllogistic reasoning, there will be a significant disordinal interaction between the learning performance of the high simultaneous - low successive and low simultaneous - high successive processing aptitude groups under the verbal and spatial instructional methods.

Statistical Hypothesis 2

There will be a significant disordinal interaction between the learning performance of the medium simultaneous - low successive and low simultaneous - medium successive processing aptitude groups (depicted below) under the verbal and spatial instructional methods.



Sub-Hypothesis 2A

In the performance on tasks classified as understanding and knowledge of elementary Set Theory and syllogisms, there will be a significant disordinal interaction between the learning performance of the medium simultaneous - low successive and low simultaneous - medium successive processing aptitude groups under the verbal and spatial instructional methods.

Sub-Hypothesis 2B

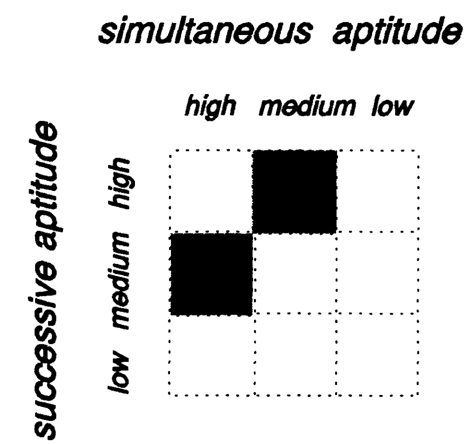
In the performance on tasks classified as manipulation of sets, there will be a significant disordinal interaction between the learning performance of the medium simultaneous - low successive and low simultaneous - medium successive processing aptitude groups under the verbal and spatial instructional methods.

Sub-Hypothesis 2C

In the performance on tasks classified as syllogistic reasoning, there will be a significant disordinal interaction between the learning performance of the medium simultaneous - low successive and low simultaneous - medium successive processing aptitude groups under the verbal and spatial instructional methods.

Statistical Hypothesis 3

There will be a significant disordinal interaction between the learning performance of the high simultaneous - medium successive and medium simultaneous - high successive processing aptitude groups (depicted below) under the verbal and spatial instructional methods.



Sub-Hypothesis 3A

In the performance on tasks classified as understanding and knowledge of elementary Set Theory and syllogisms, there will be a significant disordinal interaction between the learning performance of the high simultaneous - medium successive and medium simultaneous - high successive processing aptitude groups under the verbal and spatial instructional methods.

Sub-Hypothesis 3B

In the performance on tasks classified as manipulation of sets, there will be a significant disordinal interaction between the learning performance of the high simultaneous - medium successive and medium simultaneous - high successive processing aptitude groups under the verbal and spatial instructional methods.

Sub-Hypothesis 3C

In the performance on tasks classified as syllogistic reasoning, there will be a significant disordinal interaction between the learning performance of the high simultaneous - medium successive and medium simultaneous - high successive processing aptitude groups under the verbal and spatial instructional methods.

INSTRUCTIONAL MATERIALS

Two sets of instructional materials were prepared for the introductory Reasoning unit covering elementary tasks related to Set Theory and syllogistic reasoning. The instructional materials were labelled "Reasoning" to facilitate a simple reference for the Year 6 children. This material was new to the subjects. One of the two treatments was designed to advantage those individuals whose successive processing aptitude was superior to their simultaneous processing aptitude - this treatment, for convenient reference only, was labelled "verbal" and is presented in Appendix D, pp. 250-274. The other treatment was designed to advantage those individuals whose simultaneous processing aptitude was superior to their successive processing aptitude - this treatment, for convenient reference only, was labelled "spatial" (Appendix E, pp. 275-314). Each instructional treatment was designed for self-administration, requiring no added assistance on content from the supervising class teachers of the subjects.

Each of the two instructional treatments contained the same tasks and exercises, except for differences that related specifically to the instructional material on the two solution strategies for syllogisms - one a "spatial" strategy intended to capitalise on higher simultaneous abilities, the other a "verbal" strategy to cater for students with higher successive aptitudes - and other differences of a non-substantive nature. Conventional mathematical notation and symbols were used in both sets, consistent with the requirements of the participating schools that unorthodox or non-standard nomenclature not be employed, and that instructional material be presented in a manner consistent with that to be covered when their students progressed to high school.

In the "verbal" treatment, emphasis was placed on the verbalisation (expression in words, numbers and symbols without diagrammatic or pictorial adjuncts) of concepts, procedures and rules. It was intended that this treatment would predominantly demand successive processing in that the nature of the learning tasks would require a series of successive steps for both the learning of content and application of knowledge to operations. Although diagrammatic and spatial explication were avoided, the mathematical symbols used in the traditional teaching and testing of Set Theory were included.

The "spatial" treatment used spatial models as often as possible, including Venn diagrams where appropriate. It was intended that this treatment would predominantly demand simultaneous processing in that the nature of the learning tasks would facilitate simultaneous analysis and synthesis of content. During the instructional design stage of this treatment, it was perceived that there were numerous circumstances in which the nature of the material to be covered precluded a spatial treatment, but every effort was made in the design of this treatment to stimulate those with high simultaneous ability to develop understandings and derive solutions to the exercises and test questions by using spatial *reasoning*. In certain sections of the treatment, particularly those dealing with the meaning of symbols and terms, diagrammatic and spatial illustrations were included in addition to verbalised learning material. In these instances it was also judged that the verbalisation component was required in the spatial treatment because either the post-instruction testing necessarily, by convention, 'verbalised' questions, or because it was considered that the spatial adjuncts without the textual treatment were insufficient as sole explicators of the content to be learned. Nevertheless, by providing spatial adjuncts as alternate modes of presentation, this treatment offered the opportunity for investigation of the effect such adjuncts had on interaction with aptitude profiles.

The instructional and testing materials were divided into sections so that they could be administered by class teachers over a period of 8 lessons:

INSTRUCTION PART A

Lesson 1: Understanding and knowledge of Sets
Lesson 2: Manipulation of Sets
Lesson 3: Manipulation of Sets (cont'd)

INSTRUCTION PART B

Lesson 4: Understanding and knowledge of Syllogisms
Lesson 5: Strategies for solving syllogisms
Lesson 6: Deductive syllogistic reasoning tasks

POST-INSTRUCTION

Lesson 7: Post Test
Lesson 8: Delayed Test

TEST MATERIALS

Based upon the results of administration of a Trial Achievement Test (Appendix F, p. 316), two tests were constructed for the main study to assess the effectiveness of the instructional material and to test the research hypotheses. A Post Test (named an Achievement Test for the children, presented in Appendix G, p. 332) was administered immediately after the six lessons, and a Delayed Test (named a Follow-Up Test, given in Appendix G, p. 340). Corresponding question numbers in both post and delayed tests were equal in format and degree of difficulty, with changes made only to variables such as numbers, letters or words. All questions involved multiple choice answers. Test items were divided into three distinct categories to permit analyses in each of the domains. These were:

1. **Understanding and knowledge of Sets and syllogisms:**

   tasks related to understanding of concepts, and knowledge of the meanings of terms and symbols.

2. **Performance on Set manipulation tasks:**

   manipulatory tasks on aspects relating to set membership, subsets, union and intersection.

3. **Performance on deductive reasoning tasks related to syllogisms:**

   reasoning tasks to determine the validity of three types of affirmative linear syllogisms.

Test questions on syllogisms requiring deductive reasoning were divided into three types to facilitate finer analyses of potentially different levels of performance in the solution of (a) ordinary syllogisms, (b) nonsense syllogisms, in which mythical beings and fantasy attributes were used to represent the terms of the syllogism, and (c) abstract syllogisms in which letters were used for the terms of the syllogism.

The Post Test was administered immediately after the lessons were completed in the two Parts A and B. The students were allowed 45 minutes to complete the Post Test: 20 minutes for Part A, and 25 minutes for Part B. Schools were asked to administer the Delayed Test approximately one week after completion of the instruction, with the exact scheduling to be left to the respective class teachers in order to minimise further disruption to class timetables.

TRIAL STUDIES

There was a four stage trialing of the instructional and testing materials:

Stage 1

Four experienced teachers reviewed the materials and were asked to comment on presentation, suitability of content for early Year 6 subjects and timing of the Trial Achievement Test.

Stage 2

Four Year 6 female students from Mona Vale Public School worked through the materials under the close observation of the researcher to enable assessments of performance in each section, and particularly the timing of the various instructional materials, exercises and testing components.

Stage 3

The main trial study was conducted using the population of female students from Year 6 at Newport Public School, average age 11 years 11 months. Consistent with the relevant profiles of the subjects for the main study, this school draws its pupils from an area considered to be generally in the middle class socio-economic band in the northern beach suburbs of Sydney. Thirty-two subjects commenced the trial study and complete results were obtained for 28 of these children. Students who failed to complete the study were absent from school or class on one or more of the lessons or testing periods. The trial included the administration of the Trial Achievement Test as a pre-test, the instructional materials and the Trial Achievement Test as a post-test.

Stage 4

Additionally, the Trial Achievement Test was administered to a Year 7 class at Ravenswood School for Girls to provide further data for item analysis and refinement of the test for the main study. This class of students was instructed by the researcher in the Set Theory and syllogistic reasoning. Twenty-six students completed the test as a pre-test and again after instruction.

After the completion of lessons and tests in each of the latter three phases, the students were asked to point out difficulties they had encountered with the administrative instructions or material content of the lessons or test. The class teachers were also asked to work through the materials and make similar comments, as well as indicate any problems that they had observed, and also estimate maximum, mean and minimum times for each of the lessons and testing units.

Data from the performance of the 54 students who completed the Trial Achievement Test, post instruction, were subjected to item analysis in order to shorten the test from the trial's 40 questions, and at the same time increase its validity and reliability. The following analyses were undertaken:

(1) An Item Difficulty was obtained for each item, being the percentage of subjects who answered it correctly.

(2) The Cronbach's Coefficient Alpha provided a measure of test reliability

in terms of its internal consistency. This analysis also provided a correlation for each item with the remaining items ($r_{i(t-1)}$), and a revised Alpha coefficient should an item be deleted.

(3) A qualitative item analysis evaluated items for potential redundancy and for adequate coverage of questions regarding contribution to the testing of the breadth of instructional content, and the objectives of measurement.

The trial post test (Achievement Test) was further evaluated within the three classifications of question types:

UK: Understanding and knowledge of Sets and syllogisms (see Appendix F, p. 327 for results)

SM: Manipulatory tasks related to Sets (see Appendix F, p. 328)

SR: Deductive reasoning tasks related to syllogisms (see Appendix F, p. 329).

The analyses (1) and (2) above produced difficulty parameters and item - remaining items correlation for each item, and the alpha coefficient for each of the three sections. The general criteria used were to eliminate those questions with a $r_{i(t-1)}$ lower than 0.4, or a difficulty parameter outside the range 0.5 to 0.9[1].

An important result from the trial administration of the Achievement Test as a pre-test was the clear indication that such a pre-test was not justified as a part of the main study. It was evident to the class teachers during the testing, later confirmed by the analysis of the students answers, that the subjects at Year 6 level (and also those at Year 7) had no knowledge at all of Set Theory or syllogisms and were thus compelled to guess answers to all test items. This was not only a time-consuming activity for the students, but more importantly was found to be stressful. It was clearly perceived that the young students, academically focused by their schools, and attempting a test in which they were asked "to do their best", found such an

1 *The lower limit of .5 is generally higher than that conventionally accepted, for the reason that the trial testing was conducted using subjects in late Year 6 and late Year 7, compared with the early Year 6 students targeted for the main study.*

experience demeaning, confusing and humiliating. It was clear from the analysis of the trial pre-test data (see Appendix F, p. 330) that guessing was widespread when used as a pre-test, with the mean of the difficulty parameters for the 4-choice questions equal to .25 and for the 2-choice questions .41 .

The Achievement Test used in the trial was reduced from 40 to 26 questions for the main study, with the elimination of questions resulting in satisfactory alpha coefficients shown in Table 7.1.

TABLE 7.1 MAIN STUDY: REVISED ALPHA COEFFICIENTS.
UK - Understanding and Knowledge, SM - Set Manipulation,
SR - Syllogistic Reasoning

QUESTION TYPE	ALPHA COEFFICIENT
UK	.87
SM	.86
SR	.70

This revised test was administered as the Post Test, and with further non-substantive modifications such as changing variable names, also administered as the Delayed Test. These are presented in Appendix G, p. 332 and p. 340 respectively. Correct answers to the Post and Delayed Test questions are given in Appendix G, p. 350. Analyses of questions by broad category of content and by type of syllogism in the Post Test and the Delayed Test are included in Appendix G, pp. 351-352.

MAIN STUDY

The Subjects

The subjects involved in the study (Table 7.2) were the total female populations from the Year 6 classes at Abbotsleigh School, Pymble Ladies' College and Ravenswood School for Girls, with an average age at time of instruction 11 years 3 months (minimum 10 years 8 months, maximum 12 years 4 months). Each of these independent girls' schools draws its student population from the northern suburbs of Sydney. The area is considered to be generally in the middle class socio-economic band.

TABLE 7.2 DISTRIBUTION OF SUBJECTS COMPLETING STUDY 1, STUDY 2 POST TEST AND DELAYED TEST PARTS A & B

SCHOOL	STUDY 1	STUDY 2 PART A Unit & Post-Test	STUDY 2 PART B Unit & Post-Test	STUDY 2 PART A Delayed Test	STUDY 2 PART B Delayed Test
Abbotsleigh	89	86	84	82	81
PLC	147	143	142	139	137
Ravenswood	60	57	56	57	56
TOTALS	296	286	282	278	274

Each student was assigned scores on the two simultaneous and successive processing components obtained from Study 1. The scores for each component were divided into three approximately equal frequency bands, high-medium-low, thus partitioning the subjects into one of the nine aptitude groups as depicted in Figure 7.2.

FIGURE 7.2 SIMULTANEOUS - SUCCESSIVE APTITUDE GROUPS

		SIMULTANEOUS PROCESSING ABILITY		
		HIGH	***MEDIUM***	***LOW***
SUCCESSIVE PROCESSING ABILITY	***HIGH***	*GROUP1-HH*	*GROUP4-MH*	*GROUP7-LH*
	MEDIUM	*GROUP2-HM*	*GROUP5-MM*	*GROUP8-LM*
	LOW	*GROUP3-HL*	*GROUP6-ML*	*GROUP9-LL*

Administration of Instructional Materials

Each of the ten class teachers in the three participating schools was visited and asked to familiarise herself with the materials and procedures. Each teacher was re-visited after this process to ensure they had clear understandings of their role and responsibilities. None of the teachers raised or anticipated problems. The teachers were also reminded of the importance of not answering children's questions relating to the content of the instructional material, or permitting students to seek guidance or help in any form from peers, parents or textbooks. The instructional phase of this study involved a total of six class periods, which took place over an elapsed period of either three, four or five days, depending upon the timetabling restrictions of the respective schools and classes involved.

