# LISTENING COMPREHENSION – A FACTORIAL ANALYSIS

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*A.C.E.R. Research Series No. 76*

# LISTENING COMPREHENSION—A FACTORIAL ANALYSIS

*by*

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1962

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PRINTED BY G. W. GREEN & SONS PTY. LTD., MELBOURNE

# PREFACE

THE study reported in the following pages is the first of its kind to be published in Australia. It is a technical study, carefully devised and efficiently conducted, into the factors associated with a skill we all need in varying degrees—the skill of understanding what we hear. It adds a good deal to the evidence (as distinct from unsupported opinion) available on the relation between listening comprehension and reading comprehension, and points out the need for teachers to deal with listening as a skill requiring separate treatment from reading. Dr. Spearritt would be the first to acknowledge that there is still much to find out about this skill and how best to develop it, but his own method of inquiry has not only made a notable contribution in its own right, but has pointed out many further studies likely to bring useful results.

Although the inquiry was supported by the A.C.E.R., and helped by many others, in ways acknowledged by Dr. Spearritt, by far the greater part of the immense amount of work involved was done in his own private time.

Not all of this work is revealed in this printed version of the study, from which some of the more technical data have been excluded. Those who wish to consult the original text and discuss the procedures used should refer their enquiries to the author at the University of Sydney. A copy of the original text is also available at the A.C.E.R., and in the libraries of Harvard University and the United States Office of Education. However, it is thought that the amount of data available in this printed version of the study is sufficient for both the general reader and the majority of those whose interests may be roused by the techniques used. For the general reader likely to be unacquainted with those techniques, a simple explanation of factor analysis and a glossary of technical terms have been added to the text as Appendices E and F. It is hoped that they will simplify the reading of the more technical sections of the book, and make clearer to the reader not sophisticated in statistical matters the amount of patience, of skill, of planning, of knowledge and of intelligent interpretation that the study has required.

W. C. RADFORD,
*Director.*

## ACKNOWLEDGMENTS

I WISH to express my appreciation to a number of people and organizations from whom I have received advice, assistance and co-operation in carrying out this investigation.

My special thanks are due to Dr. John B. Carroll, my major adviser in the preparation of this thesis. In addition to his guidance in developing the plan of this investigation, he has given me valuable advice and encouragement in correspondence extending over a period of four years, and has helped me greatly by arranging for a large part of the processing of my data to be done by the Littauer Statistical Laboratory at Harvard University. I must also thank the other members of my committee, Dr. Phillip J. Rulon and Dr. Robert H. Anderson, for their comments and suggestions on the plan of investigation, and Dr. Rulon in particular for introducing me to electronic computers, which have been used extensively in the analysis of the data.

The investigation would not have been possible without the generous support and assistance of the Australian Council for Educational Research and its director, Dr. W. C. Radford. In addition to sponsoring the investigation and making available a grant of £100 for necessary expenses, the Council permitted me to use its typing and duplicating facilities for the trial tests and the final test booklets and allowed me to free myself from other duties in order to spend approximately three months in schools preparing and administering the test battery. I am most grateful for this assistance.

In preparing the tape recordings used in the study, I have had to call on the services of several people. Mr. R. Mackay, Principal of the Royal Melbourne Institute of Technology, very kindly made available the services of Mr. R. F. Burton, officer in charge of school broadcast systems in Victoria, for technical supervision in the preparation of the recordings. My sincere thanks are due to Mr. Burton for the time and interest he devoted to this phase of the investigation, for his recommendations on suitable types of equipment, and for his suggestions on methods of developing an audiometric test for group screening purposes. I should also thank the speakers who made the tape recordings—Mr. John Morgan, Miss Margaret Horne and my schoolgirl acquaintances, Valerie, Wynette, Marilyn and Ann. Dr. John E. Karlin, of the Bell Telephone Laboratories, Murray Hill, New Jersey, was kind enough to make tape recordings of four tests used in his earlier study of auditory function, and to send these to me in Australia. Mention should also be made of the co-operation of the Rola Co. (Aust.) Pty. Ltd., which provided tapes and a Byer tape recorder at very reasonable rates, and of technical advice received from Mr. W. G. Parr of Sydney Teachers' College on terminology in the measurement of sound and hearing.

My thanks are extended to Major-General Sir Alan Ramsay, Director of Education in Victoria at the time, for permission to seek the co-operation of teachers in Melbourne schools, and to the Psychology Branch of the Education Department for advice on the selection of schools. Special thanks are due to the head teachers and class teachers in the ten schools which participated in the main study for their interest and co-operation throughout the testing programme, and also to the 470 children in these schools for the effort and enthusiasm they displayed in taking the lengthy series of tests.

I am indebted to the following test publishers for permission to adapt tests for the purpose of the investigation: Australian Council for Educational Research, Educational Testing Service (Co-operative Test Division), Educational Test Bureau, and Science Research Associates. The assistance of the Australian Broadcasting Commission in providing me with several broadcast scripts as a basis for preparing a test of listening comprehension is gratefully acknowledged.

I also wish to express my thanks to the staffs of the Silliac Laboratory at the University of Sydney, the Littauer Statistical Laboratory at Harvard University and the M.I.T. Computation Center for advice and assistance in processing my data on electronic computers, and to a number of staff members of the A.C.E.R. who have been of assistance in small ways. My wife has also been of great assistance in helping me score test papers and check tabulations.

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CHAPTER 1

# THE PROBLEM AND ITS BACKGROUND

## A. INTRODUCTION

SCHOOLS in civilized societies have the fundamental task of helping children become proficient in the use of their own language. To participate fully as adults in the everyday affairs of such societies, children must be taught how to communicate effectively with other members of their society. They must be able to pass on knowledge and ideas to others, and absorb knowledge and ideas from others. As modern societies grow in size and complexity, the need for effective communication between their members becomes all the more necessary.

The process of verbal communication is carried on mainly by means of speaking, listening, reading and writing. Speaking and writing are often described as expressive skills; a person with an idea to express usually talks about it or writes about it. Listening and reading, on the other hand, are regarded as receptive or assimilative skills. School learning itself, as well as the future needs of society, requires that children develop increasing competence in these four communication skills as they progress through the school.

Although reading and writing are the more recently developed of the communication skills in human societies, they seem to have been more readily accepted as legitimate subjects of school instruction than have the older skills of listening and speaking. Since the establishment of compulsory elementary education in many countries in the nineteenth century, elementary schools have been traditionally concerned with providing training in reading and writing (as well as the third of "the three r's"), and to some extent in speaking. Formal training in listening has been virtually non-existent; any listening skills that pupils have acquired have come incidentally in the course of studying other subjects. The disproportion in the time and interest devoted to the assimilative skills of reading and listening has been strikingly illustrated by Nichols, who found that only fourteen scientific studies related to listening comprehension had been published in the United States and England by 1939, in contrast to 1,951 such studies in reading (Nichols, 1949).

Yet listening undoubtedly plays an important part in the process of communication. Various studies have indicated that, in terms of the amount of time the four communication skills are employed, listening is the most important skill. In a study of 68 adults, Rankin found that 45% of the total time they devoted to communication was spent in listening, 30% in speaking, 16% in reading and 9% in writing (Rankin, 1926; Rankin, 1930). A similar study by Bird with female college students revealed that 42% of their time was spent in listening, 25% in speaking, 15% in reading, and 18% in writing (Bird, 1953). A study carried out by Wilt on 530 elementary school children from Grades 1 through 6 in nineteen classrooms showed that children were expected to listen 57½% of the time they spent in the classroom, the median daily time being 158 minutes (Wilt, 1950). But quite apart from evidence of this kind, which cannot be properly evaluated without some assessment of the relative importance of the content that is communicated, it is obvious that listening is a significant medium of learning at all stages of education as well as in post-school life. It must continue to play a large part in the early education of children before they are able to read and write. And the need for effective listening in the higher grades of the elementary school, and in high school and college, is likely to become more pronounced as audio-visual aids are used increasingly to supplement formal lessons and lectures. At the adult level, listening opportunities have been extended spectacularly in the present century with the development of such mass media as radio, television and sound film.

Despite its obvious importance, listening does not seem to have become, for the community at large, a particularly efficient means of assimilating information. It has been found that about 50% of adults comprehend and retain very little of what they hear in an ordinary informational talk (Vernon, 1950). College students have been found to comprehend, on the average, only half (Brown, 1950; Nichols, 1949) or less than half (Irvin, 1953) of what they hear in lectures, while similar results have been obtained with tenth grade students (Cartier, 1955). Estimates of this kind depend, of course, on the difficulty levels of the questions used to assess comprehension, but there seems little doubt that there is room for improvement in the comprehension of information gained through listening.

Why have schools paid so little attention in the past to training in listening? The most likely explanation would seem to be that teachers did not perceive listening as a skill to be taught formally. Most first grade pupils could listen with some degree of understanding when they first came to school; it would be easy to assume that their skill in listening would develop as a result of the incidental training they received in the normal school programme, and that this kind of training would be sufficient to provide them with efficient listening habits in adult life. Nichols suggests that listening was neglected in schools and colleges because of a widespread assumption that efficient listening required little more than intelligence and practice (Nichols, 1949).

There have been many signs, however, in the last ten to fifteen years, that listening is becoming an accepted area of school instruction in the U.S.A. Tests of listening comprehension have been prepared within that period for students at elementary school (Educational Testing Service, 1956; Wright, 1957), high school (Brown and Carlsen, 1953; Caffrey, 1955a; E.T.S., 1956) and college level (Blewett, 1951; Brown and Carlsen, 1958; Dow, 1953; E.T.S., 1956; Nichols, 1949). College courses in listening have mushroomed since 1946 (Nichols and Stevens, 1957). Freshman courses in English have been superseded in many colleges by courses in "Communication Skills" (Nichols and Stevens, 1957), which include formal training in listening as well as in reading, writing and speaking. Summaries of research on listening have also begun to appear at regular intervals in the "Review of Educational Research" (Caffrey, 1955b; Lewis, 1958). In view of this greatly increased interest in the subject of listening, it seems pertinent to investigate the nature of this skill, and to determine how it can best be measured.

## B. Definition of Listening

Listening is considerably broader in connotation than hearing. The mere physiological reception of sounds constitutes hearing, but listening involves directed attention by a subject to these sounds, whether they be spoken words, musical sounds, mechanical or other noises. When considered in the context of verbal communication, however, "listening" is often taken to include the active process involved in attaching meanings to the sounds, that is, to the spoken words. There has been some confusion in the literature as to whether the term "listening" can properly be applied to the process of getting meaning from the spoken word, or whether it should be restricted to the process of directing attention to spoken sounds (Furness, 1957). In an effort to refine the terminology, Brown and Caffrey (Caffrey, 1956) have proposed that "auding" should be used as a more comprehensive term to include not only hearing and listening to spoken language, but recognizing and interpreting or comprehending it as well. In this sense, "auding" would be analogous to reading, which has been described as "the gross process of seeing, looking at, recognizing and interpreting written symbols." (Brown D., 1950)

This proposed distinction between "listening" and "auding" may be a useful semantic distinction, but there appear to be no practical advantages to be gained by employing the term "auding." Verbal communication is carried on chiefly so that others may comprehend the information transmitted, and in this context "listening" implies comprehension of the material heard. Moreover, difficulties in terminology are removed when "listening" is operationally defined. In the field of verbal communication, skill in listening is almost invariably assessed by determining the extent to which spoken words are correctly comprehended. "Listening" is evaluated in practice by assessing performance on tests of listening comprehension; "listening" thus becomes synonymous with "auding." Actually, there seems little need to look beyond the term "listening comprehension" for an accurate description of the task involved.

In this study, a person with a high score on a listening comprehension test is regarded as a good listener, and one with a low score as a poor listener. As most of the listening occurring in schools and colleges relates to informative or expository speech, the investigation has been limited to an examination of listening comprehension in situations of this kind. Critical listening to persuasive speech and appreciative listening to language or non-language sounds have been excluded from consideration.

## C. The Problem to be Investigated

The aim of the present study is to examine what is involved in listening comprehension, that is, in the comprehension of material such as spoken passages or short talks. The study sets out from the basic observation that some people comprehend more of what they hear than other people, or in other words, some people listen more effectively than others. To what can this be attributed? Writers in the field of listening have tended to discuss this variation in terms of individual differences along a dimension loosely referred to as "listening ability" (Anderson, 1952; Blewett, 1951; Brown, 1949; Goyer, 1954; Nichols, 1949; Pratt, 1956; Rankin, 1926). But although research studies over the last half century have shown clearly that people vary appreciably in their performance on tasks involving reasoning, verbal relationships, memory, and a host of other mental processes (French, 1951; Vernon, 1951), the relationship between listening comprehension and these tasks has received little attention. It seems imperative, then, to determine whether the variation in the performance of persons on listening comprehension tests can be adequately described in terms of already known sources of variation or whether it is necessary to postulate a further "listening factor" or "listening ability" to account for this variation.

Before re-stating the problem in a form which will enable a precise research study to be undertaken, it is necessary to review what is already known about listening comprehension. This should provide useful material for the development of hypotheses, and should also indicate with which groups and under what conditions the hypotheses could most profitably be investigated.

## D. Review of Research on Listening Comprehension

Existing research on listening comprehension has been mostly concerned with the effect of training in listening, conditions affecting performance on listening comprehension tests, and the relationships between performance on listening comprehension tests and on other audiometric and psychometric tests.

### (i) *The Effect of Training in Listening*

There is considerable evidence to indicate that instructional courses in listening lead to improvement in listening comprehension. This has been demonstrated for widely different age levels in school and college, although most of the experimental studies relate to college students. Experimental groups of college freshmen who have received systematic training in listening have in almost all cases obtained significantly higher scores on listening comprehension tests than control groups who have not received such training (Bird, 1953; Brown, 1954; Erickson, 1954; Irvin, 1953; Nichols, 1949). The training has generally comprised some instruction on how to listen, and practice exercises in listening, extending over periods of from 7 to 12 weeks. The improvement in listening comprehension is appreciable for below average listeners, but not marked for those found to be above average listeners at the initial testing (Bird, 1953; Erickson, 1954; Irvin, 1954).

Similar improvement has been noted with groups of high school and elementary students. In a study based on high school students, the experimental group received training in listening over a period of seven months (Lewis, 1956). In another study with sixth grade students, the training consisted of five lessons on listening given at weekly intervals, the lessons being designed to provide training in observing details, using contextual clues, following oral directions, noting the relation between main ideas and supporting ideas, and drawing justifiable inferences (Pratt, 1956). A further experiment at the fifth grade level provided listening training in the form of daily twenty-minute listening lessons for six weeks (Hollow, 1955). Not only did the experimental group show significantly greater improvement in listening comprehension than the control group in these studies of fifth and sixth grade children, but the training was found to be equally effective for different levels of intelligence.

(ii) *Conditions affecting Listening Comprehension*

Performance on listening comprehension tests has been found to vary with certain characteristics of the groups to which they are administered and with certain characteristics of the tests themselves.

Of the group characteristics which affect performance on these tests, the most important appear to be the educational level of a group and its sex composition. Gradual improvement in listening comprehension occurs as pupils proceed through the school, even when no explicit provision is made for formal training in listening. Improved performance in listening comprehension has been noted from Grade 2 to Grade 4 (Wright, 1957), from Grade 4 to Grade 6 (Hampleman, 1955), from Grade 9 through to Grade 12 (Brown and Carlsen, 1953; Caffrey, 1955a), among college freshmen (Erickson, 1954) and at each grade level from Grade 4 through to college level (E.T.S., 1956). Listening comprehension is more effective among adults with a good educational background than among those with poorer educational attainments (Carver, 1935).

Sex differences in performance on listening comprehension tests have appeared consistently in studies at all age levels. Males usually obtain slightly higher mean scores on these tests than females, though the difference between means is not always large enough to be statistically significant (Dow, 1953; Hampleman, 1955; Hollow, 1955). Male superiority has been noted at Grade 4 (Hampleman, 1955), Grade 5 (Hollow, 1955), Grade 6 (Hampleman, 1955; King, 1959), Grades 9 to 12 (Caffrey, 1955a), and at college freshman level (Dow, 1953; Irvin, 1954; Nichols, 1948). This pattern was not confirmed in Haberland's study of college freshmen, but the number of cases available for comparison in this study was relatively small (Haberland, 1959). Caffrey demonstrated that the male superiority among his high school student groups could not be attributed to differences in chronological age, mental age or sex bias in item content (Caffrey, 1955a).

The effect of differences in chronological age on performance on listening comprehension tests is reflected in the grade differences noted above. Within the high-school group, chronological age seems to have little effect on listening performance (Caffrey 1955a). One investigator has reported that the performance of fifth grade children on these tests bears a positive relationship to the amount of time devoted to television viewing but has little relationship to the type of programme chosen (Hollow, 1955).

There is also evidence to indicate that level of performance on listening comprehension tests is influenced by certain characteristics of the tests themselves. These relate mainly to the nature of the material used in the tests and the way in which this material is presented.

It might well be expected that the amount of material comprehended in a listening test would depend on the content of the passages used in the test. This has been found to be true in a recent experiment with sixth grade children in Britain; as a result it was suggested that a number of short passages on a variety of topics would provide a more valid assessment of listening comprehension than would one longer passage (King, 1959). It is conceivable, however, that variation due to passage content could be largely a function of the difficulty level and interest level of the material for the groups to whom it is presented. As would be expected, easy material is more readily comprehended than difficult material by both children and adults (Beighley, 1952; Carver, 1935; Hampleman, 1955). But contrary to expectations, the interest level of the material for the subjects appears to bear little relationship to the amount comprehended (Caffrey, 1955a, 1955b; Cartier, 1955). This result may be due to the way in which measures of listening comprehension are usually obtained; if adequate motivation among the subjects is secured in the testing situation, the effect of differential interest in the material presented is likely to be reduced or eliminated. It has been found, for instance, that subjects retain more material when they know they are to be tested (Knower et al., 1945); when they are unaware that they will be questioned about the subject-matter of a talk, relationships between interest and comprehension tend to be higher (Brown, 1955).

Listening comprehension is more effective with organized material (Vernon, 1953), but does not appear to be seriously impaired when paragraphs of a script are not presented in the correct order (Beighley, 1952, 1954). Variation in length of passage between 100 words and 700 words has been found to have no effect on the relative standing of fourth and of sixth grade children on listening comprehension tests (Hampleman, 1955).

Several investigations have been undertaken to determine whether scores on listening comprehension tests are affected by the way in which the material is presented. Such material can be presented either by a speaker in person, or by means of a loud speaker or a recording. Comparisons of the various types of presentation suggest that speakers in person are more effective than recordings presented by tape (Caffrey, 1955a), and that comprehension as judged by immediate retention tests is greater when the speaker is present than when his voice is heard over a loudspeaker (Goyer, 1954; Loder, 1937). Comprehension has also been reported to be greater when students see a sound film, than when they listen to the sound track without seeing the film (Nelson, 1953). On the other hand, a recent well-designed experiment by Stodola and Coffman with college students showed no significant differences in listening comprehension scores between three random groups, the first of which listened to a teacher in person, the second watching and listening to the same administration on closed circuit television, and the third listening only to the sound from this administration (Stodola and Coffman, 1959).

The latter study, however, did indicate that differences in mean scores on listening comprehension tests were significant when different speakers were used (Stodola and Coffman, 1959). This finding is at variance with results obtained by Caffrey with high school students (Caffrey, 1955a), but receives support from other investigations (Beighley, 1952; Knower et al., 1945). Greater comprehension is achieved with speakers who are vocally skilled (Beighley, 1952, 1954; Knower et al., 1945) and who make use of gestures (Goyer, 1954). The amount of material comprehended is also likely to be influenced by the perceived prestige of the speaker (Coyne, 1956; Paulson, 1952).

The rate at which spoken material is presented affects performance on listening comprehension tests. While it has been demonstrated that the rate of presentation can be increased by mechanical means to about 300 words per minute without significant loss in comprehension (Fairbanks et al., 1957), the level of comprehension is greatest when material is presented at the average rate of speech, about 150 words per minute (Goodman–Malamuth, 1957; Harwood, 1955b).

Other conditions likely to influence listening comprehension have also received attention. Results obtained by college students do not appear to be affected either by the time of day at which the tests are administered (Irvin, 1954), or by the use of various types of note-taking practices during the tests (McClendon, 1957). There is some evidence which indicates that the value of note-taking varies for different students; it aids comprehension with some, but impedes it with others (Brown, 1955; Nichols, 1955).

(iii) *Relationships between Listening Comprehension and other Psychometric Variables*

Several research studies have been concerned with investigating possible relationships between performance on listening comprehension tests and performance on other types of psychometric and audiometric tests.

Although low levels of performance on listening comprehension tests would obviously be expected among subjects with severe degrees of hearing loss, it appears that children with moderate hearing loss do at least as well on listening comprehension tests as those with no hearing disabilities (Caffrey, 1955a). College students with high and low scores on listening comprehension tests have also been reported as showing no significant differences on auditory characteristics, such as pitch, loudness, rhythm, speech-sound discrimination, and auditory memory span, among others

(Ainsworth and High, 1954). Thus, listening comprehension does not seem to be dependent on degree of hearing acuity among groups of students who are able to hear the speech samples reasonably well.

To what extent is performance on listening comprehension tests related to performance on other psychometric variables? Research on this question has proceeded in two main directions. One approach has consisted in determining the correlations between listening comprehension and other variables deemed likely to be related to listening comprehension. The second approach has involved comparisons of the relative effectiveness of the two assimilative language skills, reading and listening, in a variety of situations.

Most of the correlational studies have examined the relationship between listening comprehension tests and reading comprehension tests, or between listening comprehension tests and measures of intelligence. These relationships have naturally proved to be of most interest to investigators, because of the similarity of the end-product of both the reading and the listening processes, and the rather obvious dependence of language comprehension on the quality of a person's thinking.

A cursory examination of the experimental evidence reveals a wide range of correlations between listening comprehension and intelligence tests, usually varying between .4 and .8, but occasionally falling as low as .2. Correlations of .4 and .48 have been reported for Grade 5 children (Hollow, 1955; Caffrey, 1955b), .66 for Grade 6 children (Pratt, 1956) and .56 for children in Grades 3 to 8 (Rankin, 1926). At the high school level, correlations of .58 and .59 have been obtained with children in Grades 9 to 12 (Caffrey, 1955a), and correlations of .70 and .74 for children in Grades 10 and 11 respectively have been reported between the Brown–Carlsen Listening Comprehension Test and the Terman McNemar Test of Mental Ability (Brown and Carlsen, 1953). The varying levels of correlation reported are likely to be due not only to different degrees of selection in the groups concerned, but to differences in the type of test used in the various investigations. With the exception of the Brown–Carlsen test, the listening test used in each of the above studies was specially constructed for the particular study, and in some degree reflected each author's views of the type of passage and question appropriate for such a test.

The intelligence test employed also differed from one study to another, at least for those for which this information is reported. In one case, one form of the Pintner General Abilities Test, Verbal Series, was used as the measure of intelligence (Pratt, 1956); in others the Detroit Alpha Intelligence Test (Rankin, 1926) and the California Test of Mental Maturity (Caffrey, 1955b).

It is perhaps significant that the three intelligence tests mentioned differ in the relative emphasis given to verbal and non-verbal types of item. It could, in fact, be reasonably conjectured that the size of the correlations obtained between listening comprehension and intelligence would be associated with the relative amount of verbal and non-verbal content in the intelligence test. Some evidence for this has appeared in several studies undertaken with college freshmen. In one study the Brown–Carlsen Listening Comprehension Test was found to have a correlation of .55 with the verbal IQ obtained from the Wechsler–Bellevue Adult Intelligence test but only .22 with the performance IQ (Brown–Carlsen, 1953); another study resulted in a correlation of .54 between the Brown–Carlsen test and the Wechsler verbal IQ, but only .37 with the performance IQ (Kramar, 1955). Similarly, listening comprehension tests have been found to correlate more highly with L scores than with Q scores on the American Council on Education Psychological Examinations, .73 as against .36 in one study (Blewett, 1951), .52 as against .43 in another (Kramar, 1955), with differences of a similar order in a third (Haberland, 1959). But when listening comprehension scores are correlated with total scores on these and other intelligence tests (Biggs, 1956; Dow, 1953; Erickson, 1954; Nichols, 1948) the obtained correlations generally fall between .4 and .7.

The correlations reported between listening comprehension and reading comprehension tests are of about the same magnitude as those found between listening comprehension and intelligence tests. In the upper grades of the elementary school, typical within-grade correlations between tests of listening and reading comprehension range from about .5 to .6 (Caffrey, 1955b; Hollow, 1955; Pratt, 1956; Rankin, 1926). Somewhat higher correlations have been reported at the high school level. In a sample of children drawn from Grades 9 to 12, Caffrey obtained correlations of .72 and .68 between the California Auding Test and the total reading score from Form X of the Iowa Tests of General Educational Development (Caffrey, 1955a). Within-grade correlations of .65

and .66 for Grades 10 and 11 have also been reported between the Brown–Carlsen Listening Comprehension Test and the paragraph comprehension sub-test of the Kelley–Greene Reading Test (Brown and Carlsen, 1953). More variable results have been obtained at the college level; although most correlations between measures of listening and reading comprehension among college freshmen are around .5 to .6 (Biggs, 1956; Blewett, 1951; Dow, 1953; Erickson, 1954; Haberland, 1959; Larsen and Feder, 1940; Nichols, 1948), some rise almost to .8 (King, 1959), and others fall between .25 and .4 (Blewett, 1951; Dow, 1953; Haberland, 1959; Knower et al., 1945). The variation is probably again largely due to differences in the approach and content of the tests. Correlations are generally higher when the listening and reading comprehension measures are based on equivalent forms of an existing reading comprehension test than when the measures are obtained from independently constructed tests (Larsen and Feder, 1940). Correlations with reading comprehension tests have also been reported to be higher for the "inferential" sections than for the "factual details" sections of listening comprehension tests (Blewett, 1951), though this result must depend largely on the type of question asked in the reading comprehension test.

As a result of accumulated experimental evidence, the existence of a substantial relationship between reading comprehension and measures of intelligence, particularly verbal measures, is now generally accepted. It could be readily imagined, then, that some part of the relationship between listening comprehension and reading comprehension could be attributed to a common dependence on measures of intelligence. This possibility has received little consideration from investigators, with the exception of Caffrey and Biggs. Caffrey noted that the above-quoted correlations of .72 and .68 between listening and reading comprehension tests fell to .51 and .45 respectively when mental age was partialled out. He also found that his obtained correlation of .66 between a test of reading vocabulary and a test of hearing or listening vocabulary was reduced to .44 when mental age was held constant (Caffrey, 1955a). Biggs' results with college freshmen were still more striking. A correlation of .52 between her listening comprehension test and the Survey Section of the Diagnostic Reading Test was reduced to –.05 when scores on the A.C.E. Psychological Examination were held constant (Biggs, 1956).

Some correlations have been obtained between listening comprehension tests and other psychometric variables. The mechanics of language, such as capitalization, spelling, sentence structure and punctuation have been shown to have correlations of about .5 or .6 with the Brown–Carlsen Listening Comprehension Test among Grade 10 and Grade 11 students (Brown and Carlsen, 1953), but the correlation between spelling and listening comprehension at Grade 5 level was found to be only .33 (Hollow, 1955). The Brown–Carlsen test also correlates to the extent of .5 or .6 with study skills such as the use of dictionaries and indexes (Brown and Carlsen, 1953). Students rated as good speakers have been found to score more highly on the Brown–Carlsen test than those rated as poor speakers (Stark, 1957). At the fifth grade level, Hollow found that her listening comprehension test correlated to the extent of .56 with Arithmetic Reasoning, and .48 with Arithmetic fundamentals (Hollow, 1955). Performance on listening comprehension tests has also been shown to have within-grade correlations from .62 to .71 with scholastic success (letter-grade averages) among high school children (Still, 1955), and a correlation of .37 with first semester marks among college freshmen girls (Blewett, 1951). In other college freshmen groups, correlations between listening comprehension tests and grade point averages ranged from .24 to .62 (Haberland, 1959). Listening comprehension tests seem to be about as closely related to school marks as are reading comprehension tests (Blewett, 1951; Brown and Carlsen, 1953).

The second main line of inquiry into relationships between listening comprehension and other psychometric variables has centred on the relative effectiveness of listening comprehension and reading comprehension as a means of acquiring information. Do people understand verbal material better when they hear it or when they read it? Which mode of presentation is most effective in terms of immediate recall and delayed recall?

Comprehension in the early grades of the elementary school is clearly more dependent on listening than on reading. Research studies suggest that this initial advantage is retained by listening until about the sixth or seventh grade (Beery, 1954; Hampleman, 1955), though a recent study indicates that this trend may be more characteristic of boys than of girls, and that it is likely to vary with the type of passage used for comprehension (King, 1959).

Beyond this level, findings have been more variable. At the senior high school level, the use of printed materials has been found to lead to greater immediate comprehension than the use of phonograph recordings based on the same materials (Rulon, 1943). This superiority of reading over listening, however, occurred in another study only with "fairly difficult" and "difficult" material, listening and reading being equally effective with passages at other levels of reading ease (Harwood, 1955a). Studies at the college level generally show that reading leads to greater comprehension (Beighley, 1952; Corey, 1934; Larsen and Feder, 1940) or that reading and listening are about equally effective as means of acquiring information (Larsen and Feder, 1940; Westover, 1958). As the material becomes more difficult, comprehension tends to be achieved more effectively through reading than through listening (Carver, 1935; Harwood, 1955a; Larsen and Feder, 1940). There is some evidence that students with lower academic attainments or aptitude do relatively better on listening comprehension than on reading comprehension tests, as compared with average and above average students (Larsen and Feder, 1940; Odom and Miles, 1951). It is probably a fair generalization that the lower the reading performance of the subjects, the greater is the advantage of listening (Beery, 1954), though one of the studies on which this conclusion is based has not made the necessary allowance for the effect of regression (Anderson and Fairbanks, 1937). And although the weight of experimental evidence at high school and college level suggests that reading produces more effective comprehension at the time the test is taken (Beighley, 1952; Corey, 1934; Larsen and Feder, 1940), the advantage of reading over listening often disappears over a short period of time (Corey, 1934; Rulon, 1943).