In each class, immediately prior to the initial distribution of the instruction booklets the teacher informed her students that they were to commence a unit of work on Reasoning which required them to work individually through a printed set of materials. The students were told that the work was not difficult and that the booklets contained all of the information they would require to answer all of the exercises, and if any particular problem with content should arise they were to refer back within the materials provided. It was emphasised that as there was more than one version of the teaching unit they were not permitted to work together and not to discuss the content of the lessons or exercises after classes.

Each student was randomly assigned one of the two instructional treatments such that an approximately equal number of subjects within each of the nine groups (Figure 7.2) was administered each of the two treatments. The name and parameters identifying each subject's relevant characteristics were printed onto self-adhesive labels attached to the instructional materials, the Post Test and the Delayed Test to ensure this distribution was effected.

The booklets were handed out at the start of each of the relevant school periods and collected at the end of each lesson. This procedure was adopted to minimise interaction between students who may have exchanged or compared notes, and between parents and students, and thus ensured as far as practical that the written materials were the single source of instruction for each child. Students were not permitted to proceed past the specific lesson(s) scheduled for the day. Approximately half of the time of the final lesson period was allocated to allow students to revise the total content. Any of the exercise questions not attempted during the lessons could be completed during this period.

In order to maximise the students' motivation and concentration, the children were informed that they would be assigned marks on each of the post and delayed tests and these would be recorded by their teacher for *potential* inclusion within their final mathematics mark for the term. Whether this actually occurred was left to the discretion of the respective class teachers. It is worthy of note that each of the schools chosen for the study places a heavy emphasis on academic achievement, and its students are generally academically competitive. The indication that marks *may* be collected for reporting purposes would have been a distinct motivation for maximising many of the subjects' concentration throughout the study.

Administration of Tests

The format and requirements of the Post Test were explained to the subjects before the question paper was distributed. Two practice examples were given to provide the subjects with an opportunity to understand the nature of the test. The 45 minutes given to complete the test proved to be adequate.

Test content was identical for both of the treatment groups. Test questions were either verbal or involved the use of standard symbols, consistent with the presentation of the exercises within both treatments. It was noted in the trial administrations of the Post Test that those students using the solution strategies provided in the "spatial" treatment took considerably longer than those using the "verbal" treatment's strategies. Thus, in order to ensure that both sets of students completed the test within the allocated time, the group of students who had been instructed by the spatial treatment were provided with additional worksheets (Appendix G, p. 348). This obviated the need for these students to draw the 48 circles necessary for the solving the syllogistic reasoning questions (8 questions x 6 circles per question), label each circle (48 labels) and diagramming (shading or marking with an X) the premises (24 operations). The worksheets included the circles, labels and the diagramming of the premises. The conclusion circles were labelled but not diagrammed.

RESULTS AND INTERPRETATION OF RESULTS

Analyses of Post Test and Delayed Test Data

The research design was intended to permit comparison of mean performances of subjects on a Post Test and a Delayed Test, with the major purpose of examining the interactions between two treatments of the instructional materials and aptitude profile groupings. The Post Test, administered immediately following instruction, and the Delayed Test, administered approximately one week after the completion of the instruction, each comprised 28 multiple-choice questions. The questions in both tests were of identical format and comparable challenge, with very minor alterations being made from the Post to the Delayed only in the content of the Sets for manipulation and in the terms used in the syllogisms. One mark was awarded for each correct answer and no marks for an incorrect answer. Where students had omitted to answer a question it was scored as incorrect, but with a separate code to distinguish the subject from an absentee.

Performance on each of the tests was divided into three distinct measures of achievement, with the third of these categories, syllogistic reasoning, being further sub-divided by type of syllogism. The dependent variables used to measure test performance were named:

POST TEST (P)

UK(P) Understanding and Knowledge
SM(P) Set Manipulation
SR(P) Syllogistic Reasoning.
- **ORD(P)** Syllogistic Reasoning - ORDinary syllogisms
- **ABS(P)** Syllogistic Reasoning - ABStract syllogisms
- **NON(P)** Syllogistic reasoning - NONsense syllogisms.

DELAYED TEST (D)

UK(D) Understanding and Knowledge
SM(D) Set Manipulation
SR(D) Syllogistic Reasoning.
- **ORD(D)** Syllogistic Reasoning - ORDinary syllogisms
- **ABS(D)** Syllogistic Reasoning - ABStract syllogisms
- **NON(D)** Syllogistic reasoning - NONsense syllogisms.

MANOVA Analyses

Multivariate analyses of variance were used with the above set of variables as the dependent variables, and the nine individual difference groups, the two treatments and the three schools as the independent variables. (Although the variable 'school' was not of interest in the hypotheses of this study, it was included to reduce the error variance.) There was a total of

274 subjects with 18 (2x9) groupings forming the cells for the analysis of data, with approximately 16 subjects in each of the 18 cells. Planned comparisons were developed to analyse specific contrasts within the individual difference groups.

The contrast matrix for the nine information processing ability groups is presented in Appendix H, p. 354. Other than the arbitrary contrasts to fulfil the requirements of the MANOVA program, three orthogonal contrasts of interest were constructed (Table 7.3), represented by the following vectors V1, V2 and V3, with each corresponding to one between-cell degree of freedom.

V1 HIGH simultaneous - LOW successive (GROUP3-HL)
contrasted with
LOW simultaneous - HIGH successive (GROUP7-LH)

V2 MEDIUM simultaneous - LOW successive (GROUP6-ML)
contrasted with
LOW simultaneous - MEDIUM successive (GROUP8-LM)

V3 HIGH simultaneous - MEDIUM successive (GROUP2-HM)
contrasted with
MEDIUM simultaneous - HIGH successive (GROUP4-MH).

TABLE 7.3 VECTORS OF INTEREST FOR MANOVA OF STUDY 2 DATA

GROUP->	1	2	3	4	5	6	7	8	9
V1	0	0	-1	0	0	0	1	0	0
V2	0	0	0	0	0	-1	0	1	0
V3	0	-1	0	1	0	0	0	0	0

Other vectors were examined, and will be discussed below, but these three orthogonal contrasts were considered to be central to the hypotheses being investigated in this study. For each contrast vector of interest, the MANOVA provided two test criteria: a multivariate F-ratio and the univariate F-ratios. In the model, the main contrasts V1, V2 and V3 were tested along with their interactions with treatment. The effects were tested (processed) in the following

order: V1 GROUP3-HL:GROUP7-LH BY TREATMENT
V2 GROUP6-ML:GROUP8-LM BY TREATMENT
V3 GROUP2-HM:GROUP4-MH BY TREATMENT
SCHOOL BY TREATMENT
GROUP3-HL:GROUP7-LH
GROUP6-ML:GROUP8-LM
GROUP2-HM:GROUP4-MH
GROUP1-HH:GROUP9-LL
SCHOOL

Results of this design are reported below. The multivariate F-ratio is the most general test criterion, being a measure of the variation in the data as a whole. The univariate F-ratios are the results that would be obtained if each of the dependent variables was treated separately in a one-way analysis of variance. Where the p-level is $\leq .01$, the results were considered to be significant. Where the significance of the F-ratio is $\leq .05$, the results were discussed and interpreted for tendency. In all cases the actual probability level is reported.

The Post Test and Delayed Test observed means of achievement for each of the nine aptitude groups are given in Table 7.4, shown separately for the subjects instructed by the spatial treatment and for the subjects instructed by the verbal treatment. Figure 7.3 depicts the effect on performance of the two treatments in relation to differing information processing aptitude profiles for each of the three categories of learning investigated within the Reasoning Unit. Post Test and Delayed Test observed means and standard deviations for each aptitude group are detailed in Appendix H, pp. 355-356.

TABLE 7.4 THE POST TEST (AND DELAYED TEST) OBSERVED MEANS FOR EACH OF THE NINE APTITUDE GROUPS LEARNING FROM THE SPATIAL AND FROM THE VERBAL TREATMENT

UNDERSTANDING AND KNOWLEDGE

Spatial Treatment

successive \ simultaneous	H	M	L
H	7.21 (7.64)	6.67 (6.67)	5.19 (5.31)
M	6.46 (6.91)	5.16 (5.44)	4.50 (5.50)
L	5.80 (5.47)	5.60 (5.00)	3.75 (3.81)

Verbal Treatment

successive \ simultaneous	H	M	L
H	6.50 (6.31)	6.44 (6.71)	4.73 (4.60)
M	5.64 (7.14)	4.44 (4.38)	5.67 (5.35)
L	6.20 (6.00)	4.62 (5.05)	4.70 (4.40)

SET MANIPULATION

Spatial Treatment

successive \ simultaneous	H	M	L
H	7.50 (8.00)	5.80 (5.47)	4.83 (4.50)
M	7.18 (6.00)	6.00 (6.17)	5.14 (4.86)
L	6.07 (5.47)	5.67 (5.43)	3.81 (4.18)

Verbal Treatment

successive \ simultaneous	H	M	L
H	5.69 (6.44)	6.38 (5.36)	4.93 (4.33)
M	7.14 (7.32)	6.00 (5.78)	4.43 (5.00)
L	6.00 (6.13)	5.38 (5.52)	3.60 (4.70)

SYLLOGISTIC REASONING

Spatial Treatment

successive \ simultaneous	H	M	L
H	8.00 (8.43)	6.33 (7.00)	6.06 (5.69)
M	7.09 (7.64)	6.00 (7.33)	5.14 (5.71)
L	6.87 (7.33)	5.47 (6.93)	5.00 (6.31)

Verbal Treatment

successive \ simultaneous	H	M	L
H	7.94 (8.00)	7.44 (8.36)	7.00 (7.67)
M	5.59 (6.64)	6.00 (6.88)	5.76 (6.40)
L	4.73 (5.80)	4.86 (5.62)	4.60 (4.90)

Results related to Statistical Hypothesis 1

The study investigated the interaction between information processing aptitudes and instructional treatments designed to optimise learning performance, with hypothesis predicting that there would be disordinal aptitude-treatment interactions.

TABLE 7.5 CONTRAST V1 GROUP3-HL : GROUP7-LH BY TREATMENT
UK - Understanding and Knowledge, SM - Set Manipulation,
SR - Syllogistic Reasoning, (P) Post Test, (D) Delayed Test

MULTIVARIATE STATISTICS	F	Sig. of F
Hotellings (Effect size .09)	3.81	<.001
UNIVARIATE STATISTICS		
UK(P)	.70	.403
SM(P)	.05	.823
SR(P)	8.88	.003
UK(D)	2.19	.140
SM(D)	1.46	.228
SR(D)	12.73	<.001

There was a significant disordinal interaction between the verbal and spatial instructional treatments and the high simultaneous - low successive and low simultaneous - high successive processing ability groups (multivariate F-ratio 3.81, $p < .001$, effect size .09) using post and delayed test performance in 'understanding and knowledge', 'set manipulation' and 'syllogistic reasoning' as dependent variables. The associated univariate F tests (Table 7.5) indicated that the dependent variable responsible for the significant effect was that category of test items classified as syllogistic reasoning, namely SR(P) in the Post Test and SR(D) in the Delayed Test (for the Post Test: univariate F-ratio 8.88, $p=.003$; for the Delayed Test: F-ratio 12.73, $p<.001$). Thus, in relation to Statistical Hypothesis 1, Hypothesis 1C has been supported, with Statistical Hypotheses 1A and 1B not supported. These results suggest that the degree of interaction between information processing abilities and matching treatments is dependent upon the nature of the task demands placed upon the subjects by the content of instruction.

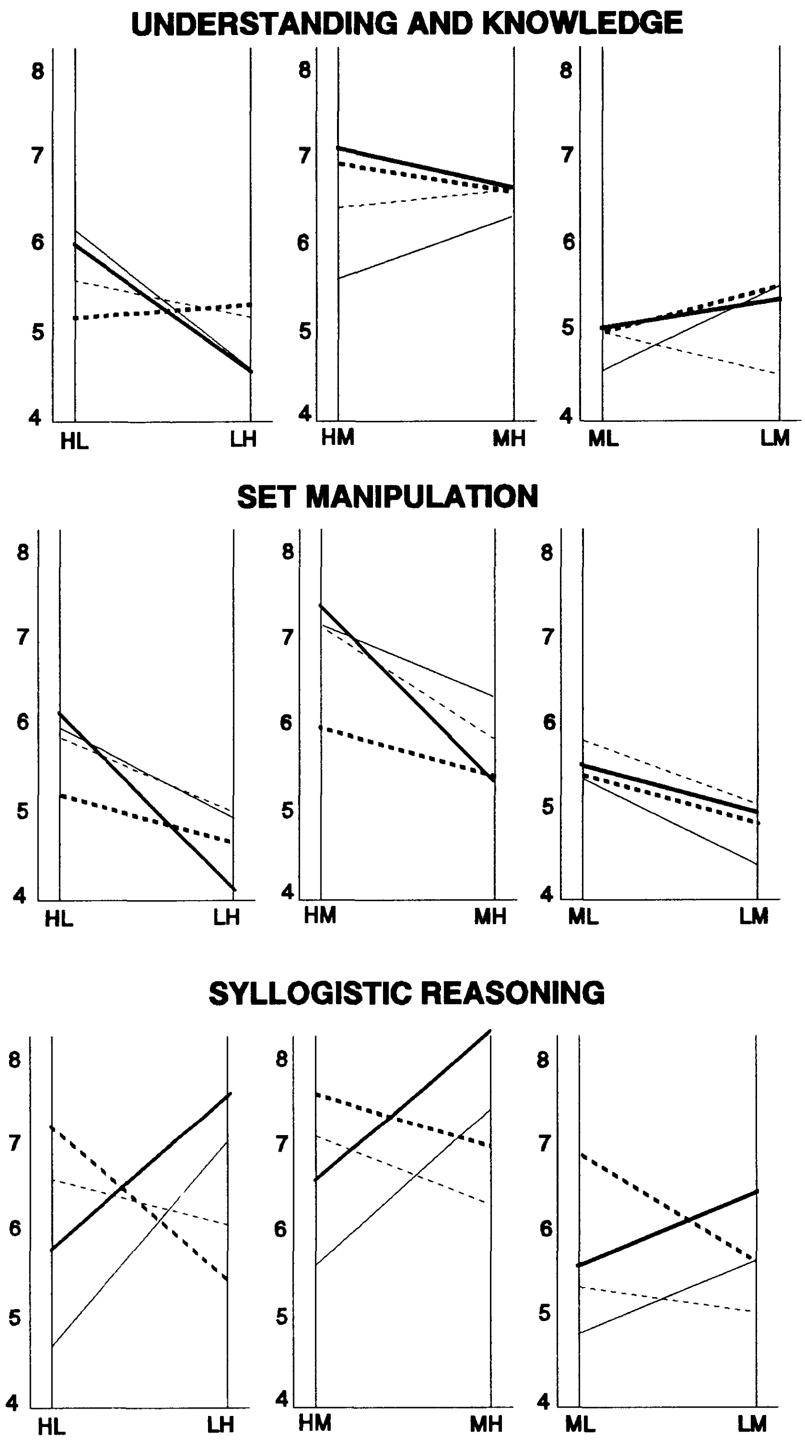
Results related to Statistical Hypothesis 2

The interaction between the two treatments and the medium simultaneous - low successive and low simultaneous - medium successive ability groups was not significant at the .01 level. As indicated in Table 7.6, the multivariate F was 2.21, probability .044, and the effect size .05. However (consistent with a similar trend suggestive of disordinal interaction for the high simultaneous - medium successive and medium simultaneous - high successive processing ability groups reported below, and consistent with the significant interaction reported above) it would have been an error if this trend, clearly depicted in Figure 7.3, was not considered. Also consistent with these findings, this effect was due to the subjects' performance in the syllogistic reasoning tasks in the Delayed Test, F ratio 4.49, p=.035, with the effect related to the syllogistic reasoning task data from the Post Test being less pronounced.

TABLE 7.6 CONTRAST V2 GROUP6-ML : GROUP8-LM BY TREATMENT
UK - Understanding and Knowledge, SM - Set Manipulation,
SR - Syllogistic Reasoning, (P) Post Test, (D) Delayed Test

MULTIVARIATE STATISTICS	F	Sig. of F
Hotellings (Effect Size .05)	2.21	.044
UNIVARIATE STATISTICS		
UK(P)	3.40	.067
SM(P)	.22	.642
SR(P)	1.05	.312
UK(D)	.04	.843
SM(D)	.00	.996
SR(D)	4.49	.035

FIGURE 7.3 INTERACTIONS BETWEEN APTITUDE GROUPS AND TREATMENTS FOR EACH CATEGORY OF LEARNING:



LEGEND:

———— verbal treatment - post test
━━━━ verbal treatment - delayed test
- - - - - - - spatial treatment - post test
•••••••• spatial treatment - delayed test

H - high, M - medium, L - low aptitude: first letter indicates simultaneous, second successive.

Results related to Statistical Hypothesis 3

There was a similar trend, although not significant, (Table 7.7, and depicted in Figure 7.3) suggestive of disordinal interaction between high simultaneous - medium successive and medium simultaneous - high successive ability groups and treatment. The effect contrast V3 by treatment produced a multivariate significance F 2.32, p=.034, effect size .05. An inspection of the univariate F tests indicated that this effect was primarily due to the performance of the subjects in the syllogistic reasoning tasks, in both the Post Test and the Delayed Test. (For the Post Test: SR(P) univariate F-ratio 4.97, p=.027; for the Delayed Test: SR(D) F-ratio 3.41, p=.066). This is consistent with the trend reported above for the contrast vector V2 (GROUP6-ML:GROUP8-LM) and the significant interaction of contrast vector V1 (GROUP3-HL:GROUP7-LH by treatment).

TABLE 7.7 CONTRAST V3 GROUP2-HM : GROUP4-MH BY TREATMENT
UK - Understanding and Knowledge, SM - Set Manipulation,
SR - Syllogistic Reasoning, (P) Post Test, (D) Delayed Test

MULTIVARIATE STATISTICS	F	Sig. of F
Hotellings (Effect Size .05)	2.32	.034
UNIVARIATE STATISTICS		
UK(P)	.08	.777
SM(P)	.08	.782
SR(P)	4.97	.027
UK(D)	1.81	.180
SM(D)	3.32	.070
SR(D)	3.41	.066

Other Results of Interest

Pearson's correlation coefficients for the relationships between component scores and test performances in syllogistic reasoning (Table 7.8) indicate a significant correlation between the successive component and test performance for subjects administered the verbal treatment of .53** for Post Test and .51** for the Delayed Test. However the imposition of the verbal treatment on those subjects with superior simultaneous abilities resulted in an absence of any meaningful correlation between performance and the simultaneous component (.09 for the Post Test and .05 for the Delayed Test). The above coefficients clearly indicate that the verbal treatment of syllogistic reasoning tasks was successful in catering for successive aptitude.

A corresponding result is indicated for the spatial treatment, in that the coefficients for the relationships between component scores and test performance in syllogistic reasoning (Table 7.8 below) demonstrate that this treatment advantaged those subjects with superior simultaneous aptitudes. This was a significant relationship, indicated by the correlation between performances in the Post and Delayed Tests and the simultaneous component (coefficients of .34** and .38**), whereas for subjects higher in successive aptitude being administered the spatial treatment the correlation between performances and the successive component were weaker (coefficients of .22* and .10 respectively).

The Pearson's correlation coefficients in Table 7.8 also indicate that the successive aptitude may be more dominant for solving the restricted class of affirmative syllogistic reasoning tasks undertaken by the subjects. The spatial treatment appears to have inhibited the use of successive solution strategies. For subjects higher in successive aptitudes, the correlation between the successive component and performances in both tests were .53* and .51** when administered the verbal treatment, which is in contrast with correlations of .22* and .10 when subjects were administered the spatial treatment; whereas, correspondingly, the correlation coefficients for subjects whose cognitive style would suggest a habitual preference for spatial solution strategies were, when administered the spatial treatment, .34** and .38** for both tests between performance and the spatial component, and .09 and .05 when the successive treatment was imposed.

TABLE 7.8 PEARSON'S CORRELATION COEFFICIENTS: APTITUDE COMPONENTS AND SYLLOGISTIC REASONING TEST PERFORMANCE
[SR - Syllogistic Reasoning, P - Post Test, D - Delayed Test]

VERBAL TREATMENT	
POST TEST SR(P)	
COMPONENT1 (SUCCESSIVE)	.53 **
COMPONENT2 (SIMULTANEOUS)	.09
DELAYED TEST SR(D)	
COMPONENT1 (SUCCESSIVE)	.51 **
COMPONENT2 (SIMULTANEOUS)	.05
SPATIAL TREATMENT	
POST TEST SR(P)	
COMPONENT1 (SUCCESSIVE)	.22 *
COMPONENT2 (SIMULTANEOUS)	.34 **
DELAYED TEST SR(D)	
COMPONENT1 (SUCCESSIVE)	.10
COMPONENT2 (SIMULTANEOUS)	.38 **

With regard to the Set manipulation tasks undertaken by the Year 6 subjects, the correlation coefficients in Table 7.9 indicate that the simultaneous processing aptitude is the more dominant influence on performance. This relationship was clear irrespective of whether they were administered the verbal or the spatial treatment. For subjects who learnt from the verbal treatment, Set manipulation test performance correlated with the simultaneous aptitude component at .39* and .36** in the Post and Delayed Tests respectively, whereas the corresponding coefficients with the successive aptitude were .11 and -.04 respectively. For those who learnt from the spatial treatment, Set manipulation test performance again correlated significantly with the simultaneous aptitude component at .41* and .34** in the Post and Delayed Tests respectively, whereas the correlation coefficients with the successive aptitude were .22* and .24* respectively.

TABLE 7.9 PEARSON'S CORRELATION COEFFICIENTS: APTITUDE COMPONENTS AND SET MANIPULATION TEST PERFORMANCE

SM - Set Manipulation, (P) - Post Test, (D) - Delayed Test

VERBAL TREATMENT	
POST TEST SM(P)	
COMPONENT1 (SUCCESSIVE)	.11
COMPONENT2 (SIMULTANEOUS)	.39 **
DELAYED TEST SM(D)	
COMPONENT1 (SUCCESSIVE)	.04
COMPONENT2 (SIMULTANEOUS)	.36 **
SPATIAL TREATMENT	
POST TEST SM(P)	
COMPONENT1 (SUCCESSIVE)	.22 *
COMPONENT2 (SIMULTANEOUS)	.41 **
DELAYED TEST SM(D)	
COMPONENT1 (SUCCESSIVE)	.24 **
COMPONENT2 (SIMULTANEOUS)	.34 **

A further finding of interest was that the subjects, over all categories of learning, improved their performance from the Post to the Delayed Test, as shown in Table 7.10. (Detailed data on the observed means and standard deviations for the Post Test and Delayed Test by school are presented in Appendix H, p. 357, by school class in Appendix H, p. 358, and by type of instructional treatment in Appendix H, p. 361).

TABLE 7.10 PERCENTAGE GAINS IN OBSERVED MEANS DELAYED TEST TO THE POST TEST BY SCHOOL.

DELAYED (%) - POST (%)	COMBINED (% change)	SCHOOL 1 (% change)	SCHOOL 2 (% change)	SCHOOL 3 (% change)
TOTAL SCORES	3.0	2.8	2.2	5.4
UNDERSTANDING & KNOWLEDGE	1.9	2.4	0.1	5.8
SET MANIPULATION	-0.5	-2.7	-0.1	3.5
SYLLOGISTIC REASONING	7.2	8.3	6.8	6.4

General reasons for the 3% overall improvement in observed means from the Post Test to the Delayed Test for the sample population can only be speculative, but it is suggested that one or more of the following factors may have contributed:

1. As the three schools are particularly academic in focus, it is likely that numbers of students sought explanations for material they did not understand from either parents or teachers in the period between the Post Test and commencement of the Delayed Test.

2. Three specific school classes appeared to have been given help or instruction in the period between the two tests. See below for more detailed analysis.

3. There may have been a more settled and confident ambience for the second testing period for numbers of subjects.

4. Cognisant of the possibility that student concentration may have needed re-kindling from the Post Test, students sitting for the Delayed Test were advised that they would each be given a chocolate frog for doing their very best on every question. This reward for concentration was not offered for the Post Test.

5. Three syllogisms in the Delayed Test were more readily "guessed" correctly by weaker students. See below for analyses.

Particular explanation was sought for the substantial 7.2% improvement (see Table 7.10) in the observed means for the syllogistic reasoning tasks from Post to Delayed Tests. (Observed means and standard deviations for performance in the Post and Delayed Tests for types of syllogism are presented in Appendix H, pp. 359-360.) Two possible reasons for this rise can be offered:

1. It appears that classes 1-H, 2-H and 3-G (see Appendix H, p. 358) may have had additional instruction in strategies for the solution of syllogisms in the period between the completion of the Post Test and the commencement of the Delayed Test. These three classes raised their performance in the three categories of syllogisms (Ordinary, Nonsense and Abstract) as follows: 1-H by 32%, 11% and 12% respectively; 2-H by 18%, 25%, 0%; and 3-G by 20%, 20% and 7%. These figures compare with mean improvements for the population of 9%, 10% and 3%. It is worthy of note that two of the these classes (2-H and 3-G) also were identified as being two of three classes with substantially increased performance in Set manipulation between the two tests: 7.0% and 7.4% respectively, compared with a fall of .5% for the population (data in Appendix H, p. 360).

2. There was an improvement in performance by type of syllogism from Post Test to Delayed Test, for Ordinary Syllogisms of 9.1%, Abstract Syllogisms of 3.2% and Nonsense Syllogisms of 10.6%, as shown by the changes in test means:

	Ordinary	Abstract	Nonsense
Post Test (P) %	54.9	68.1	56.8
Delayed Test (D) %	64.0	71.3	67.4
Change [(D)-(P)] %	9.1	3.2	10.6

The reasons for these differential rises may be partly explained by the analysis of two nonsense syllogism questions (Q21, Q22) and one ordinary syllogism question (Q27) being more readily guessed by weaker students: from the tabulation below, empirical guesses in the Post Test for the validity of the conclusions would have resulted in all three being incorrect, whereas in the Delayed Test all three would have resulted in correct answers.

Post Test Conclusions		**EMPIRICAL GUESS**	**CORRECT RESPONSE**
Q21.	All dogs bark.	**valid**	**invalid**
Q22.	Some snowdrops like to sing.	**invalid**	**valid**
Q27.	All gums are trees.	**valid**	**invalid**

Delayed Test Conclusions		EMPIRICAL GUESS	CORRECT RESPONSE
Q21.	All big cats roar.	**invalid**	**invalid**
Q22.	Some macropods like to hop.	**valid**	**valid**
Q27.	All Australians are artists.	**invalid**	**invalid**

Evidence that weaker students applied experiential knowledge and differentially benefited from this situation in the Delayed Test, compared with the Post Test, is provided from the performance of the high aptitude GROUP1-HH compared with the low aptitude GROUP9-LL. For GROUP1-HH in the Post Test the percentage of correct answers to the above three syllogistic reasoning questions was 72.2% which rose to 81.1% in the Delayed Test, whereas for GROUP9-LL in the Post Test the percentage of correct answers to the above three syllogistic reasoning questions was only 38.5% but rose considerably to 66.7% in the Delayed Test. The conclusion that weaker students adopted an empirical strategy when compared with stronger students is given further support by noting the contrast of this change with the relatively stable percentage of correct responses to the remaining seven syllogistic reasoning questions: for GROUP1-HH, 82.8% (Post) 82.3% (Delayed); for GROUP9-LL, 52.7% (Post), 53.8% (Delayed). These findings confirmed that when the arrangement of terms in the conclusion of a (non-abstract) syllogism can be related directly to either clearly reinforcing or countering real-world experience, young students, and particularly those in the lower ability levels, may be induced to provide the empirical solution that they experientially "know" to be correct and ignore the methodology they had been taught for solving syllogisms. This finding is consistent with that reported by Scribner (1977) and Koopmans (1987), the latter reporting "... 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 ...". Hawkins et al. (1984) also found this same source of error repeatedly surfacing in numerous studies in which there was evidence of the dichotomy between formal reasoning in accord with logical procedures and ignoring the truth of the premises, and providing simplistic intuitive answers derived by analogy from practical experience.