Surprisingly enough, the most effective means of analysing relationships between listening comprehension and other psychometric variables has been employed in only a few instances, and even then, only on a limited scale. Factor studies designed to investigate the factorial structure of listening comprehension tests as well as other variables have been confined to two minor studies undertaken by Caffrey, and by Caffrey and Smith. From a large correlation matrix of thirty-two variables obtained with high school children, Caffrey selected nine variables for a centroid analysis—three measures of reading comprehension, four sub-test totals from the California Auding Test, and two measures of self-rated interest in the latter test. In addition to a reading factor and an "interest" factor, he obtained what appeared to be a separate auding factor, although the reading tests also had high loadings on this factor in his unrotated factor matrix (Caffrey, 1955a). His rotated factor matrix was not available to the author, but in any case, his results can be regarded as suggestive only, because of the limited variety of tests included in the analysis and the absence of intelligence measures. Stronger indications of an auding factor were obtained in Caffrey and Smith's study of the factors involved in the Davis–Eells games; this factor, described as an auditory–verbal factor, accounted for most of the variance among the orally-administered Gates Reading Tests. The same factor, however, was found to be rather highly correlated with each of the other identified factors, namely .53 with visual-verbal achievement and .67 with the Davis–Eells problem-solving factor (Caffrey and Smith, 1956).

Two major factor studies have been made in areas which might be expected to have some bearing on listening comprehension. The first of these is Karlin's study of auditory function among high school students (Karlin, 1942). This study disclosed an auditory resistance factor in certain orally presented tests, indicating the extent to which subjects were able to resist distortion of words resulting from variations in the rate of presentation and the degree of intelligibility. A span memory factor was also found to be common to tests involving the memorization of nonsense syllables, regardless of whether the visual or auditory mode of presentation was employed. In a factorial study of variables related to speech perception, Hanley identified factors of verbal facility, voice memory, auditory resistance and auditory synthesis among others, but the verbal facility factor, which was defined by a vocabulary test of Thurstone's presented in an interrupted and uninterrupted form, did not appear to be related to measures of speech perception in her sample of college students (Hanley, 1956).

Two other studies have been concerned with the "factors" involved in listening comprehension, but the "factors" discussed are not "factors" in the statistical sense. On the basis of ratings made by college freshmen of the importance of various "factors" in listening, and of the correlations he obtained between his listening comprehension test and other psychometric tests, Nichols has listed the "factors" involved in listening comprehension as intelligence, reading comprehension, recognition of correct English usage, size of listener's vocabulary, ability to make inferences and to sense the organization of spoken material, interest in and emotional attitude towards the topic, audibility of the speaker and physical fatigue of the listener (Nichols, 1948). To test hypotheses about the factors constituting the listening process, Biggs developed a listening test which required subjects to grasp ideas, retain content, recognize main and supporting ideas, differentiate meaning, recognize correct word usage, understand words, and comprehend instructions. She claimed partial confirmation of the hypothesis that there is an independent listening trait on the grounds that when intelligence test scores were held constant, her listening test still correlated to the extent of ·50 with instructors' estimates of listening ability, but was virtually uncorrelated with a test of reading comprehension (Biggs, 1956).

## E. Evaluation of Research

What does the research evidence reveal about the nature of the task involved in listening comprehension tests? Are the differences in the performance of persons on these tests independent of or associated with the differences in their performance on other tests?

Research studies have been too limited in number and scope to support the notion of a separate listening factor with any certainty. It was stated in 1954 that "considerable difficulty has been experienced in isolating listening ability from other personal characteristics" (Goyer, 1954). There has been little progress in this direction in the past few years. The auding factor reported by Caffrey and by Caffrey and Smith rests on too slender evidence to be regarded as more than suggestive, and the listening trait suggested by Biggs would appear, from the nature of her test battery, to reflect differences in verbal comprehension generally, rather than listening comprehension as such. Nor can a listening factor be affirmed on the basis of the evidence that listening comprehension can be improved through training; such improvement could well result from improved verbal comprehension, rather than from the fact that it was achieved through listening. In the analogous case of reading, it is worth noting that it has not been found necessary to postulate a reading factor despite the fact that there is ample evidence in school programmes to indicate that reading comprehension can be improved through the provision of training in reading.

The most significant point emerging from the available research concerns the relationship between tests of listening comprehension and other psychometric tests, especially tests of reading comprehension and intelligence. Correlations between listening comprehension and reading comprehension tests are relatively high, regardless of the type of test used to assess listening comprehension. The size of the correlations between listening comprehension and reading comprehension tests can be partly attributed to a common association between these variables and measures of intelligence, but, except in one study, the two types of comprehension test are still substantially related when the effect of intelligence is removed. It is also of some importance to find that correlations between tests of listening comprehension and intelligence are generally considerably higher for verbal than for non-verbal measures of intelligence, and to note the reasonably high correlations between listening comprehension tests and other language and verbal type scholastic tests. Taken in conjunction, these facts suggest that individual differences in performance on listening comprehension tests may largely reflect differences in the performance of these persons on intelligence or reasoning type tests on the one hand, and on tests involving language comprehension on the other.

There is little in the research evidence to indicate what other forms of mental activity might be involved in listening comprehension tasks. The studies by Karlin (Karlin, 1942) and Hanley (Hanley, 1956) show that persons differ in their ability to resist distortion of speech due to variation in intelligibility or time intervals, but the effect of such distortion on performance on listening comprehension tests has not been explored. Inability to concentrate is mentioned in Larsen and Feder's study as a frequent cause of large differences between listening and reading comprehension scores, but it occurred with both types of test (Larsen and Feder, 1940). Apart from motivational aspects such as interest in and emotional attitude towards the topic, Nichols' "factors" (Nichols, 1948) can be readily subsumed under reasoning factors and a verbal comprehension factor.

Despite the number of studies in which both reading and listening comprehension tests have been employed, the extent to which the two types of test are measuring the same skills and different skills is still not known. In the Fifth Mental Measurements Yearbook (Buros, 1959) Lindquist draws attention to the fact that no satisfactory evidence has been produced to show that either the Brown–Carlsen Listening Comprehension Test or the STEP Listening Comprehension Tests measure anything not already measured by a silent reading test. Evidence of this kind is needed to ensure that there is some difference in what is being measured by the two types of test, and that testing time and effort are not being duplicated unnecessarily when both types of test are used in the same battery. Without knowing what is involved in listening comprehension, it is difficult to determine in what ways it can best be improved. It is also difficult to decide what types of item should be included in a listening comprehension test. Is it preferable, for instance, to test specific skills as the Brown–Carlsen test does, or to obtain a more general assessment of listening comprehension as is given by the STEP Listening Comprehension Tests?

One of the most serious gaps in research in this area is the failure to examine the place of listening comprehension in the general scheme of what are referred to as mental abilities. The appropriate experimental technique for studying relations between mental tests is factor analysis, but while there have been full-scale factor analytic studies of numerous types of mental activity, none of these studies has included listening comprehension tests. The employment of factor analytic techniques in the past twenty to thirty years has enabled the more prominent types of mental activity to be identified experimentally, and a comprehensive picture of the various types of mental activity has emerged from these studies. Procedures have also been developed for extending this picture systematically so that newly identified factors can be incorporated easily into the existing framework (French, 1951). As the place of tests of intelligence, reading comprehension and other language skills has already been thoroughly investigated in the context of this framework, it is desirable that tests of listening comprehension be examined in the same way.

Research studies on the conditions affecting listening comprehension have given rather clear indications of the precautions that should be observed in selecting groups and specifying suitable conditions for factorial studies of listening comprehension. In an exploratory investigation of this area, there would appear to be an advantage in using groups at the upper elementary or early secondary school levels, by which stage reasonable proficiency in both listening and reading could be expected. Children in the lower elementary grades would generally not have attained the necessary proficiency in reading, while students in the final years of high school and at college or university would tend to be among the better readers of their age groups. The persistent evidence of sex differences in listening comprehension tests points to the desirability of separate factorial studies for each sex, and the inclusion of test variables with differential appeal for the two sexes. There are strong theoretical and empirical grounds for having the spoken tests presented by one person only (Lindquist, 1959; Stodola and Coffman, 1959), and preferably by means of recordings for an investigation of the kind envisaged. The most appropriate rate for presenting the tests would appear from the evidence to be about 150 words per minute.

## F. Development of Hypotheses

The present study was designed to investigate the factorial content of tests which measure the degree to which spoken passages or short talks are properly understood. The study aims to show the extent to which the variance of listening comprehension tests of this type can be accounted for by established factors, such as reasoning and verbal comprehension, and the extent of similarity in the factorial content of reading comprehension and listening comprehension tests. The main task in setting up the factor study consisted in determining what factors were likely to be involved in listening comprehension. Appropriate measures of these factors, or reference tests, were then chosen.

The task of comprehending all but the simplest material would generally be regarded as demanding some reasoning on the part of a subject. The existence of a substantial relationship between reading comprehension tests and reasoning or intelligence tests is well accepted. It is apparent from the research evidence that a similar relationship is found between listening comprehension tests and reasoning or intelligence tests. This evidence is sufficient to indicate that tests designed to measure reasoning should be included in a study of this kind. As various types of reasoning factors have been identified, the inclusion of reference tests to measure the main sub-factors in the reasoning area might be expected to yield a clearer definition of the place of reasoning in listening comprehension tests.

The comprehension of verbal material, whether it be in printed or spoken form, is also likely to be influenced by individual differences in language or verbal competence. Experimental confirmation of this is evident in the relatively high correlations obtained between listening comprehension and reading comprehension tests, and in the fact that in most cases there is still a substantial relationship between these tests when the effect of intelligence is held constant. Differences in verbal competence appear most clearly in vocabulary tests (French, 1954), so it was considered appropriate to include tests of reading and listening vocabulary in the study. Verbal comprehension or verbal knowledge is also involved in reading comprehension tests (French, 1951). Because of this, and because of the interest in the comparative factorial structure of reading and listening comprehension, it was decided to include reading comprehension tests in the battery, and to present equivalent forms of these tests as listening comprehension tests.

The relevance of reasoning and verbal factors to listening comprehension has been strongly indicated by experimental evidence. There are minor experimental indications of other relevant factors, but the choice of such factors must rest more heavily on a consideration of the differences between the processes of listening and reading.

The need for close attention to the material to be understood (that is, to the referents rather than to the mere symbols) appears to be characteristic of both listening and reading comprehension. Such attention or concentration could be expected to be of somewhat more importance in the listening situation, however, as the material is not available for further study once the words have been spoken. Although there are minor indications that this may not be true (Larsen and Feder, 1940; Wittenborn, 1943) the relevance of attention in both types of comprehension test justified the inclusion of measures of attention in the factor study.

The fact that listening comprehension tests depend on apprehension of the spoken word, while reading comprehension tests do not, suggests that some measures of auditory performance should be included in a factorial study of listening comprehension. Empirical evidence with students not suffering from a serious hearing defect, suggests that variations in auditory acuity do not affect listening comprehension, and that there is little loss in intelligibility with some types of speech distortion. Nevertheless, it would seem essential that some auditory tests be included in an experimental battery. Tests which would enable the effect of distortion in intelligibility or time patterns to be assessed, such as Karlin's tests for the auditory resistance factor, were obviously appropriate. In contrast with the reader, the listener cannot progress at his own speed or regulate the grouping of words and phrases as he wishes (Carver, 1935). And while it is commonly assumed that the intelligibility of speech samples in listening comprehension tests is of a sufficiently high level to avoid giving rise to differences in comprehension, this may not be true. Comprehension could well be impaired among pupils with low auditory resistance to variations in speech stimuli, particularly as such pupils are also likely to have developed consequent habits of inattention.

Since the degree to which a passage or talk has been comprehended is usually determined by questions administered at the completion of the talk, it is likely that memory may play some part in listening comprehension. A comprehensive study of memory ability by Kelley has demonstrated that there are at least three types of memory factor (Kelley, 1954). The meaningful memory factor, which represents "the ability to remember meaningful material" in both visual and auditory presentations is the most relevant to the present investigation. However, since listening comprehension tests often require the recall of details mentioned in the spoken passage, the factors of rote memory and span memory could also be quite relevant. It was considered advantageous to include both auditorily-presented and visually-presented tests to represent each of the memory factors, because of a possible parallel between the two forms of presentation and the two types of comprehension being considered.

It is obvious from the above discussion that the hypothesized factors are not all considered to be of equal importance in listening comprehension. The relatively high correlations between listening comprehension tests and tests of intelligence and reading comprehension suggest that the factorial content of listening comprehension tests may be rather similar to that of other comprehension tests and that the effect of an auditory or listening factor is likely to be small. This can be formally stated as the first hypothesis to be examined in the investigation:—

*Hypothesis 1.* The variance of listening comprehension tests can be accounted for by reasoning, verbal comprehension, attention and memory factors, and no separate listening factor need be postulated.

The second major hypothesis arises out of the difference in the mode of presentation of listening comprehension and reading comprehension tests. In the usual reading comprehension test, the subject is able to re-read the passage or part of the passage if he so wishes. This opportunity is not available in listening comprehension tests as passages are spoken once only and the subject is not provided with a script of the spoken material. Differences in the factorial content of listening and reading comprehension tests would therefore be expected to occur mainly in the attention and memory factors. The second hypothesis to be examined can be stated as follows:—

*Hypothesis 2*. Listening comprehension tests have similar loadings to reading comprehension tests on reasoning and verbal comprehension factors, but higher loadings on attention and memory factors.

The study will also allow certain subsidiary hypotheses to be investigated. In Wittenborn's study of the attention factor (Wittenborn, 1943) and in Kelley's study of the memory factor (Kelley, 1954), the factors identified were found to be unrelated to the mode of presentation of the test material. A third hypothesis can therefore be examined in this study.

*Hypothesis 3*. Visually-presented memory tests and auditorily-presented memory tests do not differ significantly in their correlation with either reading comprehension tests or listening comprehension tests.

A fourth hypothesis arises out of expected differences in the relationship of the different types of memory factors to listening comprehension:—

*Hypothesis 4*. Listening comprehension tests have significant loadings on the meaningful memory factor, but non-significant loadings on rote memory and span memory factors.

The indications that the interest of the material for subjects is of minor importance in a well-motivated listening situation leads to a fifth hypothesis:—

*Hypothesis 5*. The factorial content of listening comprehension tests does not differ with variations in the interest level of the topics presented.

## Chapter 2

# PREPARATION OF TEST BATTERY AND DESCRIPTION OF TESTS

To test the hypotheses advanced in Chapter 1, a battery of tests was assembled to measure the performance of individuals on the types of task indicated. Standard tests were available for a number of the hypothesized factors. Reference tests for the Inductive Reasoning and Deductive Reasoning factors were selected from the "Kit of Selected Tests for Reference Aptitude and Achievement Factors" published by the Educational Testing Service (French, 1954). As the test battery was to be applied to Australian children, tests by the Australian Council for Educational Research were substituted for similar tests listed in the E.T.S. kit or in French's monograph (French, 1951) as reference tests for the factors of general reasoning and verbal comprehension. Reference tests for memory factors were selected from both those listed in the E.T.S. kit and those identified in the more comprehensive study of memory ability carried out by H. P. Kelley after the E.T.S. kit had been prepared (Kelley, 1954). Tests with high loadings on the Attention and Auditory Resistance Factors listed in French's monograph were selected as reference tests for these factors.

Nine tests of listening comprehension were prepared or adapted for inclusion in the battery. These were designed to sample various types of situation in which listening occurs, and to reflect some of the different purposes for which people listen. Only one of these tests contained material from a published listening comprehension test. This was an adaptation of the Co-operative Listening Comprehension Tests in the Sequential Tests of Educational Progress Series (E.T.S., 1956); this series had been carefully prepared by a competent committee, who had chosen passages which would provide natural listening motivation and which were typical of common oral situations, such as giving directions, telling a story, explaining how something works, and the like. New tests based on three short talks were prepared for the battery, as one of the more common listening experiences involves the comprehension of material presented orally in short expository talks. One of these talks was of general interest to both sexes. The other two talks were respectively designed to appeal to boys but not to girls, and to girls but not to boys; they were included to assess whether the factorial structure of listening comprehension tests differed with the degree of interest in the material presented. A further test was prepared to represent another common situation in which listening occurs, namely, listening to everyday conversation or spontaneous discussion among two or more persons.

The remaining four tests of listening comprehension were reading comprehension tests, presented in "listening" form. It is sometimes questioned whether reading comprehension test passages should be presented as "listening" tests (Goyer, 1954); selections suitable for listening comprehension may well differ in content and style from those suitable for reading comprehension tests. For an adequate comparison of listening and reading comprehension, however, it appeared desirable to include some listening tests similar in type to the reading comprehension tests to be used in the study. There were already in existence two equivalent forms of reading comprehension tests prepared by the A.C.E.R. for Australian children; in addition to vocabulary tests, this series included tests designed to assess understanding of different aspects of the passages—the main ideas, details and implications. By presenting one form of each test as a reading test and the other form as a listening test, a comparison of the factorial structure of reading and listening comprehension could be made for passages of similar content and style. It was useful also to have separate measures of listening for detail, and listening for inference, as previous research had distinguished between the two types of listening (Blewett, 1951).

Most of the reference tests had been originally designed for U.S.A. children above the Grade 8 level or for still older groups. As children of these age levels would be in specialized types of secondary schools in Victoria, and as there would be many organizational difficulties in scheduling a lengthy testing programme for such children, younger children were used for this investigation. Children in Grade 6, the highest grade level of the elementary school, were chosen for the purpose. It was therefore necessary to ensure that all existing tests were suitable for Grade 6 children, and to prepare new instructions and practice examples where required.

All of the tests were therefore pre-tested on Grade 6 children before being included in the final battery. The pre-testing, which was spread over a period of a year, involved 18 different Grade 6 classes of between 40 and 60 children in 10 different schools. Generally between two and six tests were pre-tested on any one class of children. The purpose of the pre-testing was to ensure that existing or new instructions and practice examples could be understood by Grade 6 children, that existing or new items were of appropriate difficulty level and discriminating power, that time limits were appropriate and that rates of presentation of orally-presented tests were satisfactory. Item analyses were undertaken for most tests, and were used as a basis for retaining items in existing tests and selecting items in newly prepared tests. Time limits for new and adapted tests were determined experimentally and were set so that almost all of the children could attempt all items in the time allowed, except in the case of speeded tests where the original time limits had to be retained to preserve the factor content of the tests. In selecting items for tests and in setting time limits and rates of presentation, it was aimed to achieve something like a normal distribution of raw scores for each test. In one case, this required five revisions of a test on five different classes of children.

The original intention of using the existing equivalent forms of the A.C.E.R. Reading Comprehension Tests (Reading for General Significance, Reading to Note Details, Reading for Inference) had to be abandoned. Pre-test results indicated that the tests were functioning as speed of reading tests when given to Grade 6 children with the set time limits. In both "reading" and "listening" form, most of the early items in the tests could be correctly answered by most Grade 6 children. The retention of such items would not have made effective use of the available testing time. The existing tests were therefore used as pools of items for the preparation of shorter tests. Sufficient items were selected in each case to construct a listening test which would require about 10 minutes' testing time. This was necessarily an unspeeded test, as the children were allowed sufficient time in which to choose an answer after each question had been presented orally. The question then arose as to whether the corresponding reading comprehension test should be speeded or unspeeded. The usual measures of reading comprehension take account of rate of reading as well as accuracy of understanding. In listening, however, the rate of presentation is constant for all children, and the listening comprehension score depends only on the accuracy of understanding of the material presented. It was therefore decided to eliminate the influence of rate of reading from the reading comprehension score, and to allow the reading comprehension tests to become power tests by setting time limits which would permit the majority of the children to complete the tests. So the corresponding measures of listening and reading comprehension used in this study refer to the relative amount understood when material is presented in two different ways, and not to the relative amount understood when each of these processes is employed for the same fixed interval of time. It was still possible, however, to detect any difference in the factor structure of reading and listening comprehension tests that might be related to rate of reading, as a separate speed of reading test was also included in the battery.

Twenty of the tests selected for the final battery had to be presented orally. It was decided to present these tests by means of tape recordings, so that they would be presented in exactly the same way to all classes participating in the experiment. The use of tape recordings for listening comprehension tests would remove some of the realism of the ordinary listening situation in schools, and would perhaps result in lower scores on such tests than might have been achieved with a visibly present speaker. It could also be argued that tape recorded listening comprehension tests might not be as practicable for use in schools as "teacher-administered" tests. Nevertheless, in an experimental investigation of this type, it seemed important to control all sources of variation other than those being examined. The use of tape recordings appeared to be the most effective means of standardizing the manner in which passages for listening comprehension were presented to each class, the rate of delivery of the material in the orally-presented tests, and the length of pauses between test items and test passages.

Tests which were to be orally presented were first pre-tested in "live" form by the author. When items had been selected on the basis of indices of difficulty level and discriminating power to provide a suitable test for Grade 6 children, or when rates of presentation or the amount of material to be memorized had been adjusted to secure a near normal distribution of raw scores, the test passages and questions were then put on tape. While it was considered preferable that the instructions for each test should be introduced in "live" form and that the earliest practice examples should be explained in detail by the author, part of the instructions and some of the later practice examples and explanations were also recorded on tape, so that the children would become accustomed to the tape presentation of material in each test. A male speaker, with considerable experience in giving radio talks in the Schools' Broadcast sessions of the Australian Broadcasting Commission, was engaged to make the tape recordings for all but two of the orally-presented tests. The recordings were made in studios at the Royal Melbourne Technical College in the presence of the author and under the technical supervision of the officer responsible for school broadcast systems in government schools in Victoria. One three-hour and three two-hour sessions were required to make the recordings, a high quality tape recorder (a Byer 66 machine) being used for this purpose. Excellent clarity and interesting presentation of material were achieved in the recordings.

Two of the tests were recorded by other persons. As Karlin's test of Singing had originally been presented by a soprano, it was thought desirable to re-make the test with a female rather than a male voice. Accordingly, the test was re-made under the conditions described above by a young female soprano, who listened carefully to the original American test before making its Australian counterpart. Another test, designed to assess comprehension of poorly organized spontaneous speech, required an unprepared and unrehearsed discussion of a topic by a group of children. A tape recording of such a discussion by a group of four school girls was made in a private home. The quality of the tape recordings for the Singing and Listening to Spontaneous Speech tests was not as good as for the other recordings, but the level of intelligibility achieved in these two recordings was considered to be quite adequate for use in school classrooms. Several of the tests—Triplet Numbers, Listening to Short Talk, Listening to Spontaneous Speech, and the four tests of auditory resistance—were further pre-tested in tape recorded form, to ensure that the final form of each test was suitable for Grade 6 children.

The procedures adopted in the preparation of the listening comprehension tests generally followed the recommendations of the committee responsible for preparing the S.T.E.P. series of listening comprehension tests (Educational Testing Service, 1955). Options for each question in these tests were printed on the test booklets, so that children were not required to remember the options as well as the material in the passage or talk itself.

Although the multiple-choice form of question was used in a number of tests, a correction for guessing was not generally applied. The decision in the case of each individual test rested on the practice that had been followed in other studies in which that test had been used; factor loadings obtained in this investigation could then be more readily compared with those reported in the previous studies. As a result, a correction for guessing was applied only for Triplet Numbers, with essentially two-choice items, and for Letter List, which contained three-choice items.

Each of the tests included in the battery is described in the following pages. A sample item from each test is given in Appendix B. The steps involved in adapting the tests for use with Grade 6 children are described in some detail to indicate clearly what changes have been made to the original reference tests.

## A. Reasoning Tests

### I. Inductive Reasoning

1. *Letter Grouping*

This test, which was developed by Thurstone, is named as a reference test for the Induction factor in the E.T.S. kit of reference tests. Each item consists of four sets of four letters. The task is to find the rule which relates three of the sets to each other and to mark the set which does not fit the rule. The original test was said to be suitable for children in Grade 8 and above. Additional easy items prepared for Grade 6 children did not prove to be required, but the time limit was extended from three to four minutes to allow the younger children to attempt a reasonable number of items in the test. The instructions for the test were amplified slightly.

The test contained thirty items, the score being taken as the number correct.

2. *Letter Series*

This test, which was developed by Thurstone, forms the "Reasoning" sub-test of the Primary Mental Abilities for ages 11-17, published by Science Research Associates. It was selected as a reference test for the Induction factor because of its loading on this factor in an earlier study (Thurstone and Thurstone, 1941). Some easier items were prepared, but did not prove to be required. Experimental trials indicated that the first twenty-five items of the Science Research Associates' test with a six minute time limit would provide adequate discrimination among Grade 6 children. The score on the test consisted of the number of items correct.

3. *Raven's Progressive Matrices*

This test, which was developed by J. C. Raven, is named as a reference test for the induction factor in the E.T.S. kit of reference tests. It consists of five sets (A, B, C, D and E) of twelve items each. The sets can be administered with either an overall time limit or with fixed time limits for each set. The latter procedure was chosen in this study, as the test had been standardized for Australian children with time limits of two minutes for Set A, three minutes for Set B, four minutes for Set C, five minutes for Set D and six minutes for Set E. The score on the test was taken as the number of items correct on all five sub-tests, giving a possible total score of 60. An IQ (intelligence quotient) based on the overall score was determined for each child; this was not used as an experimental variable, but was made available to teachers whose classes participated in the experiment.

Each of the items in the Progressive Matrices test presents a geometrical pattern or matrix which is either symmetrical in form or involves a serial progression in horizontal and/or vertical directions. A part of the pattern is omitted, and the subject is required to choose from six or eight alternatives the figure that would best complete the pattern. Items in Set A involve the completion of simple patterns. In Set B, each item is a 2 x 2 matrix, with the fourth corner missing; an analogous relationship which exists both horizontally and vertically among the four corners enables the form of the missing part to be determined. Items in Set C are 3 x 3 matrices, with the lower right corner of each matrix missing. The figure in the upper left hand corner is developed in serial fashion in horizontal and/or vertical directions, and the overall effect of this two-way development in such characteristics as size and number of component elements has to be determined. Items in Sets D and E are also presented in the form of 3 x 3 matrices, with the lower right corner missing. In each item in Set D, three figures (or groups of figures) occur in cyclical order, often with simultaneous background development from row to row or column to column or in cyclical order also. The missing figure is the one which completes the third cycle simultaneously for both types of development. In the Set E matrices, however, the third figure in each row or column is obtained by combining the first and second figures in the corresponding row or column. The figures are combined by the processes of addition and/or cancellation of the various elements. The missing figure is found by applying the correct processes to the first and second figures in the third row or column.

## II. Deductive Reasoning

4. *Reasoning*

This test, which was developed by Thurstone, is named as a reference test for the Deduction factor in the E.T.S. kit of reference tests. It consists of thirty formal syllogisms of this type: A is greater than B, and B is greater than C, therefore A is ? than C. The subject is required to write in the correct word. The instructions for the test were amplified for use with Grade 6 children. Experimental trials of the test indicated that additional easy items were not required, but the item analysis data were used to modify the original test so that the easiest three items for Grade 6 children would appear earliest in the test. When administered in this form with a five minute time limit, the test proved to be suitable for Grade 6 children.

The score on the test is the number of items correct.

5. *Word Squares*

This test was based on a test originally prepared by Adkins and Lyerly for application to enlisted men in the U.S. Army (Adkins and Lyerly, 1952). The test is named as a reference test for the Deduction factor in the E.T.S. kit of reference tests. Part A of the original test consists of verbal matrices containing two rows of two words each; two (or three) of the four words are missing, however, and have to be selected from five alternatives so that the two words in each row will be related in the same way. Part B of the original test involved 3 x 3 and 4 x 4 matrices of the same type, and was considered to be too difficult for Grade

6 children. A trial test was prepared, using all of the items in Part A, and preceding them by the verbal analogies sub-test of the A.C.E.R. Junior B intelligence test, arranged in "word squares" form. The instruction page was expanded and simplified, and the trial test was administered to three groups of Grade 6 children with appropriate modifications after each administration. The final test contained fifteen items—eight from the A.C.E.R. Junior B test and seven from the Adkins and Lyerly test—to be administered with a time limit of seven minutes.

The score on the test is the number of items correct.

### III. **General Reasoning**

#### 6. *Arithmetical Reasoning*

This test was adapted from Form B of the A.C.E.R. Problem Arithmetic test. This type of test is named as a reference test for the general reasoning factor in the E.T.S. kit of reference tests. The items consist of arithmetical problems which require little numerical computation for their solution. Seventeen of the original twenty-six items were selected on the basis of an item analysis of the results of a class of Grade 6 children. The time limit for the revised test was determined experimentally and set at eight minutes so that almost all Grade 6 children would have sufficient time to attempt all the items.

The score on the test is the number of items correct.

## B. VERBAL COMPREHENSION TESTS

#### 7. *Reading Vocabulary*

This test was adapted from Form A of the A.C.E.R. Word Knowledge test. The subject is required to select from five words the one which is most nearly the same in meaning as the test word printed at the beginning of each question. A general vocabulary test of this kind is considered to be a suitable reference test for the verbal factor (French, 1954). Thirty of the original one hundred items were selected for the revised test on the basis of item analysis data obtained for a group of Grade 6 children. The number of items selected was governed by the number that could be administered in ten minutes in a listening vocabulary test based on a parallel form (Form B) of the A.C.E.R. Word Knowledge test. The experimental data indicated that a time limit of

6 minutes would be sufficient to allow almost all Grade 6 children to attempt all the items.

The score on the test was taken as the number of items correct.

8. *Speed of Reading*

This test, which was prepared by Chapman and Cook, is published by the Educational Test Bureau. It consists of thirty short paragraphs; in the second half of each paragraph, there is one word which spoils the meaning of the paragraph. The subject is required to cross out in each paragraph the word which should not be there, and to check as many paragraphs as he can in 2½ minutes. The level of the material is well within the grasp of Grade 6 children. Some minor modifications in wording were necessary to adapt the test for Australian conditions. A preliminary trial of the test with Grade 6 children indicated that the time limit of 2½ minutes was satisfactory for Australian children.

The score on the test is the number of wrong words correctly identified.

9. *Reading for General Significance*

10. *Reading to Note Details*

11. *Reading for Inference*

These three tests were adapted from Form A of the corresponding A.C.E.R. reading tests. In each case, preliminary trials of the A.C.E.R. tests with Grade 6 classes showed that the original tests required too much testing time and contained too many easy items for Grade 6 children. Item analysis data obtained in the preliminary trials were used to prepare a shorter form of each test which was appropriate for children of this grade level. Items selected for the shorter tests were matched in difficulty level and discriminating power with corresponding items in the tests of Listening for General Significance, Listening to Note Details and Listening for Inference respectively. The number of items used in each of the revised reading tests was determined by the number that could be administered in about 10 minutes in the corresponding listening test. Data obtained in the preliminary trials were used to set a time limit for each reading test which would allow almost all Grade 6 children to complete the test.

The revised test of Reading for General Significance contains fourteen short passages which are to be read silently. The subject is required to answer a question about each passage by selecting one of five words which best describes the sense of the passage. The time limit for the test was set at 10 minutes.

In the revised test of Reading to Note Details, the subject is required to read a passage silently and then answer from three to five questions about details mentioned in the passage. The correct answer to each question has to be chosen from five suggested answers. The test comprises nineteen questions based on five passages, and has a time limit of 12 minutes.