In the present research, the general level of performance on *abstract* syllogisms, in which the potential for analogy with personal experience is inherently precluded, are taken to be true indicators of reasoning capacity. In solving abstract syllogisms in affirmative categorical form (performance detailed in Appendix H, p. 359 and p. 362), the young subjects (average age 11 years 3 months) demonstrated they had reached cognitive maturation adequate for sophisticated deductive reasoning tasks. This finding supports studies by Johnson (1984), Markovits et al. (1989) and Mason (1980).

TABLE 7.11 PERFORMANCE ON SYLLOGISM TYPES AS DEPENDENT VARIABLES - CONTRASTS GROUP3-HL : GROUP7-LH BY TREATMENT, GROUP6-ML : GROUP8-LM BY TREATMENT, GROUP2-HM : GROUP4-MH BY TREATMENT

ORD - Ordinary Syllogisms, ABS - Abstract Syllogisms, NON - Nonsense Syllogisms, (P) Post Test, (D) Delayed Test

	GROUP by	HL : LH treatment	GROUP by	ML : LM treatment	GROUP by	HM : MH treatment
MULTI-VARIATE	F	Sig. of F	F	Sig. of F	F	Sig. of F
Hotellings	3.32	.004	1.87	.088	1.67	.129
UNI-VARIATE						
ORD(P)	3.16	.077	1.65	.201	0.72	.396
ABS(P)	3.85	.051	1.29	.258	5.71	.018
NON(P)	4.79	.030	0.04	.851	1.41	.237
ORD(D)	14.70	<.001	1.68	.196	4.10	.044
ABS(D)	5.10	.025	8.28	.004	3.22	.074
NON(D)	2.06	.152	0.05	.830	0.49	.826

A final MANOVA of performance was conducted using the three types of syllogisms (ordinary, abstract and nonsense) in the Post and Delayed Tests (Table 7.11). The effect was significant (multivariate F-ratio 3.32, p=.004) for the contrast vector of central interest to this study, namely treatment with the high simultaneous - low successive group (GROUP3-HL) with the low successive - high simultaneous group (GROUP7-LH). At the level of significance accepted for this study, the dependent variable most responsible for the significant effect was performance in ordinary syllogisms in the delayed test (univariate F-ratio 14.70, p<.001). There are interesting analogous trends in the other categories of syllogism for this contrast, and also within the other contrasts shown in Table 7.11. Variability in the data can be attributed to the small number of items within each of the three sub-categories of syllogisms (3 ordinary syllogism test items, 3 nonsense syllogisms, 4 abstract syllogisms).

Supplementary Analyses

Although not part of the main study design, it seemed desirable to investigate aptitude-treatment interactions foı a broader partitioning of subjects than that reported above, with a view to potential application to classroom management. The aim was to investigate the ATI when a typical classroom of students, in the normal school situation, is divided into three aptitude groups of practical and meaningful size. This partitioning produced interesting and positive implications for the individual difference model as a basis for optimising learning by accommodating individual differences in cognitive abilities. The MANOVA analysis was performed with the division of subjects based upon the 3x3=9 cell matrix analysed above (refer to Chapter 6, and Figure 6.3) but with subjects aggregated into one of the three broader information processing aptitude groups:

GROUP **SIM** This group subsumed the three (of the original nine) groups GROUP2-HM, GROUP3-HL and GROUP6-ML, containing subjects who have a simultaneous aptitude superior to their successive aptitude

GROUP-EQUAL This group subsumed GROUP1-HH, GROUP5-MM and GROUP9-LL, containing subjects who were assessed as having approximately equal aptitudes for both simultaneous and successive processing

GROUP SUC This group subsumed GROUP4-MH, GROUP7-LH and GROUP8-ML), containing subjects who have a successive aptitude superior to their simultaneous aptitude

The MANOVA used performance in the Post and Delayed Tests (within the three categories of tasks 'understanding and knowledge', 'Set manipulation', 'and syllogistic reasoning') as the dependent variables, and the three groups GROUP SIM, GROUP SUC and GROUP EQUAL, treatments and schools as the independent variables. Results are shown in Table 7.12.

TABLE 7.12 CONTRAST GROUP SIM : GROUP SUC BY TREATMENT
UK - Understanding and Knowledge, SM - Set Manipulation,
SR - Syllogistic Reasoning, (P) Post Test, (D) Delayed Test

MULTIVARIATE STATISTICS	F	Sig. of F
Hotellings (Effect Size .09)	5.68	<.001
UNIVARIATE STATISTICS		
UK(P)	.37	.540
SM(P)	.19	.664
SR(P)	10.19	.002
UK(D)	1.86	.173
SM(D)	2.33	.128
SR(D)	16.11	<.001

There was a significant interaction between the verbal and spatial instructional treatments and the contrast of GROUP SIM (higher simultaneous than successive) with GROUP SUC (higher successive than simultaneous) ability groups (multivariate F-ratio 5.68, p <.001, effect size .09). The associated univariate F tests (Table 7.12) indicated that the dependent variable responsible for the significant effect was again, consistent with the analyses reported above, the test tasks classified as syllogistic reasoning (for the Post Test: univariate F-ratio 10.19, p=.002; for the Delayed Test: F-ratio 16.11, p<.001). In practical terms, this result is of some importance as it indicates that the individual difference model has utility when students are partitioned into these broader groups based upon readily measurable differences in cognitive abilities.

A further contrast of interest was GROUP1-HH with GROUP9-LL. Although not the basis of a specific hypothesis of this research, it is interesting to examine the effects of the "high simultaneous - high successive" aptitude group and the "low simultaneous - low successive" aptitude group within this individual difference model.

TABLE 7.13 CONTRAST GROUP1-HH : GROUP9-LL
UK - Understanding and Knowledge, SM - Set Manipulation,
SR - Syllogistic Reasoning, (P) Post Test, (D) Delayed Test

MULTIVARIATE STATISTICS	F	Sig. of F
Hotellings (Effect Size .20)	9.89	<.001
UNIVARIATE STATISTICS		
UK(P)	19.87	<.001
SM(P)	22.70	<.001
SR(P)	38.20	<.001
UK(D)	27.87	<.001
SM(D)	27.22	<.001
SR(D)	23.76	<.001

This effect, as indicated in Table 7.13, was significant (multivariate F 9.89, p <.001, effect size .20) with the univariate F tests indicating that the effect was uniformly due to the range of tasks in both the Post Test and in the Delayed Test.

DISCUSSION

The principal aim of the study was to examine the effect on learning when instructional materials are tailored to suit individual ability patterns. The senior primary school subjects were grouped according to differences in cognitive abilities as characterised in the model of A. R. Luria (1966a - 1982). Two treatments of an elementary Reasoning Unit were developed, one a "spatial" treatment designed to optimise learning for subjects high in simultaneous processing, the other a "verbal" treatment to advantage those high in successive processing. Performance on post and delayed tests was analysed in three distinct categories of learning, namely 'syllogistic reasoning', 'Set manipulation' and 'understanding and knowledge'.

For the dependent variable syllogistic reasoning, analyses confirmed significant disordinal interaction between treatment and the contrast high simultaneous - low successive (HL) aptitudes versus low simultaneous - high successive (LH) aptitudes. As hypothesised, the performance of the HL cognitive ability group, in both post and delayed tests, was better under spatial instruction than verbal instruction, and the performance of the LH group better under verbal than spatial instruction. A non-significant disordinal interaction was reported for syllogistic reasoning tasks between treatment and the medium simultaneous - low successive vs low simultaneous - medium successive ability groups, and between treatment and the high simultaneous - medium successive vs medium simultaneous - high successive groups. The finding of significant disordinal interaction for the HL vs LH contrast by treatment for syllogistic reasoning tasks generally supports the results from a similar study conducted by

Walton (1983) using Year 11 subjects (Walton's Study 3 also found significant disordinal interaction between the aptitude contrast high simultaneous - low successive vs low simultaneous - high successive and treatment for syllogistic reasoning tasks.) The findings of the present study are consistent with a series of studies on the solution of syllogisms by Sternberg and Weil (1980) who confirmed an aptitude-strategy interaction in syllogistic reasoning tasks. Analogous to the present study, Sternberg and Weil's "spatial" treatment presented a distinctive spatial strategy for the solution of affirmative linear syllogisms, in marked contrast to the "verbal" treatment strategy involving successive solution procedures. They concluded:

> "The effectiveness of a given strategy for solving linear syllogisms depends on one's pattern of abilities. ... the strategy represented by the linguistic model seems 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)

For the performance on Set manipulation tasks, hypotheses of significant disordinal interactions between aptitude and treatment were not supported. For these tasks, the level of ability for simultaneous processing appeared to be the most influential variable affecting achievement, regardless of treatment, and an aptitude x treatment effect did not occur. Performance on Set manipulation test tasks was positively related to simultaneous ability, irrespective of which treatment was administered (Figure 7.3). The relationship between the simultaneous component and test performance on Set manipulation was confirmed by Pearson's correlation coefficients (Table 7.9), suggesting that the inherent nature of the demands of Set manipulation tasks would seem to involve a major component of simultaneous processing. An analysis of the test items on Set manipulation in both the Post Test and the Delayed Test indicates that all but two of the nine questions required the inspection of two or three Sets and the making of decisions on either sub-sets, or unions, or intersections. It seems likely that students would normally use simultaneous processing in these tasks, in that more than one structure may be comprehended and processed simultaneously for the correct answer to be derived. It would, of course, be possible for each of these items to be processed cognitively by successively dealing with each of the elements in each of the sets serially and in the process identify the required elements and progressively arrive at the answer. However, it is unlikely that many students would adopt this mode of solution, being rather laborious, when compared with the strategy of solving the question "by inspection", by simultaneous inspection. The predominant use of simultaneous processing in Set manipulation tasks indicated by the results of this study is consistent with Luria's view that "arithmetic operations always depend upon the integrity of simultaneous syntheses" and is generally supportive of Ashman and Das (1987) who assert that the essence of simultaneous processing is "the integration of information into a quasi-spatial, holistic manner so that the relationship between elements can be immediately determined". Other researchers, including Krutetskii (1976), Skemp (1971) and Sultan (1962), have also linked spatial abilities with mathematics generally.

In relation to the 'understanding and knowledge' tasks, hypotheses of significant disordinal interaction were not supported. For the paired associate type learning in this topic area, (such as learning the meaning or equivalence of terms and symbols 'element', 'empty set', $\subset$, $\cap$, $\cup$ and $\in$ in Set Theory, and syllogistic terms such as 'middle term', 'premise' and 'conclusion'), the spatial instructional treatment *necessarily* required a high component of verbal material. Notwithstanding endeavours to minimise this verbal content and design into the spatial treatment diagrammatic and pictorial adjuncts that would require spatial *reasoning*, the results indicated that the information processing contrasts were not variables significantly related to learning performance. It appears that the use of the diagrammatic and pictorial adjuncts did not materially advantage those students with high simultaneous processing ability. The findings of this study related to 'understanding and knowledge' parallel those of a study by King, Roberts and Kropp (1969) which found no significant interaction between aptitude and treatment for the learning of elementary Set Theory concepts. In their study there was no indication that material presented with figural adjuncts advantaged subjects whose "figural" aptitude was higher than their "verbal" aptitude. King, Roberts and Kropp (1969) suggested that the lack of significant interaction in this area was due to the two treatments being insufficiently different, even though the use of diagrams and symbols was maximised in the figural treatment and the verbal content of the figural treatment was minimised. These researchers concluded that the figural enhancements of the verbal treatment were not instrumental in optimising learning for those with higher abilities in this dimension of cognitive ability. The results of the present study also replicate numerous studies reviewed by Cronbach and Snow (1977), including those of Bracht (1969), Gagné and Gropper (1965), Roberts and Kropp (1969) and Salomon (1971). It appears that the presence of diagrams does not necessarily transform a treatment into one requiring spatial reasoning within the domain of simultaneous information processing.

In summary, varying patterns of aptitude x treatment interaction were found for the three categories of learning investigated, suggesting that the task demands placed upon the learner by the *content* of the instructional material is a major determinant of the occurrence and/or nature of interaction. For syllogistic reasoning tasks, significant disordinal interaction was indicated between aptitude and treatment. This interaction was facilitated by the nature of the tasks being amenable to the development of a disparate solution strategy for each of the two treatments - one a "spatial" strategy using Venn diagrams and necessitating spatial *reasoning*, and the other a verbal treatment emphasising step-wise procedures necessitating successive information processing. For content involving 'understanding and knowledge', the task demands - the coding processes required to input and process the content - were such that there was no significant learner aptitude x treatment effect. The alternate spatial and verbal treatments did not appear to call predominantly upon simultaneous analysis / synthesis and successive analysis / synthesis respectively. For 'Set manipulation' tasks, it appears that the content primarily called upon only one of the information processing abilities under study, results indicating that these tasks demand predominantly simultaneous processing. The relationship of only one of the two abilities under consideration with a sub-set of the independent variables precluded ATI effects in relation to that sub-set. This finding is consistent with the conclusions of Cronbach and Snow (1977) following reviews of ATI research and with Hunt and Randhawa (1983) who reported:

> "What appears to emerge from the research in this area is that the interaction of [the dimensions of the Luria model] is complex and is not dependent upon whether the individual has other processes at his/her disposal to use at his/her option for the attainment of a particular goal, but also dependent upon whether the nature of the task itself requires specific processes for its completion."
> (Hunt and Randhawa, 1983, p. 207)

The finding of Study 2 indicating that the nature of the content to be learnt is critical in producing ATI effects suggested a follow-up study. The design of Study 3 allowed a more detailed investigation into the nature of the interactions between patterns of cognitive abilities and matching treatments by employing clinical interview and observation of individual subjects as they worked through Set Theory tasks. This study strategy allowed an in-depth exploration of strategies and processes of learners performing on those tasks that had failed to exhibit aptitude x treatment effects in Study 2, and for qualitative and quantitative assessment of the influence on learning of pictorial and diagrammatic adjuncts to verbal instructional materials.