The revised form of the test of Reading for Inference contains twelve "stories," ranging between 40 and 90 words in length. The subject is required to read each story silently and then select which one of four alternative sentences tells what is most likely to happen next. A time limit of 9 minutes was set for the test.

For each of the three reading tests, the score was taken as the number of items correct.

12. *Matching Words*

This test was prepared by J. B. Carroll. The subject is required to recognize the function that is performed by a given word in a particular sentence, and then to select the word that performs a similar function in a second sentence. The functions are limited to the use of verbs and adjectives and to the use of a noun or pronoun as subject or object of a sentence. Minor modifications in wording were required to make the test suitable for Australian children. A preliminary trial with Grade 6 children indicated that the original time limit of 8 minutes would be sufficient to allow most children to attempt all thirty items in the test.

The score on the test is the number of items correctly answered.

## C. Attention Tests

The three tests in this group were originally used by Wittenborn in a factorial study of attention tests (Wittenborn, 1943). They were prepared for use with men ranging in age from 18 to 30 entering an Air Corps Technical School in Illinois.

13. *Triplet Numbers*

This test was developed from a description of the original test given by Wittenborn. Sets of three digits were presented to Wittenborn's subjects by means of phonograph records. The subject had to write a plus if the first number of the set was the largest and the second the smallest, or if the third number of the set was the largest and the first the smallest. If neither of these conditions was fulfilled, no response was to be made. As it was considered that Grade 6 children might not give an independent response if they were able to observe when others in the class were making a written response, Wittenborn's procedure was adapted slightly. The children were required to make a tick if either of the conditions was fulfilled, and to make a cross otherwise. The instructions for the test were expanded considerably, and ample practice examples were provided so that the children would be familiar with the task to be performed. Pre-test results indicated that simplification of the rules was unnecessary for Grade 6 children. Wittenborn had presented the digits in each set at the rate of 96 beats per minute, but it was expected that a slower rate of delivery would be required for Grade 6 children. However, "live" form trials of the test with the digits presented at 2 second, then 1½ second, then 1 second intervals resulted in highly negatively skewed distributions of scores. In the tape recorded form of the test, digits were therefore presented at the rate of approximately 90 beats a minute. Subsequent trials indicated that there would be too many high scores if the break between sets was longer than one beat. The final form of the test consisted of twenty-five sets of three digits, with a pause of six beats between Sets 12 and 13 and an interval of one beat between every other set.

The score on the test was obtained by the formula "(Rights — Wrongs) + 25," the constant being added to avoid negative scores.

14. *Letter List*

This test was developed from a description of the original test given by Wittenborn. In the original test, a series of letters was presented on phonograph records. The subject was to respond by marking a plus for a vowel following a consonant, and a minus for a consonant following a vowel. When a vowel followed a vowel or a consonant followed a consonant, he was to respond to the next letter with a plus no matter what it was. The task was simplified for Grade 6 children by requiring them to mark a plus for a vowel following a consonant, a minus for a consonant following a vowel and a tick for a vowel following a vowel or a consonant following a consonant. Simplified instructions were prepared for the test, with ample practice exercises. It was considered that the rate of delivery of the letters used by Wittenborn would be too rapid for Grade 6 children, but successive trials of the test in "live" form at slower delivery rates indicated that the original rate of delivery in which letters were called on alternate beats of a metronome set at 66 beats a minute, would be suitable for Grade 6 children. When the tape recorded form of the test was prepared, a stop watch was used to time delivery rates. The practice exercises were applied with 3 second intervals between letters. Letters in the three lists in the real test were called at the rate of one every two seconds. An interval of eight seconds was allowed between the lists, and the next list was announced during this interval.

Each of the three lists in the real test consisted of ten letters, but as no response was to be made for the first letter of each set, the total possible score was 27. The score on the test was obtained by the formula "(Rights — $\frac{1}{2}$ Wrongs) + 15," the constant being added to avoid negative scores.

15. *Five Letters*

This test was developed from a description of the original test given by Wittenborn. The sequence of letters, A, B, C, D, E, was presented orally to the subject at the beginning of each question but he was not allowed to write the sequence down. The task required the subject to interchange mentally two of the letters and then place one of the five letters between two of the others before writing his answer. Fifteen questions of this kind were selected from a larger number pre-tested in "live" form with two groups of Grade 6 children; these questions were arranged in order of difficulty, and the final test was presented in tape recorded form. Extensive instructions were prepared for the test, and these were presented partly in "live" form and partly by tape.

The score on the test consisted of the number of sequences completely correct.

## D. Auditory Resistance Tests

The four tests in this group were originally used by Karlin in a factorial study of auditory function (Karlin, 1942). They were designed to tap the ability of subjects to resist distortion of meaning due to disturbance of the temporal sequence of sounds, and were originally presented on records. Karlin's study was based on the test performance of two hundred high school students at Whiting High School, Indiana.

### 16. *Rapid Spelling*

The subject is required to write down familiar words which have been spelled out very rapidly. Karlin's description of the original test was used as a basis for preparing such a test, using words from the official spelling lists prepared by the Victorian Education Department for Grades 2, 3, 4 and 5. A test of twenty-one such words was pre-tested in "live" form with two classes of Grade 6 children, and the results were used to prepare a test of ten words of suitable difficulty level for Grade 6 children. A tape recording of the original test made available by Karlin indicated that most of the six words he used would be unfamiliar to Grade 6 children in Australia, but one of the words—"multiplication"—was added to the existing ten word test to help ensure that the obtained score distribution would be symmetrical and that the test would discriminate sufficiently among children at this grade level. The eleven item test was then recorded on tape by the Australian speaker, ample time being allowed for the children to write down each word. As satisfactory results were obtained when the tape recorded test was tried with another class of Grade 6 children, it was accepted in this form for inclusion in the test battery.

The score on the test is the number of words correctly understood.

### 17. *Singing*

The subject is required to write down the words of a short vocal selection sung by a female voice. Each selection is played twice, and is preceded by a piano chord, played either simultaneously or in arpeggio form. Karlin's test could not be used in its original form because of the differences in accent and intonation of American and Australian speech. A new tape was prepared by an Australian soprano, using the original four selections. Pre-tests of this tape with two classes of Grade 6 children indicated that the difficulty levels of the first three selections were suitable for this group. The fourth selection was not used in the test battery as it was too easy for the group. One six-word and two seven-word selections were used in the test. The score on the test is the number of words correctly understood.

18. *Haphazard Speech*

The subject is required to write down the words of a short sentence spoken with unusual inflection and pitch changes. The five sentences used in Karlin's original test were pre-tested in "live" form with a class of Grade 6 children and proved to be of suitable difficulty level. A new tape was prepared by the Australian speaker, who attempted to reproduce the inflections and pitch changes in Karlin's original test as faithfully as possible. This tape was administered to a further group of Grade 6 children, and the results indicated that each of the five sentences should be retained in the test.

The score on the test is the number of words understood. There are thirty-five words altogether.

19. *Illogical Grouping*

The subject is required to write down the words of a short sentence spoken with a grouping arrangement contrary to the sense of the passage. Karlin's original test was administered in "live" form with two slight modifications to a class of Grade 6 children, and was found to be of suitable difficulty level for this group. The modifications were designed to ensure that only words which were familiar to Grade 6 children would be used in the sentences. The Australian speaker who prepared the new tape made a careful attempt to reproduce the sentences in exactly the same way as they were spoken in the original test. As a result of a further trial with the new tape, only the first six of the seven sentences were used in the battery. The last sentence was too easy for the group and was omitted in order to reduce testing time. The six sentences used in the test contained fifty-one words. The score is the number of words understood.

## E. Memory Tests

With the exception of the Word-Number test, all of the tests in this section were originally prepared by H. Paul Kelley for a factor study of memory ability (Kelley, 1954). Kelley's subjects comprised 480 U.S. Air Force pilot cadets entering basic pilot training at Lackland Air Force Base, San Antonio, Texas.

### I. Meaningful Memory

20. *Sentence Completion*

This test was based on Kelley's original test, as described in the "directions" page for the test included in Kelley's Ph.D. dissertation. The subject is required to learn a group of unrelated sentences so that when he is presented with a sentence with one word omitted he can reproduce the missing word. When studying the sentence, the subject does not know which word will be omitted. A new test of this kind was prepared, incorporating 25 sentences appropriate for Grade 6 children. This test was administered to a class of Grade 6 children according to the plan originally adopted by Kelley for his 40 sentence test with the U.S. Air Force group. The children were allowed to study the sentences for 4 minutes, and were then required to take another unrelated test occupying about 10 minutes before being asked to complete the sentences studied originally. The test proved to be suitable in this form and with these timing arrangements.

The score on the test was the number of words correct.

21. *Consequences*

The type of task involved in this test is illustrated in the "directions" page for Consequences Test II (Verbal) in Kelley's Ph.D. dissertation. The subject hears several pairs of sentences read aloud; the first sentence in each pair states a condition and the second sentence of the pair states a consequence of that condition. When the first sentence of each pair is heard again, the subject must correctly reproduce in his own words the consequence of that condition. A set of fifteen pairs of sentences pre-tested in "live" form with a Grade 6 class did not have sufficient ceiling, so additional items were added to make a final test of twenty pairs of sentences which proved to be suitable for Grade 6 children. The initial reading of the pairs of sentences and the subsequent reading of the first sentence of each pair were then recorded for presentation on tape. Approximately half a minute was allowed for the subjects to write each of the consequent sentences.

The score on the test was the number of ideas correct.

## II. Rote Memory

22. *Word-Number Recall*

This test, which was developed by Thurstone, is named as a reference test for the Associative Memory or Rote Memory factor in the E.T.S. kit of reference tests. The subject is required to study fifteen word-number pairs for a period of six minutes. Later, when the words are presented to him in a different order, he has to write the appropriate number beside each word, for which a period of five minutes is allowed. The test proved to be too difficult for a Grade 6 class when these study and recall periods were applied. The effect of extending the time limits was therefore assessed with two other Grade 6 classes, and the test was finally applied with a nine minute study period and a five minute recall period.

The score on the test was the number of words correctly numbered.

23. *Memory for Words*

This test was developed from Kelley's description of the Memory for Words Test I (Unrelated words) used in his factor study of memory ability. In this test the subject is required to learn pairs of unrelated one-syllable nouns so that when he is presented with the first word of a pair he can reproduce the second word. The test consists of two parts, administered consecutively, with ten pairs in each part. The pairs are read aloud twice at the rate of approximately 2 seconds per pair, the order of the pairs being altered for the second reading. Then the first word of each pair is read again in a different order, and ample time is allowed for the subject to record his response. A test comprising twenty pairs of four letter words was prepared and proved to be suitable for Grade 6 children when administered in "live" form. The reading of the paired words and the subsequent reading of the stimulus word were then recorded for tape presentation in the final battery.

The score on the test consisted of the number of words for which the correct response was supplied. Alternative responses were allowed in cases where the final consonant had not been sufficiently distinct; for example, "car" was accepted in lieu of "calf," "land" in lieu of "lamb," and so on.

**III. Span Memory**

24. *Letter Span I (Visual)*

This test was based on Kelley's description of the Letter Span Test I (Visual) used in his factor study of memory ability. After seeing a sequence of letters, the subject is required to reproduce the sequence. In Kelley's test, the sequences ranged in length from three to eleven letters, and two sequences of each length were presented one letter at a time by flash cards on a display stand. A test involving three sequences of each length from 3 to 7 letters, two sequences of 8 letters and two sequences of 9 letters was prepared and administered by flash cards (8 in. x 7½ in.) to a Grade 6 class. The results indicated that the two nine-letter sequences were too difficult for this grade level, so the final test comprised seventeen sequences ranging in length from 3 to 8 letters. Each letter was exhibited for 2 seconds.

The number of sequences completely correct constituted the score on the test.

25. *Letter Span II (Auditory)*

This test was based on Kelley's description of the Letter Span II (Auditory) test used in his factor study of memory ability. After hearing a sequence of letters, the subject is required to reproduce the sequence. Kelley's procedure of using two sequences of each length from 3 to 11 letters was modified to provide a nineteen item test including three sequences at each length from 3 to 7 letters, two sequences of 8 letters, and two sequences of 9 letters. The test was administered in "live" form to a Grade 6 class at the rate of 1 second per letter reading time and was found to be suitable in this form. The actual test items and part of the instructions were subsequently recorded for presentation in tape form in the final battery.

The score on the test consisted of the number of sequences completely correct.

## F. Experimental Tests of Listening Comprehension

26. *Listening Vocabulary*

This test was adapted from Form B of the A.C.E.R. Word Knowledge test, which, in its original form, was a reading vocabulary test. The subject is required to select from five words the one which is most nearly the same in meaning as the test word read aloud by the speaker. The test word is not printed on the subject's test booklet, but the five alternatives are printed on the test booklet as well as being read aloud by the speaker. Thirty of the 100 items in the original test were selected for inclusion in the listening test on the basis of item analyses of the results obtained by children in two Grade 6 classes to whom the test was administered in "live" form. The length of the test was set at 30 items, as this proved to be an appropriate number of items for a 10 minute test of listening vocabulary. The items included in the test were selected so that the distribution of item difficulty levels for these classes was the same for this test as for the modified version of Form A of the test (Test 7), which was administered as a reading vocabulary test.

The score on the test was the number of items correct.

27. *Listening for General Significance*

28. *Listening to Note Details*

29. *Listening for Inference*

These three tests were adapted from Form B of the A.C.E.R. tests of Reading for General Significance, Reading to Note Details and Reading for Inference respectively. Each of these reading comprehension tests was first presented to various groups of Grade 6 children as a listening test, the passages, questions and alternative answers being read aloud by the author, but only the alternative answers being printed on the child's test booklet. These preliminary trials indicated that far too much time would be required to present the complete tests in listening form, and that each test contained many items that were too easy for Grade 6 children. Shorter forms of each test were therefore prepared for use as listening tests, using the item analysis data obtained in the preliminary trials. Each of these short listening tests was designed to give a raw score distribution similar to that given by the corresponding short reading test. (See Tests 9, 10, 11.) This was achieved by constructing the listening test and its associated reading test from items which were roughly matched in difficulty level and discriminating power. The criterion used for determining the number of items to be included in each listening test (and consequently in each reading test) was the number that could be administered in 10 minutes of testing time.

The test of Listening for General Significance comprises fourteen short passages on various topics. After listening to a passage, the subject is required to select which one of five alternative answers best describes the general sense of the passage.

In the test of Listening to Note Details, the subject is required to listen to a short passage, and then to answer three or four questions relating to various details given in the passage. The correct answer to each question has to be chosen from one of five alternatives. There are five passages in the test, and eighteen questions based on these passages.

The test of Listening for Inference consists of thirteen "stories," each containing between 30 and 70 words. The subject is required to listen to each story, and then to select which one of four alternative sentences states what is most likely to happen next in the story.

The instructions and practice examples for each of the three listening tests were presented by the author, except for the last practice example in each test, which was presented from the tape recorder. All of the passages, questions and alternative answers in the actual tests were presented from the tape recorder, but the alternative answers were also printed on the test booklets for the subjects to follow as they listened to the tape recording.

The score on each of these tests was taken as the number of items correct.

30. *Listening to Short Talk*

This test was designed to represent the type of listening situation often encountered by Grade 6 children both in the classroom and in schools' radio broadcast sessions. The test was based on a talk that had actually been presented in a schools broadcast by the Australian Broadcasting Commission. From a number of broadcast scripts made available by the Commission, a talk on mosaics was chosen as being most suitable for Grade 6 children. The talk briefly traced the development of mosaics from the earliest known examples, showing how the idea spread to various countries and eventually to Australia, and concluded with a description of some important mosaic work being carried out in Australia at the present time. This talk had not been broadcast to schools in Melbourne.

Twenty four-choice questions were prepared on this talk, testing comprehension of main ideas and details, and the implications of the material presented. The talk was read to a Grade 6 class by the author, and was found to require 12 minutes' reading time. The results of this pre-testing were used to shorten the talk by deleting some sections, and to select fifteen questions suitable for Grade 6 children. The talk and the questions were then recorded on tape by the speaker, and this tape recorded form of the test was found to be quite satisfactory when applied to another Grade 6 class. In the tape recorded version, the talk itself occupies about 7½ minutes.

When answering the questions on the test, the subject is able to follow the printed options on his booklet as they are being presented by the tape recorder. The score on the test is the number of correct answers.

31. *Listening to Spontaneous Speech*

This test was designed to represent one of the more common types of listening situations, when a person is expected to pick up the thread of a conversation or discussion among a group of people. In such a situation, the subject being discussed is usually not as well organized as when it is presented in a formal lesson or talk. With children, particularly, spontaneous speech of this kind is likely to be marked by the introduction of ideas in an unorganized fashion and by lack of continuity in the discussion.

It was considered that the best means of obtaining a sample of poorly organized spontaneous speech for use in the battery would be to record an ad lib. discussion of a topic by a group of children. In the ordinary course of events, it would be difficult to obtain such a speech sample which was of interest outside the group and which was long enough to provide material for a test of about fifteen questions. The most practicable procedure appeared to consist in asking a number of children to discuss a given topic. People experienced in school broadcast work indicated that it would be difficult to obtain even a reasonably coherent discussion of an unprepared topic by a class of Grade 6 children, as the children would be unlikely to talk freely. The author therefore enlisted the aid of four schoolgirls of his acquaintance, two of whom were aged 14 years, one 12 and one 9. It was hoped they would be able to discuss a topic at a level suitable for Grade 6 children, most of whom would be between 11 and 12 years.

The topic for discussion was chosen by the author. The girls were asked to imagine that they were members of a club discussing where they would go for their annual picnic. This topic was considered to have sufficient general interest for Grade 6 children, and to provide sufficient scope for a ten minute discussion. While it seemed undesirable to structure the topic too greatly, it was thought necessary to let the girls know just prior to their discussion the sort of things that could be considered, such as when the club should go on the picnic, where and how it should go, and what the children could do at the picnic. The discussion was recorded, and provided a very satisfactory sample of poorly organized spontaneous speech, complete with some irrelevant material introduced by the youngest of the four speakers.

The recording was administered to a class of Grade 6 children, followed by 29 four-choice questions in "live" form relating to details of the discussion and inferences that could be drawn from the discussion. On the basis of a complete analysis of the distractors, seventeen questions were retained for inclusion in the final test. These questions were recorded on tape by the speaker.

The options for each question are printed in the test booklet. The score on the test is the number of correct answers.

32. *Listening to Boys' Talk*

33. *Listening to Girls' Talk*

These two tests are described together, as their development was closely linked. The aim in including these talks in the test battery was to assess whether the factorial structure of listening differed according as the material presented for listening was intrinsically interesting or uninteresting. Two talks were prepared for this purpose. The boys' talk was designed to appeal to boys but not to girls, while the girls' talk was designed to appeal to girls but not to boys.

Two topics were chosen which were considered to have differential appeal for boys and girls. A six minute talk designed to interest boys was prepared on the subject of how aeroplanes fly, indicating in simple terms how and why aeroplanes become airborne, and the functions of the main controls. A magazine article on applique work with plastic material was re-written to provide another six-minute talk which was designed to be interesting to girls in Grade 6 but not to boys. These two talks were given in "live" form to a class of 45 Grade 6 children, the talk on aeroplanes being administered first. Each talk was followed by 15 four-choice questions relating to the main ideas and details presented, and inferences that could be drawn from the material presented. The mean score obtained by the girls and the boys on the aeroplane talk was almost identical (7.1 as against 7.3), while the girls attained an average score of 7.3 and the boys an average of 7.5 on the plastic decorations talk. Immediately after both talks and their associated questions had been administered, the children were asked to write down which of the two talks they had thought to be the more interesting. Twenty-four of the 27 boys preferred the aeroplanes talk, but 6 of the 18 girls also preferred this talk. Although the hypothesis that there was no relationship between sex and the type of talk preferred could be rejected on these figures at the .1 per cent. level by the chi-square test, it was considered that there was still too much "drift" on the part of the girls towards the "boys' talk," i.e., aeroplanes. As it was also thought that some of the questions on the boys' talk might possibly depend on mechanical aptitude, it was decided to prepare another boys' talk which would more closely parallel the nature and the content of the girls' talk on plastic decorations.

A talk was therefore prepared on a craft activity which was likely to appeal to boys but not to girls. It was based on an article in a boys' hobby book and consisted of a description of how to make a scale-model garage, but was couched in general terms, so that girls would not be at any disadvantage with regard to the content of the talk. This talk was administered in "live" form to another Grade 6 class of 39 children, together with the talk on plastic decorations. On the garage talk, for which 17 questions had been prepared, the boys obtained a mean score of 11.3 and the girls a mean score of 9.4. In contrast, the mean score for the girls on the plastic decorations talk was 11.3 and for the boys 9.0. The children were again required to state which talk they thought was the more interesting, immediately on completion of both talks. Seventeen of the 19 boys preferred the talk on garages, and all of the 20 girls preferred the talk on plastic decorations. This evidence was taken to indicate that the two talks had differential appeal for boys and girls in the directions desired. Item analyses of the questions were used to determine which questions should be retained in the two tests. The talks and questions were then recorded on tape by the speaker.

The "boys' talk" on model garages occupies 6 minutes 10 seconds, while the "girls' talk" on plastic decorations takes 5 minutes 45 seconds. There are 15 questions on the boys' talk, and 14 questions on the girls' talk. The alternative answers for each question are printed on the child's test booklet, as well as being presented on the tape recording. In each test, the score is the number of correct answers.

34. *S.T.E.P. Listening Test*

This test, which was adapted from Forms 3A and 4A of the Listening Tests in the Co-operative Sequential Tests of Educational Progress, was the only standard listening comprehension test included in the battery. It was hoped that Form 4A for Grades 4 to 6 in U.S.A. would be suitable for Grade 6 children in Australia, but this did not prove to be so. Certain passages could not be used because either the content or the style of talk was unfamiliar to Australian children. Preliminary trials of the other passages in "live" form indicated that many of the passages and questions were too easy for Australian Grade 6 children. It was therefore necessary to supplement the suitable passages with other passages from the next higher level, Form 3A (Grades 7 to 9 in U.S.A.), which had been pre-tested on another class of Grade 6 children and found to be suitable for children at this grade level. The version of the S.T.E.P. Listening Test used in this battery comprises three passages from Form 4A and three from Form 3A. They include a short poem and a recipe, as well as narrative and expository prose passages, and the passages require from 30 seconds to 2 minutes 30 seconds to be read aloud by a speaker. Questions on the passages relate to the main ideas put forward, the more important details, the speaker's attitudes, the implications of statements made and the adequacy of the presentation.

The present version of the test differs in some important ways from the original Co-operative Listening tests. The latter consist of 12 or 13 passages to be read aloud by the teacher; the first 6 passages are given in a 40 or 45 minute period, and the remainder in a later period of similar duration. Limitations in available testing time did not allow more than 6 passages to be used in the present modified version; total administration time for these occupied just over 30 minutes, but preliminary instructions and practice items required an additional 10 minutes. In order to standardize testing conditions, the passages and questions in the present version were recorded on tape by the speaker. Even the pauses between questions were included in the tape recording; observations made during the "live" form trials of the passages were used to determine the length of these pauses. The preliminary instructions for the test were introduced by the author. The practice example was first presented by the author, and was then presented a second time by tape recording.

As in the other listening tests, the children are able to read the alternative answers on their test booklets while these answers are being presented to them from the tape recording. The modified version of the test contains thirty-eight questions. The score on the test is the number of correct answers.

### G. School Achievement Variables

35. *School Arithmetic*

36. *School Reading*

37. *School Composition*

It seemed useful to make some assessment of the extent to which children's levels of achievement in their school work were related to their performance on listening comprehension tests. This could have been done most effectively by including scholastic achievement tests in various subject areas in the test battery. But as the time required to administer the battery was already extensive, it was considered that the marks awarded by teachers in the ordinary school examinations could be used for the purpose.

A copy of the marks gained by each child in each subject in one or more of the regular school examinations was therefore obtained for each class participating in the experiment. For most schools, the marks were based on one examination only. In other schools, however, the mark for each child in each subject was an average obtained over two or more monthly examinations. The range of subjects for which marks were available differed from school to school, so the "aggregate marks" in different schools could not be regarded as measures of the same variable. The only subjects for which marks were available in all ten schools were Arithmetic, Reading, Written Composition and Spelling/Dictation. As the ability to spell words that had already been learned did not appear to be relevant to listening comprehension, only the first three of these subjects were selected for study. Although these subjects had identical names in the various schools, they were not all identical in content. Arithmetic generally consisted of a mixture of problems and mechanical processes, almost certainly weighted differently from school to school. Reading marks were awarded entirely on the basis of oral reading performance in some schools; in others they were awarded entirely on the basis of comprehension of material read, or on the basis of both oral performance and comprehension of subject matter. Written Composition marks were generally awarded for a short composition of a page or two on a particular theme, and are likely to be measuring the same type of performance in different schools.

The marks assigned to children on these three achievement variables were generally out of a total of 10, but sometimes out of a total of 20, 50 or 100.

### H. Audiometric Screen Test

38. *Modified Spondee Test*

Some method was required for detecting children whose hearing loss was pronounced enough to affect their performance on the tape recorded tests. Very few of the children had ever undergone an audiometric test. While it would have been desirable to apply a pure-tone threshold test or at least a pure-tone sweep test to each child with an audiometer (Scottish Council for Research in Education, 1956), the additional class time required for this procedure made it impracticable. It was considered, however, that a quick screening test, such as a gramophone audiometric test, would be quite suitable for the purpose.

The Spondee records developed by the Psycho-Acoustic Laboratories of Harvard University and recorded by Amplivox Ltd. were modified for the purpose. These consist of four equivalent forms of 70 two-syllable words, spoken in such a manner that the peak intensity level of each syllable of each word is the same within about 2 db. A pure tone of 1000 cycles per second at the same intensity level is added to each record for calibrating purposes. During the playing of this calibrating tone, the volume control on the record player is adjusted so that the decibel meter on the audiometer reads at the 0 db mark. The record is then played at increasing intensity levels until 50% of the words are heard and repeated correctly by the person being tested. The level at which this occurs for a person is taken as his hearing loss, which is read directly from the decibel meter. Thus, a person hearing 50% of words correctly at 80 db would have a hearing loss for speech of 80 db.

As these records were designed to test the hearing loss of individual persons, the above procedures had to be modified for group testing. By playing the records at different intensity levels (10 words at 50 db, 10 at 60 db, and so on), and allowing sufficient time between words for the children to write down what they had heard, an estimate could have been obtained of the db level of hearing loss for each child. The purpose of using the test, however, was not to establish the level of hearing loss, but to distinguish between those children who could hear the tape recordings satisfactorily and those who could not. This objective could be achieved by playing the records at a sound pressure level slightly lower than the level at which the tape recorded tests were played. Children who could pass the Spondee test, when played at a weak speech level of 55 to 60 db, for instance, could be assumed to have satisfactorily heard tape recordings played at this sound pressure level and certainly to have had no difficulty in hearing tape recordings played at the normal classroom speech level, which in Victorian classrooms is about 70 db sound pressure level.

The records could not be used in their existing form on account of the accent of the speaker, the difficulty of some of the words for Grade 6 children, and the short interval between the words. A modified test was therefore prepared, using thirty-five of the words which would be familiar to Grade 6 children. This was considered to be a sufficient number for the purpose, and with 15 second intervals between words, the test would require about 10 minutes for administration. A tape recording of the thirty-five selected words was prepared by the Australian speaker, who listened to the Amplivox records and attempted to reproduce the spoken words as accurately as possible. The meter on the tape recorder was used to check that the peak sound pressure level of the two syllables of each word was the same. (Allowance was made later for one word—"headlight"—which did not meet this condition.) A pure tone of 1000 cycles per second was subsequently added to the tape recording at the same meter reading for classroom calibration purposes.

The modified test was applied in the following manner. The calibrating tone was played first, and the volume control on the tape recorder was adjusted so that the signal was just comfortably audible to children at the back of the classroom. A note was made of the "setting" of the volume control, which was found to be much the same in all classrooms. By playing the calibrating tone at this setting, it was possible to use a sound level meter at a later stage to determine the level of sound pressure at which the calibrating tone and the test words themselves had been presented. This level was found to be 64 db above the zero reference level for sound pressure of 0.0002 dynes/cm$^2$. Children who could write 75% or more of the 34 words (i.e., 26 words or more) correctly at this level were regarded as being able to hear satisfactorily under classroom conditions.

It should also be pointed out that the modified test gives a conservative estimate of the number of children who could hear the tape recordings satisfactorily. The test was scored according to the number of words correctly spelt, or spelt in such a way that it was clear that the child had understood the word. Thus, children who could hear satisfactorily but whose spelling was so poor that the words they wrote did not even bear a phonetic resemblance to the correct words, were excluded from the groups used for the final analysis of results.

## CHAPTER 3

# DATA COLLECTION AND ANALYSIS

THE investigation was designed to provide for separate analyses of the results for boys and girls, so that the effect of sex differences on the factorial structure of listening comprehension tests could be examined. Two independent analyses could also be expected to aid in the identification of factors. To obtain a sample of 200 boys and 200 girls, it was proposed to administer the complete battery of tests to approximately ten Grade 6 classes in Melbourne. Pre-test trials with the various tests had indicated that it would take 9 hours to administer the battery. It was therefore decided that the battery should be administered in six separate sessions over six days, each session requiring 90 minutes. Testing sessions of this duration were considered reasonable for Grade 6 children, who were mostly 11 or 12 years of age.

## A. SELECTION OF SCHOOLS

A sample of Grade 6 children was selected which was considered to be broadly representative of children at this grade level in government schools in Melbourne. From a preliminary list of about forty government schools drawing pupils from a wide variety of living areas, a short list of sixteen schools was selected in consultation with officers of the Psychology Branch of the Victorian Education Department. Schools were eliminated from consideration if other experimental work was already proceeding, if their Grade 6 classes had already been given attainment or intelligence tests in the current year or if these classes contained a considerable number of children who had recently arrived in Australia from non-English-speaking countries. The latter provision was particularly important, as lack of familiarity with the English language would not only affect the performance of these children on the various tests, but would perhaps affect their listening comprehension and reading comprehension results differentially.

Permission to approach ten of the sixteen schools, and more if necessary, was sought from and granted by the Director of Education in Victoria. The headmasters of each of the ten schools approached agreed to co-operate in the experiment. The selected schools were variously located in old established and newly established suburbs, in residential and industrial areas, and in predominantly middle class and predominantly working class areas.