CHAPTER 8

STUDY 3: AN APTITUDE-TREATMENT INTERACTION STUDY IN ELEMENTARY SET THEORY

INTRODUCTION

Review of Study 2

The results for the three categories of learning in Study 2 indicated that the interaction between treatment and information processing aptitude varied with the nature of content of the instructional materials. Study 2 demonstrated that for the criterion 'syllogistic reasoning' there was significant disordinal aptitude x treatment interaction, but not for the criterion tasks that involved 'understanding and knowledge' and 'Set manipulation'. It was suggested that for the type of paired associate learning tasks involved in the 'understanding and knowledge' category of learning the diagrammatic and pictorial adjuncts to verbal material within the "spatial" treatment did not require the subjects to engage in spatial processing in the sense of active spatial reasoning. For the criterion tasks 'Set manipulation', Study 2 findings suggested that the absence of disordinal aptitude x treatment interaction could be explained by the significant correlation between learning performance and simultaneous ability, the dependency being such that alternate treatments were not able to influence markedly the task-dependent nature of the processing demands placed upon the learner.

Aims of Study 3 and Study Strategy

As a result of this analysis, a third study was conducted to explore in more depth the relationships between individual differences in cognitive abilities and matching treatments of the two categories of learning in elementary Set Theory that had not exhibited significant disordinal interaction in Study 2. The follow-up study involved individual observation and clinical interview of each subject as she worked through the instructional materials, in contrast to the group-administered pen-and-paper approach of Study 2. This study strategy allowed a probing analysis of each subject's learning strategies and underlying cognitive processes, and a fuller exploration of the influence on attitudes and learning performance of pictorial and diagrammatic supplements to verbal instructional materials. Thus two treatments of elementary Set Theory (based on the materials used in Study 2) were designed for Study 3, one a "verbal" treatment containing only words, letters, numbers and symbols, and the other, for convenience only called a "spatial" treatment, which was in effect the verbal treatment supplemented with pictorial and diagrammatic adjuncts. Although the tasks of Study 3 were confined to an understanding of the basic concepts of Set Theory and the manipulation of Sets, it is likely that the study could have potentially broader ramifications for ATI investigations and the practical implementation of findings into the primary school classroom. Much of the nature of learning at this level of schooling involves simple knowledge acquisition such as the paired associate type learning investigated as part of this study.

Using a new group of female Year 6 subjects (N=251), the preliminary phase of Study 3 involved the administration of five of the six information processing aptitude tests used in

Study 1, plus a sixth Sets test. The latter test was designed to examine the loading of the Set manipulation tasks on the two dimensions of information processing defined by the Luria model and investigated in this research. Component scores were used to identify within the total population two sub-groups of students (N=49) with a pattern of cognitive abilities of either "high simultaneous - low successive" or "low simultaneous - high successive" processing aptitudes. These individuals were then involved in the major phase of Study 3 as each undertook learning and exercises prescribed in one of the alternative (randomly assigned) "spatial" or "verbal" instructional treatments on elementary Set Theory designed for the study. These subjects also completed a post test.

REVIEW OF RELATED RESEARCH

A central concern of this study was to identify and explore the characteristics of a "spatial" treatment that would advantage subjects with high spatial aptitudes, with specific regard to the interaction between learner-aptitudes and pictorial and diagrammatic adjuncts to verbal instructional materials. Thus it seemed appropriate to examine the Luria model's dimension of simultaneous information processing within the context of recent research investigating mental imagery and spatial processing generally, and also the findings of studies that have specifically explored learner-picture interaction.

Simultaneous Processing and Spatial Processing

It is useful to compare the "simultaneous information processing" dimension of the Luria model with Paivio's (1971, 1976) depiction of the "imaginal processing mode" as part of his dual coding model, and also with recent researchers' (eg. Kosslyn, 1984, 1988; Poltrock and Brown, 1984) work proposing a multi-faceted componential view of "spatial abilities".

The information processing models of Luria (1966a, 1976b) and Paivio (1971, 1976) have been the two most influential models upon which much of the later research in the area has been based. Luria's work has been discussed in Chapter 4 and later chapters, and Paivio's model in Chapter 3. Paivio advanced an information processing model which proposed a dual coding modality that individuals use to represent external stimuli at the mnestic level. Paivio envisaged a "sensory modality" as incorporating visual-auditory coding, and a "symbolic modality" as a verbal - non verbal continuum. Paivio (1976) suggested that the tasks used to define Luria's simultaneous and successive processing dimensions may also be considered to involve "visual" and "verbal" processing respectively. The modality of sensory coding, in the sense envisaged by Paivio, has been investigated by Kosslyn (1983), Kosslyn and Pomerantz (1977), Metzler and Shepherd (1974), and Shepard (1982) whose research has been directed at the encoding and storing of images. Their studies have proposed that visual images are encoded in picture analogue format (rather than in a propositional format that would be required as the retention pattern for verbal information). One of the contributions these researchers (particularly Kosslyn and colleagues) have made to the conception of spatial abilities has been the indications arising from their research which suggest that "imagery is carried out by multiple processes, not all of which are implemented equally effectively in the same part of the brain" (Kosslyn, 1988). This multi-faceted view of image encoding followed earlier work by Bishop (1983) who conceived of "visual information processing" as comprising two abilities: one for interpreting figural information such as charts and diagrams, and the other for visual processing as culture-independent processing (manipulation, translation) of visual imagery. The growing body of recent research findings (e.g. Kosslyn and Shepherd and their co-workers) suggests that visual processing is comprised of a number of component abilities and that the individual employs a specific sub-set of these according to the nature of the task at hand and the cognitive style of that individual.

There is a conceptual distinction between the image encoding cognitive activity which is the focus of these researchers and the simultaneous information processing dimension of the Luria model. Image encoding, itself appearing to be a multi-faceted dimension, may be appropriately viewed as one of the available component processes which form part of simultaneous analysis / synthesis of the Luria model. Kirby and Das (1976) also see Paivio's view of image coding as a *partial* description of Luria's simultaneous dimension. Luria's research suggests that simultaneous processing embraces both the encoding of the image *and* the necessary information *processing* (see below), depending on the tasks demanded by the nature of the content. It is considered useful to envisage Luria's simultaneous analysis / synthesis of information in this manner as comprising a number of sub-processes. Some justification for this view may be derived from a consideration of the component activities that are required to answer a test item in the criterion tests of simultaneous processing ("Shapes", "Paper" and "Matrix A"). Dependent upon the task and the individual's momentary conscious aims, simultaneous information processing may include one or more of the activities: (i) discerning the characteristics of the image they perceive as pertinent to the task, (ii) coding at the requisite quality, (iii) transforming, (iv) comparing, (v) editing, and (vi) retrieving. As suggested in the discussion of the findings of Study 2, the demands of the task within the content of instructional materials is an influential factor in determining which sub-abilities are required.

Learner-Picture Interaction

One aim of Study 3 was to investigate learner interaction with diagrams and pictures supplementing verbal instructional material. The verbal material consisted of words, letters, numbers and symbols, devoid of diagrams and pictures. In earlier discussion in Chapter 7, consideration was given to a major class of learning in primary school curricula, analogous to simple associative type learning, which includes symbol-word or word-phrase equivalence (eg.

">" means "greater than", "maison" means "house", "octagon" has "eight" sides, "middle term" - "occurs in both premises"). It was suggested that, for this category of simple associative learning, the addition of pictorial and/or diagrammatic material which merely requires the subjects to code (inspect) the images but not to *further process* them in the sense of employing *spatial reasoning*, may not enhance the learning process for those higher in simultaneous abilities. Though these images may be coded, perhaps in a manner analogous to the picture analog theorists' view of mental pictures being replicas of spatial images, it is likely that they do not require further spatial transformation.

On the other hand, some research suggests that the presentation of additional pictorial information, even though not encouraging further image processing at a level deeper than that of simple image encoding, does in fact assist the learning of subjects high in simultaneous processing. For example, as well as iconic representation persisting longer as retrieval clues, Stader et al (1990), in their studies on the conjoint retention hypothesis (a derivative of the dual coding theory, in which semantic propositions are assumed to represent verbal / linguistic information, and images represent perceptual / spatial information) found that the two types of code can provide retrieval clues to one another. They report:

> "Kulhavy, Caterino and Melchiori (1990) validated and extended predictions based on the conjoint retention hypothesis. They replicated the finding that verbal content is best remembered when it is tied to an intact spatial representation during encoding." (Stader et al, 1990, pp. 1-2)

Burton and Wildman (1978) also support the use of iconic material as aids to recall. They operationalised Paivio's dual systems of imaginal and verbal coding as acoustic and visual systems. In a study with Grade 3 children, a pool of 75 monosyllabic nouns (such as bird, star etc.) were presented auditorily and by visual stimuli in the form of reverse field slides (yellow on black) containing either a line drawing or block printed word. They concluded:

> "The present results argue for the applicability of the dual coding hypothesis to young children. In general, recall of pictures was superior under all interference conditions."
> (Burton and Wildman, 1978, p. 7)

In a study of the use of picture adjunct aids with Grade 4 students, Hughes and Hall (1983) classified the subjects into a 2x2=4 cell matrix they defined as HH (high picture-high word), HL, LH and LL (low picture-low word). The study examined interaction between these groups of subjects and experimenter-provided picture adjunct aids on simple prose recall tasks. The researchers found the learner x picture interaction was not significant in every analysis, although the significant interactions that were found and the general pattern of results supported the hypothesis that picture adjunct aids are of more advantage to the LLs than the HHs. It is of interest to this study that Hughes and Hall (1983) did not find significant interaction between treatment and the HL:LH aptitude groups. The researchers observed that some subjects may need to be induced to notice and actively code the pictures for a facilitating effect to be observed. With regard to this need for cueing the adjuncts, Beck (1991) found that:

> "Cueing strategies can help young learners increase their knowledge of pictorially-related information; instructional designers should probably devote more attention to cueing illustrative materials."
> (Beck, 1991, p. 19)

However the research work on learner x picture interaction has principally elaborated on aids to recall rather than on the *process* dimension of simultaneous analysis / synthesis of the Luria model.

RESEARCH QUESTIONS FOR STUDY 3

Study 3 was designed to provide the necessary data to address three specific research questions.

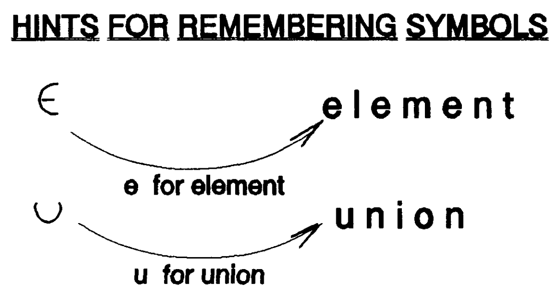
Question 1 Do the demands placed upon the learner by elementary *Set manipulation* tasks, such as union, intersection and sub-set exercises, inherently require application of simultaneous ability?

Some affirmative evidence was provided by the Study 2 finding that simultaneous ability was correlated with test performance measures for these tasks. This relationship was indicated irrespective of whether a subject was administered a "spatial" treatment or a "verbal" treatment of the material. To examine further the proposition that Set manipulation tasks inherently demand spatial aptitudes, a further criterion test "Sets" was designed to be administered in conjunction with criterion aptitude tests used in Study 1. This first phase of Study 3 involved principal component analyses of data from the administration of the criterion tests (the five derived from Study 1 plus the new Sets Test) and examine the component loadings of the Sets Test.

Question 2 In acquiring *understanding and knowledge* of elementary Set Theory, is there an aptitude x treatment interaction between 'high simultaneous - low successive' and 'low simultaneous - high successive' ability profiles and alternate 'verbal' and 'spatial' treatments, when the 'verbal' treatment is designed to instruct using only words, numbers, letters and symbols, and the 'spatial' treatment is constructed by supplementing the verbal presentation with diagrammatic and pictorial adjuncts?

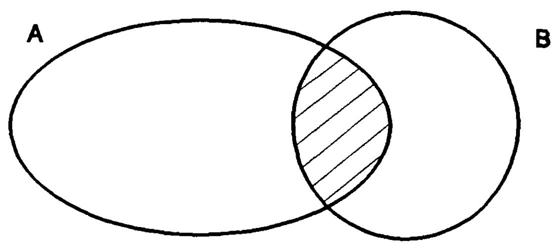
Paired associate type learning is a common requirement for much of the introductory material of elementary Set Theory. It is also a significant form of learning in primary school curricula, being involved in learning dates, place names, elementary number facts, native - foreign language vocabulary and symbol equivalence. The learning tasks used in the exploration of this research question were word / phrase equivalences of Set Theory symbols such as $\in$ $\}$ $\cap$ and $\cup$. Such tasks can be characterised as factual learning necessitating rote learning for fast unprocessed parrot-like recall (a Leont'ev 'operation'), with a minimal component of understanding or cognitive reasoning. Study 3 explored the effect on learning of diagrammatic and pictorial adjuncts to verbal materials, such as depicted in Figure 8.1, designed to teach these simple associative learning tasks.

FIGURE 8.1 EXAMPLE I OF DIAGRAMMATIC ADJUNCT



In addition to factual learning, the study included tasks that required concept understanding. Examples of the type of concept understanding required, within the primary curricula, are grammatical structures of language, natural science phenomena and mathematical concepts such as place value. The tasks chosen for this study were the understanding of terms "set" and "element", and the understanding of concepts of "union", "intersection" and "sub-set". These tasks demands are similarly a follow-on from Study 2, treated in some greater depth so as to facilitate the investigation of this research question. An example, from Study 3 materials, of diagrammatic presentation of content designed to aid subjects in these tasks is shown in Figure 8.2.

FIGURE 8.2 EXAMPLE II OF DIAGRAMMATIC ADJUNCT



An INTERSECTION contains elements that are common to both sets.

The study design allowed for the investigation of individual learning processes and measurement of learning performance for the concept understanding and associative learning tasks categorised as 'understanding and knowledge'. Study 3 specifically addressed the potential benefits to students high in spatial aptitudes of having the presentation of instructional material for these tasks augmented with diagrams and pictorial representation in the manner typified in Figures 8.1 and 8.2, and generally investigated picture-learner interaction.

Question 3 In acquiring the ability to perform *Set manipulation tasks*, is there an aptitude x treatment interaction between 'high simultaneous - low successive' and 'low simultaneous - high successive' ability profiles and the alternate 'verbal' and 'spatial' treatments?

Although Study 2 failed to demonstrate a significant aptitude-treatment interaction for tasks designated as Set manipulation, the clinical interview of individual subjects as they proceeded through the instructional materials permitted a more detailed appraisal of the effect such adjuncts have on learning procedures and attitudes, in addition to the resultant effect on performance of Set manipulation tasks as measured by a Post Test.

PILOT STUDY OF SETS TEST

The new Sets Test involved Set Theory questions of three types: union, intersection and sub-set. The administration of the test was similar in format to that used for Matrix A in Study 1 in which a series of patterns were displayed for 5 seconds, and, after each one was removed from view, the students' task was to copy each pattern by joining nine dots on their answer sheets. In the Sets Test, two groupings of characters (numbers, letters, or words) were displayed for 5 seconds whilst the students were asked to respond to one of three item types:

A) *Write the members common to both groups.*

EXAMPLE: { *G, A, D* } { *D, K* }

or B) *Write all members in both groups, but do not repeat any member.*

EXAMPLE: { *F, P, B, A, K* } { *A, F* }

or C) *Are all the members in the bottom group in the top group. (Yes or No?)*

EXAMPLE: { *7, axe, P, 3* }

{ *P, A, 3* }

The phrasing of questions in this way obviated the need for the students to know the meaning of Set Theory terms intersection, union and sub-set. The Sets Test was trialled in conjunction with items from the three Span Tests and the Paper Folding Test used in Study 1. The number of items in each of the latter four tests was reduced by approximately 30% for the trial. (Marking of the Study 1 criterion tests had indicated that shorter tests would provide equally well-defined outcomes for the identification of the two information processing dimensions of the Luria model.) Thirty-two Year 6 students from Oxford Falls Grammar School were used as subjects for the pilot study. The underlying structure of the battery of all five tests was investigated using Principal Component Analysis. The Varimax rotated factor matrix supported the existence of two components, consistent with the findings in Study 1, with component loadings (Appendix I, p. 364) indicating as anticipated that the Sets Test loaded more heavily on the simultaneous component than on the successive component. Data from the performance on the Sets test were subjected to item analyses (Item Difficulty and Cronbach's Alpha) and a qualitative review for homogeneity within the three item types, namely intersection, union and sub-sets (for results see Appendix I, pp. 365-367). Sixteen questions from the 28 used in the Trial Sets Test were selected for use in the main study. This process resulted in a satisfactory Alpha for each of the three types of questions (union .72, intersection .78, sub-sets .70), as presented in Appendix I, p. 368. The indications were that data derived from the shortened versions of the four criterion tests were adequate to provide satisfactory aptitude measures.

APTITUDE TESTING

Test Materials and Administrative Instructions

The aptitude testing comprised six tests:

1. Number Span Test (as trailed - Study 1 test, but with reduced items)
2. Letter Span Test (as trialled - Study 1 test, but with reduced items)
3. Word Span Test (as trialled - Study 1 test, but with reduced items)
4. Shapes Test (as trialled - Study 1 test, but with reduced items)
5. Paper Folding Test (as used in Study 1, same items)
6. Sets Test (new test - described above)

The administrative instructions and scoring for the first five of these tests were identical to those used in Study 1 and are included in Appendix A, pp. 225, 227, 229 and Appendix B, pp. 232 and 237. The test items used in Study 3 are presented in Appendix J, pp. 370-374. Administrative instructions for the Sets Test are given in Appendix J, p. 375 and test items in Appendix J, p. 376. Correct answers for Tests 4, 5 and 6 are provided in Appendix J, p. 377.

The Subjects

The Year 6 classes from five independent girls' schools were used for Study 3. The schools were similar in socio-economic status (middle class) and geographical location (northern suburbs of Sydney) to those chosen for Studies 1 and 2. Two hundred and fifty-one students completed the testing (Table 8.1).

TABLE 8.1 DISTRIBUTION OF SUBJECTS - PRELIMINARY PHASE - STUDY 3

SCHOOL	STUDENTS COMPLETING APTITUDE TESTING
LORETTO	63
QUEENWOOD	49
ROSEBY	39
TARA	60
WENONA	40
TOTAL	251

Results of Aptitude Testing

The observed means and standard deviations of the test variables used in the study for the population (N=251) and for each of the five participating schools is presented in Appendix K, p. 379, with the correlation matrix for the six test variables in Appendix K, p. 380.

Initially, data from the first five of the above six tests, namely Number, Letter, Word, Shapes and Paper Folding, were analysed using principal component analysis with varimax rotation. The rotated component structure (detailed in Appendix K, p. 381) resulted in Number, Letter and Word tests loading respectively .90, .88, and .83 and defining a successive component; and a simultaneous component also well defined by Shapes and Paper Folding tests loading .84 and .83 respectively, explaining 73.8% of the variance.

A second Principal Component Analysis was then performed on the complete battery of six tests, thus adding the Sets variable into the analysis. As anticipated, the latter primarily loaded on the simultaneous component, as shown in Table 8.2. A clear factor structure again emerged with the first three tests (Number Span, Letter Span and Word Span) loading .90, .88 and .83

respectively on the successive component, and the latter three tests (Shapes, Paper Folding and Sets) loading .80, .76 and .80 on the simultaneous component, accounting for 69.4 % of the variance.

TABLE 8.2 VARIMAX COMPONENT LOADINGS OF THE SIX VARIABLES NUMBER SPAN, LETTER SPAN, WORD SPAN, SHAPES, PAPER FOLDING AND SETS ON THE TWO COMPONENTS OBTAINED FROM THE PRINCIPAL COMPONENT ANALYSIS OF RAW SCORE DATA (N=251)

	COMPONENT 1	COMPONENT 2
NUMBER SPAN	.90	.03
LETTER SPAN	.88	.05
WORD SPAN	.83	.16
SHAPES	-.02	.81
PAPER FOLDING	.06	.76
SETS	.13	.80

Thus it can be concluded that Set manipulation tasks of the nature provided to the subjects of this study, with test items displayed for the times specified in the administrative instructions, call upon information processing aptitudes that are primarily simultaneous in nature.

INDIVIDUAL SUBJECT OBSERVATIONS AND CLINICAL INTERVIEWS

Subject Selection and Instructional Treatment Allocation

Using component scores obtained from the aptitude testing phase of Study 3, students were partitioned into one of nine aptitude groups (Appendix K, p. 382) by dividing these scores representing each of the two dimensions of the Luria model into approximately three equal frequency bands named "high", "medium" and "low". The two groups of interest for the clinical phase of this study were defined as those with "high" simultaneous and "low" successive aptitudes (HL)[1] and those with "low" simultaneous and "high" successive aptitudes (LH). These two groups, GROUP-HL and GROUP-LH, formed the sub-sample of subjects (N=49) selected for individual observations and clinical interviews.

Two new treatments were designed. The "verbal" treatment (Appendix L, pp. 385-391) presented the instructional material in a textual format comprising words, letters, numbers and the necessary Set Theory symbols. The "spatial" instructional materials (Appendix L, pp. 392-402) provided diagrammatic and pictorial adjuncts to the text of the verbal treatment. Each of these two subject sub-groups, GROUP-HL and GROUP-LH, were then divided at random into two further sub-groupings (Appendix K, p. 383) such that half of each group could be given the "verbal" treatment of the Study 3 instructional materials and the other half the "spatial" treatment. Thus four cells were formed, each containing approximately 12 subjects. All students classified into the two groups of interest completed the clinical phase of the study, the researcher returning to the schools in two cases of absenteeism.

Interview Process: Development and Organisation

It has long been realised by psychometric researchers engaged in exploring cognitive processes and mental abilities (eg. Frederiksen, 1986, Markovits et al, 1989, Mason, 1980, Posner and Gertzog, 1982) that an item in a "paper-and-pencil" test may be measuring one ability in one subject and a quite different ability in another. In a pragmatic sense, "paper-and-pencil" group testing may be the only sensible testing strategy for large numbers of subjects, but it does not offer the researcher the opportunity to investigate underlying strategies and processes employed in answering a test item - all that is available for analysis is the *result* of these

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1 *In all GROUP names in this research the first identifying letter represents the level of simultaneous aptitude and the second the successive aptitude. Example: HL indicates high simultaneous - low successive.*

processes recorded as a simple end-of-cognition response on paper. Sternberg and Weil (1980) and Frederiksen (1986) specifically warn of the risks involved in drawing conclusions on cognitive processes based upon analysis of answers to pen-and-paper tests designed to investigate the application of information processing abilities. They contend, for example, that an item that requires the inversion and then reproduction of a geometrical figure may be solved using spatial processing ability by a subject proficient at imagining the rotation of figures in space, or that the solution may be derived by using successive ability by an individual who is proficient at solving the same problem in a step-by-step analytical fashion. This concern is considered relevant to the particular task demands and aptitudes being investigated in this research. For example, given adequate time, it is obvious that individuals may either solve, or potentially at least check their solution to, Set manipulation problems, hypothesised to be indicators of spatial aptitude, by employing predominantly successive processes by dealing with each Set's members sequentially. Further, there is the probability that the solution process chosen by a subject may be neither wholly spatial nor wholly successive, the proportions perhaps varying with the specifics of each item (such as number of elements in a Set).

To investigate the cognitive processes of subjects in this phase of Study 3, the individuals were interviewed as they worked through the instructional materials and exercises. The procedures adopted were based upon the technique developed by Piaget (1967) in his *clinical method*:

> "'The clinical method ... does not confine itself to superficial observations, but aims at capturing what is hidden behind the immediate appearance of things' (Piaget 1926, pp. xiii-xiv). The method is highly flexible, allowing a skilful researcher both to probe the areas of knowledge domain of particular interest and to let the subject speak freely, while constantly checking his or her spontaneous remarks for those that will prove genuinely revealing."
> (Posner and Gertzog, 1982, p. 197.)

Ginsberg (1981) and Markovits et al (1989) assert that an observation and clinical interview strategy is particularly appropriate for the discovery of cognitive processes and reasoning methods. The observation and interview procedure developed for this study essentially consisted of a number of pre-determined structured probes (Appendix L, p. 403), with supplementary opportunities for obtaining non-directed comment, both during instruction (detailed within the instructional materials as Exercises 1, 2 and 3 and included in Appendix L, pp. 385-391 - Verbal, pp. 392-402 - Spatial) and post instruction (given as a Post Test, Appendix L, p. 406-408). This procedure permitted exploration of individual underlying cognitive processes employed during both the learning phase as the subject proceeded through the self-administered lessons *and* as each worked through the set exercises.

Crawford (1986) used the clinical interview process to illustrate the relationships between cognitive variables of the Luria model and mathematical problem solving behaviours. As part of her rationale for the use of this process, she highlighted a potential problem relevant to this study:

> "Ericsson & Simon (1984) provide a detailed argument supporting the use of verbal protocols as useful and valid means of testing data. They point out that from an information processing point of view, subjects can only report the information they are "heeding" in immediate memory. Thus information about tasks involving automatic elements is not readily accessible to awareness and is difficult to obtain through verbal protocols. In the study reported here, it might be expected that subjects will effectively report surveyable simultaneous processing but be less able to explain automated operational routines. It would be expected that operational routines will be encoded in the successive mode."
> (Crawford, 1986, p. 175)

Crawford (1986) also draws attention to a further barrier to an experimenter recording data during a clinical interview that truly reflects the unaffected thinking of the subject. The problem she highlights is likely to arise when the interview is conducted in a "cooperative mode". She suggests that interviewer-subject interaction of a collaborative nature may develop which "may influence the thinking processes used" (Crawford, 1986, p. 176). However, in the present study, the mode of interview is not interactive in the sense that the experimenter did not work through the lessons and exercises cooperatively *with* the subject, as was the case in Crawford's (1986) study in which she identified step-by-step processes a subject performed in solving multi-step mathematical problems. In contrast, in the present study, the subject was questioned on processes undertaken immediately after each unique task or exercise, rather than during the process.

Pilot Study of Instructional Treatments and Interview Process.

Trials were conducted using students from Oxford Falls Grammar School who had participated in the aptitude testing trials (as described above). Of the thirty-two subjects originally tested for information processing aptitudes, six were classified as either high-low or low-high in each of the two information processing dimensions of the Luria model. As a result of the trial process, changes to the planned procedures were made to include a formalised "counter-suggestion" technique to discern manufactured responses, which tended to be unstable, from genuine beliefs. It was further decided to introduce the subjects to the interview session by saying: "These lessons have been made in different ways. So it doesn't matter what you say about this version. Please don't think you'll upset me if you criticise this version. Say what you really think." Also, taping recording was suspended for the last two trial interviews because it seemed that the young subjects were coming into an environment that was too controlled and pressured - tape recorder, stop watch and questioning. More open and forthright comments and reactions seemed to flow from a more relaxed environment.

The final interview, exercise and testing procedure required the subject to provide:

- 16 separate ratings, on a scale of 1 to 7, of various aspects of the instructional materials, (refer to Appendix L, p. 403 for structured probes),
- descriptive answers to 6 directive process questions,
- responses to a number of non-directive "comment" opportunities - the number varying with the need or otherwise for follow-up,
- answers to 11 exercise questions undertaken during instruction (questions are given within the instructional materials as Exercises 1, 2 and 3 in Appendix L,

pp. 385-391 - Verbal and pp. 392-402 - Spatial, and the correct answers in Appendix L, p. 409),

- answers to a Post Test - 14 questions immediately post instruction (Appendix L, pp. 406-408, with answers in Appendix L, p. 409).

ANALYSES OF RESULTS

Analyses of Post Test Data - Learning Performance

Analysis of learning performance was restricted to data from the Post Test undertaken by the subjects immediately upon completion of the self-administered lessons. In some instances during the Observed Exercises, answered by the subjects at intervals throughout the observation / interview session, minor hints were provided by the researcher in the interests of maintaining a productive and interactive session, and thus the performance data from this facet of the study (detailed in Appendix M, p. 412) were not used in the analysis of results. The correlation between achievement in the Observed Exercises and in the Post Test was .93, $p<.01$.

The quantitative data from the Post Test was analysed for performance on:

UK: understanding and knowledge

and SM: Set manipulation tasks (intersection, union and sub-sets).

The observed means and standard deviations are shown in Table 8.3 for subjects in the high simultaneous-low successive (GROUP-HL) and low-simultaneous-high successive (GROUP-LH) with regard to the specific treatment administered. These data are depicted in Figure 8.3. The observed means and standard deviations by school are presented in Appendix M, p. 411.