### B. Arrangement of Tests and Testing Schedule

The length of the test battery, and the resultant possibility of boredom and fatigue on the part of the children, made it necessary to give careful consideration to the order of presentation of the tests. Because of the novelty of the tape recorder, it was decided to devote the first half of each session (approximately 45 minutes) to tape recorded tests. An attempt was made to maintain the interest of the children by providing several different types of tests on any one day. Thus, a tape recorded session might consist of a listening comprehension test, an attention test, and an auditory memory test, while a paper-and-pencil session might include a reasoning test, a memory test and a reading test. Each of the experimental tests of listening comprehension developed for the investigation was placed at the beginning of a testing session. The modified form of the Co-operative Test Division's S.T.E.P. Listening Comprehension Test was selected as the opening test in the battery on the grounds that it was a standard listening comprehension test, it provided good introductory explanations and examples, and it contained a wide variety of interesting test material. The hearing screen test was applied at the sixth testing session after all other tape recorded tests had been administered, so that children excluded from the sample because of hearing loss would include any whose hearing might have been deteriorating during the course of the testing programme. A detailed plan of the order of administration of the tests and their approximate administration times is given in Appendix A.

Possible ways of scheduling the six sessions were discussed with the headmasters of the earliest schools contacted. The proposal to conduct the sessions at weekly intervals over a period of six weeks was considered to be more practicable than conducting them on six successive days. The six weekly sessions would avoid prolonged interruption to the school programme at any one time, and would be less likely to arouse adverse parental comment than a six-consecutive-morning programme. It was also considered that motivation and interest in the tests would be better maintained with a weekly interval between sessions. The schedule was therefore arranged on this basis, but because of special holidays and annual sports days, it was necessary to allow a two week interval between some sessions in two schools.

The complete testing programme occupied a period of thirteen weeks, commencing on September 15 and ending on December 16, 1958. The programme commenced each morning between 9.30 and 9.45 with the administration of the tape recorded tests, and continued, after a 15 minute break between 10.30 and 10.45, with the administration of two or three paper-and-pencil tests, ending usually between 11.30 and 11.45 a.m. Details of the testing schedule are given in Table 1.

TABLE 1

*Testing Schedule*

| *School* | *Day of testing* | *Dates of sessions (1958)* | *Number tested at first session* | *Number tested at any session* |
|---|---|---|---|---|
| **First Round** | | | | |
| A | Monday | September 15, 22, 29 .. .. October 6, 13, 20 | 46 | 52 |
| B | Tuesday | September 16, 23, 30 .. .. October 7, 14, 21 | 48 | 49 |
| C | Wednesday | September 17, 24 .. .. .. October 1, 8, 15, 22 | 44 | 46 |
| D | Thursday | September 18 .. .. .. October 2, 9, 16, 23, 30 | 45 | 47 |
| E | Friday | September 19, 26 .. .. .. October 3, 10, 17, 24 | 43 | 46 |
| **Second Round** | | | | |
| F | Monday | November 3, 10, 17, 24 .. .. December 1, 8 | 34 | 37 |
| G | Tuesday | October 28 .. .. .. .. November 11, 18, 25 December 9, 12 (Friday) | 49 | 52 |
| H | Wednesday | November 5, 12, 19, 26 .. .. December 3, 10 | 45 | 48 |
| I | Thursday | November 6, 13, 20, 27 .. .. December 4, 11 | 43 | 44 |
| J | Friday | October 31 .. .. .. .. November 7, 14, 21, 28 December 5 | 45 | 49 |
| | | Total .. .. | 442 | 470 |

Two additional sessions were conducted with two small groups of children, six of whom had missed the third session at one school, and seven who had missed the sixth session at another school as a result of having to attend their prospective secondary schools for preliminary interviews. Also, at the end of the sixth session in schools in the second round of the testing programme, a test which had been administered earlier in the programme was re-applied. This provided data for the computation of test-retest reliability co-efficients on six speeded tests, for which Kuder-Richardson or split-half reliability co-efficients would have been inappropriate.

## C. Administration of Tests

In order that conditions of presenting the test battery to the various groups might be as uniform as possible, each of the 62 testing sessions was conducted by the author. Each test was administered strictly in accordance with the instructions prepared for it. The use of tape recordings ensured that there was no variation in rate of presentation of test items, and pauses of up to 20 seconds between test items were also built into the tape recorded tests. Pauses of longer duration were timed by the author with a stop watch. Instructions for the tape recorded tests were delivered partly by the author, and partly from the recording itself; the actual instructions for administration are reproduced in Appendix C of the author's original thesis. Generally the author introduced the description of the task and explained one or two practice examples; subsequent practice examples were then given from the tape recording, which in some cases also followed with the explanation of these examples. The change from one speaker to another did not seem to have any disturbing effect; children often made audible answers to questions put by the recorded voice in the same way as they did to questions asked by the author.

The selection of the equipment used to present the tape recorded tests followed the recommendations of the officer in charge of the installation and testing of school broadcast systems in Victorian government schools. A high quality tape recorder, a Byer 66 machine (Serial No. 070) with press-button start and stop control was hired for the course of the investigation. The output of the tape recorder was fed into a 9 inch portable school vented speaker, enclosed in a baffle box especially designed by the

Royal Melbourne Institute of Technology to achieve optimum broadcast reproduction in Victorian school classrooms. For each testing session, the portable speaker was set at a level about 3 feet above the children's heads and directed towards them from a central position at the front of the classroom. The sound pressure level at which the tapes were presented was determined for each school at the first testing session by playing over an introductory passage. The volume control setting at which this passage was found to be comfortably audible for all children in the room was noted, and except for two tests, the remainder of the tapes were presented at this setting. A higher setting was required for Listening to Spontaneous Speech, as the recorded conversation among the four girls was not as clear as the recordings made by the regular speaker. For the screen test of hearing, the Spondee test, a lower setting was determined for each class at the level at which a 1,000 cycle per second pure tone signal was just comfortably audible to children at the back of the room. When these various levels were subsequently measured by a sound level meter, it was found that the calibrating tone had been played at a sound pressure level of 64 db, and that the majority of the tapes had been presented at the average level for conversational speech, ranging between sound pressure levels of 65 and 72 db. The test described as Listening to Spontaneous Speech had been played at an average sound pressure level of 73 db with a maximum of 80 db. It could thus be assumed that any child who had heard 75% of the words correctly at the sound pressure level of 64 db would have little difficulty in hearing tape recorded tests played at 65 to 72 db and at 73 to 80 db.*

The children generally maintained a high level of interest in the various sessions of the testing programme. In the introductory remarks at the commencement of the first testing session, the author explained the purpose of the investigation in simple terms, and attempted to motivate the children to do as well as they could in each of the testing sessions. The general attitude of the children at the various testing sessions suggested that most of them were putting forth their best efforts. Factors which could be regarded as contributing to good motivation were the novelty of the tape

*Measurements have been given in terms of decibels of sound pressure level, not in terms of phons. For the range of sound pressure levels (64 to 80db) and frequencies (approximately 300 to 4,000 cycles per second) under consideration, the difference between sound pressure levels measured in decibels and sound levels measured in phons would not exceed 4db.

recorder and the recorded presentation of tests (the atmosphere was almost one of excitement when the equipment was being set up at the first testing session), the clarity of the recordings, the pleasant voice and interesting manner of the speaker who had made the recordings, the wide variety of tests and the rather different character of the tests from the usual routine school work.

The class teachers remained in the room as interested observers in most schools, but limited their participation to assistance in distributing test booklets. The children were seated two to a desk. While this was not an ideal seating arrangement, it was the best that could be realised in the schools, where accommodation was generally fully taxed. Although the children were constantly reminded of the need for independent work, and close supervision was maintained by the author, some cases of cheating were detected. The results of these children were excluded from the sample used for analysis.

While the testing programme was in progress, the author inquired from the class teacher and head teacher in each school whether the Grade 6 class had received any special training in listening. It was found that all classes listened to school broadcast sessions on such topics as Health, Social Studies and Heritage of English, and that it was the general practice for children to make notes during or after the broadcast. This appeared to be the only formal training received in listening, and the amount of training could consequently be expected to be similar for each class. While teachers were well aware of the importance of reading comprehension, they had not previously been acquainted with the concept of listening comprehension.

### D. Scoring of Tests

All tests were hand-scored with the aid of stencils or strip keys in accordance with the scoring formulas given in Chapter 2. The scoring of tests arranged in multiple choice form was undertaken by the author, with the assistance of a second marker. Tests requiring some interpretation, such as those in which the score consisted of the number of words understood, were all scored by the author. A re-checking of the thirty-four tests and the Spondee test for a random sample of 50 boys and 50 girls revealed very few discrepancies in scores. A complete re-marking of all test papers was carried out for the four tests in which the majority of one point discrepancies occurred.

## E. The Composition of the Final Samples

Owing to the extension of the testing programme over six weeks, it was to be expected that absences of children from one or more testing sessions would reduce the number of cases available for analysis. The children present at the first testing session in each school constituted the pool from which the final sample could be selected. Absence from one or more sessions proved to be the main reason for eliminating cases, but children who had been found to be cheating, or whose test papers showed evidence of irregularities, such as missing out a page of questions, were also excluded. A few children who had completed all tests but who failed to reach the required level of 26 words on the hearing screen (Spondee) test, were excluded from the final sample on the grounds that they could not be assumed to have heard the tape recordings clearly. Migrant children from non-English-speaking countries ("New Australians") were excluded from the final sample if they had been in Australia for less than five years. If such a child had been living in Australia for at least five years, it could be assumed that he had passed right through the elementary school in Australia, and that initial language handicaps were likely to have been largely or completely overcome.

Table 2 gives details of the number of children excluded from the sample, and the reasons for their exclusion:—

Table 2

*Exclusion of children from experimental samples*

| | *Boys* | *Girls* | *Total* |
|---|---|---|---|
| Number present at first testing sessions .. .. | 237 | 205 | 442 |
| Number excluded: | | | |
| (a) Number absent from second and/or later sessions .. .. .. .. .. .. | 61 | 50 | 111 |
| (b) Number with test irregularities, cheating, etc. .. .. .. .. .. .. .. | 7 | 4 | 11 |
| (c) Number of non-English-speaking migrants with less than 5 years' residence .. .. | 4 | 9 | 13 |
| (d) Number with scores of less than 26 on Spondee hearing test .. .. .. .. | 1 | 2 | 3 |
| (e) Number for whom school examination results not available .. .. .. .. | 3 | 1 | 4 |
| Total number excluded . .. .. .. .. .. | 76 | 66 | 142 |
| Number available for final samples .. .. .. | 161 | 139 | 300 |

Among the children included in category (a) in Table 2, there were a number who could also have been included in categories (b), (c) or (d).

The final sample of 161 boys included 9 New Australian boys of 5 years' residence or more. The final sample of 139 girls included 8 New Australian girls of 5 years' residence or more, and 5 girls from one school who took the third series of tests a few days after completing the sixth series. Because complete results on all tests were available for these children, they were included in the samples; the advantages of including the additional 22 cases were considered to outweigh the possible effects of slight variation in testing order and differences in performance of these New Australian children.

### F. Coding of Test Scores

As was indicated in Chapter 2, all tests were designed to give approximately normal distributions of raw scores for Grade 6 children. Inspection of the raw score distributions obtained with the final samples of boys and girls suggested that this goal had been achieved in most cases. Some distributions were skewed, however, and others tended to be platykurtic, probably because of differences in the characteristics of the particular classes used for pre-testing and the final samples of Grade 6 children. It was essential that the variables to be used in the study should be normally distributed, as disparate distributions of test scores can affect the magnitude of product-moment correlation co-efficients and thus the factorial structure (Carroll and Schweiker, 1951). All raw score distributions for each of the final samples were therefore normalized before correlation co-efficients were computed.

The choice of a normalized scale to which raw scores could be transformed was determined chiefly by the range of raw scores in the various tests. This was found to be 10 points or less in more than two-thirds of the tests; a normalized scale with this number of steps was therefore appropriate. A suitable scale for the purpose was the stanine scale, in which variables are assigned the values 1 through 9, with relative frequencies in 100 cases of 4, 7, 12, 17, 20, 17, 12, 7 and 4 respectively. These correspond to the areas under the normal curve for the $\pm \frac{1}{4}$ S.D. interval about the mean, and for $\frac{1}{2}$ S.D. units ranging upwards from $+ \frac{1}{4}$ S.D.

and downwards from — ¼ S.D. For the boys' sample, the desired frequencies for each value from 1 to 9 were 7, 11, 19, 28, 31, 28, 19, 11 and 7; for the girls' sample, the corresponding frequencies were 6, 9, 17, 24, 27, 24, 17, 9 and 6. Raw score distributions were converted to stanines for all but one of the experimental and reference test variables in the girls' sample, and for all but seven variables in the boys' sample. The desired frequencies for coded scores could not always be attained, as the limits of the raw score intervals and the coded score intervals did not necessarily coincide. Alternative frequency distributions were prepared in those cases where a raw score could be assigned to either of two coded scores, and that distribution which gave the closest fit (as determined by the chi-square test) to the model distribution was selected. When the hypothesis that the distribution of stanine scores was normal could be rejected at the 5% level by the chi-square test, the relevant raw score distributions were normalized by means of percentiles to T scores with a mean of 50 and an S.D. of 10. The T scores obtained for the one non-normal distribution in the girls' results, viz., Reading for Inference, were rounded to one digit scores to avoid increasing unduly the amount of work required to prepare the data for processing by an electronic computer. Data relating to the score distributions and to the normality of the stanine score distributions are summarized in Tables 1 to 4 in Appendix D of the author's original thesis.

The process of normalizing scores for the three school achievement variables, Arithmetic, Reading and Composition, was somewhat more difficult. The distribution of marks for these subjects differed markedly between schools, approaching a rectangular distribution on a 4 point scale in some instances. There appeared to be no satisfactory method of allowing for differences in the general level of performance in these subjects among the Grade 6 classes in the different schools. By assigning a stanine score of 9 to the highest mark in each school, a score of 8 to the next highest, etc., and following the corresponding procedure with the lowest marks, distributions of stanine scores which did not differ significantly from the normal model were achieved for the Arithmetic test. The coarser marking scales used for Reading and Composition precluded the use of stanine scores (and even a 5 point scale) for these variables. Instead, a 4 point normalized scale analogous to a stanine scale was developed, with a base unit of 1¼ S.D.; as near as practicable the highest 10½% of boys and girls in Reading and Composition marks in each school were assigned a score of 4, the next 39½% a score of 3, and so on.

### G. Computation of Correlation Co-efficients

The thirty-seven normalized scores for each boy and each girl in the final samples were punched on paper tapes by the author at the Silliac laboratory at the University of Sydney. With the aid of an existing library programme, the product-moment correlation co-efficients among the thirty-seven variables were obtained by the Silliac high-speed computer for both the boys' sample and the girls' sample. The correlation co-efficients for each sample are shown in Table 1 in Appendix C.

### H. Computation of Principal Factor Loadings

The correlation co-efficients between the thirty-four experimental and reference variables for each of the two samples were rounded to four decimal places and punched on IBM cards in Melbourne in a format suitable for computing principal axes factor loadings. Diagonal unities were replaced by estimated communalities, namely, the highest correlation in each column. The correlations with the school achievement measures (variables 35, 36 and 37) were not included in the matrices to be factored, as these variables did not form part of the main study. The IBM cards were forwarded to the Littauer Statistical Laboratory at Harvard University, where the principal factors for the boys' matrix and for the girls' matrix were extracted on an IBM 650.

Initially, three factors were extracted for the boys' matrix and four factors for the girls' matrix, the extraction process being halted when the size of the eigenvalues fell below unity. However, the relatively high values of some of the residual correlations and the results of preliminary rotations with the obtained factors indicated that a greater number of factors should be extracted. Accordingly, the principal axes factor programme was again applied to the two correlation matrices, and on this occasion, nine factors were extracted for the boys' matrix and ten factors for the girls' matrix. By this stage, the eigenvalue corresponding to the last factor extracted had fallen below .4 in each case, and the residual correlations were mostly very low in value, as indicated in Table 3.

TABLE 3

*Distribution Statistics for Residual Correlations*

| | BOYS (9 factors) | GIRLS (10 factors) |
|---|---|---|
| Range | –.0938 to .0839 | –.0774 to .0711 |
| Mean | .0003 | .0003 |
| S.D. | .0256 | .0257 |

The subsequent analysis of the obtained factors, compared with the preliminary analysis attempted with the smaller number of factors, suggests that it may not always be appropriate to limit the extraction of factors to those corresponding to eigenvalues greater than unity, as recently recommended by Kaiser (Kaiser, 1960).

The unrotated orthogonal factor matrices for boys and girls are presented in Tables 2 and 3 respectively in Appendix C. The residual correlations for the two samples are given in Table 4 of Appendix E in the author's original thesis.

## I. ROTATION OF AXES

The principal axes factors for each of the two matrices were rotated independently by Professor John B. Carroll and by the author, the former using an analytic method of rotation, the latter using graphical methods. The restriction of orthogonality among the factors was not made in either case; the criterion of simple structure was used as a basis for making rotations, and it was left to the configuration of test vector termini to determine whether factors would be orthogonal or oblique.

Following on his earlier approaches to an analytic solution for the oblique factor case (Carroll, 1953, 1956), Carroll developed the "biquartimin" method (Carroll, 1957), which he has programmed for the IBM 704 computer. This method, which has been found to yield results very similar to those obtained in graphical solutions, requires that the expression

$$\sum_{p<q}^{m} \left( \sum_{j=1}^{n} v^2_{jp} v^2_{jq} + \sum_{j=1}^{n} c_{jp} c_{jq} \right)$$

be a minimum,
where $v_{jp}$ is the general element of the rotated factor matrix V, $c_{jp} = (v^2_{jp} - \overline{v^2_{jp}})$, and where j represents the test variables (j = 1,2,. . . . .,n), and p the rotated factors (p,q = I,II,. . . . .,m).

Carroll applied this method to the F matrix for boys and girls. To avoid the possibility of rotating too many factors, he began with eight factors in each case, and subsequently repeated the programme with nine factors. A satisfactory approximation to oblique simple structure was obtained for all four solutions, but the eight-factor solution for boys and the nine-factor solution for girls provided a more acceptable psychological interpretation than the alternative solutions. Quite high correlations were obtained between some of the factors. The transformation matrix Λ for the two more acceptable solutions and the V matrix of factor loadings for each of the four solutions are given in Tables 4, 6, 7, 11, 13 and 14 in Appendix C.* Cosines between the reference vectors and correlations between the primary factors for the two more acceptable solutions are presented in Tables 9 and 16 in Appendix C.

Graphical rotations undertaken by the author were made by inspection of two-dimensional plots of the columns of factor loadings in the F matrices for boys and girls. The chief criterion used in locating the position of reference vectors was to maximize the number of test vectors with zero projections on the new axes (Thurstone, 1947). Consideration was also given to the groupings of tests which had been included to represent established factors, and factors were restricted to the positive manifold as far as possible. Although all ten factors were used in rotating axes for the girls' matrix, only eight factors were used in making rotations for the boys' matrix; the closeness of the test points to the origin in all plots involving the ninth factor from the boys' matrix indicated that this was a residual factor. Satisfactory approximations to oblique simple structure were reached in each case after seven rotations of the orthogonal reference frame, involving about 190 changes in the position of individual axes. The matrix multiplications required to compute the new V matrix after each successive round of rotations were performed on Silliac, which was also used to find the inverse of $\Lambda'\Lambda$ and to compute the correlations between the primary factors from the relation

$$R_{pq} = D(\Lambda'\Lambda)^{-1}D.$$

Tables 5, 8, 12 and 15 in Appendix C present the oblique transformation matrices and the V matrices obtained for boys and

*Corresponding tables for the nine-factor solution for boys and the eight-factor solution for girls are given in the author's original thesis.

girls by application of the graphical methods. The V matrices show substantial agreement with those obtained by the biquartimin method, and appear to give a clearer definition of factors in some instances. There is evidence in Tables 10 and 17 in Appendix C of a number of high correlations among the primary factors in these solutions also, though there are more cases of negatively correlated factors than in the corresponding biquartimin solutions.

### J. Analysis of Higher Order Factors

The need for an analysis of second order factors was indicated by the presence of high correlations among the primary factors. Second order analyses were undertaken for the two graphical solutions and for the more psychologically acceptable biquartimin solutions, namely, the 8 factor solution for boys and the 9 factor solutions for girls. The diagonal unities in each of the four $R_{pq}$ matrices were replaced by estimated communalities (the highest correlation in the column), and the principal axes factors for each of the resulting matrices were computed on Silliac. Factors corresponding to positive eigenvalues above an arbitrary level of about .14 were then rotated to a position which approximated an oblique simple structure in each case. There was considerably less agreement among the four rotated matrices than had been found in the first order domain. Because of the difficulty in arriving at a clear interpretation of the second order factors from the various solutions, loadings of the original tests on the second order factors were not computed. An extension of the 8 factor biquartimin solution for boys to third and fourth order factors in accordance with the procedure described by Schmid and Leiman (Schmid and Leiman, 1957) failed to give results which could be considered meaningful. In general, rotations in the second and higher order domains could not be considered compelling.

The principal axis factor matrices and the associated transformation and rotated factor matrices for each of the four second order solutions are not presented in this volume, but are available in the author's original thesis.

### K. Estimation of Factor Loadings for School Achievement Variables

As the relationship between listening comprehension and elementary school subjects was only a subsidiary aspect of the investigation, it was considered desirable to avoid increasing the rank of the factor matrices by including the school achievement variables in the main analyses. Loadings of school achievement variables on the factors identified in the main study were therefore estimated by means of Mosier's generalisation (Mosier, 1938) of Dwyer's extension (Dwyer, 1937). This consists in solving the matrix equation

$$V_{tp} = R'_{tj}F'_{jm}(F_{mj}F'_{jm})^{-1}\Lambda_{mp},$$

where $V_{tp}$ represents the loadings of the new tests on the rotated factors,

$R'_{tj}$ represents the correlations between the new tests and the original tests,

$F'_{jm}$ represents the loadings of the original tests on the unrotated factors,

$(F_{mj}F'_{jm})$ represents the diagonal matrix of the eigenvalues corresponding to the unrotated factors, and $\Lambda_{mp}$ represents the transformation matrix which converts the original unrotated $F_{jm}$ matrix to the rotated factor matrix $V_{jp}$.

This equation was solved for each of the graphical solutions and for two biquartimin solutions (8 factors for boys, and 9 factors for girls) by using the matrix multiplication programme on Silliac. The estimated loadings of the three school achievement measures (variables 35, 36 and 37) on the factors obtained in the main study are presented in the last three rows of Tables 6, 8, 14 and 15 in Appendix C. Although these loadings were determined quite independently of the main study, they were subsequently found to be very consistent with the factor interpretations made in the main study.

### L. Computation of Reliability Co-efficients

Reliability co-efficients are not generally computed for the tests employed in factor studies, most investigators being content to regard the final computed communality estimate for each test as a lower-bound estimate of the reliability co-efficient for that test (Adkins and Lyerly, 1952; French, 1951; Kelley, 1954). But it was considered advisable to compute reliability co-efficients for tests used in the present battery; certain of the orally presented tests appeared likely to be susceptible to momentary fluctuations in attention on the part of the subject, and consequent misplacement of responses in the attention tests could have been serious enough to make it doubtful whether these tests were giving consistent measures of any function at all.

Reliability co-efficients for all of the listening comprehension tests and for most of the other tests in which the time limits were sufficient to allow 90% of the children to attempt all items, were computed by means of Kuder-Richardson Formula 20. These estimates were obtained from a sample of 50 boys and 50 girls, drawn at random from the final groups of 161 boys and 139 girls respectively. The necessary estimates of item variance and raw score variance for each test were computed for this sample of 100 cases.

The Kuder-Richardson formula was not appropriate for the tests of Singing, Haphazard Speech and Illogical Grouping. The correct identification of individual words in these tests was likely to be associated with the correct identification of adjacent words or of the sentence as a whole. Reliability co-efficients for these tests were therefore computed by correlating the total number of words correctly identified in the odd-numbered sentences with the total number correctly identified in the even-numbered sentences, and applying the Spearman-Brown formula (for a test twice as long) to these correlations.

Reliability co-efficients for the six speeded tests were computed by the test-retest method. The retest data were obtained for one of the classes participating in the second round of the testing programme. The interval between test and re-test ranged from one to five weeks.

The reliability co-efficients for each of the 34 experimental and reference tests are given in Appendix D. It will be seen that most of the reliability co-efficients are lower than the accepted levels for individual diagnosis. To keep the total testing time within reasonable limits, and to use the time available to the best effect for studying the factorial structure of tests, it is necessary to use much shorter tests than those used in the diagnosis of individual examinees. Considering the small number of items in most tests, the reliability co-efficients are generally of a satisfactory level and are sufficiently high for purposes of factor analysis (Kelley, 1954). The test-retest co-efficients, which are less dependent on test length than are the co-efficients of internal consistency, are generally satisfactory, except in the case of Triplet Numbers and Letter List, which suggests that these tests are not providing very consistent measures of the attention factor. Of the tests for which Kuder-Richardson or split-half co-efficients are available, Singing and Listening to Spontaneous Speech are the least reliable. This could be due to the poorer quality of the tape recordings for these two tests. But the fact that relatively low reliabilities have also been obtained with some high quality recordings, namely, Listening to Short Talk, Listening to Boys' Talk, and Listening for General Significance, coupled with the fact that the reliability co-efficient for Haphazard Speech is also low, suggests that tests involving a considerable amount of auditory synthesis may tend to be less reliable than those in which the speech sample is clearly presented.

Comparison of Tests 7, 9, 10 and 11 with Tests 26, 27, 28 and 29 respectively, suggests that tests of listening comprehension are slightly less reliable than corresponding tests of reading comprehension.

## CHAPTER 4

# INTERPRETATION OF FIRST ORDER FACTORS

THE results of the factor analyses of the intercorrelation matrices for boys and girls are discussed in this chapter. In identifying the various factors, consideration has been given to the factor loadings obtained in each of the three solutions (one graphical, two analytic) for boys and girls. The fact that there was a high degree of correspondence between the rotated factors obtained for both boys and girls and for both types of solution made it possible to group the information from all solutions in discussing particular factors. Tests with significant loadings on the corresponding factors in each solution have been listed for each of the factors considered. Factor loadings which exceed three times the standard error of a correlation co-efficient of zero for 161 cases and 139 cases respectively have been regarded as significant; accordingly, the lists of tests include only those tests with loadings of .24 and above in the V matrices for boys, and of .25 and above in the V matrices for girls.

The various factors are discussed in the following pages, commencing with the reference-test factors. In the list of tests for each factor, tests with significant factor loadings in only one of the three solutions for boys and for girls have been separated from those with significant loadings in more than one solution. As an aid in the interpretation of factors, factor loadings have been marked with an asterisk when they represent the highest factor loading for the test concerned.

### FACTOR A′

BOYS

| *Test* | Loadings *Graphical* | *Biquartimin* | |
|---|---|---|---|
| | (8) | (8) | (9) |
| 6. Arithmetic Reasoning | .48* | — | .27 |
| 15. Five Letters | .42* | .24 | .27* |
| 2. Letter Series | .41* | .28* | .34* |
| 3. Progressive Matrices | .37* | .28* | .30* |
| 1. Letter Grouping | .33* | .44* | .48* |
| 12. Matching Words | .48* | — | — |
| 5. Word Squares | .35* | — | — |

FACTOR A′ (contd.)

BOYS (contd.)

| Test | Loadings Graphical (8) | Biquartimin (8) | (9) |
|---|---|---|---|
| 35. (School Arithmetic) .. .. .. .. | .35* | — | — |
| 14. Letter List .. .. .. .. .. | .33* | — | — |
| 33. Listening to Girls' Talk .. .. .. | — | .30 | — |
| 4. Reasoning .. .. .. .. .. | .25 | — | — |
| 7. Reading Vocabulary .. .. .. | .25 | — | — |
| **GIRLS** | (10) | (8) | (9) |
| 2. Letter Series .. .. .. .. .. | .56* | — | .45* |
| 3. Progressive Matrices .. .. .. | .45* | .42* | .46* |
| 13. Triplet Numbers .. .. .. .. | .44* | — | .47* |
| 15. Five Letters .. .. .. .. .. | .44* | — | .44* |
| 35. (School Arithmetic) .. .. .. | .43* | — | .35* |
| 6. Arithmetic Reasoning .. . .. | .38* | .27* | .27* |
| 1. Letter Grouping .. .. .. .. | .35* | — | .27 |
| 5. Word Squares .. .. .. .. | .27* | .36* | .35* |
| 14. Letter List .. .. .. .. .. | .33* | — | — |
| 4. Reasoning .. .. .. .. .. | .29 | — | — |
| 21. Consequences .. .. .. .. | — | .30* | — |
| 32. Listening to Boys' Talk .. .. .. | — | .29* | — |
| 8. Speed of Reading .. .. .. .. | — | –.29 | — |

*Highest loading for the test.

*Factor A′: Induction.* This factor corresponds to Factor C in Table C8, Factor G in Tables C6 and C7, Factor B in Table C15, Factor E in Table C13 and Factor B in Table C14. The factor seems to be best interpreted as the inductive reasoning or induction factor described by French (French, 1951, 1954). The reference tests included to represent the induction factor—Letter Grouping, Letter Series and Progressive Matrices—have their highest loadings on this factor in all solutions except the 8-factor biquartimin solution for girls, where the factor in question does not appear to admit of a very clear interpretation.

There would be some justification for advancing the view that the factor may be a general reasoning rather than an inductive reasoning factor. The two graphical solutions and the 9-factor biquartimin solution for girls indicate that the other reasoning tests (Arithmetic Reasoning, included to represent a general reasoning factor, and Reasoning and Word Squares, included to represent a deductive reasoning factor) and the attention tests (Triplet Numbers, Letter List and Five Letters) also have significant loadings on this factor. But the more widely accepted induction factor (French, 1951, 1954) appears adequate to describe the pattern of test loadings; the task of discovering a rule or principle is certainly involved in Arithmetic Reasoning, Word Squares and Matching Words, even if not so clearly as in Letter Grouping, Letter Series and Progressive Matrices, which tend to have higher loadings than most other tests on the factor. The loadings of the Word Squares test on this factor are quite consistent with Adkins and Lyerly's study, where the test was found to have a loading on an inductive as well as on a deductive factor (Adkins and Lyerly, 1952). It is more difficult to account for the loadings of the attention tests on this factor, as they would generally seem to call for application of rules rather than discovery of rules. To the extent that the rules had not been thoroughly learned, and had to be re-formulated by the pupils in the course of answering the test items, reasoning of the inductive type could have been involved.

The estimated loadings of School Arithmetic on this factor are consistent with the factor interpretation. School arithmetic at the sixth grade level requires pupils not only to demonstrate speed and accuracy in computation, but also to find answers to problems presented in verbal form.

FACTOR B′

BOYS

| *Test* | *Loadings* | | |
|---|---|---|---|
| | *Graphical* | *Biquartimin* | |
| | (8) | (8) | (9) |
| 4. Reasoning | .47* | .48* | .48* |
| 13. Triplet Numbers | .31* | .31* | .32* |
| 32. Listening to Boys' Talk | –.25 | — | –.32* |
| 29. Listening for Inference | .29* | — | — |
| 26. Listening Vocabulary | — | — | –.25* |
| 33. Listening to Girls' Talk | — | — | –.31* |
| 23. Memory for Words | –.28 | — | — |

GIRLS

| | *Graphical* | *Biquartimin* | |
|---|---|---|---|
| | (10) | (8) | (9) |
| 4. Reasoning | .33* | .30* | .43* |
| 13. Triplet Numbers | .28 | — | — |
| 31. Listening to Spontaneous Speech | — | .33* | — |
| 3. Progressive Matrices | — | — | –.32 |

*Highest loading for the test.

*Factor B′: Deduction.* This factor corresponds to Factor E in Table C8, Factor D in Table C6, Factor D (reflected) in Table C7, Factor I (reflected) in Table C15, Factor F in Table C13 and Factor I in Table C14. It is most strongly represented in Thurstone's test of Reasoning, in which the subject is required to solve logical problems involving "greater than, equal to, or less than" relationships. In the boys' solutions and in the graphical solution for girls, this factor is also represented in Triplet Numbers. This is the only other test in the battery requiring the subject to make "greater than" and "less than" comparisons between three elements.

This factor has been tentatively interpreted as Deduction, as the test is a reference test for the Deduction factor (French, 1954). Word Squares, the other reference test for this factor, had no significant loadings on the factor. The verbal analogy type of item in the Word Squares test offers little scope for making comparisons of relative magnitude, and with these subjects at least, appears to call for discovery of rules as in Induction rather than application of rules. More positive identification of the factor is difficult, as the Reasoning test has had a rather varied pattern of factor loadings in Thurstone's studies. At the eighth grade level, no Deduction factor was isolated, but the test had a significant loading on a number factor (Thurstone, 1941); with University students a similar test, labelled Syllogisms, had higher loadings on spatial, verbal and inductive factors than on the deductive factor, though its loading on the latter factor was still significant (Thurstone, 1938). The test was not included in Adkins and Lyerly's battery (Adkins & Lyerly, 1952). It is possible that syllogistic tests involving "greater than" and "less than" comparisons may be represented by a distinct sub-factor in a wider domain of deductive reasoning.

The suggested interpretation of the factor is not affected by the nature of the other tests which have significant loadings on it. In any case, it does not seem that much importance should be attached to these loadings, most of which occurred in only one of the six solutions. Neither the Progressive Matrices test nor Listening to Boys' Talk, both of which have significant negative loadings on the factor, would be expected to involve the type of logical reasoning which the factor appears to indicate. In the Adkins and Lyerly study (Adkins & Lyerly, 1952), as in the present study, Progressive Matrices had significant positive loadings on inductive reasoning factors only.

FACTOR C′

BOYS

| Test | Loadings Graphical (8) | Biquartimin (8) | Biquartimin (9) |
|---|---|---|---|
| 19. Illogical Grouping .. .. .. .. | .47* | .35* | .38* |
| 25. Letter Span II (Auditory) .. .. | .46* | .57* | .59* |
| 24. Letter Span I (Visual) .. .. .. | .39* | .53* | .50* |
| 16. Rapid Spelling .. .. .. .. | .34* | .26* | .32* |
| 17. Singing .. .. .. .. .. .. | .28 | — | — |
| 18. Haphazard Speech .. .. .. .. | .28 | — | — |

GIRLS

| Test | Graphical (10) | Biquartimin (8) | Biquartimin (9) |
|---|---|---|---|
| 25. Letter Span II (Auditory) .. .. | .59* | .53* | .58* |
| 24. Letter Span I (Visual) .. .. .. | .51* | .58* | .58* |
| 16. Rapid Spelling .. .. .. .. | .45* | .29* | .34* |
| 17. Singing .. .. .. .. .. .. | .32* | — | .25* |
| 18. Haphazard Speech .. .. .. .. | .36 | — | — |
| 19. Illogical Grouping .. .. .. .. | .32* | — | — |
| 30. Listening to Short Talk .. .. .. | — | –.28 | –.30 |

*Highest loading for the test.

*Factor C′*: *Span Memory*. This factor corresponds to Factor B in Table C8, Factor C in Table C15, and Factor A in Tables C6, C7, C13 and C14. It is one of the most clearly defined factors in the battery, and is best represented in the reference tests for the Span Memory factor, namely Auditory Letter Span and Visual Letter Span. These two tests have the highest loadings on the Span Memory factor in Kelley's study of memory factors (Kelley, 1954).

The other four tests with loadings on this factor were all included as reference tests for Karlin's factor of Auditory Resistance (Karlin, 1942). Some of these tests also define an Auditory Resistance factor in the present study. It appears likely that all four of the auditory resistance tests involve span memory, and that the absence of significant loadings for two of these tests on the span memory factor in the biquartimin solutions can be attributed to the fact that the span memory and auditory resistance factors are much more highly correlated in the biquartimin than in the graphical solutions.

Kelley has described the span memory factor as "the ability to recall perfectly for immediate reproduction a series of unrelated items after only one presentation of the series" (Kelley, 1954). This adequately describes the task involved in the Auditory and Visual Letter Span tests, and also in the Rapid Spelling test; it is quite conceivable that many pupils would obtain correct answers in the latter test by merely memorizing the sequence of letters without necessarily synthesizing them into a recognized word. But the present factor seems wider than this, for it is represented also in the tests of Singing, Haphazard Speech and Illogical Grouping, all of which require the pupil to memorize a sequence of related words included in a sentence.

At first glance, Kelley's claim that this factor is common to visually-presented and auditorily-presented span tests (Kelley, 1954) would seem to be supported by the present study, as the factor is well represented in the one visually-presented test (Visual Letter Span) as well as in the five auditorily-presented tests. From observations made by the author during the course of the experiment, however, it would seem more correct to infer that the factor was an auditory span memory factor than that it transcended the modality of presentation. Although Test 24, the Visual Letter Span test, was presented visually, it was clear that many if not most of the children were vocalizing the letters and thus effectively converting the task to one of auditory memory. Even after they were cautioned against saying the letters audibly, it was strongly suspected that they were performing the task by sub-vocalizing the letters. It seems likely that this approach to tests of visual memory is not confined to well-motivated children, and that visual span memory would be better tested by extremely short tachistoscopic presentations of groups of letters than by sequential presentations of one letter at a time.

In his factorial study of auditory function (Karlin, 1942), Karlin identified a memory span factor ("General Span") which was represented in auditory and visual span tests similar to those used in the present study. However, the tests of Rapid Spelling, Singing, Haphazard Speech and Illogical Grouping did not have significant loadings on this factor. Significant loadings for the Rapid Spelling and visual memory span tests were obtained on another factor, but Karlin interpreted this as a speed of closure factor. The other three tests had significant loadings on the auditory resistance factor as they have in the present study. The fact that these tests appear in a span memory factor in this study and not in Karlin's study is probably best attributed to a difference in the nature of the two span memory factors; Karlin's general span factor is also represented in two masking tests, which do not appear to involve the type of task required in the Auditory and Visual Letter Span tests in the present battery.

FACTOR D′

BOYS

| *Test* | *Loadings* | | |
|---|---|---|---|
| | *Graphical* | *Biquartimin* | |
| | (8) | (8) | (9) |
| 22. Word Number | — | .46* | .34* |
| 14. Letter List | — | .45* | .47* |
| 15. Five Letters | — | .31* | .24 |
| 6. Arithmetical Reasoning | — | — | .28* |

GIRLS

| | *Graphical* | *Biquartimin* | |
|---|---|---|---|
| | (10) | (8) | (9) |
| 22. Word Number | .38* | .47* | .54* |
| 23. Memory for Words | .34* | .52* | .51* |
| 20. Sentence Completion | — | .39* | .35* |

FACTOR E′

BOYS

| *Test* | *Loadings* | | |
|---|---|---|---|
| | *Graphical* | *Biquartimin* | |
| | (8) | (8) | (9) |
| 23. Memory for Words | .42* | .24* | — |
| 20. Sentence Completion | .39* | .34* | — |
| 21. Consequences | .38* | .30* | .34* |
| 30. Listening to Short Talk | — | .24 | .24 |
| 22. Word Number | .33* | — | — |
| 33. Listening to Girls' Talk | — | .34* | — |
| 32. Listening to Boys' Talk | — | .24 | — |
| 5. Word Squares | — | — | –.26 |

GIRLS

| | *Graphical* | *Biquartimin* | |
|---|---|---|---|
| | (10) | (8) | (9) |
| 21. Consequences | .51* | — | — |
| 20. Sentence Completion | .43* | — | — |
| 32. Listening to Boys' Talk | .26 | — | — |

*Highest loading for the test.

*Factor D′ (Rote Memory) and Factor E′ (Meaningful Memory)*. These factors are presented and discussed together, as the reference tests (Tests 20, 21, 22 and 23) did not separate clearly into two memory factors in all solutions. This provided some difficulties in matching corresponding factors from the various solutions. As presented in the above table, Factor D′ corresponds to Factor E in Tables C6 and C7, to Factor F in Table C15, to Factor C in Tables C13 and C14, and does not appear in Table C8. Factor E′ corresponds to Factor G in Table C8, Factor F in Tables C6 and C7, to Factor E in Table C15, and fails to appear in Tables C13 and C14.

Factor D′ has been interpreted as rote memory, and factor E′ as meaningful memory. These interpretations have been based mainly on the loadings of the reference tests for these factors, namely, Tests 22 and 23 for the rote memory factor, and Tests 20 and 21 for the meaningful memory factor. Tests 22 and 23, Word Number and Memory for Words, are both paired associate tests, with no apparent meaningful relationship between the separate elements of each pair. Such tests have been shown to be the best measures of the associative or rote memory factor (French, 1951; Kelley, 1954). By contrast, Tests 20 and 21, Sentence Completion and Consequences, require the subject to memorize material presented in a meaningful context. Both of these tests had high loadings on the meaningful memory factor in Kelley's study (Kelley, 1954).

A clear separation of the two pairs of reference tests into the two factors was achieved only in the case of the graphical solution for girls. In most of the other solutions there was a tendency for some reference test loadings to drift to the other memory factor. This can be largely accounted for by variations in the size of the correlations between the two factors in the various solutions. The drift was, of course, most noticeable in the solutions in which only one of the two factors was identified. In the case of the biquartimin solutions for the girls, the significant loadings of the Sentence Completion test on the rote memory factor pose no great problem; as this was a completion recall test and not a free recall test like Consequences, it could be readily conceded that rote memorization might play some part in the task (Kelley, 1954). The difficulty in the other case is a result of the decision to identify the particular factor in the graphical solution for boys as a meaningful memory rather than a rote memory factor. This interpretation was preferred not only because it allowed of closer matching with the biquartimin solutions for boys, but also because of comments made about the Memory for Words test by an observer at one of the testing sessions. As this person indicated that he had simplified the task of remembering unrelated words like shoe and tree by mentally picturing a shoe hanging on a tree, it is quite conceivable that some of the children adopted this approach, thus injecting some meaning into a supposedly meaningless relationship.

Some justification is required for interpreting Factor D′ in the biquartimin solutions for boys as a rote memory rather than an attention factor, particularly as Letter List and Five Letters were reference tests for the latter factor. Consideration of the nature of the task in these two tests and in Word Number appears to favour the existing interpretation. Whereas all three tests require the subject to memorize meaningless symbols, the need for responding quickly to a series of directions does not occur at all in the Word Number test.

Of the remaining tests with significant loadings on either of the two factors, only Arithmetic Reasoning appears to be inconsistent with the interpretation offered. The listening tests based on the three short talks could well be expected to have significant loadings on a meaningful memory factor.

FACTOR F′

BOYS

| *Test* | *Loadings* *Graphical* | *Biquartimin* | |
|---|---|---|---|
| | (8) | (8) | (9) |
| 17. Singing .. .. .. .. .. .. | .37* | .40* | .28* |
| 18. Haphazard Speech .. .. .. .. | .33* | .39* | .44* |
| 5. Word Squares .. .. .. .. | — | — | .27* |

GIRLS

| | *Graphical* | *Biquartimin* | |
|---|---|---|---|
| | (10) | (8) | (9) |
| 18. Haphazard Speech .. .. .. .. | .36* | .48* | .52* |
| 19. Illogical Grouping .. .. .. .. | .31 | .36* | .36* |
| 16. Rapid Spelling .. .. .. .. | — | .26 | .33 |
| 12. Matching Words .. .. .. .. | — | .27 | — |

*Highest loading for the test.

*Factor F′: Auditory Resistance.* This factor corresponds to Factor H in Tables C6, C7, C8 and C15, and to Factor G in Tables C13 and C14. The interpretation of the factor is quite clear. It is the auditory resistance factor identified by Karlin (Karlin, 1942), and with two exceptions, is represented only in the reference tests included to measure this factor. The exceptions are the Word Squares test and the Matching Words test. Being non-auditory tests, their loadings on this factor in two of the biquartimin solutions are incongruous, and provide evidence that the 9-factor biquartimin solution for boys and the 8-factor biquartimin solution for girls are less acceptable psychologically than the alternative biquartimin solutions.

In Karlin's study, the factor was best represented in the tests of Singing, Haphazard Speech and Illogical Grouping. Karlin's interpretation of the factor implies that pupils with the highest scores on these tests would be those best able to resist the effects of distortion in speech brought about by temporal disarrangement of words and inflectional disturbances. The present results suggest that the factor may be affected by the sex of the speaker in relation to that of the respondents. The Singing test, in which a female voice was employed, evidently involved considerably less distortion for the girls than it did for the boys. Similarly, Illogical Grouping offered less distortion for the boys, and became for them more a measure of span memory. Haphazard Speech, the test involving the greatest amount of distortion, had significant loadings for both sexes.

FACTOR G′

BOYS

| *Test* | *Loadings* | | |
|---|---|---|---|
| | *Graphical* | *Biquartimin* | |
| | (8) | (8) | (9) |
| 8. Speed of Reading | .52* | .54* | .49* |
| 36. (School Reading) | .47* | .40* | |
| 10. Reading to Note Details | .44* | .42* | .42* |
| 11. Reading for Inference | .41* | .46* | .46* |
| 7. Reading Vocabulary | .41* | .43* | .35* |
| 9. Reading for General Significance | .32* | .34* | .31* |
| 12. Matching Words | .34 | .29* | — |
| 37. (School Composition) | .33* | .38* | |
| 26. Listening Vocabulary | .33* | .36* | — |
| 27. Listening for General Significance | .32* | .34* | .26* |
| 5. Word Squares | .25 | — | — |

GIRLS

| | Loadings | | |
|---|---|---|---|
| | Graphical | Biquartimin | |
| | (10) | (8) | (9) |
| 11. Reading for Inference .. .. .. .. | .41* | .55* | .54* |
| 10. Reading to Note Details .. .. .. | .33* | .47* | .49* |
| 8. Speed of Reading .. .. .. .. | .32* | .62* | .65* |
| 9. Reading for General Significance .. | .27* | .47* | .47* |
| 7. Reading Vocabulary .. .. .. | .25* | .43* | .43* |
| 27. Listening for General Significance .. | .27 | .39* | .41* |
| 26. Listening Vocabulary .. .. .. | .24 | .36* | .39* |
| 31. Listening to Spontaneous Speech .. | .24* | .28 | .28 |
| 34. STEP Listening .. .. .. .. | — | .43* | .40* |
| 29. Listening for Inference .. .. .. | — | .36* | .34* |
| 28. Listening to Note Details .. .. | — | .34* | .35* |
| 36. (School Reading) .. .. .. .. | — | | .27* |

*Highest loading for the test.

*Factor G′: Verbal Comprehension.* This factor corresponds to Factor B in Tables C6 and C7, and to Factor D in Tables C8, C13, C14 and C15. It is clearly the well-established verbal factor, variously described as verbal comprehension (French, 1951; Thurstone, 1941), verbal knowledge (French, 1954) and verbal relations (Adkins and Lyerly, 1952; Thurstone, 1938). The five reference tests for this factor (Tests 7, 8, 9, 10 and 11) require the subject to demonstrate his understanding of the meaning and relations of words or verbal concepts. Each of these reference tests had its highest loading on this factor in all six solutions. The significant loadings obtained for Word Squares and Matching Words in certain of the boys' solutions are not unexpected, as the former test requires understanding of verbal relations and the latter demands appreciation of the functions of words in sentences.

The most interesting aspect of this factor for the present investigation is its relationship to the experimental tests of listening comprehension. In most solutions the factor is quite closely related to another factor which is represented mainly in the listening tests, and which is described in the next section as a listening comprehension factor. The correlation between the two factors ranges from .08 in the graphical solution for girls to .77 in the graphical solution for boys. In all solutions there are some listening tests with significant loadings on this verbal factor; in the biquartimin solutions for girls, most of the listening tests have significant loadings on the factor. It would appear in the latter case that some of the listening test variance which has been attributed to the verbal factor could well have been transferred by means of further rotations to a "listening" factor, giving a pattern of results similar to those obtained in both graphical solutions and in the biquartimin solutions for boys.

The separate grouping of the reading and listening tests in the above list draws attention to the fact that the loadings of the listening tests are mostly considerably lower than those of the reading tests. However, two of the listening tests, Listening Vocabulary and Listening for General Significance, appear consistently in the lists of tests for this verbal factor. In the boys' solutions, there are significant loadings for the two tests on this factor, but not on the "listening" factor. Upon examination, these tests are found to depend mostly on knowledge of the meanings of particular words, in contrast to the other listening tests, which all require comprehension of detail and inference in selected passages. In the Listening Vocabulary test, the words are presented out of context, whereas in Listening for General Significance, the subject has to choose from five words the one most appropriate to describe a given context. This finding suggests that understanding of the meaning of words may be more central to the verbal comprehension factor than comprehension of the relations between words. On the other hand, the fact that Speed of Reading, Reading to Note Details and Reading for Inference have higher loadings than Reading Vocabulary and Reading for General Significance indicate that comprehension of verbal relations is also important. Because of the high loadings for the Speed of Reading test, the argument could be advanced that reading speed contributed to the factor; this possibility seems unlikely as ample time limits were allowed for all of the other reading tests, and no time limits were involved in the listening tests.

The estimated loadings of School Reading on the factor are consistent with the factor interpretation. It is not surprising that School Composition has a significant loading on the factor, as writing as well as reading requires an understanding of the meaning of words and of the relations between words.

FACTOR H'

BOYS

| Test | Graphical (8) | Loadings Biquartimin (8) | (9) |
|---|---|---|---|
| 33. Listening to Girls' Talk | .36 | .26 | — |
| 32. Listening to Boys' Talk | .36* | .25* | — |
| 34. STEP Listening | .32* | .37* | .32* |
| 30. Listening to Short Talk | .30* | .41* | .34* |
| 29. Listening for Inference | .26 | .50* | .43* |
| 28. Listening to Note Details | — | .29* | .29* |
| 10. Reading to Note Details | — | — | .24 |
| 31. Listening to Spontaneous Speech | .23 | — | — |
| 23. Memory for Words | — | –.28 | –.46 |
| 8. Speed of Reading | –.36 | — | — |

GIRLS

| Test | Graphical (10) | Biquartimin (8) | (9) |
|---|---|---|---|
| 32. Listening to Boys' Talk | .56* | — | .39* |
| 28. Listening to Note Details | .52* | — | .29 |
| 30. Listening to Short Talk | .48* | — | .28* |
| 21. Consequences | .46 | — | .44* |
| 33. Listening to Girls' Talk | .43* | — | — |
| 29. Listening for Inference | .39* | — | — |
| 34. STEP Listening | .34* | — | — |
| 26. Listening Vocabulary | .30* | — | — |
| 27. Listening for General Significance | .27* | — | — |

*Highest loading for the test.

*Factor H': Listening Comprehension. (Comprehension of verbal material presented in spoken form.)* This factor corresponds to Factor A in Tables C8 and C15, Factor C in Tables C6 and C7, Factor E in Table C14 and does not appear in Table C13. Reasons for its non-appearance in the latter table have already been advanced in the discussion on the verbal comprehension factor. The rather weak definition of the present factor in the 9-factor biquartimin solution for girls probably also results from assigning most of the variance of the listening tests to the verbal comprehension factor.

The present factor is clearly both confined to and common to the experimental tests of listening comprehension. In the graphical solution for girls, all of the listening comprehension tests have significant (and their highest) loadings on this factor, except for Listening to Spontaneous Speech, which almost attained the requisite significance level with its loading of .21, despite its very low communality. And although Consequences was included as a test of meaningful memory and not as an experimental test of listening comprehension, the task of reproducing the substance of a series of meaningful consequents in relation to given orally-presented antecedents is virtually a form of listening comprehension.* In the boys' solutions, the only listening tests missing from the above list are Listening Vocabulary and Listening for General Significance. Because of the emphasis on word meanings in these tests, they appear to be related to reading comprehension as closely as or more closely than to listening comprehension tests. Although Listening to Note Details did not have a significant loading on the factor in the boys' graphical solution, its loading of .20 approached the necessary significance level. In the same solution, Listening to Girls' Talk had its highest loading of .43 on a factor which was not interpreted (Factor F), but which seemed to be confined to listening tests based on long rather than short selections.

What is the nature of the present factor? It is not represented in the other auditory tests in the battery, nor is it represented in the reading comprehension tests. Yet the task involved in all of the experimental listening tests does call for the understanding of words and the comprehension of verbal relations, and the material is certainly received by the subject in the form of auditory stimuli. The questions in the tests range from matters of detail to inferences and implications based on the material presented. Considering the nature of the tests, the task would appear to be adequately described as "comprehension of verbal material presented in spoken form," or more simply but less accurately as listening comprehension or auditory comprehension. By contrast, the usual verbal comprehension factor might be better described as "comprehension of verbal material presented in printed (or written) form," except that it seems to extend in this study to certain types of verbal test presented in spoken form. In view of the lower loadings of the reading and listening vocabulary tests (numbers 7, 9, 26 and 27) on Factors G′ and H′ and the loadings of the latter two tests on the verbal factor, it might be more satisfactory to

*In the case of the 9-factor biquartimin solution for girls, this factor could also have been interpreted as meaningful memory.

postulate three factors—"comprehension of meaningful verbal *passages* presented in *spoken* form," "comprehension of meaningful verbal *passages* presented in *printed* form" and "knowledge of word meanings." This third vocabulary-type factor would appear to be similar in some ways to Carroll's "C" factor—"the richness of the individual's stock of linguistic responses" (Carroll, 1941). This suggested division of the verbal domain would, of course, need to be substantiated by further research.

The present study confirms the finding of a separate auding factor in the smaller factor studies of Caffrey (Caffrey, 1955a) and Caffrey and Smith (Caffrey and Smith, 1956). In both of these studies, the reading or visual-verbal factor and the auding factor were highly correlated (.79 in the former study, .56 in the latter). This accords generally with the level of correlation between the verbal and listening factors in the present study. Interestingly enough, Caffrey suggested in his article (Caffrey, 1955a) that "the" verbal factor might be "further reducible according to input channel type," while Caffrey and Smith (Caffrey and Smith, 1956) drew a distinction between a visual-verbal achievement factor as found in tests of reading comprehension and an auditory-verbal factor involving comprehension of spoken language.

## UNIDENTIFIED FACTORS

*Graphical solutions*

BOYS

*Factor F*

| | |
|---|---|
| 33. Listening to Girls' Talk .. | .43* |
| 32. Listening to Boys' Talk .. | .30 |
| 22. Word Number .. .. | −.30 |

GIRLS

*Factor G*

No significant loadings.

*Factor J*

No significant loadings.

*Eight-factor biquartimin solutions*

*Factor B*

| | |
|---|---|
| 13. Triplet Numbers .. .. | .41* |
| 15. Five Letters .. .. .. | .26* |

*Factor H*

| | |
|---|---|
| 14. Letter List .. .. .. | .33* |
| 12. Matching Words .. .. | .32* |
| 2. Letter Series .. .. | .26* |
| 17. Singing .. .. .. | −.27 |

*Nine-factor biquartimin solutions*

*Factor I*

No significant loadings.

*Factor F*

| | | |
|---|---|---|
| 31. | Listening to Spontaneous Speech .. .. .. | .37* |
| 35. | (School Arithmetic) .. | .30 |
| 1. | Letter Grouping .. .. | –.29 |

*Factor H*

| | | |
|---|---|---|
| 14. | Letter List .. .. .. | .36* |
| 12. | Matching Words .. .. | .36* |
| 35. | (School Arithmetic) .. | .28 |
| 6. | Arithmetic Reasoning .. | .26 |
| 37. | (School Composition) .. | .25* |

*Highest loading for the test.

*Unidentified Factors:* Among the boys' solutions, the only unidentified factor is Factor F from the graphical solution. Only Listening to Girls' Talk and Listening to Boys' Talk had significant loadings on the factor, but the loading of Listening to Short Talk (.23) was almost significant. As these three tests were the only tests based on expository talks of about six or seven minutes' duration, the factor could possibly represent a particular form of listening comprehension. Its failure to appear in other solutions, however, does not justify any attempt at a definite interpretation.

Some comment is required on Factor H, which appears in both biquartimin solutions for girls. Although the factor is best represented in Letter List and Matching Words, these two tests do not seem to have anything in common. Letter List requires the subject to distinguish quickly between consonants and vowels, while Matching Words demands understanding of the function of words in sentences. There seems to be no sound basis for interpreting the factor as it stands. The significant loadings of Letter Series and Arithmetic Reasoning on the factor in the respective solutions, coupled with the estimated loading for School Arithmetic, suggests that it may be basically a reasoning factor. In the graphical solutions, the highest loadings for Letter List and Matching Words were obtained on reasoning factors.

Factor F in the 9-factor biquartimin solution for girls is represented only in Listening to Spontaneous Speech, apart from the estimated significant loading for School Arithmetic. As Listening to Spontaneous Speech was the only listening test of its kind in the battery, the hypothesis that the factor represents a form of listening comprehension peculiar to poorly organized spontaneous speech cannot be verified. The rather varied pattern of factor loadings obtained for this test in the various solutions (including loadings on deductive reasoning, meaningful memory, verbal comprehension and listening comprehension factors) may be a reflection of the low reliability of the test.

Three reference tests, namely Triplet Numbers, Letter List and Five Letters, were included in the battery to identify the Attention factor. Although there were some indications of such a factor in the results, it failed to emerge with any clarity. Factor B in the 8-factor biquartimin solution for girls could be identified as the Attention factor. Factor E in the biquartimin solutions for boys could also be identified as the Attention factor, but in the discussion relating to Factor D′, arguments have been advanced for naming this factor rote memory rather than attention. In the present study, the highest loadings for the three tests of attention have mostly appeared on the inductive or deductive reasoning factors. The difference between the age levels of the subjects participating in this study and in Wittenborn's study (Wittenborn, 1943) may explain the absence of a well-defined Attention factor in the present case; it is conceivable that the factor could be better defined among older subjects, or that it is difficult to measure reliably with 11 and 12 year old children, as is suggested by the reliability co-efficients obtained for two of these tests. On the other hand, it cannot really be claimed that the Attention factor is a well-established factor. It is based chiefly on Wittenborn's studies (Wittenborn, 1943; Wittenborn and Larsen, 1944), and even in these studies there are indications that the factor is also represented in reasoning tests.

## Chapter 5

# INTERPRETATION OF SECOND ORDER FACTORS

As indicated in Chapter 3, second order factors were computed only for the two graphical solutions and for the more psychologically acceptable biquartimin solutions, that is, the 8-factor solution for the boys and the 9-factor solution for the girls. Although the first order domain had been characterized by a high degree of correspondence between factors from the various solutions, there was little correspondence between the second order factors obtained in the four solutions. In only two instances was it possible to match a factor from one solution with a factor from another solution with any degree of assurance.

This lack of correspondence stems largely from differences in the pattern of intercorrelations among the primary factors. Negative intercorrelations in the $R_{pq}$ matrices are more numerous in the graphical solutions, and include a number of relatively high correlations in the graphical solution for boys. These differences led to rather different patterns of principal axis factor loadings, particularly in the graphical solution for boys, where the first factor had as many significant negative as positive loadings. When differences of this kind occur in the second order F matrices, lack of agreement between the subsequent rotated factor (V) matrices is not surprising. But correspondence between factors was still not achieved even when there was less difference among the $R_{pq}$ matrices, as in the biquartimin solutions for boys and girls. While this could possibly indicate a fundamental difference in the manner in which boys and girls approach a particular task, inferences of this kind are hardly justified in the absence of any clear pattern of results among the second order factors.

It is possible that greater clarity could be achieved in the second order domain by further rotations or revised rotations of the relevant F matrices. The plotted points representing the primary factors, however, are so few in number and so widely scattered that it seems difficult to avoid rather arbitrary placements of reference vectors. The extraction of further principal axis factors is also unlikely to result in greater clarity in and between solutions.

In any case, only four factors can be determined with eight variables (Thurstone, 1947) and three of the solutions have been carried to this stage. It is also worth noting that a clear pattern of results in the first order domain does not necessarily imply similar clarity in the second order domain (Thurstone, 1947).

Because of the differences between the second-order factors obtained in the four solutions, attempts to interpret these factors individually would not seem to be justified. Examination of the primary factor loadings on the second order factors, however, revealed a possible division of second order factors according to two broad groupings of primary factors. After the individual second order factors have been presented, a tentative interpretation of the second order domain will be suggested.

The table below lists the primary factors which have loadings of .25 and above on the second order factors in each of the four solutions.