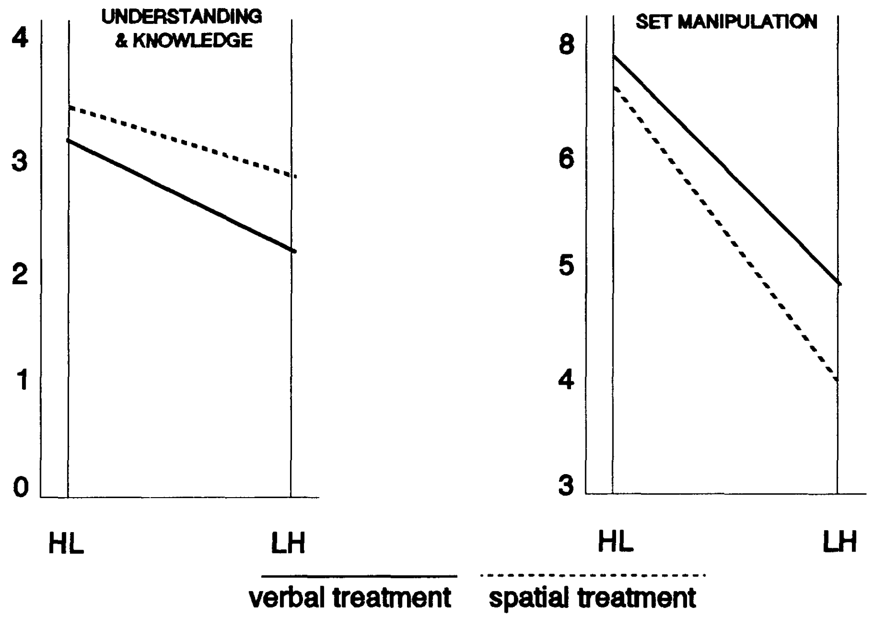
TABLE 8.3 POST TEST OBSERVED MEANS

UK: Understanding and Knowledge SM: Set Manipulation
GROUP-HL: High Simultaneous - Low Successive
GROUP-LH: Low Simultaneous - High Successive

		UK	SM
"SPATIAL" TREATMENT			
GROUP-HL	$\bar{x}$ s	3.46 0.69	6.55 1.18
GROUP-LH	$\bar{x}$ s	2.86 1.41	4.00 2.35
"VERBAL" TREATMENT			
GROUP-HL	$\bar{x}$ s	3.15 1.57	6.85 2.19
GROUP-LH	$\bar{x}$ s	2.18 0.98	4.82 1.66

The data indicate that the addition of diagrams and pictorial representations to verbal instructional materials did not advantage learning performance, as measured by the Post Test, of those subjects with high-simultaneous - low successive processing aptitudes, relative to subjects with low simultaneous - high successive aptitudes, for either the gaining of understanding of primary concepts and factual knowledge related to Set Theory or for Set manipulation tasks. The relevant observed means from Table 8.3, presented diagrammatically in Figure 8.3, indicate that the Post Test Set manipulation tasks demanded predominantly simultaneous aptitudes, supporting the finding from Study 2 and also consistent with that from the Sets Test administered as part of aptitude testing phase of this study.

FIGURE 8.3 APTITUDE-TREATMENT INTERACTIONS
OBSERVED MEANS - POST TEST
GROUP-HL: High Simultaneous - Low Successive
GROUP-LH: Low Simultaneous - High Successive



For the sample population, the Pearson's correlation coefficient between performance on Set manipulation tasks and the simultaneous processing component based on incomplete distributions was .46 ($p \leq .001$) and with the successive component was -.48 ($p \leq .001$), also indicating subjects predominantly apply simultaneous processing abilities for Set manipulation tasks with perhaps successive processing abilities interfering with performance. This quantitative data was supported by anecdotal evidence collected during the interview and observation procedure when subjects responded to queries on the method they adopted to solve Set manipulation tasks that were part of the set exercises within the instructional treatments. Over 80% of the subjects (see Appendix M, p. 413 for detail) indicated that for "intersection", "union" and "sub-set" tasks, the procedure they adopted was to span the two sets given in the question and while doing so arrive at their answer from this total perspective, rather than deal with individual set elements successively. It is worthy of note that some students found it hard to verbalise the method they had used to derive their solutions. Some of the responses recorded as subjects were queried on their procedure for solving Set manipulation tasks were:

> "I looked at one whole set at a time."
> "I could see the answer straight off."
> "I looked at the question and got the answer in one go."
> "Because I just saw blue in both of them at once."
> "I looked at all the numbers in [Set] A and I remembered the numbers in B were in A as well."
> "I did not need to read the numbers one a time."
> "My eyes went straight across, and I saw the answer immediately."

More detailed answers of interest were provided by the following students:

Kim[1]: "I looked at one Set with the other Set. I didn't need to say one number at a time to myself because there were only a small number of numbers. It's like reading a word to yourself instead of its letters."

Katie: "I looked at Set B first because I realised it had less numbers, and then I said to myself it's orange and blue and kept them in my head, then looked at Set A and found no orange so I said blue."

Odette: "The union is all. First there was blue in both, I could see that at once, so I called out blue, then I read the rest."

Aimee: "I saw if any colours were in both of the sets, and dropped the common one out, and I could do that in one go."

Olivia: "With words, I looked at each word. With numbers and letters, I looked at the whole set. But I suppose it would depend on how long the sets were."

Alison: "With little sets you can see them at once and keep them in your head, and then look at the other set."

Learning Processes and Opinions on Instructional Materials

Options displayed within the probe materials (Appendix L, p. 403) sought expression of attitudes to learning from text only, from text with diagrammatic adjuncts and from text with picture adjuncts. Five of the structured probes presented treatment options for each of the

1 *Names of students used throughout this thesis are fictitious.*

specific tasks being studied at the time of the probe, and a sixth concluding probe asked for an overall view. Subjects indicated their attitudes to each style of presentation via a 7-point rating scale (1-poor to 7-good) for each option. The results are shown in Table 8.4, which give the mean of the ratings given by the subjects for "text only", "text with picture adjuncts" and "text with diagram adjuncts". The subjects' ratings are given within each of the aptitude groups (GROUP-HL and GROUP-LH) partitioned into the two treatments administered ("Spatial" and "Verbal").

TABLE 8.4 RATINGS OF INSTRUCTIONAL MATERIALS
GROUP-HL:high simultaneous - low successive
GROUP-LH:low simultaneous - high successive
"S":"Spatial" treatment, "V":"Verbal" treatment

	GROUP HL		GROUP LH		
	"S"	"V"	"S"	"V"	COMBINED
TEXT ONLY	4.52	5.86	4.90	5.63	5.23
DIAGRAM ADJUNCTS	4.12	3.21	3.80	2.53	3.43
PICTURE ADJUNCTS	5.22	4.81	5.79	4.77	5.17

It may have been anticipated that the pattern of preferences would reflect subjects high in simultaneous aptitude favouring "spatial" presentation, and subjects high in successive preferring "verbal" treatment. Table 8.4 indicates that this was not the case. Rather, the administered treatment appears to have influenced positively the subjects toward similar style preferences within the structured probes, with subjects working through the spatial treatment provided higher ratings to both the diagram and picture adjuncts supplementing the text compared with their peers who were administered the verbal treatment, regardless of aptitude group. Similarly, subjects working through the verbal instructional materials rated the text only treatment more highly than those subjects working through the spatial treatment. It is interesting to speculate on the reasons why the young subjects were influenced positively towards the presentation style they were administered. It is unlikely that they were, in providing these opinions, trying to please the researcher. Each session was introduced, at length, by explaining to the individual that there were a number of versions of the lessons and elaborating on the theme that they should say what they really think and be "honest and frank" so that the best set of instructional materials, "which may not be this one", can be identified.

Responses to the first five of the six probes seeking preferences for style of presentation for specific learning tasks are presented in Appendix M, p. 414. Responses to the concluding probe seeking an overall view on their preferred treatment of instructional materials ("How do you think you would learn best?") are shown in Table 8.5.

TABLE 8.5 RESPONSES TO OVERALL PROBE (10D) ON PREFERRED PRESENTATION
"T": Text only instruction, "D": Diagrammatic adjuncts to text
"P": Picture adjuncts to text, "E": Equal preference

TREATMENT	GROUP	"T"	"D"	"P"	"E"
"SPATIAL":	HL	4	1	4	2
	LH	5	1	8	-
"VERBAL":	HL	9	1	2	1
	LH	6	-	4	1
OVERALL		24	3	18	4

Some anecdotal evidence, collected as the subjects rated the final overall probe, provides further insight into the processes some of the more thoughtful children adopted when determining their responses to the usefulness or otherwise of adjuncts to textual instructional materials as a style of presentation in general :

Gina: "It depends on what age the lessons are for. When I was little I would have liked the pictures, but now I like lessons to have only some pictures and diagrams."

Joanne: "Maybe pictures brighten up the page, but they don't help me learn anything."

Kim: "By the time you work out the diagram, what it means, you could be further ahead with the lessons. Pictures and diagrams would only help if they are big, and simple, and can tell more than words."

Penny: "When I was little I liked the pictures, but now they are not interesting. I didn't look at them too much in these lessons. It didn't say 'look at this and do something' so I didn't need to look at it."

Additional anecdotal evidence is included in Appendix M, p. 416.

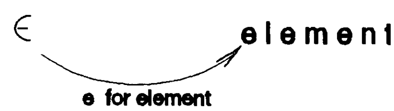
It was quite clear that each subject closely inspected the options provided and expressed a considered judgment through the marked rating, which was often supported by a spontaneously offered reasoned verbal response. For example, a comparison of the two probes that follow (Probe 4 and Probe 8B) is illustrative of this point.

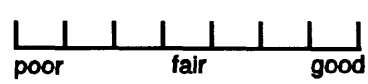
PROBE 4: **Show by rating, which way would help you remember that $\in$ means "is an element of":**

TEXT

$\in$ means "is an element of"

DIAGRAMMATIC

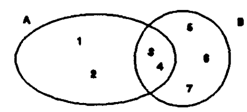




Positive verbal responses for the diagrammatic option, recorded when subjects were rating Probe 4, included:

"The diagram will help me to remember."
"You get two chances of remembering what that [$\in$] means."
"That is good. It gives a clue." [pointing to diagram]

PROBE 8B: Show by rating, which way would help you understand "union of sets"?:

TEXT only	DIAGRAMMATIC additions
if A = {1,2,3,4} and B = (3,4,5,6,7} then $A \cup B$ = {1,2,3,4,5,6}	
poor — fair — good	poor — fair — good

On the other hand, a number of responses to Probe 8B were negative toward the diagrammatic presentation:

> "The circles cross and it is a messy diagram."
> "I voted for the diagram before [probe 7B] because it is good for showing intersection, but it does not show union."

Comments such as the above at least partially explain the subjects' ratings which, overall, resulted in a drop from 23 to 12 of children preferring the diagrammatic adjunct for probes 4 and 8B respectively.

Another result of interest related to suggestions in the literature regarding poorer students preferring pictorial instructional materials. There was no correlation (-.08, $p = .564$) between Post Test achievement and "picture rating". However it would be misleading to assume that students who performed poorly in the Post Test would be classified as poor students in the normal primary school academic sense. As support for this statement, data reported above demonstrated that this test was heavily biased towards students with high simultaneous aptitudes, and although these same students may perform favourably in mathematics tests, they may, as other studies have shown, perform less well (than their peers with high successive aptitudes) in subjects such as spelling.

Analyses of Post Test Data - Time Taken

During the Post Test, subjects were timed for the completion of each item. In addition to the performance measures given above, time taken was also analysed. For items grouped within the two categories of learning, the means and standard deviations of time taken in seconds are shown in Table 8.6 for subjects in the high simultaneous - low successive (GROUP-HL) and low simultaneous - high successive (GROUP-LH) with regard to the specific treatment administered.

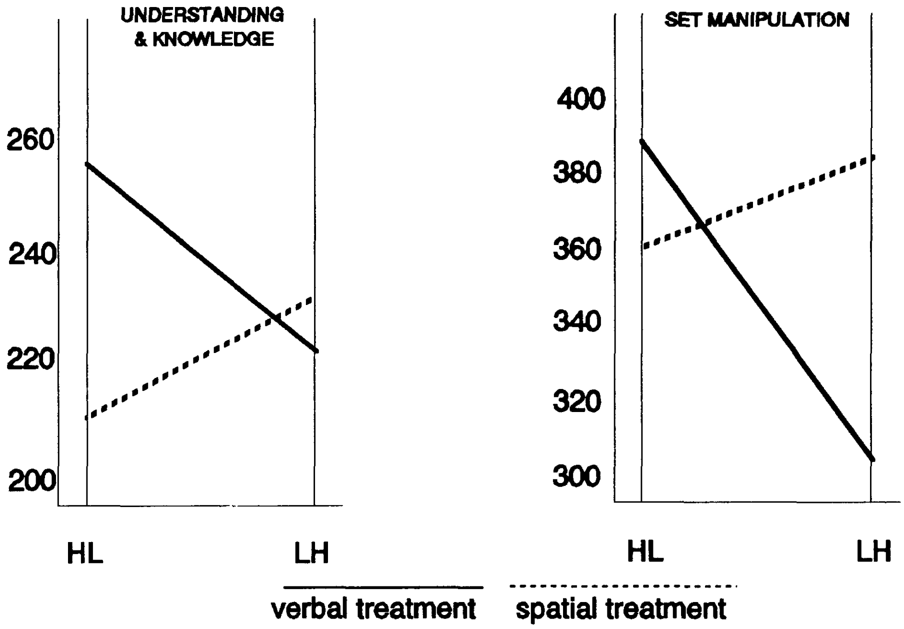
TABLE 8.6 POST TEST MEAN TIMES (SECONDS)

UK:Understanding and Knowledge SM: Set Manipulation
GROUP-HL: High Simultaneous - Low Successive
GROUP-LH: Low Simultaneous - High Successive

		UK	SM
"SPATIAL" TREATMENT			
GROUP-HL	$\bar{x}$ s	210 42	362 73
GROUP-LH	$\bar{x}$ s	231 84	385 93
"VERBAL" TREATMENT			
GROUP-HL	$\bar{x}$ s	256 80	390 131
GROUP-LH	$\bar{x}$ s	225 67	305 75

These data indicate that an interesting interaction occurred between treatment and aptitude group profiles and this is clearly depicted in Figure 8.4.