**Boys' Graphical Solution**

| | |
|---|---|
| *Factor $A_2$* | |
| Listening Comprehension | .54 |
| Verbal Comprehension ... | .40 |
| *Factor $B_2$* | |
| Deduction ... ... ... | .73 |
| Unidentified ... ... ... | .51 |
| Auditory Resistance ... | .51 |
| Verbal Comprehension ... | .25 |
| *Factor $C_2$* | |
| Induction ... ... ... | .58 |
| Listening Comprehension | .35 |
| Auditory Resistance ... | –.42 |
| *Factor $D_2$* | |
| Meaningful Memory ... | .47 |
| Span Memory ... ... ... | .26 |

**Girls' Graphical Solution**

| | |
|---|---|
| *Factor $A_2$* | |
| Meaningful Memory ... | .90 |
| Unidentified ... ... ... | .87 |
| Induction ... ... ... | .87 |
| Auditory Resistance ... | .86 |
| Verbal Comprehension ... | .81 |
| Unidentified ... ... ... | .77 |
| Deduction ... ... ... | .64 |
| Listening Comprehension | .33 |
| *Factor $B_2$* | |
| Listening Comprehension | .77 |
| Span Memory ... ... ... | .62 |
| Unidentified ... ... ... | .57 |
| Induction ... ... ... | .31 |
| *Factor $C_2$* | |
| Rote Memory ... ... | .72 |
| Verbal Comprehension ... | .51 |
| Span Memory ... ... | .40 |
| Deduction ... ... ... | –.53 |

**Boys' 8-factor Biquartimin Solution**

*Factor $A_2$*

| | |
|---|---|
| Induction ... ... ... | .61 |
| Listening Comprehension | .59 |
| Auditory Resistance ... | .43 |
| Verbal Comprehension ... | .27 |

*Factor $B_2$*

| | |
|---|---|
| Meaningful Memory ... | .71 |
| Auditory Resistance ... | .51 |

*Factor $C_2$*

| | |
|---|---|
| Deduction ... ... ... | .56 |
| Span Memory ... ... | .44 |
| Verbal Comprehension ... | .36 |
| Rote Memory ... ... ... | .32 |

*Factor $D_2$*

| | |
|---|---|
| Rote Memory ... ... ... | .42 |

**Girls' 9-factor Biquartimin Solution**

*Factor $A_2$*

| | |
|---|---|
| Listening Comprehension | .89 |
| Unidentified ... ... ... | .73 |
| Unidentified ... ... ... | .67 |
| Verbal Comprehension ... | .64 |
| Span Memory ... ... ... | .61 |
| Induction ... ... ... | .55 |
| Rote Memory ... ... ... | .36 |

*Factor $B_2$*

| | |
|---|---|
| Unidentified ... ... ... | .59 |
| Deduction ... ... ... | .39 |
| Auditory Resistance ... | –.50 |

*Factor $C_2$*

| | |
|---|---|
| Unidentified ... ... ... | .51 |

*Factor $D_2$*

| | |
|---|---|
| Span Memory ... ... ... | .50 |
| Listening Comprehension | .43 |
| Unidentified ... ... ... | .43 |

*Factor $E_2$*

| | |
|---|---|
| Rote Memory ... ... ... | .46 |

Apart from the obvious correspondence between Factor $B_2$ in the second and Factor $D_2$ in the fourth solution above, and between Factors $D_2$ and $E_2$ in the third and fourth solutions respectively, the lists of primary factors do not agree for any other pair of second-order factors. The two corresponding pairs are marked by the presence of the span memory or rote memory factors. Upon closer examination, it will be noted that the later second order factors listed in each solution involve the primary factors of rote memory or span memory or both,* while the remaining earlier factors (except for Factor $A_2$ in the girls' biquartimin solution) do not. This distinction affords a basis for discussing second-order factors in terms of two broad groupings of primary factors.

*The "meaningful memory" factor listed under Factor $D_2$ in the boys' graphical solution included both meaningful memory and rote memory tests.

Despite the lack of correspondence among the earlier factors in the second order solutions, they appear, when considered in combination, to encompass the same list of primary factors, namely, Induction, Deduction, Listening Comprehension, Verbal Comprehension, Meaningful Memory and Auditory Resistance. In the girls' graphical solution, these primary factors are all included under the one second order factor (Factor $A_2$); in each biquartimin solution, with one exception they are all included in Factors $A_2$ and $B_2$; in the boys' graphical solution, they divide into Factors $A_2$, $B_2$ and $C_2$. It is possible therefore to regard these second order factors and the primary factors subsumed under them as a group displaying some evidence of homogeneity.

The second group consists of the remaining second order factors, Factor $D_2$ in the boys' graphical solution, Factors $B_2$ and $C_2$ in the girls' graphical solution, Factors $C_2$ and $D_2$ in the boys' biquartimin solution, and Factors $D_2$ and $E_2$ in the girls' biquartimin solution. All of these factors are characterized by significant loadings for the primary factors of span memory or rote memory, whereas with one exception referred to earlier, these primary factors do not have significant loadings on the first group of second-order factors.

A tentative interpretation of the two groups of second-order factors can be made on the basis of the differences in the type of task involved in the associated primary factors. The distinctive feature of the second group is found in the types of test used to define the primary factors of span memory and rote memory. Essentially, these tests call for the "memorization of meaningless material," presented in either paired associate form or longer sequences of letters or words. The subject is merely required to reproduce given material in the form in which it was originally presented, and is not called upon to place any meaningful interpretation upon the material. This does not imply that the second order factor is limited to tests employing meaningless material. Children who are proficient at remembering meaningless material might well be expected because of this to obtain higher scores on tests involving meaningful content. It is quite reasonable to expect scores on listening comprehension tests to be partially determined in this way, and it is certainly not inconceivable that scores on some of the tests representing the Verbal Comprehension, Induction and Deduction factors (as listed under Factors $B_2$ and $C_2$ in the girls' graphical solution, and under Factor $C_2$ in the boys' biquartimin solution) could be similarly influenced.

The task involved in the second group of second order factors thus appears mainly to call for passive reproduction of material by the subject. By contrast, the primary factors appearing in the first group of second order factors (i.e., Induction, Deduction, Listening Comprehension, Verbal Comprehension, Meaningful Memory and Auditory Resistance) all appear to be represented in tests which require the subject to interpret the material in his own way rather than merely reproduce it. In other words, he must make an active search for meaning in the material presented before he can answer the questions based on the material. The task that is common to this group of second order factors can therefore best be described as comprehension or interpretation. As the process of interpretation would involve the manipulation of verbal symbols in all of the relevant tests, with the possible exception of Progressive Matrices, the task might be more fully described as "verbal interpretation." This is to be preferred to "verbal comprehension," because of the established connotation of the latter term in the domain of primary factors.

Tests of listening comprehension obviously depend on verbal interpretation, and it has already been indicated how such tests are also likely to be associated with the second order group of memory factors. Likewise, verbal comprehension tests, involving questions of both detail and inference, could be expected to be associated with both groups of second order factors. The above tentative interpretation of the second order factors also provides a reasonable explanation of the variance of scores on the tests of auditory resistance. Part of this variance can be attributed to the fact that some children can remember longer sequences of letters and words than others; part can also be attributed to differences in the extent to which children can make sense from distorted speech samples. The first part would be represented by the loadings of the auditory resistance tests on the span memory factor, and thus on the second order group of memory factors. The second part, which involves the actual interpretation of the verbal messages, would be represented by the loadings of the tests on the primary factor of auditory resistance, which in turn is represented only in the group of second order factors which has been labelled "verbal interpretation."

CHAPTER 6

# SUMMARY, CONCLUSIONS AND IMPLICATIONS

THIS study was undertaken to investigate the factorial structure of listening comprehension tests. Since World War II an increasing amount of attention has been devoted to formal training in listening comprehension and to the assessment of listening comprehension. A survey of the literature has revealed that although it has been commonly assumed that individual differences in performance on listening comprehension tests can be explained in terms of a separate "listening ability" or listening factor, there is very little experimental evidence to justify this assumption. Indeed, the high correlations typically found between these tests and tests of reading comprehension and reasoning suggested that differences in the performance of subjects on listening comprehension tests might be almost completely accounted for by their differences in performance on reading comprehension and reasoning tests.

The problem was investigated in terms of the framework established for identifying the main types of mental activity involved in aptitude and achievement tests, as described by French (French, 1951, 1954). Hypotheses concerning factors likely to be involved in listening comprehension were developed by examining the correlations between listening comprehension tests and other tests, and by considering the differences between the processes of listening and reading. The following established factors were judged to be relevant to the investigation: verbal comprehension, reasoning (induction and deduction), attention, auditory resistance, meaningful memory, span memory and rote memory. Five specific hypotheses about listening comprehension tests were also advanced.

A battery of 34 tests was prepared and assembled to test the various hypotheses. The battery comprised nine experimental tests of listening comprehension, all of which were either specially constructed or modified for the investigation. They included a number of reading comprehension tests presented in listening form, a modified version of the S.T.E.P. Listening Comprehension test, a test designed to measure comprehension of the poorly organized spontaneous speech which is characteristic of many conversational situations, and three tests based on short talks of about six or seven minutes' duration. One of these talks was of general interest to both sexes. The other two talks were respectively designed to appeal to boys but not to girls, and to girls but not to boys, so as to assess the effect of differential interest in material presented on the factorial structure of listening comprehension tests.

The remaining tests in the battery were reference tests for the hypothesized factors listed above. The selection of reference tests was based mainly on the recommendations in French's monograph (French, 1951) and the E.T.S. kit of reference tests (French, 1954), supplemented by the information available in the more comprehensive studies of attention, auditory function and memory which had been made by Wittenborn (Wittenborn, 1943), Karlin (Karlin, 1942) and Kelley (Kelley, 1954) respectively. One form of a series of vocabulary and reading comprehension tests prepared by the Australian Council for Educational Research was modified to serve as reference tests for the verbal comprehension factor; the presentation of the parallel series as listening comprehension tests allowed for more precise comparisons between the factorial structure of the two types of test.

The tests of listening comprehension, attention and auditory resistance, and also three of the memory tests, were presented by means of tape recordings to ensure that there would be no differences in the manner of presentation or the rate of delivery in different schools. All but two of the recordings were made under technical supervision by a male speaker with considerable experience in making broadcasts to schools; the others were made by a female soprano and by a small group of schoolgirls. A high quality tape recorder and a portable speaker specially designed for classrooms were used to present the recordings. Children who were unable to hear the recordings satisfactorily were detected by applying a modified version of the Harvard Spondee test as an audiometric group screen test.

The tests were applied by the author to over 400 Grade 6 children in ten schools in Melbourne, the sample being chosen so as to be broadly representative of sixth grade children in government schools in that city. The test battery was administered to each of the ten classes in six testing sessions of approximately ninety minutes' duration and spaced at weekly intervals, the complete testing programme occupying a period of three months.

Children who had not been present at all testing sessions or whose test papers showed evidence of poor hearing or irregularities, and children from non-English-speaking countries who had been in Australia for less than five years, were not included in the samples used for analysis; the final samples consisted of 161 boys and 139 girls, for whom results on all tests were available.

Raw scores on the 34 tests and on school examinations in arithmetic, reading and composition were normalized for each of the two samples, and the intercorrelations of the 37 variables for each sample were computed on Silliac at the University of Sydney. These intercorrelations were punched on IBM cards and forwarded to the Littauer Statistical Laboratory at Harvard University, where the loadings of the tests on the principal axes were computed on an IBM 650 and subsequently rotated analytically by Carroll's "biquartimin" method on an IBM 704 computer. Independent graphical rotations of the principal factor loadings on eight factors for the boys' sample and ten factors for the girls' sample were undertaken by the author, who also computed second order factors from the correlations between the primary factors obtained in the graphical and two of the biquartimin solutions. Factor loadings of the three school achievement variables on the primary factors were estimated by means of Mosier's generalization (Mosier, 1938) of Dwyer's extension (Dwyer, 1937), and an appropriate reliability co-efficient was computed for each of the 34 tests.

Satisfactory approximations to oblique simple structure among the first order factors were obtained in the graphical solutions and also in the two biquartimin solutions (one based on eight factors, the other on nine factors) for both boys and girls. There was a high degree of correspondence in the pattern of factor loadings obtained from each of the six solutions, but because of some incongruous loadings for certain tests on some factors, the 9-factor biquartimin solution for boys and the 8-factor biquartimin solution for girls were less acceptable on psychological grounds than the other solutions. Nevertheless, the first order factors were easily interpretable. The reference tests included in the battery clearly identified the factors of Induction, Deduction, Verbal Comprehension, Auditory Resistance, Span Memory, Meaningful Memory and Rote Memory, but the factor of Attention failed to emerge, possibly because of the low reliabilities of the Attention test or their closer association with reasoning tests among younger age groups.

Of greatest interest was the identification of a separate "listening comprehension" factor, described in more exact terms as "comprehension of verbal material presented in spoken form." This factor, which was common to most tests of listening comprehension and generally confined to these tests, is discussed more fully below. The first order factor interpretations tended to be confirmed by the pattern of estimated loadings of the school achievement variables, which had not been included in the main analysis. School Arithmetic had significant loadings on the induction factor and School Reading and School Composition had significant loadings on the verbal comprehension factor.

Second order analyses for the two graphical and for two biquartimin solutions showed little correspondence from one solution to another, and a definite interpretation of the second order factors was not attempted. However, as the second order factors seemed to fall into two groups, according to whether they were or were not represented in the rote memory and span memory factors, it was tentatively suggested that the primary factors might be divided into those requiring active "verbal interpretation" on the part of the subject and those requiring him "to memorize meaningless material." The listening comprehension factor had significant loadings in both groups, suggesting that performance on listening comprehension tests depended both on how well a subject could interpret the material and on how well he could remember it.

These general conclusions about the nature of listening comprehension can be supplemented by the answers to the five specific hypotheses set out at the end of the first chapter. Each of these hypotheses is discussed below. In marshalling the necessary evidence to examine each hypothesis, little cognizance has been taken of the less acceptable 9-factor biquartimin solution for boys and 8-factor biquartimin solution for girls, and of the second order analyses, as interpretations were less certain in these instances because of lack of clarity in certain aspects of the analyses.

*Hypothesis 1.* The variance of listening comprehension tests can be accounted for by reasoning, verbal comprehension, attention and memory factors, and no separate listening factor need be postulated.

This hypothesis must be rejected, as a definite listening comprehension factor was identified in the first order domain. For both boys and girls, the experimental group of listening comprehension tests tended to occupy a position in the common factor space which differentiated them from the reference tests for other factors. Most of the listening comprehension tests had their highest significant loadings on this factor, and very few of them had significant loadings on any other factor. Listening Vocabulary and Listening for General Significance, however, appeared to be more closely related to the verbal comprehension than to the listening comprehension factor. These tests were found to depend more on the extent of a subject's vocabulary than on his grasp of the content of spoken passages. But although this separate listening comprehension factor was identified, it was found to be associated with certain of the other primary factors. The correlations between this factor and other factors indicate that performance on listening comprehension tests is most closely associated with performance on verbal comprehension tests, and fairly closely associated with performance on span memory and inductive reasoning tests. There is also a moderate degree of association between performance on listening comprehension tests and performance on tests of rote memory and auditory resistance. Thus, while the hypothesis must be rejected in the form in which it is stated, there is some evidence that performance on listening comprehension tests is related to performance on inductive reasoning, verbal comprehension and certain types of memory tests.

*Hypothesis 2*. Listening comprehension tests have similar loadings to reading comprehension tests on reasoning and verbal comprehension factors, but higher loadings on attention and memory factors.

Since the obtained factor structure in the first order domain was oblique, it is necessary in examining this hypothesis to consider not only the relative size of the loadings of the listening comprehension and reading comprehension tests on the factors indicated, but also the magnitude of the correlations between these factors and the listening comprehension and verbal comprehension factors. The various solutions approximated oblique simple structure fairly closely; as a result, comparisons between the tests of listening comprehension and reading comprehension have to be based mainly on non-significant loadings. Because of this, it was considered that an examination of trends in these comparisons would be a sufficient test of the hypothesis. The hypothesis has therefore been examined by comparing the loadings of Tests 7 to

11 with those of Tests 26 to 34 on each of six factors for each of four solutions, and by comparing the correlations of the listening comprehension and verbal comprehension factors with Induction, Deduction, and the three memory factors.

The evidence reveals that the hypothesis can be accepted insofar as it affects the inductive and deductive reasoning factors. There are no consistent differences in the loadings of the two groups of tests on these factors, nor in the correlations of the factors with the listening comprehension and verbal comprehension factors. The predicted similarity of loadings on the verbal comprehension factor, however, was not attained. Reading comprehension tests had much higher loadings than listening comprehension tests on the verbal comprehension factor. This may, of course, be a direct result of the fact that the verbal comprehension factor was defined in this study largely by reading comprehension tests. The loadings of Listening Vocabulary and Listening for General Significance on the verbal comprehension factor suggest that the hypothesis may not have been rejected if vocabulary tests had been used to define the verbal comprehension factor. The idea that listening comprehension tests would make more demands than reading comprehension tests on attention and memory is mostly discounted by the evidence. The hypothesized attention factor was not identified at all, and the loadings of the two groups of tests on the three memory factors show no trace of any difference in the hypothesized direction. On the other hand, inspection of the correlations between the two comprehension factors and the memory factors suggests that the hypothesis can be rejected in relation to the meaningful memory and rote memory factors only. In three of the four solutions, the span memory factor is much more closely related to the listening comprehension factor than it is to the verbal comprehension factor.

*Hypothesis 3.* Visually-presented memory tests and auditorily-presented memory tests do not differ significantly in their correlation with either reading comprehension tests or listening comprehension tests.

In the three pairs of tests defining the three memory factors, one test in each pair was presented by visual means and the other from a tape recording. This afforded an opportunity of confirming Kelley's finding (Kelley, 1954) that the memory factors were not related to the mode of presentation of the test material. The form in which this third hypothesis is stated requires a comparison of the correlations of the visual and auditory memory tests in each pair with the reading comprehension tests and the listening comprehension tests.

The correlations between Test 20 and Tests 7 to 11 were therefore compared with those between Test 21 and Tests 7 to 11 for both boys and girls. Similar comparisons were made between Tests 22 and 23 and Tests 7 to 11, Tests 24 and 25 and Tests 7 to 11, and between each of the three pairs of tests and Tests 26 to 34. As the main interest lay in determining whether the paired visual and auditory correlations within each set of reading comprehension or listening comprehension tests could arise by random sampling from the same population, it was considered appropriate to employ non-parametric tests to examine the hypothesis. The Wilcoxon matched-pairs signed-ranks test was used for comparisons within each set of listening comprehension tests, but as the number of reading comprehension tests fell below the tabled values for the Wilcoxon test, the less powerful sign test for correlated samples was employed in the latter case* (Ferguson, 1959).

Application of the non-parametric tests revealed that the hypothesis was supported for both boys and girls in the span memory tests, and for girls in the rote memory tests. Among the boys, however, both the reading comprehension and listening comprehension tests had significantly higher correlations with the visual rote memory test (Word Number) than with the auditory rote memory test (Memory for Words), indicating that the hypothesis cannot be sustained in this instance. The hypothesis is also untenable in relation to the meaningful memory tests for both boys and girls. For both sexes, the reading comprehension and listening comprehension tests have significantly higher correlations with the auditory memory test (Consequences) than with the visual memory test (Sentence Completion).

The rejection of the hypothesis as it applies to the meaningful memory tests and to the rote memory tests for boys does not pro-

*In the Wilcoxon tests a probability level below .05 was required to reject the hypothesis that the two sets of correlations were from the same population. In the sign tests the hypothesis was rejected when the probability level was .06; this corresponded to the maximum possible discrimination between the two sets of correlations when N was equal to 5.

vide grounds for concluding that these memory factors are related to the mode of presentation of the material. It will be noted that the visual rote memory test (Word Number) has higher correlations not only with the visually-presented reading comprehension tests but also with the auditorily-presented listening comprehension tests. Similarly, the auditory meaningful memory test (Consequences) has higher correlations with reading comprehension as well as with listening comprehension tests. It appears therefore that the significantly higher correlations associated with the visual test in the one comparison and the auditory test in the other comparison cannot be attributed to the fact that one test was presented visually and the other auditorily.

*Hypothesis 4.* Listening comprehension tests have significant loadings on the meaningful memory factor, but non-significant loadings on rote memory and span memory factors.

As the primary factors were not orthogonal or near-orthogonal in many instances, it is necessary in assessing the validity of this hypothesis to consider the correlations between the listening comprehension factor and memory factors as well as the loadings of the nine listening comprehension tests (Tests 26 to 34) on the memory factors specified.

Examination of the loadings of the listening comprehension tests on the three memory factors shows that the hypothesis cannot be sustained. Although Listening to Short Talk, Listening to Boys' Talk and Listening to Girls' Talk had significant loadings on the meaningful memory and not on the rote memory and span memory factors in one or two of the solutions, there was no further support for the hypothesis in either the matrices of factor loadings or in the correlational evidence. In the solutions in which the meaningful memory factor was clearly identified, its correlation with the listening comprehension factor was very close to zero. By comparison, the listening comprehension factor had correlations of .35 and .43 with the rote memory factor, and of .27, .49, .55 and .57 with the span memory factor, indicating that scores on listening comprehension tests are related to individual differences in the types of task represented in these memory factors.

*Hypothesis 5.* The factorial content of listening comprehension tests does not differ with variations in the interest level of the topics presented.

The test of this hypothesis rests on a comparison of the factor loadings of the two tests designed to appeal differentially to boys and girls. Although the two tests, Listening to Boys' Talk and Listening to Girls' Talk, were found to have this differential appeal,* it was predicted that with a well-motivated group of children who know they will be questioned, the tests would fail to exhibit any differences in factorial structure. The results generally confirm this prediction. Both tests tend to have significant loadings on the same factors (generally Listening Comprehension and Meaningful Memory) in the two graphical and the two biquartimin solutions. There is some evidence of a tendency for the Boys' Talk to have higher loadings than the Girls' Talk on these factors in the girls' solutions, and for the Girls' Talk to have higher loadings in the boys' solutions, but the trend is not consistent enough in the various comparisons to be accepted as a basis for rejecting the hypothesis. The absence of a difference in factorial content does not, of course, preclude the existence of differences in mean score, and differences in the expected direction were found in the main study, though they were significant only for the Boys' Talk.†

To what extent can the above conclusions be generalized beyond the group for which the data was obtained? As factor structure has been shown to change with increase in age in at least some of the relevant investigations (e.g., Reichard, 1944; Richards, 1941), the present findings should probably be limited to children aged about 10 to 12 years. At younger age levels, correlations between listening comprehension tests and reading comprehension tests are likely to be lower, as the mechanics of reading may not have been fully mastered by many children. Factor patterns at older age levels may differ also, as the increasing amount of reading and independent study demanded of the secondary

*In the main factor study, 145 of 161 boys (90%) preferred the boys' talk, while 118 of 139 girls (85%) preferred the girls' talk. On these figures the hypothesis of independence of sex and preference for the talks was rejected by the chi-square test at the .1% level.

†

| | *Boys* | *Girls* | *Difference* | *Significance level* |
|---|---|---|---|---|
| List. Boys' Talk. mean .. .. | 9.42 | 8.43 | .99 | $p < .01$ |
| S.D. .. .. | 2.61 | 2.43 | | |
| List. Girls' Talk. mean .. .. | 8.11 | 8.51 | .40 | not significant |
| S.D. .. .. | 2.92 | 2.47 | | |

school pupil might affect his performance on reading comprehension and listening comprehension tests differentially. On the other hand, the verbal comprehension factor has been identified over a wide range of age levels (French, 1951), and the listening comprehension factor could well follow the same pattern.

It is pertinent, too, to consider how widely the findings can be generalized beyond children in government schools in Melbourne. There have been no comparative studies of listening comprehension in the different Australian States or in government and non-government schools. Although the norms for reading comprehension tests differ in the various States (A.C.E.R., 1950), the basic similarity among the States in curricula and pattern of instruction and in their incidental approach to listening comprehension would suggest that the results could be safely generalized to Australian children in the age groups concerned. Generalization to children in other English-speaking countries, and to America in particular, may be less justified. Not only is the teaching and testing of listening comprehension more widespread in the U.S.A.; Australian observers tend to remark on a basic difference in emphasis in the two countries on the teaching of language at the elementary school level, with Australian schools devoting more attention to reading and writing, and less to speaking and listening. But the fact that the reference factors identified in this study were mostly established on American students in the first place, coupled with the evidence of an auding factor with American high school and fifth grade groups (Caffrey, 1955; Caffrey and Smith, 1956) suggests that the factorial content of listening comprehension tests among American school children may be similar to that found in the present study.

## IMPLICATIONS

The implications of the findings of this study can be conveniently considered under three headings.

### *1. Implications for Testing Practice*

The identification of a separate listening comprehension factor indicates that listening comprehension tests do measure something not already measured by reading comprehension and reasoning tests, thus providing an answer to Lindquist's criticism of listening comprehension tests in the Fifth Mental Measurements Yearbook. Although there is a substantial positive correlation between the listening comprehension factor and certain other factors, especially verbal comprehension, the results of the study indicate that listening comprehension cannot be adequately measured by tests of reading comprehension, reasoning, memory and auditory resistance, and that it needs to be measured specifically by tests of listening comprehension. The application of such tests is not an unnecessary duplication of testing time and effort.

What should be measured in tests of listening comprehension? To answer this question, the purpose for which the measurement is required should be known. For a measure of general achievement in this area, the study shows that questions based on short talks, or on short selections as in the S.T.E.P. Listening Comprehension Test, provide a satisfactory measure of listening comprehension. For diagnostic purposes, a test like the Brown-Carlsen Listening Comprehension test, with its sub-tests of immediate recall, following directions, recognizing transitions and word meanings, and lecture comprehension, might be more useful. In addition to providing a direct measure of listening, the latter test gives measures of span memory and reasoning, which are shown in the present study to be correlated with listening comprehension. It would seem advisable also to use a hearing screen test in conjunction with listening comprehension tests, unless recent information about children's hearing is available from school records or other sources.

The study has revealed that, for well-motivated children who know they are to be tested, the task of comprehending spoken material is performed in the same way for passages differing widely in interest level. But variations in interest level can still be reflected in differences between the mean scores of various groups, even though the passages do not differ in factorial content. In developing listening comprehension tests, it would therefore be advisable to select passages which did not, for instance, favour one sex as against the other, or alternatively to provide separate norms for boys and girls. It would also seem desirable to use several short passages rather than one long passage in order to sample a wider range of topics; except for an unidentified factor in one solution, the study gave no indications that comprehension of the three short talks was different in character to comprehension based on a number of short passages.

The question of whether much is to be gained by measuring listening vocabulary in addition to reading vocabulary is also raised by the study. The results show that the two listening tests based mainly on knowledge of word meanings (Listening Vocabulary and Listening for General Significance) are more closely related to the verbal comprehension than to the listening comprehension factor. There would thus seem to be less need for two separate measures of vocabulary than for two separate measures of comprehension. A more definitive study of vocabulary and comprehension tests, however, would be required to establish this point. Pending such a study, it would probably be desirable to continue to test both reading vocabulary and listening vocabulary. Useful indications of children who could profit from remedial instruction in either area were obtained even in the present study, where the correlation between Reading Vocabulary and Listening Vocabulary was the highest obtained (.73) in the boys' matrix and the second highest (.68) in the girls' matrix.

### 2. *Implications for School Programmes*

The development of comprehension of spoken passages has been treated as an incidental matter in Australian schools, and also, until quite recently, in most American schools. The present investigation draws attention to the fact that pupils differ markedly in the extent to which they comprehend spoken material.

The establishment of a separate listening comprehension factor is not necessarily an indication that the school should do anything about it. If pupils were found to exhibit considerable differences in mirror writing, for instance, it would not follow that schools should provide formal instruction in mirror writing. The case for formal teaching of listening comprehension must be decided on its own merits.

Is it desirable that children and adults should be able to comprehend spoken passages effectively? Is this an important educational objective? It seems rather obvious that it is. Not only does much of the learning in kindergartens and elementary schools take place in this form; the discussion method and the lecture method are in wide use in secondary schools and universities. Probably the larger part of adult learning, both formal and informal, takes place in this form, through contact with other people, radio, and television. Although this type of learning is so common in the community, several studies have demonstrated that members of the community could become much more efficient at comprehending spoken material than they are at present.

Teachers have tended to assume that increasing competence in listening comprehension comes incidentally in the school programme. It is true that children obtain higher scores on listening comprehension tests as they become older, even when they receive no formal instruction in listening comprehension. In establishing a separate listening comprehension factor, this investigation has shown that this type of comprehension can be developed specifically; the fact that school arithmetic, reading and composition do not have significant loadings on the factor indicates that development in the ordinary school subjects does not guarantee development in listening comprehension, and that the latter objective needs to be attended to explicitly. There is ample evidence in other studies that listening comprehension is trainable; this study has suggested that increments in score resulting from training are not entirely due to increased comprehension of verbal material generally, but are due in part to increased comprehension of verbal material presented in spoken form.

The question of how listening comprehension may be best taught has not been a major concern of this investigation; this would need to be determined by further studies employing appropriate experimental designs for this purpose. From the evidence obtained, however, it appears that specific training in span memory tasks would be useful. Examination of the types of items in the listening comprehension tests suggests that the types of training employed in other studies, such as exercises in observing details, making use of contextual clues, distinguishing between main and supporting ideas, and drawing inferences, would also be effective.

A further question of considerable importance for school programmes is raised by the demonstration that tests of reading comprehension and listening comprehension differ in factorial content. Correlations between the equivalent tests presented as reading and listening comprehension tests (excluding the vocabulary tests) ranged from .33 to .64, the median correlation being .52. Evidence from other studies suggests that the provision of formal instruction in listening comprehension would tend to increase these correlations, as improvement is generally greater for poorer listeners than for good listeners. In the meantime, the correlations are low enough to suggest that children who are good at reading and poor at listening, and those who are poor at reading and good at listening should be identified so that they could be studied in greater detail and appropriate remedial measures instituted. A study of the reasons for the difference in their performance on the two types of comprehension test should be profitable. Those who were good at listening but poor at reading would probably show a record of failure in their reading experiences. Why others were good at reading but poor at listening could only be conjectured; such possibilities as lack of security in face-to-face contacts and the development of habits of inattention as a result of prolonged exposure to radio and television would need to be investigated. Comparison of performance on the two types of test also raises the issue involved in determining whether a pupil is performing up to expectation in a given area. It has been customary in educational and psychological practice to use a score on an intelligence or reasoning test as the criterion of what might be expected of a pupil; in deciding what might be expected of a pupil in the field of reading comprehension, however, it would appear that his score on a listening comprehension test might be a more legitimate criterion than his score on an intelligence test.

### 3. *Implications for Further Research*

The findings in this study give rise to a number of suggestions which could be profitably explored in further factor studies. Foremost among these is one relating to the domain of comprehension of verbal material. The finding that listening tests based mainly on vocabulary knowledge have greater affinity with the verbal comprehension than with the listening comprehension factor suggests that knowledge of word meanings might be a sub-factor of the domain which transcends the modality of presentation, and that "comprehension of verbal passages presented in spoken form" (listening comprehension) and "comprehension of verbal passages presented in printed form" (reading comprehension) might be other sub-factors, each correlated with the vocabulary sub-factor. This notion would be worth investigating with a test battery which included several tests of reading vocabulary and listening vocabulary as well as a variety of reading comprehension and listening comprehension tests.

The factorial structure of tests of poorly organized spontaneous speech has not been sufficiently established in this investigation. Apart from the fact that only one such test was included in the study, its pattern of factor loadings failed to indicate clearly its relationship with the listening comprehension factor. Although its loadings were mostly non-significant, its loadings on the listening comprehension factor generally approached the level required for significance. In one solution, however, it appeared to define a separate factor. The factor pattern of such tests should obviously be examined more thoroughly in a battery which included several reliable tests of this kind. Its weak factor pattern in this study is probably due to its extremely low reliability, which in turn can be attributed to the rather poorer quality of the tape recording for this test.

Further research into the nature of the Attention factor is required. Tests of attention or concentration are affected far more than other types of tests by mechanical features of the task, such as registering answers. It seems essential then to determine test-retest reliability co-efficients for these tests before employing them in a factor investigation. If the attention tests used in the present study could be modified to make them more reliable, it is possible that an attention factor would be obtained at the Grade 6 level. The strong association found between these tests and reasoning tests, however, indicates that it would also be desirable to cross-validate Wittenborn's attention factor at older age levels in a test battery which included several types of reasoning tests.

Research is also required into the nature of visual memory and the methods of testing it. In the course of conducting this study, it was observed that so-called tests of visual memory were probably measuring auditory memory to a large extent. This may explain why the same memory factors have previously been found in both visually-presented and auditorily-presented test material. If a visually-presented memory task can be vocalized or sub-vocalized, is it really a test of visual memory? There would seem to be considerable scope for developing tests of visual memory which could not be vocalized by subjects, and assessing both the factorial content of these tests and their relevance to learning.

Finally, there remains the wider question of whether the factors obtained in the present investigation would appear in the same or in modified form if the test battery were to be applied in "live" listening situations and to other populations. The effect of having the tests administered by classroom teachers, of accompanying the listening comprehension tests by demonstrations of what is being discussed in the passages, of applying similar tests to older age groups and to groups in other English-speaking countries, can only be ascertained by further research studies of the present kind.

## Appendix A

## ORDER OF ADMINISTRATION OF TESTS

| Test No. | Test Title | Time Limit (mins.) | Total Time (mins.) |
|---|---|---|---|
| | **First Day** | | |
| 34 | S.T.E.P. Listening .. .. .. .. | — | 45 |
| | *Break* | | |
| 1 | Letter Grouping .. .. .. .. | 4 | 20 |
| 22 | Word Number .. .. .. .. | 5 | 20 |
| | **Second Day** | | |
| 30 | Listening to Short Talk (ST) .. .. | — | 19 |
| 13 | Triplet Numbers .. .. .. .. | — | 10½ |
| 21 | Consequences .. .. .. .. | — | 18 |
| | *Break* | | |
| 2 | Letter Series .. .. .. .. .. | 6 | 18 |
| 12 | Matching Words .. .. .. .. | 8 | 20 |
| | **Third Day** | | |
| 31 | Listening to Poorly Organised Spontaneous Speech .. .. .. | — | 20 |
| 14 | Letter List .. .. .. .. .. | — | 12 |
| 28 | Listening to Note Details .. .. .. | — | 17 |
| | *Break* | | |
| 3 | Raven's Progressive Matrices (1938) | 20 | 30 |
| 24 | Letter Span I (Visual) .. .. .. | — | 22 |
| | **Fourth Day** | | |
| 32 | Listening to Boys' Talk (BT) .. .. | — | 18 |
| 16 | Rapid Spelling .. .. .. .. | — | 4½ |
| 17 | Singing .. .. .. .. .. .. | — | 5½ |
| 18 | Haphazard Speech .. .. .. .. | — | 5½ |
| 19 | Illogical Grouping .. .. .. .. | — | 7 |
| 29 | Listening for Inference .. .. .. | — | 17 |
| | *Break* | | |
| 4 | Reasoning .. .. .. .. .. .. | 5 | 13 |
| 20 | Sentence Completion .. .. .. | 8½ | 18 |
| 9 | Reading for General Significance .. | 10 | 14 |

APPENDIX A (Continued)

| *Test No.* | *Test Title* | *Time Limit* (mins.) | *Total Time* (mins.) |
|---|---|---|---|
| | **Fifth Day** | | |
| 33 | Listening to Girls' Talk (GT) .. .. | — | 16 |
| 15 | Five Letters .. .. .. .. .. | — | 22 |
| 23 | Memory for Words .. .. .. | — | 10 |
| | *Break* | | |
| 5 | Word Squares .. .. .. .. | 7 | 13 |
| 11 | Reading for Inference .. .. .. | 9 | 12 |
| 7 | Reading Vocabulary .. .. .. | 6 | 9½ |
| | **Sixth Day** | | |
| 27 | Listening for General Significance .. | — | 16 |
| 25 | Letter Span II (Auditory) .. .. | — | 12 |
| 26 | Listening Vocabulary .. .. .. | — | 18 |
| — | Spondee Test .. .. .. .. .. | — | 10 |
| | *Break* | | |
| 6 | Arithmetic Reasoning .. .. .. | 10 | 11 |
| 8 | Chapman–Cook Speed of Reading, Form A .. .. .. .. .. | 2½ | 7½ |
| 10 | Reading to Note Details .. .. .. | 12 | 14½ |

## APPENDIX B

## SAMPLE ITEMS FROM TESTS

(Tape recorded tests are marked with an asterisk)

1. *Letter Grouping*

Three of the groups of letters are alike in some way. Underline the one that is different.

XURM ABCD MNOP EFGH

2. *Letter Series*

Decide what the next letter in this series should be, and mark it with an X in the box of answers.

c a d a e a f a

| a | c | d | e | f | g |
|---|---|---|---|---|---|

3. *Progressive Matrices, 1938*

Diagrammatic material.

4. *Reasoning*

M is younger than N.
K is older than N, therefore K is ————— than M.

5. *Word Squares*

Find the words that are missing from the square, and write the letters for these words in the blank spaces.

| bird | sings |
|---|---|
| ___ | ___ |

A. smiles
B. barks
C. bites
D. man
E. dog

6. *Arithmetic Reasoning*

John has 9d., Will has 1s. 4d., and Ted has twice as much as John and Will put together. How much money have the three boys between them?

7. *Reading Vocabulary*

Find the word or phrase which has the same or most nearly the same meaning as the underlined word, and write its number in the brackets.

ship 1. jump 2. boat 3. tree 4. stick 5. sail ............ ( )

8. *Speed of Reading*

Cross out, in the second part of each paragraph, the one word which spoils the meaning.

There was a fire last night, and five houses were burned to the ground. It all happened because someone was careless, and threw a nail into the waste-paper basket.

9. *Reading for General Significance*

The children had a fine time in the snow. They built a snowman, put a pipe in his mouth and a hat on his head. They laughed merrily when Tom knocked the hat off with a snowball.

The children were

(1) cold (2) very happy (3) hungry (4) naughty (5) sad .......................... ( )

10. *Reading to Note Details*

In the Australian bush there is a strange bird called the laughing jackass. Every morning it wakens with its loud laughter people living in the country.

1. The jackass ........................

(1) crows (2) laughs (3) brays (4) dances (5) swims ........................ ( )

2. Its laughter is............................

(1) awful (2) sweet (3) quiet (4) foolish (5) loud ........................ ( )

11. *Reading for Inference*

From the sentences following this story, choose the sentence which tells what is most likely to happen next, and write its number in the brackets.

Slowly but surely the keen-edged axe ate its way into the heart of the forest giant. As the great tree began to creak and sway the axeman leaped to safety.

1. Many woodmen were killed.
2. The tree grew taller the next year.
3. The tree fell with a mighty crash.
4. The birds protested against the felling of the tree.

............................ (            )

12. *Matching Words*

Mark the word that does the same job in the second sentence as the Key Word (capitals) does in the first sentence.

SUSAN hurt her finger.

My puppy eats biscuits.

13. *Triplet Numbers**

Listen to the following sets of three numbers. Place a tick in the space on your answer sheet when the first number of a set is the largest and the second number the smallest, or when the third number of a set is the largest and the first number is the smallest. When the numbers do not fit either of these rules, make a cross.

Set A. 7 – 4 – 5.
Set B. 3 – 6 – 8.
Set C. 8 – 5 – 2.

14. *Letter List**

When a vowel comes after a consonant, write a plus. When a consonant comes after a vowel, write a minus. When a vowel comes after a vowel, or a consonant comes after a consonant, make a tick.

| T | O | B | A | U | D |
|---|---|---|---|---|---|
| 1. | 2.............. | 3.............. | 4.............. | 5.............. | 6.............. |

15. *Five Letters**

Start with the letters A, B, C, D, E. Now change over A and E, then put D in between B and C. Write down the new order of the letters.

16. *Rapid Spelling**

As soon as the speaker has finished spelling a word, write that word in the space provided.

a - l - s - o

17. *Singing**

Write down the words that have been sung.

Bloom the sweetest flower in the field.

18. *Haphazard Speech**

The following short sentences are spoken in an unusual way. After each sentence is completed, write out exactly what the speaker said, or as near to it as you can.

1. On, / not under the table lay / a / cat.

19. *Illogical Grouping**

The following short sentences are spoken in another unusual way. After each sentence is completed, write out exactly what the speaker said, or as near to it as you can.

1. We, the / fourteen of / us, saw him.

20. *Sentence Completion*

Study the following sentences:—

George's house is green.
The sun causes the trees to grow.

The sentences below are the ones you studied just a few minutes ago. Fill in the blank space in each sentence with the word which was in it before.

The ................ causes the trees to grow.

George's house is ................

21. *Consequences**

This is a test to see how well you can remember pairs of sentences. The speaker will read out 20 pairs of sentences, like this pair:—

The violent storm unroofed several houses.
Many people had to stay with friends.

Later, when the speaker reads out the first sentence in each pair again, you have to write down the second sentence which completes the pair.

22. *Word Number*

Study these pairs of words and numbers:—

| | |
|---|---|
| box | 66 |
| chair | 21 |
| fan | 92 |
| lamp | 77. |

Later: Write the number of each of the objects:—

chair .................
lamp .................
box .................
fan .................

23. *Memory for Words**

This is a test to see if you can remember pairs of words which you have heard. The speaker will read out a list of pairs, like this:

First reading:

mule – gold
nail – wren
lark – seal

Second reading:

lark – seal
nail – wren
mule – gold

Then, when the speaker reads out the first word of each pair, you have to write down the word which was paired with it in the list.

24. *Letter Span I (Visual)*

In this test you will be shown some cards with letters on them. ................After each set of letters, write down the letters in the exact order in which they were shown to you.

1. H R L
2. G K P

25. *Letter Span II (Auditory)**

In this test, the speaker will call out a series of letters. After he finishes, you are to write down the letters in the exact order in which they were called out.

"Series 1. H R L."

26. *Listening Vocabulary**

This is a test to see how many words you know when you hear them spoken. When you are asked what a certain word means, choose the right answer from the five words printed on your test paper.

*Remain* means most nearly the same as

1. stay 2. follow 3. come 4. question 5. make .................
( )

27. *Listening for General Significance**

28. *Listening to Note Details**

29. *Listening for Inference**

These tests were composed of passages similar to those in Tests 9, 10 and 11 respectively. The passages were presented on tape. The questions were also presented on tape, but the options were printed in the test booklets.

30. *Listening to Short Talk**

This is a test to see how well you can understand the kinds of talks you are likely to hear on the radio or in school. You will hear a short talk about designs or patterns, and when the talk is over, you will be asked to answer some questions about it.

*Sample item—*

Why did the speaker mention that the Spaniards sailed the seas to America?

1. To show us how they got to America.
2. To tell us where they settled in America.
3. To tell us about the mosaics they took to America with them.
4. To show us how the idea of mosaics reached parts of America.

31. *Listening to Spontaneous Speech**

This is a test to see how much you understand when you hear a group of people or children talking together. You will hear a recording of a conversation in which a number of children were talking about going somewhere. When the recording is finished, you will be asked to answer some questions to see if you understand this conversation or discussion.

*Sample item—*

The children decided that the best time of the year to have their day out was

1. in the spring.
2. early in autumn.
3. late in autumn.
4. in summer.

32. *Listening to Boys' Talk**

. . . You will hear a short talk about making toy models. When the talk is over, you will be asked to answer some questions about it.

*Sample item*—

The frame described in the talk was to

1. hold the side walls in position.
2. support the base of the garage.
3. support the roof of the garage.
4. strengthen the openings around the doors.

33. *Listening to Girls' Talk**

. . . You will hear a short talk about plastic decorations, and when the talk is over, you will be asked to answer some questions about it.

*Sample item*—

The decoration becomes part of the article because of

1. the heat of the iron.
2. the weight of the iron.
3. the lightness of plastic material.
4. the smoothness of plastic material.

34. *S.T.E.P. Listening Test**

*Sample passage*—

The old man hurried back to his house, and his mind was full of many things. When he suddenly saw a fat, yellow cat sitting in his best armchair, he could only stand there rubbing his eyes and wondering whose house he was in.

*Sample item*—

When the old man saw the yellow cat in his best armchair, how did he feel?

1. pleased 2. surprised 3. sad 4. angry ............. (   )

35. *Arithmetic—School Marks*

36. *Reading—School Marks*

37. *Composition—School Marks*

38. *Modified Spondee Test**

. . . All you have to do is to write down the words that the speaker says. For example, the speaker might say "note-book," so you would write down "note-book"; if the speaker said "good-bye," you would write down "good-bye." . . . . . If you are not sure how to spell a word, just write it down the way you think it is spelt.

## APPENDIX C

# CORRELATION AND FACTOR MATRICES

### Table C1

Intercorrelations of 37 variables for 161 boys (Below Diagonal) and for 139 girls (Above Diagonal)

(Decimal points omitted)

| Test | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup | | 4745 | 3815 | 2339 | 1303 | 3285 | 3247 | 3054 |
| 2. LetterSer ... | 4628 | | 6225 | 2128 | 4021 | 6554 | 4536 | 3222 |
| 3. Raven'sPM ... | 3856 | 6342 | | 1325 | 4788 | 6272 | 4776 | 2280 |
| 4. Reasoning ... | 2742 | 3978 | 1824 | | 1539 | 2052 | 2291 | 2561 |
| 5. WdSquares ... | 3047 | 4722 | 5696 | 2381 | | 4719 | 3761 | 1664 |
| 6. ArithReas ... | 3561 | 5951 | 6094 | 3158 | 4500 | | 6156 | 4174 |
| 7. RdgVocab ... | 3460 | 5946 | 5897 | 3224 | 5146 | 5820 | | 5916 |
| 8. Sp.of Rdg ... | 2936 | 4033 | 3912 | 3180 | 3017 | 3354 | 5915 | |
| 9. RdgGenSig ... | 3114 | 5749 | 6235 | 1866 | 5731 | 5560 | 6942 | 5066 |
| 10. RdgDetails ... | 2385 | 4936 | 5199 | 2124 | 4576 | 5656 | 6848 | 4332 |
| 11. RdgInfer ... | 2914 | 5301 | 4855 | 2297 | 4192 | 4894 | 6551 | 5765 |
| 12. MatchWds ... | 3820 | 5769 | 6140 | 2951 | 5608 | 6308 | 6633 | 4261 |
| 13. TripletNos ... | 2496 | 3667 | 2401 | 3151 | 1860 | 2352 | 2963 | 3051 |
| 14. LetterList ... | 1812 | 3950 | 3520 | 1300 | 2795 | 3849 | 3542 | 1800 |
| 15. FiveLett ... | 3424 | 4450 | 4878 | 2968 | 3895 | 4766 | 3807 | 1129 |
| 16. RapidSpell ... | 1009 | 2848 | 2907 | 1381 | 1665 | 2473 | 2726 | 1644 |
| 17. Singing ... | 2047 | 3502 | 3509 | 2223 | 3274 | 3490 | 4001 | 3208 |
| 18. HapSpeech ... | 2127 | 3429 | 3954 | 2109 | 3828 | 3055 | 3965 | 2244 |
| 19. IllGroup ... | 2524 | 4946 | 4396 | 2322 | 3887 | 4416 | 4951 | 3908 |
| 20. SentComp ... | 1399 | 3060 | 3322 | 1646 | 2469 | 2611 | 3876 | 2898 |
| 21. Conseq ... | 2309 | 3793 | 4218 | 2703 | 3581 | 4346 | 4870 | 3515 |
| 22. WdNumber ... | 0807 | 2385 | 2279 | 1830 | 1908 | 2656 | 3315 | 2275 |
| 23. MemWds ... | 0382 | 1005 | 1605 | -0997 | 0516 | 1181 | 1236 | 1607 |
| 24. VisLetSpan ... | 1938 | 2974 | 3822 | 1185 | 3542 | 3672 | 4057 | 2686 |
| 25. AudLetSpan | 2451 | 3430 | 3732 | 2083 | 3088 | 3777 | 3865 | 3016 |
| 26. ListVocab ... | 3008 | 5007 | 5666 | 2020 | 5078 | 4832 | 7295 | 4717 |
| 27. ListGenSig ... | 2288 | 4393 | 4213 | 2276 | 4691 | 4422 | 6223 | 3889 |
| 28. ListDetails ... | 3256 | 5300 | 5931 | 2302 | 5128 | 5196 | 5943 | 3720 |
| 29. ListInfer ... | 1290 | 4151 | 4307 | 3471 | 3582 | 3248 | 4998 | 2825 |
| 30. ListShTalk ... | 3118 | 4329 | 4150 | 2078 | 3812 | 3691 | 5127 | 2808 |
| 31. ListSponSp ... | 1242 | 2486 | 2522 | 0442 | 2629 | 3192 | 3611 | 1556 |
| 32. ListBoysT ... | 2360 | 4354 | 6091 | 1559 | 4209 | 4074 | 5531 | 2906 |
| 33. ListGirlsT ... | 2959 | 4666 | 4982 | 1256 | 3744 | 3608 | 4862 | 2701 |
| 34. STEP List ... | 2903 | 5871 | 5343 | 2575 | 4581 | 4737 | 6271 | 3342 |
| 35. SchArith ... | 3104 | 5027 | 4803 | 2452 | 3524 | 5781 | 5355 | 3567 |
| 36. SchRdg ... | 3049 | 5321 | 4792 | 2281 | 4295 | 4122 | 5638 | 4970 |
| 37. SchComp ... | 1869 | 4125 | 4035 | 1386 | 3432 | 3471 | 5010 | 4136 |

TABLE C1 (Continued)

Intercorrelations of 37 variables for 161 boys (Below Diagonal) and for 139 girls (Above Diagonal).

(Decimal points omitted)

| Test | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup | 2801 | 2794 | 3068 | 3265 | 1611 | 3137 | 2159 | 2513 |
| 2. LetterSer ... | 3717 | 3433 | 3204 | 4233 | 2956 | 4098 | 4575 | 2984 |
| 3. Raven'sPM ... | 3436 | 3599 | 4391 | 4136 | 2302 | 3802 | 4662 | 2452 |
| 4. Reasoning ... | 2917 | 1204 | 1551 | 2370 | 1395 | 1315 | 3442 | 0746 |
| 5. WdSquares ... | 2771 | 2390 | 3587 | 3704 | 1866 | 2834 | 3360 | 1525 |
| 6. ArithReas ... | 4728 | 4662 | 4890 | 5143 | 2171 | 4749 | 3155 | 2247 |
| 7. RdgVocab ... | 7044 | 5829 | 6723 | 4475 | 0733 | 3436 | 2537 | 3682 |
| 8. Sp.of Rdg ... | 5976 | 5775 | 5353 | 4430 | 1298 | 2310 | 1296 | 2951 |
| 9. RdgGenSig ... | | 4727 | 5804 | 4516 | 0136 | 3311 | 2155 | 3003 |
| 10. RdgDetails ... | 6878 | | 5336 | 4021 | 0858 | 3159 | 2161 | 1336 |
| 11. RdgInfer ... | 6714 | 6215 | | 3533 | 1162 | 2779 | 2585 | 2751 |
| 12. MatchWds ... | 6145 | 5187 | 5432 | | 0732 | 3818 | 2520 | 2123 |
| 13. TripletNos ... | 2791 | 2806 | 2922 | 2923 | | 2381 | 2107 | 0904 |
| 14. LetterList ... | 4038 | 2749 | 3614 | 3401 | 1482 | | 3375 | 1982 |
| 15. FiveLett ... | 3695 | 3291 | 3009 | 4621 | 2239 | 4275 | | 2000 |
| 16. RapidSpell ... | 2852 | 2825 | 2359 | 1527 | 1188 | 1274 | 1809 | |
| 17. Singing ... ... | 4392 | 3979 | 3995 | 4148 | 1205 | 2192 | 2398 | 3655 |
| 18. HapSpeech ... | 4591 | 3057 | 3645 | 3216 | 1745 | 1906 | 3712 | 3154 |
| 19. IllGroup ... | 5290 | 5150 | 4455 | 4351 | 1520 | 2394 | 2437 | 4427 |
| 20. SentComp ... | 3878 | 2670 | 3337 | 2586 | 2511 | 1806 | 1538 | 2983 |
| 21. Conseq ... ... | 5797 | 4593 | 4825 | 4170 | 2785 | 2475 | 3199 | 3589 |
| 22. WdNumber ... | 2950 | 1529 | 2441 | 2643 | 2423 | 3252 | 1948 | 1043 |
| 23. MemWds ... | 0926 | 0455 | 1736 | 0470 | -0054 | 0095 | 0833 | 2435 |
| 24. VisLetSpan ... | 4788 | 3551 | 3367 | 3832 | 2177 | 3456 | 3371 | 3188 |
| 25. AudLetSpan | 4586 | 3798 | 2909 | 3316 | 2953 | 1750 | 3296 | 3547 |
| 26. ListVocab ... | 6648 | 6458 | 5745 | 6022 | 2456 | 2615 | 4074 | 2753 |
| 27. ListGenSig ... | 5151 | 5905 | 5557 | 4908 | 2471 | 2538 | 2800 | 2507 |
| 28. ListDetails ... | 6439 | 6113 | 5500 | 5156 | 2012 | 3428 | 3903 | 2942 |
| 29. ListInfer ... | 4542 | 4560 | 3793 | 3865 | 2051 | 2398 | 3143 | 2242 |
| 30. ListShTalk ... | 5537 | 5542 | 4483 | 3762 | 1410 | 2492 | 3023 | 2143 |
| 31. ListSponSp ... | 3758 | 3466 | 3148 | 3401 | 0649 | 2112 | 2905 | 2016 |
| 32. ListBoysT ... | 5677 | 5468 | 4526 | 4421 | 1629 | 2719 | 3842 | 2025 |
| 33. ListGirlsT ... | 4940 | 4503 | 4755 | 4203 | 1578 | 2643 | 3540 | 2864 |
| 34. STEP List ... | 6241 | 5491 | 4899 | 5101 | 2287 | 3767 | 4013 | 2617 |
| 35. SchArith ... | 4752 | 4273 | 4383 | 5665 | 3235 | 2856 | 3793 | 1896 |
| 36. SchRdg ... ... | 5036 | 5304 | 5287 | 5173 | 3469 | 2128 | 3145 | 1468 |
| 37. SchComp ... | 3834 | 3568 | 4274 | 5165 | 3631 | 1331 | 1952 | 1419 |

TABLE C1 (Continued)

Intercorrelations of 37 variables for 161 boys (Below Diagonal) and for 139 girls (Above Diagonal).

(Decimal points omitted)

| Test | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup | 1160 | 0938 | 1580 | 1091 | 2987 | 1168 | 0781 | 3176 |
| 2. LetterSer ... | 1676 | 2688 | 3881 | 1129 | 2498 | 0465 | 0024 | 3487 |
| 3. Raven'sPM ... | 2269 | 2324 | 2230 | 1594 | 2935 | 0110 | 1043 | 3876 |
| 4. Reasoning ... | 0645 | 0786 | 1354 | 1833 | 2113 | 0900 | 0976 | 0423 |
| 5. WdSquares ... | 1726 | 1130 | 1301 | 1193 | 1862 | 0346 | 1013 | 1242 |
| 6. ArithReas ... | 2448 | 2193 | 4099 | 1742 | 3570 | 0612 | 0215 | 3629 |
| 7. RdgVocab ... | 3248 | 2878 | 4479 | 3712 | 5406 | 1373 | 1941 | 4746 |
| 8. Sp.of Rdg ... | 2496 | 1663 | 3292 | 1345 | 3160 | 1356 | 0744 | 2997 |
| 9. RdgGenSig ... | 3130 | 2371 | 3729 | 3350 | 5118 | 0634 | 1085 | 4211 |
| 10. RdgDetails ... | 2224 | 0763 | 2610 | 2264 | 3757 | 1453 | 0720 | 2602 |
| 11. RdgInfer ... | 3294 | 1999 | 2828 | 1233 | 3199 | 1995 | 1975 | 2628 |
| 12. MatchWds ... | 2154 | 2320 | 3873 | 2292 | 2297 | 0732 | 1067 | 2924 |
| 13. TripletNos ... | 0559 | 0708 | 0214 | –0384 | 0301 | –0801 | 0532 | –0460 |
| 14. LetterList ... | 1308 | 1840 | 3316 | 1894 | 2943 | 1379 | 0637 | 1975 |
| 15. FiveLett ... | 2031 | 1393 | 2265 | 2538 | 2127 | 1318 | 1221 | 2307 |
| 16. RapidSpell ... | 3230 | 4959 | 4330 | 2029 | 1608 | 1307 | 1703 | 4170 |
| 17. Singing ... ... | | 2792 | 2794 | 1671 | 2380 | –0786 | 1244 | 3105 |
| 18. HapSpeech ... | 4547 | | 4455 | 0986 | 1905 | –0127 | 0849 | 3242 |
| 19. IllGroup ... | 4578 | 4075 | | 2523 | 2788 | –0303 | 0794 | 5130 |
| 20. SentComp ... | 2755 | 2843 | 3984 | | 4254 | 2774 | 3459 | 2353 |
| 21. Conseq ... ... | 3835 | 3075 | 3819 | 4157 | | 1046 | 2404 | 2797 |
| 22. WdNumber ... | 1623 | 1181 | 2034 | 2537 | 2474 | | 2997 | –0869 |
| 23. MemWds ... | 1139 | 0622 | 1835 | 2782 | 1948 | 2393 | | 0367 |
| 24. VisLetSpan ... | 2356 | 3087 | 4388 | 2801 | 2058 | 3867 | –0083 | |
| 25. AudLetSpan | 3091 | 2854 | 5425 | 3282 | 3240 | 2027 | 1086 | 5543 |
| 26. ListVocab ... | 3903 | 4065 | 5374 | 4593 | 4122 | 3218 | 1833 | 4245 |
| 27. ListGenSig ... | 3566 | 4032 | 3964 | 3045 | 4192 | 1699 | 0802 | 2865 |
| 28. ListDetails ... | 4092 | 4848 | 5443 | 2905 | 4902 | 1954 | 0193 | 3599 |
| 29. ListInfer ... | 2465 | 3384 | 3274 | 2170 | 3005 | 2492 | –0830 | 2730 |
| 30. ListShTalk ... | 3351 | 3064 | 3772 | 3101 | 4901 | 2090 | 0316 | 2027 |
| 31. ListSponSp ... | 3304 | 2403 | 3420 | 3952 | 3121 | 1728 | 1842 | 2689 |
| 32. ListBoysT ... | 3528 | 2911 | 3243 | 2929 | 4268 | 2010 | 1679 | 2557 |
| 33. ListGirlsT ... | 2790 | 2830 | 3862 | 3607 | 4730 | 0810 | 0857 | 3000 |
| 34. STEP List ... | 3532 | 4172 | 3811 | 3177 | 5181 | 2015 | –0024 | 3548 |
| 35. SchArith ... | 2818 | 2345 | 4422 | 3093 | 3420 | 3269 | 1513 | 2855 |
| 36. SchRdg ... ... | 3745 | 2792 | 4487 | 2388 | 2859 | 2055 | 0309 | 2755 |
| 37. SchComp ... | 2957 | 1530 | 2942 | 2351 | 2498 | 3253 | 2251 | 3057 |

TABLE C1 (Continued)

Intercorrelations of 37 variables for 161 boys (Below Diagonal) and for 139 girls (Above Diagonal).

(Decimal points omitted)

| Test | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup | 2339 | 2243 | 2562 | 2467 | 1598 | 2484 | 2006 | 2237 |
| 2. LetterSer ... | 2841 | 3368 | 3074 | 3477 | 1612 | 3164 | 1748 | 1652 |
| 3. Raven'sPM ... | 2503 | 3169 | 3119 | 3316 | 2516 | 3369 | 1959 | 2680 |
| 4. Reasoning ... | 0164 | 1724 | 1975 | 1034 | 1904 | 1760 | 2204 | 1260 |
| 5. WdSquares ... | 1391 | 2888 | 3281 | 3385 | 2866 | 3090 | 3250 | 3221 |
| 6. ArithReas ... | 3324 | 4578 | 4477 | 4369 | 2946 | 2992 | 3216 | 2294 |
| 7. RdgVocab ... | 4122 | 6774 | 5952 | 5974 | 5691 | 4028 | 4776 | 4438 |
| 8. Sp.of Rdg ... | 3510 | 5064 | 4958 | 4855 | 4310 | 2858 | 2844 | 2176 |
| 9. RdgGenSig ... | 3902 | 5922 | 6093 | 5404 | 5195 | 3797 | 5103 | 3986 |
| 10. RdgDetails ... | 2267 | 5616 | 4726 | 4255 | 3282 | 4313 | 3126 | 3131 |
| 11. RdgInfer ... | 2838 | 5546 | 5514 | 4798 | 4622 | 4121 | 4713 | 4147 |
| 12. MatchWds ... | 3026 | 4550 | 4105 | 4590 | 2949 | 4108 | 3276 | 1739 |
| 13. TripletNos ... | -0060 | -0455 | 0290 | 0198 | 0308 | 0813 | -0294 | -0299 |
| 14. LetterList ... | 1775 | 2949 | 2624 | 1937 | 1912 | 2425 | 2430 | 1359 |
| 15. FiveLett ... | 1155 | 2106 | 2334 | 1902 | 1613 | 2293 | 2082 | 2161 |
| 16. RapidSpell ... | 5778 | 3276 | 2628 | 2794 | 2954 | 2612 | 1606 | 2418 |
| 17. Singing ... ... | 3421 | 3514 | 2757 | 2596 | 2559 | 2167 | 3282 | 2757 |
| 18. HapSpeech ... | 3095 | 3273 | 3189 | 2967 | 2380 | 2637 | 2355 | 1933 |
| 19. IllGroup ... | 4321 | 4510 | 3367 | 3254 | 2583 | 2311 | 1569 | 1823 |
| 20. SentComp ... | 2489 | 3629 | 3106 | 2389 | 2696 | 1154 | 3294 | 3214 |
| 21. Conseq ... ... | 2242 | 4384 | 3604 | 4709 | 4199 | 3599 | 3486 | 4795 |
| 22. WdNumber ... | -0385 | 1445 | 1437 | 0834 | 1715 | 0867 | 1653 | 1271 |
| 23. MemWds ... | 0226 | 1508 | 1278 | 0794 | 1941 | 2023 | 0935 | 2921 |
| 24. VisLetSpan ... | 6380 | 3388 | 2878 | 2610 | 2243 | 1138 | 1801 | 1489 |
| 25. AudLetSpan | | 3943 | 3105 | 2360 | 1983 | 1719 | 2139 | 1337 |
| 26. ListVocab ... | 3769 | | 6561 | 6116 | 5015 | 4706 | 4220 | 4212 |
| 27. ListGenSig ... | 2148 | 5570 | | 5542 | 4109 | 4003 | 5035 | 4146 |
| 28. ListDetails ... | 3686 | 5891 | 5541 | | 5990 | 5437 | 3729 | 5027 |
| 29. ListInfer ... | 2668 | 4066 | 4468 | 5743 | | 3108 | 3705 | 4062 |
| 30. ListShTalk ... | 3179 | 5129 | 4662 | 6064 | 5080 | | 2811 | 4346 |
| 31. ListSponSp ... | 2887 | 3749 | 2912 | 3110 | 2286 | 2910 | | 3315 |
| 32. ListBoysT ... | 2678 | 5859 | 5196 | 6005 | 4455 | 5160 | 3645 | |
| 33. ListGirlsT ... | 2616 | 5753 | 4723 | 6185 | 3835 | 5030 | 3781 | 6410 |
| 34. STEP List ... | 3876 | 5109 | 5492 | 6264 | 5556 | 5944 | 3754 | 6217 |
| 35. SchArith ... | 3673 | 4878 | 3854 | 4142 | 2736 | 2978 | 3631 | 3605 |
| 36. SchRdg ... ... | 3808 | 5255 | 4264 | 4346 | 3832 | 3698 | 2332 | 4255 |
| 37. SchComp ... | 2996 | 4574 | 3713 | 2863 | 2250 | 2114 | 1427 | 3816 |

TABLE C1 (Continued)

Intercorrelations of 37 variables for 161 boys (Below Diagonal) and for 139 girls (Above Diagonal).