FIGURE 8.4 APTITUDE-TREATMENT INTERACTION
MEAN TIMES (SECONDS) FOR UNDERSTANDING AND KNOWLEDGE,
SET MANIPULATION - POST TEST
GROUP-HL: High Simultaneous - Low Successive
GROUP-LH: Low Simultaneous - High Successive



To assess the validity of the assumption of normality of the distribution of the times taken by subjects on each of the Post Test items (detailed in Appendix M, p. 415) they were plotted and a skewness of distribution was observed. Both *square root* and *log* transformation were computed for the dependent variable, and it was found that the log-transformed values were more normally distributed. A MANOVA of the log-transformed times for the effect contrast GROUP-HL : GROUP-LH by treatment produced a multivariate F-ratio of 1.97, p=.151. The associated univariate F tests indicated the dependent variable most responsible for the influence was that category of items in the Post Test classified as Set manipulation tasks (F-ratio 3.83, p=.056), as shown in Table 8.7. Thus for items in this category of learning it can be observed that although the influence of treatment administered on test time taken by the two groups HL and LH was not significant, there was an interesting trend.

TABLE 8.7 TIME TAKEN - CONTRAST GROUP-HL:GROUP-LH BY TREATMENT
UK(TIM) - Time taken on 'understanding and knowledge' tasks in Post Test
SM(TIM) - Time taken on 'Set manipulation' tasks in Post Test

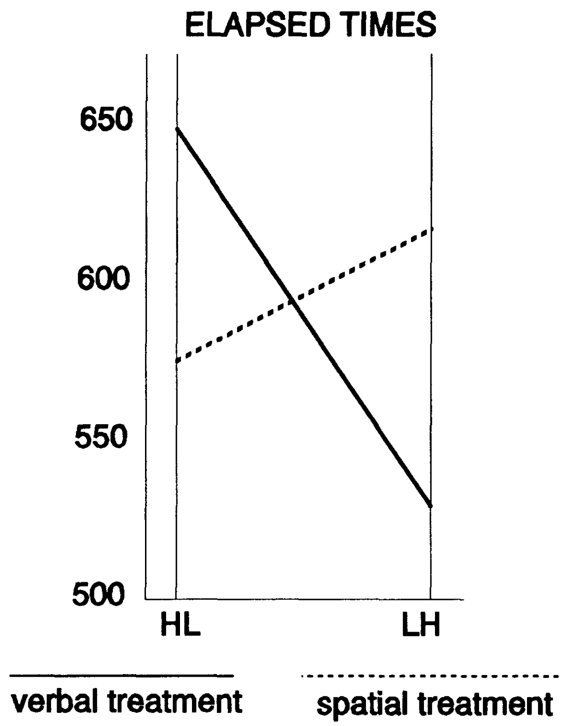
MULTIVARIATE STATISTICS	F	Sig. of F
Hotellings	1.97	.151
UNIVARIATE STATISTICS		
UK(TIM)	1.13	.292
SM(TIM)	3.83	.056

An inspection of the mean times taken by subjects to complete *all* Post Test items (Table 8.8) indicates that GROUP-HL subjects (high simultaneous - low successive) took less time on the Post Test than GROUP-LH students (low simultaneous - high successive) when instructed by the "spatial" treatment, and GROUP-HL subjects took less time than GROUP-LH subjects on the Post Test having been instructed by the "verbal" treatment. This interaction is depicted in Figure 8.5. The disordinality of interaction is evident, and although not significant (F 3.99, p=.052) the tendency could be viewed with interest by those preparing instructional materials for primary school mathematics syllabi and who are cognisant of the need to cater for individual differences.

TABLE 8.8 MEANS TIMES (SECONDS) TAKEN ON ALL POST TEST ITEMS
GROUP-HL: High Simultaneous - Low Successive
GROUP-LH: Low Simultaneous - High Successive

GROUP - HL		GROUP - LH	
"SPATIAL"	"VERBAL"	"SPATIAL"	"VERBAL"
572.3	646.5	530.0	595.1

FIGURE 8.5 APTITUDE-TREATMENT INTERACTION
MEAN TIMES (SECONDS) FOR ALL POST TEST ITEMS

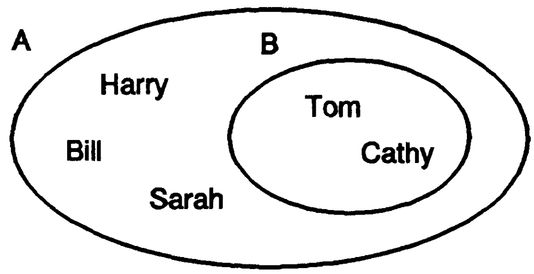


Multivariate analysis of variance was also used with the log-transformed times taken by subjects to answer the questions in the Post Test as dependent variables, with the two individual difference groups and the two treatments as the independent variables. Although the multivariate effect involving the interaction between the ability groups and treatment was not significant (F-ratio 1.27, p=.277), there was a significant univariate effect (F-ratio 8.25, p=.006) for the time taken on Question 10 of the test. It is noteworthy that this question was the only one of the 14 items that exclusively required the subjects to perform a sub-set manipulation task. It is likely that the finding of significant disordinal interaction with regard to the time taken by subjects to answer this question related to the mode of information processing for sub-set manipulation designed into, and thus promoted by, the respective treatments. The explication in the "verbal" treatment was:

If A = {Tom, Harry, Bill, Sarah, Cathy} and B = {Tom, Cathy}
Set B is a <u>subset</u> of set A because every element of set B is also an element of set A.
To save time, this is written: $B \subset A$ **The symbol $\subset$ means "is a subset of".**

This same textual presentation was also included in the "spatial" treatment and supplemented by a Venn presentation:

This diagram shows B is a subset of A:



It may be assumed that the use of this particular diagrammatic adjunct was more effective for GROUP-HL subjects than it was for GROUP-LH subjects relative to other adjuncts within the spatial treatment. Also potentially bearing upon the task time on this sub-set item in the Post Test was the alternative styles of presentation to help subjects remember the meaning of the sub-set symbol included in the "summary" section of the respective verbal and spatial treatments, as shown below.

TEXT	PICTURE IMAGE
$\subset$ means "is a subset of"	$\subset$ *means* **s u b s e t** **(like jaws biting a piece of a set)**

Subjects were asked, as one of the structured probes, to "show by rating, which way would help you remember that $\subset$ means 'is a subset of' ". (Detailed responses are included in Appendix M, p. 414.) There was no indication of GROUP-HL subjects preferring the pictorial presentation over the textual presentation in this probe (text - 11, picture - 11) compared with the GROUP-

LH subjects (text - 14, picture 11). It is of note, however, that the responses to this probe did indicate that the above pictorial presentation was perceived as more beneficial by those subjects who were *administered* the spatial treatment than those who were administered the verbal treatment. Of the 25 subjects administered the spatial treatment, 17 provided a higher rating for the picture image compared with 8 for the text alone, whereas conversely of the 24 subjects administered the verbal treatment, the majority preferred the text only treatment (text - 18 subjects, picture - 8 subjects, rated equally - 3 subjects). These data support the earlier suggestion that the nature of the presentations in the respective treatment administered to each subject was more influential than individual differences in cognitive abilities.

DISCUSSION

Consistent with the results from Study 2, findings from both the preliminary aptitude testing phase and the major ATI phase of Study 3 indicated that Set manipulation tasks predominantly require the application of simultaneous processing abilities:

- In the preliminary phase of this study, a Sets Test was designed to establish the respective loadings of the simultaneous and successive processing components to indicate abilities that Set manipulation tasks require. Data from the administration of this test, in conjunction with that from five other traditionally applied criterion tests of proven construct validity, indicated that these task demands principally require simultaneous processing ability with a loading of .80 on the simultaneous component and .13 on the successive component.
- In the major phase of this study, for the sample population undertaking Set manipulation tasks, the Pearson's correlation coefficients between Post Test performance on Set manipulation tasks and the simultaneous processing component was .46 ($p \leq .001$) and with the successive component -.48 ($p \leq .001$).
- Anecdotal evidence collected during the observation and interview process in which a clear majority of students reflected that they had used a simultaneous solution strategy.

It is suggested that the task demands of Set manipulation, in requiring this dominant application of one of the two aptitudes under study, precluded a disordinal interaction effect between the "verbal" and "spatial" instructional treatments and the high simultaneous - low successive and the low simultaneous - high successive processing ability groups.

In acquiring an understanding of primary concepts and factual knowledge related Set Theory, the addition of diagrams and pictorial representations to textual instructional materials did not assist learning performance as measured by the post test for those students with high-simultaneous-low successive processing aptitudes, relative to subjects with low simultaneous - high successive aptitudes, even though the times taken on the post test items suggested the expected aptitude x treatment interaction. It seems that the nature of the diagrammatic and pictorial adjuncts presented within the "spatial" treatment did not significantly advantage subjects with high spatial aptitudes in that they did not appear to call upon spatial *reasoning*. This is analogous to the findings of King, Roberts and Kropp (1969) who reported that instructional materials with figural adjuncts did not differentially advantage those subjects whose figural aptitudes were higher than their verbal aptitudes. It seems likely that King, Roberts and Kropp (1969) had similar difficulties to those experienced in this study in preparing two treatments sufficiently tailored to the contrasting ability groups. Walton (1983) found disordinal interaction between the high simultaneous - low successive ability group and low simultaneous - high successive ability group and spatial and verbal treatment in his study using Year 11 students studying elementary Set Theory and probability. He found the interaction to be significant for tasks classified as "understanding and knowledge" and "computational skills", which are equivalent to those of 'understanding and knowledge' and 'Set manipulation' used in this study. While the results of this study demonstrated aptitude-treatment interaction in relation to reasoning tasks, unlike Walton's findings, there was no suggestion of an aptitude-treatment interaction related to achievement.

The general findings of Study 3 regarding learners interacting with diagrammatic and pictorial adjuncts are consistent with the Hughes and Hall (1983) learner x picture interaction study which found no significant interaction between the HL ("high picture - low word") and LH ("low picture - high word") aptitudes of the Grade 4 students and treatment in prose recall tasks. It is of note that anecdotal evidence from the present study also support the Hughes and Hall (1983) observation that not all subjects actively encode the pictorial adjuncts. A number of the learners in the present study, young independent school female students seemingly focused on academic mastery, appeared to be concerned in dealing with only with the minimum (textual) content if that was sufficient to meet their learning objectives. It was found that numerous subjects chose to ignore the pictorial adjuncts, perceiving them as peripheral to their aims and believing that closer inspection and encoding would be potentially time wasting.

There was, however, an interesting aptitude x treatment interaction with regard to total time taken to complete the Post Test. It appears that the instructional materials tailored to advantage learning performance by matching treatments to aptitude strengths influenced time taken by subjects to complete the test items. Although the effect resulted in a disordinal interaction that was generally not significant ($p=.151$), analysis by individual items indicated a significant interaction effect when the item required subjects to perform a sub-set manipulation task ($p = .006$). This trend is worth noting by instructional designers. Tobias (1982) suggests that "what counts is how the student uses [time on task]", with a focus on the "frequency and intensity with which students cognitively process instructional input". Further research is required to investigate the interaction between aptitude and treatment with regard to both time of learning and time of carrying out exercises and achievement tests. In the event that such research replicates the finding of this study, there are notable contributions to be realised in the area of learning productivity by instructional designers tailoring treatments to cater for individual differences in information processing aptitudes.

A number of the structured probes investigated the subjects' reactions to alternate presentations of instructional material for various tasks demanded of the learner at certain stages throughout the individual interview and observation sessions. It was clear that *each* subject was surprisingly discriminating in her assessment of the value of the various diagrammatic and pictorial adjuncts, and appeared to consider carefully the potential value of each related to its contribution to her understanding and learning. There was no indication of a pattern of relationships between cognitive ability and expressed preferences for "verbal" or "spatial" treatment. It was apparent that each subject varied her ratings to each probe dependent upon the specific alternates presented. For example, not one subject consistently elected the "picture" option, which may have been anticipated as an easy "light" choice by subjects having difficulty with the material. Two examples of this discernment in the value of pictorial and diagrammatic adjuncts were provided by the analysis of responses to the two structured probes that sought ratings on alternate treatments for understanding the concept of sets and for learning that $\subset$ is the symbol for sub-set. For these two probes, less that one half of the students gave the lowest rating to the text only presentation (33% and 43% of subjects respectively), whereas the assessment value was reversed for the other three probes of this type (53%, 61% and 73%). Verbal responses (often spontaneous, at other times in response to "Why did you decide on that rating?") proved very valuable in providing insight into individuals' reasoning for each of their ratings. It may be concluded, overall, that the subjects' views were shaped generally by their focus on learning, and learning in the most productive manner, which was aptly summarised by Tracey, accompanied by a wry grin: "I got the story without the pictures! I guess you could say I got the picture without the pictures." This general message was conveyed by numerous subjects as a result of the largely academic focus of the relatively homogeneous sample of students.

In summary, the findings from Study 3 provided clarification of the quantitative evidence of

Study 2, and additionally provided insight into each subject's cognitive processes and attitudes as they worked through the instructional materials and completed exercises and test items. It appears that when task content permits two treatments sufficiently dissimilar, such as when the learning strategies can be designed as distinctly spatial and distinctly verbal, a treatment x information processing aptitude interaction effect is likely. It is evident that an important precursor criterion for the instructional designer is to ensure that the spatial treatment, even though containing verbal content, requires spatial reasoning and therefore involves the use of simultaneous processing aptitudes. The indications from this study are that it is likely to be the design of the spatial alternative treatment which will present instructional designers with the greater challenge. It appears that a significant body of primary curricula content may not be amenable to spatial treatments that promote and stimulate, if not compels, the use of spatial reasoning.

When task *content* dictates that, despite the best efforts of the instructional designer, both treatments necessarily contain similar teaching strategies and procedures and the spatial treatment contains the major part of the (verbal) content of the verbal treatment, then a treatment x information processing aptitude interaction is unlikely to occur. The spatial treatments in these latter circumstances are prone to contain pictorial and diagrammatic adjuncts that are not essential components for learning. This was exemplified in Study 3 and, possibly, in comparable studies reviewed earlier reporting no significant ATI. In the present study, the subjects tended to view pictorial or diagrammatic adjuncts simply as ancillary, serving only to amplify or reinforce, rather than carry the burden of primary instructional content within the treatment. A number of subjects perceived such adjuncts as merely decorative peripherals. It was apparent that the majority of subjects in this study indicated that they were not favourably disposed to "pictures just dressing up the text" unless their inclusion would lead to an increase in learning productivity.