(Decimal points omitted)

| Test | 33 | 34 | 35 | 36 | 37 |
|---|---|---|---|---|---|
| 1. LetterGroup | 2246 | 2542 | 1945 | 2325 | 1342 |
| 2. LetterSer ... | 2903 | 3287 | 4536 | 4312 | 2871 |
| 3. Raven'sPM ... | 3373 | 2881 | 5156 | 4260 | 2730 |
| 4. Reasoning ... | 2390 | 2545 | 1579 | 2602 | 1574 |
| 5. WdSquares ... | 2939 | 3481 | 5078 | 3279 | 2213 |
| 6. ArithReas ... | 3696 | 4295 | 4934 | 4873 | 3964 |
| 7. RdgVocab ... | 5693 | 6300 | 3951 | 5784 | 3743 |
| 8. Sp.of Rdg ... | 3194 | 4925 | 1430 | 4520 | 3952 |
| 9. RdgGenSig ... | 4673 | 5942 | 2913 | 4934 | 3411 |
| 10. RdgDetails ... | 3034 | 4703 | 2728 | 4357 | 2937 |
| 11. RdgInfer ... | 4771 | 5290 | 3320 | 4553 | 2522 |
| 12. MatchWds ... | 2660 | 3740 | 3593 | 4542 | 3763 |
| 13. TripletNos ... | 0292 | 1249 | 1733 | 0179 | 0907 |
| 14. LetterList ... | 2336 | 1794 | 3292 | 2767 | 1304 |
| 15. Five Lett ... | 2712 | 2808 | 4424 | 2049 | 1082 |
| 16. RapidSpell ... | 3361 | 3004 | -0258 | 2299 | 0421 |
| 17. Singing ... ... | 3543 | 4173 | 0449 | 1007 | 0561 |
| 18. HapSpeech ... | 2333 | 1833 | 0303 | 2188 | 0592 |
| 19. IllGroup ... | 3261 | 3463 | 1000 | 4388 | 3756 |
| 20. SentComp ... | 3330 | 3775 | 1929 | 2534 | 3256 |
| 21. Conseq ... ... | 4647 | 4402 | 1360 | 2482 | 2500 |
| 22. WdNumbers | 1484 | 1502 | 0775 | 0792 | 0839 |
| 23. MemWds ... | 2056 | 1253 | 0398 | 0486 | 0886 |
| 24. VisLetSpan ... | 2433 | 2917 | 0837 | 3526 | 1828 |
| 25. AudLetSpan | 2352 | 3403 | 0380 | 2897 | 2066 |
| 26. ListVocab ... | 4920 | 5444 | 3016 | 4107 | 3550 |
| 27. ListGenSig ... | 5422 | 5398 | 3116 | 4283 | 3333 |
| 28. ListDetails ... | 4508 | 5611 | 1905 | 3144 | 2170 |
| 29. ListInfer ... | 4441 | 4848 | 1540 | 2998 | 1535 |
| 30. ListShTalk ... | 4419 | 4309 | 2531 | 2793 | 1419 |
| 31. ListSponSp ... | 3406 | 4199 | 2935 | 2674 | 1427 |
| 32. ListBoysT ... | 4869 | 4846 | 1508 | 2584 | 1569 |
| 33. ListGirlsT ... | | 5109 | 2387 | 3252 | 2014 |
| 34. STEP List ... | 5820 | | 2606 | 3822 | 3496 |
| 35. SchArith ... | 3658 | 4001 | | 4805 | 4567 |
| 36. SchRdg ... ... | 3526 | 3844 | 5313 | | 5415 |
| 37. SchComp ... | 3010 | 3122 | 5476 | 4978 | |

TABLE C2

Principal Axis Factor Matrix (F) for 161 Boys.
(Decimal points omitted)

| | Factor | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test | I | II | III | IV | V | VI | VII | VIII | IX | $h^2$ |
| 1. LetGroup | 433 | –059 | 300 | –009 | 001 | –310 | –052 | 211 | 026 | 425 |
| 2. LetSer ... | 726 | –058 | 262 | –009 | 010 | –198 | 030 | 040 | –038 | 643 |
| 3. Raven'sPM | 746 | –064 | 099 | –130 | –163 | –120 | –101 | 058 | 065 | 645 |
| 4. Reasoning | 364 | –016 | 358 | 109 | 312 | –125 | 195 | –074 | 074 | 435 |
| 5. WdSquar | 641 | –097 | 108 | –086 | –058 | 012 | –185 | –062 | 160 | 506 |
| 6. ArithRe | 696 | 010 | 238 | –071 | –134 | –088 | –094 | –068 | –177 | 616 |
| 7. RdgVoc ... | 829 | –041 | 046 | 219 | –063 | 105 | –022 | –019 | 051 | 757 |
| 8. SpRdg ... | 556 | 125 | 122 | 486 | 027 | 026 | –042 | 067 | 019 | 584 |
| 9. RdgGenS | 830 | 008 | –038 | 056 | –055 | 130 | –084 | 006 | –112 | 733 |
| 10. RdgDet ... | 753 | –113 | –098 | 152 | 040 | 142 | –154 | 055 | –176 | 693 |
| 11. RdgInf ... | 729 | –009 | –015 | 299 | –087 | 038 | –052 | –076 | –131 | 656 |
| 12. MatWds ... | 733 | –073 | 246 | 032 | –160 | –012 | –151 | –057 | 041 | 657 |
| 13. TripNos ... | 362 | 106 | 302 | 167 | 109 | –018 | 226 | 117 | 049 | 341 |
| 14. LetList ... | 450 | –010 | 195 | –205 | –199 | 134 | 133 | –173 | –188 | 424 |
| 15. FiveL ... | 540 | –049 | 245 | –355 | –104 | –114 | 071 | –073 | 038 | 515 |
| 16. RapSpl ... | 403 | 360 | –204 | –124 | 215 | –144 | –009 | –045 | –064 | 422 |
| 17. Singing ... | 538 | 167 | –111 | –001 | 147 | –129 | –150 | –251 | –030 | 455 |
| 18. HapSpch | 533 | 085 | –055 | –149 | 231 | –065 | –130 | –246 | 188 | 486 |
| 19. IllGrp ... | 649 | 312 | –096 | –026 | 160 | –011 | –185 | 048 | –032 | 592 |
| 20. SenCom ... | 484 | 327 | –204 | 071 | –052 | –084 | 218 | 036 | 131 | 463 |
| 21. Conseq ... | 632 | 069 | –150 | 083 | 036 | –188 | 221 | –065 | –193 | 561 |
| 22. Wd.No. ... | 353 | 254 | 152 | 026 | –193 | 230 | 318 | –131 | 060 | 425 |
| 23. MemWds | 155 | 341 | –204 | 100 | –290 | –218 | 081 | –062 | 046 | 335 |
| 24. VisSpan | 525 | 326 | 131 | –242 | –007 | 361 | –053 | 129 | 028 | 609 |
| 25. AudSpan | 534 | 385 | 062 | –177 | 183 | 098 | –035 | 269 | –061 | 588 |
| 26. LisVoc ... | 785 | 031 | –122 | 108 | –152 | 085 | –076 | 088 | 226 | 738 |
| 27. LisGenS | 678 | –172 | –129 | 163 | 052 | 058 | –039 | –132 | 094 | 567 |
| 28. LisDet ... | 778 | –192 | –126 | –096 | 129 | 028 | –051 | 013 | –017 | 688 |
| 29. LisInf ... | 587 | –237 | –017 | –058 | 273 | 213 | 190 | –073 | 101 | 576 |
| 30. LisST ... | 650 | –228 | –205 | –011 | 131 | 007 | 153 | 070 | –098 | 571 |
| 31. LisS Sp ... | 462 | 139 | –237 | –131 | –150 | –006 | 045 | –052 | –010 | 333 |
| 32. LisBT ... | 686 | –251 | –248 | –077 | –160 | –035 | 093 | 075 | 083 | 648 |
| 33. LisGT ... | 657 | –196 | –285 | –117 | –075 | –128 | 090 | 213 | 037 | 642 |
| 34. STEP Lis | 749 | –222 | –086 | –120 | 087 | 039 | 143 | 021 | –056 | 665 |

| Eigenvalues | | % of trace |
|---|---|---|
| I | 12.866 | 67.8% |
| II | 1.223 | 6.4% |
| III | 1.155 | 6.1% |
| IV | .889 | 4.7% |
| V | .771 | 4.1% |
| VI | .635 | 3.3% |
| VII | .619 | 3.3% |
| VIII | .462 | 2.4% |
| IX | .371 | 2.0% |

TABLE C3

Principal Axis Factor Matrix (F) for 139 Girls.
(Decimal points omitted)

| Test | I | II | III | IV | V | VI | VII | VIII | IX | X | $h^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Factor | | | | | | | | | | |
| 1. LetGroup | 439 | 248 | –116 | 034 | 198 | 138 | –210 | 118 | 154 | –210 | 453 |
| 2. LetSer ... | 583 | 541 | –183 | 024 | –012 | 036 | –053 | –035 | 074 | –004 | 678 |
| 3. Raven'sPM | 585 | 428 | –236 | 098 | –120 | –135 | –175 | 049 | –116 | 028 | 671 |
| 4. Reasoning | 303 | 016 | –206 | 132 | 190 | 048 | 282 | 069 | 300 | –053 | 367 |
| 5. WdSquar | 475 | 148 | –310 | 068 | –253 | –159 | 099 | 024 | –172 | 054 | 480 |
| 6. ArithRe | 688 | 356 | –182 | –140 | 012 | –114 | –001 | –076 | –099 | 120 | 696 |
| 7. RdgVoc ... | 847 | –081 | 024 | –107 | 080 | –069 | –066 | 042 | –042 | 149 | 769 |
| 8. SpRdg ... | 634 | –060 | 036 | –360 | 193 | 234 | 040 | 140 | 088 | 068 | 662 |
| 9. RdgGenS | 767 | –144 | 057 | –179 | 139 | –111 | 092 | 030 | 112 | 025 | 698 |
| 10. RdgDet ... | 626 | –058 | –158 | –292 | 144 | 069 | –151 | –016 | –085 | –076 | 567 |
| 11. RdgInf ... | 711 | –115 | –125 | –168 | –060 | 089 | –010 | 258 | –217 | 005 | 688 |
| 12. MatWds | 600 | 177 | –083 | –125 | 050 | 081 | 109 | –223 | –032 | –101 | 496 |
| 13. TripNos ... | 134 | 313 | –247 | 058 | –063 | 142 | 081 | 197 | 123 | 140 | 285 |
| 14. LetList ... | 460 | 302 | –179 | 078 | 146 | 061 | 061 | –186 | –077 | 058 | 414 |
| 15. FiveL ... | 419 | 269 | –239 | 326 | 041 | –073 | 150 | 062 | 041 | –054 | 449 |
| 16. RapSpl ... | 481 | 154 | 444 | 253 | –095 | 283 | 011 | 141 | –049 | 025 | 628 |
| 17. Singing ... | 445 | –024 | 228 | 077 | –174 | –132 | 105 | 211 | –003 | –091 | 368 |
| 18. HapSpch | 403 | 135 | 354 | 168 | –271 | 182 | 160 | –150 | 027 | 029 | 490 |
| 19. IllGrp ... | 538 | 205 | 364 | 044 | 027 | 049 | 082 | –217 | 067 | 095 | 536 |
| 20. SenCom | 418 | –220 | 061 | 362 | 316 | –152 | 025 | –126 | –053 | 015 | 500 |
| 21. Conseq ... | 591 | –203 | –045 | 163 | 126 | –161 | –206 | –105 | 218 | 061 | 566 |
| 22. Wd.No. ... | 169 | –219 | –165 | 224 | 273 | 257 | –002 | –010 | –243 | 014 | 354 |
| 23. MemWds | 222 | –221 | –060 | 416 | 109 | 160 | –105 | 037 | –141 | 055 | 348 |
| 24. VisSpan | 512 | 297 | 480 | 003 | 142 | –205 | –151 | 041 | 000 | –022 | 668 |
| 25. AudSpan | 498 | 216 | 553 | –021 | 092 | –050 | –046 | 121 | –097 | –089 | 646 |
| 26. LisVoc ... | 762 | –194 | 102 | –126 | –017 | 038 | 015 | –178 | –083 | –043 | 671 |
| 27. LisGenS | 717 | –190 | –003 | –121 | –036 | 001 | 154 | –064 | –081 | –133 | 618 |
| 28. LisDet ... | 703 | –207 | –030 | –135 | –229 | 045 | –107 | –153 | 113 | 059 | 662 |
| 29. LisInf ... | 606 | –306 | 007 | –001 | –076 | 046 | 014 | 036 | 063 | 317 | 575 |
| 30. Lis ST ... | 569 | –104 | –155 | 037 | –279 | 202 | –129 | –126 | 086 | –220 | 567 |
| 31. LisS Sp ... | 549 | –222 | –061 | 003 | 029 | –161 | 277 | 021 | –124 | –150 | 496 |
| 32. Lis BT ... | 545 | –328 | –087 | 229 | –188 | –073 | –191 | 033 | 049 | –064 | 549 |
| 33. Lis GT ... | 645 | –198 | –019 | 190 | –116 | –048 | –016 | 055 | 071 | –009 | 516 |
| 34. STEP Lis | 721 | –204 | –017 | –025 | –021 | –072 | 059 | 167 | 113 | –018 | 612 |

| Eigenvalues | | % of trace |
|---|---|---|
| I | 10.843 | 57.8% |
| II | 1.892 | 10.1% |
| III | 1.604 | 8.5% |
| IV | 1.092 | 5.8% |
| V | .802 | 4.3% |
| VI | .602 | 3.2% |
| VII | .540 | 2.9% |
| VIII | .532 | 2.8% |
| IX | .491 | 2.6% |
| X | .368 | 2.0% |

TABLE C4

Oblique Transformation Matrix Λ for
8 factor biquartimin solution for boys.
(Decimal points omitted)

Factor

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| I ... ... ... | 095 | 248 | 121 | –020 | 104 | 052 | 102 | 104 |
| II ... ... ... | 549 | –072 | –477 | 062 | 091 | 081 | –165 | 124 |
| III ... ... ... | –013 | –011 | –317 | 363 | 328 | –457 | 230 | 004 |
| IV ... ... ... | –347 | 795 | –172 | 077 | –240 | –073 | –216 | –071 |
| V ... ... ... | 279 | –152 | 516 | 541 | –524 | –024 | –238 | 186 |
| VI ... ... ... | 368 | 314 | 333 | –410 | 239 | –321 | –557 | –151 |
| VII ... ... ... | –189 | –423 | 497 | 612 | 378 | 743 | 066 | –507 |
| VIII ... ... ... | 566 | 028 | 069 | –152 | –584 | 348 | 701 | –809 |

TABLE C5

Oblique Transformation Matrix Λ for
graphical solution for boys.
(Decimal points omitted)

Factor

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| I ... ... ... | 093 | 166 | 274 | 281 | 023 | 015 | 162 | 055 |
| II ... ... ... | –297 | 557 | –022 | –212 | 142 | –235 | 329 | 105 |
| III ... ... ... | –449 | 031 | 659 | 145 | 537 | –583 | –066 | –151 |
| IV ... ... ... | –593 | –212 | –064 | 671 | –066 | –099 | –014 | –019 |
| V ... ... ... | –079 | 270 | –307 | 080 | 721 | –046 | –307 | –001 |
| VI ... ... ... | 010 | 015 | –314 | 088 | 201 | –410 | –479 | –239 |
| VII ... ... ... | 584 | –718 | –276 | –576 | 337 | 066 | 664 | –330 |
| VIII ... ... ... | –044 | 167 | –467 | 245 | –115 | 649 | –310 | –893 |

TABLE C6

Rotated Oblique Factor Matrix V for 8 factor biquartimin solution for boys.
(Decimal points omitted)

| Test | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| | Factor | | | | | | | |
| 1. LetterGroup ... ... | 023 | 031 | –127 | 160 | –077 | 016 | 442 | –058 |
| 2. LetterSer ... ... | –016 | 099 | –009 | 175 | 093 | 014 | 284 | 054 |
| 3. Raven'sPM ... ... | 042 | 116 | –058 | –103 | 120 | –014 | 277 | 070 |
| 4. Reasoning ... ... | –055 | 003 | 131 | 481 | 051 | –002 | 055 | 068 |
| 5. WdSquares ... ... | 024 | 185 | –017 | –126 | 114 | –179 | 076 | 192 |
| 6. ArithReas ... ... | 003 | 143 | –134 | –016 | 222 | –129 | 166 | 171 |
| 7. RdgVocab ... ... | –006 | 434 | 058 | –074 | 106 | –052 | –004 | 064 |
| 8. Sp.of Rdg ... ... | 015 | 537 | –108 | 047 | –070 | –069 | –017 | 007 |
| 9. RdgGenSig ... ... | 117 | 335 | 072 | –161 | 085 | –044 | 002 | 091 |
| 10. RdgDetails ... ... | 082 | 422 | 145 | –185 | –077 | –078 | –020 | 073 |
| 11. RdgInfer ... ... | –082 | 464 | –017 | –080 | 078 | –053 | –050 | 119 |
| 12. MatchWds ... ... | –037 | 293 | –126 | –093 | 200 | –207 | 131 | 160 |
| 13. TripletNos ... ... | 078 | 097 | 040 | 309 | 062 | 089 | 134 | –146 |
| 14. LetterList ... ... | –024 | –042 | 029 | –009 | 447 | –051 | –003 | 076 |
| 15. FiveLett ... ... | 018 | –199 | 011 | 093 | 314 | 004 | 237 | 098 |
| 16. RapidSpell ... ... | 265 | –098 | 019 | 108 | –087 | 172 | –041 | 197 |
| 17. Singing ... ... ... | 024 | 116 | –038 | 038 | 017 | –069 | –148 | 402 |
| 18. HapSpeech ... ... | 075 | 001 | 083 | 073 | 038 | –096 | –140 | 393 |
| 19. IllGroup ... ... | 346 | 171 | –046 | –060 | –114 | –017 | –012 | 194 |
| 20. SentComp ... ... | 137 | 045 | 011 | 076 | 065 | 343 | 032 | –052 |
| 21. Conseq ... ... ... | –067 | 059 | 139 | 185 | 061 | 302 | 065 | 043 |
| 22. WdNumber ... ... | 058 | 051 | –005 | 082 | 456 | 090 | –129 | –059 |
| 23. MemWds ... ... | –042 | 035 | –282 | –057 | 123 | 237 | 043 | 038 |
| 24. VisLetSpan ... ... | 525 | 053 | 007 | –166 | 180 | –099 | –030 | –021 |
| 25. AudLetSpan ... | 568 | –012 | 020 | 019 | –090 | 075 | 131 | –065 |
| 26. ListVocab ... ... | 109 | 364 | 019 | –227 | 039 | 041 | 069 | 003 |
| 27. ListGenSig ... ... | –116 | 335 | 195 | –058 | 022 | –026 | –107 | 164 |
| 28. ListDetails ... ... | 067 | 143 | 293 | –056 | –042 | 044 | 062 | 099 |
| 29. ListInfer ... ... | 023 | 060 | 501 | 151 | 071 | 064 | –115 | 017 |
| 30. ListShTalk ... ... | –007 | 090 | 405 | 048 | –068 | 243 | 083 | –072 |
| 31. ListSponSp ... ... | 087 | 004 | 027 | –140 | 139 | 174 | 004 | 065 |
| 32. ListBoysT ... ... | –075 | 105 | 252 | –152 | 052 | 244 | 187 | –088 |
| 33. ListGirlsT ... ... | 035 | 027 | 262 | –104 | –097 | 341 | 303 | –162 |
| 34. STEP List ... ... | 016 | 047 | 374 | 045 | 064 | 168 | 100 | –020 |
| 35. SchArith ... ... | 041 | 172 | –156 | 003 | 195 | 011 | 195 | 005 |
| 36. SchRdg ... ... ... | 088 | 401 | –035 | –053 | –067 | –134 | 102 | 022 |
| 37. SchComp ... ... | 038 | 381 | –171 | –089 | 109 | –026 | 090 | –074 |

TABLE C7

Rotated Oblique Factor Matrix V for 9 factor biquartimin solution for boys. (Decimal points omitted)

| Test | Factor A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup ... | 025 | −004 | −052 | −095 | −078 | −028 | 480 | −025 | 016 |
| 2. LetterSer ... ... | 009 | 084 | 025 | −134 | 099 | 030 | 335 | 013 | −049 |
| 3. Raven'sPM ... | 027 | 038 | −039 | 173 | 048 | −128 | 296 | 114 | 070 |
| 4. Reasoning ... ... | −039 | 009 | 109 | −482 | 031 | 057 | 091 | 074 | 031 |
| 5. WdSquares ... | −012 | 091 | 024 | 128 | 006 | −261 | 106 | 268 | 118 |
| 6. ArithReas ... | 056 | 173 | −036 | −021 | 279 | 003 | 266 | 018 | −205 |
| 7. RdgVocab ... | −016 | 354 | 053 | 022 | 046 | −118 | −005 | 071 | 026 |
| 8. Sp.of Rdg ... ... | 028 | 491 | −082 | −184 | −075 | −082 | −003 | −021 | −050 |
| 9. RdgGenSig ... | 139 | 314 | 110 | 115 | 116 | −003 | 019 | 006 | −111 |
| 10. RdgDetails ... | 110 | 420 | 240 | 114 | 020 | 041 | 003 | −047 | −183 |
| 11. RdgInfer ... ... | −040 | 459 | 008 | −011 | 122 | 018 | −006 | −017 | −169 |
| 12. MatchWds ... | −042 | 228 | −041 | 042 | 140 | −218 | 196 | 149 | −014 |
| 13. TripletNos ... | 079 | 071 | 007 | −321 | 030 | 040 | 114 | −104 | 051 |
| 14. LetterList ... ... | 016 | 003 | 049 | −008 | 471 | 064 | 049 | −060 | −161 |
| 15. FiveLett ... ... | 016 | −226 | −002 | 014 | 241 | −043 | 274 | 119 | 062 |
| 16. RapidSpell ... | 322 | −048 | −085 | −060 | −040 | 198 | −030 | 118 | −056 |
| 17. Singing ... ... | 079 | 146 | −073 | −067 | 037 | 028 | −069 | 285 | −098 |
| 18. HapSpeech ... | 071 | −040 | 017 | −047 | −056 | −123 | −101 | 436 | 128 |
| 19. IllGroup ... ... | 379 | 170 | −041 | 022 | −081 | 008 | 010 | 144 | −058 |
| 20. SentComp ... ... | 135 | −019 | −222 | 018 | −046 | 085 | −052 | 029 | 179 |
| 21. Conseq ... ... | 008 | 113 | 012 | −104 | 138 | 342 | 073 | −110 | −149 |
| 22. WdNumber ... | 054 | 014 | −147 | −116 | 336 | −033 | −171 | −033 | 086 |
| 23. MemWds ... ... | −018 | 010 | −463 | 109 | 045 | 039 | 024 | 031 | 055 |
| 24. VisLetSpan ... | 504 | 010 | 042 | 098 | 131 | −146 | −066 | 038 | 055 |
| 25. AudLetSpan ... | 586 | −007 | 041 | −027 | −044 | 071 | 102 | −057 | −022 |
| 26. ListVocab ... ... | 051 | 209 | −055 | 253 | −121 | −231 | 003 | 155 | 231 |
| 27. ListGenSig ... | −131 | 263 | 149 | 058 | −041 | −079 | −112 | 182 | 067 |
| 28. ListDetails ... | 064 | 106 | 292 | 126 | −034 | 045 | 053 | 092 | 010 |
| 29. ListInfer ... ... | −011 | 007 | 429 | −091 | 011 | 038 | −171 | 093 | 138 |
| 30. ListShTalk ... | 004 | 081 | 339 | 067 | −020 | 236 | 033 | −104 | −020 |
| 31. ListSponSp ... | 097 | −022 | −093 | 217 | 094 | 059 | −027 | 054 | 038 |
| 32. ListBoysT ... ... | −114 | 002 | 139 | 322 | −037 | 022 | 109 | 006 | 167 |
| 33. ListGirlsT ... | 007 | −057 | 154 | 313 | −138 | 123 | 213 | −072 | 145 |
| 34. STEP List ... | 017 | 022 | 323 | 067 | 072 | 151 | 067 | −031 | 013 |

TABLE C8

Rotated Oblique Factor Matrix V for graphical solution for boys. (Decimal points omitted)

Factor

| Test | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup ... ... | −114 | 118 | 331 | 226 | 060 | 107 | 079 | −125 |
| 2. LetterSer ... ... | −015 | 083 | 406 | 224 | 123 | −019 | 181 | −004 |
| 3. Raven'sPM ... ... | 071 | 155 | 368 | 199 | −113 | 069 | 118 | 032 |
| 4. Reasoning ... ... | −096 | −031 | 253 | 114 | 465 | −209 | 145 | −006 |
| 5. WdSquares ... ... | −010 | 181 | 348 | 246 | −030 | −077 | −026 | 124 |
| 6. ArithReas ... ... | −045 | 162 | 478 | 199 | 012 | −132 | 143 | 118 |
| 7. RdgVocab ... ... | −067 | 067 | 246 | 407 | −006 | −080 | 075 | 029 |
| 8. Sp.of Rdg ... ... | −358 | 112 | 163 | 519 | 067 | −111 | 047 | −036 |
| 9. RdgGenSig ... ... | 015 | 178 | 195 | 320 | −046 | −025 | 036 | 043 |
| 10. RdgDetails ... ... | −037 | 159 | 094 | 441 | −062 | 045 | −110 | 009 |
| 11. RdgInfer ... ... | −120 | 054 | 236 | 413 | −076 | −072 | 109 | 112 |
| 12. MatchWds ... ... | −113 | 137 | 484 | 338 | −026 | −153 | 050 | 099 |
| 13. TripletNos ... ... | −114 | −020 | 140 | 141 | 312 | −119 | 160 | −193 |
| 14. LetterList ... ... | 181 | −057 | 328 | −104 | 075 | −234 | 198 | 077 |
| 15. FiveLett ... ... | 217 | 052 | 415 | −118 | 095 | −079 | 216 | 063 |
| 16. RapidSpell ... ... | 074 | 342 | −021 | −077 | 087 | 072 | 210 | 170 |
| 17. Singing ... ... ... | −039 | 283 | 225 | 124 | 035 | −093 | 144 | 368 |
| 18. HapSpeech ... ... | 053 | 279 | 218 | 051 | 143 | −117 | 070 | 327 |
| 19. IllGroup ... ... | −097 | 468 | 092 | 215 | 055 | 011 | 033 | 104 |
| 20. SentComp ... ... | 126 | 075 | −048 | −044 | −042 | 117 | 388 | 006 |
| 21. Conseq ... ... ... | 184 | −042 | 085 | 040 | 008 | 120 | 380 | 093 |
| 22. WdNumber ... ... | 083 | −100 | 150 | −126 | 153 | −295 | 331 | −020 |
| 23. MemWds ... ... | 016 | 038 | 058 | −095 | −283 | 099 | 416 | 154 |
| 24. VisLetSpan ... ... | 004 | 387 | 082 | 028 | 180 | −189 | −059 | −136 |
| 25. AudLetSpan ... ... | −033 | 463 | −013 | 068 | 221 | 023 | 002 | −188 |
| 26. ListVocab ... ... | 019 | 150 | 127 | 329 | −178 | 089 | 072 | −011 |
| 27. ListGenSig ... ... | 055 | −001 | 132 | 317 | −038 | −005 | 031 | 152 |
| 28. ListDetails ... ... | 203 | 113 | 100 | 222 | 009 | 127 | −018 | 042 |
| 29. ListInfer ... ... | 262 | −095 | −010 | 087 | 287 | −055 | −018 | −038 |
| 30. ListShTalk ... ... | 303 | −086 | −069 | 134 | 013 | 231 | 080 | −072 |
| 31. ListSponSp ... ... | 226 | 093 | 036 | −073 | −176 | 104 | 233 | 111 |
| 32. ListBoysT ... ... | 359 | −115 | 034 | 107 | −248 | 298 | 150 | −039 |
| 33. ListGirlsT ... ... | 364 | −035 | −057 | 089 | −232 | 434 | 140 | −128 |
| 34. STEP List ... ... | 321 | −052 | 073 | 098 | 064 | 128 | 099 | −042 |
| 35. SchArith ... ... | −061 | 098 | 345 | 179 | −019 | −066 | 221 | −011 |
| 36. SchRdg ... ... ... | −222 | 182 | 222 | 466 | 042 | −044 | −081 | −064 |
| 37. SchComp ... ... | −196 | 063 | 209 | 328 | −072 | 076 | 115 | −081 |

TABLE C9

8 Factor Biquartimin solution for Boys.
(Diagonal and above) Cosines of Angles between Reference Vectors: Matrix $\Lambda'\Lambda$
(Diagonal and below) Correlations between Primary Factors: Matrix $R_{pq}$
(Decimal points omitted)

Factor

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| A ... ... | 1.000 | –123 | 025 | –201 | –322 | 013 | 105 | –263 |
| B ... ... | 510 | 1.000 | –251 | –426 | –197 | –448 | –284 | 076 |
| C ... ... | 271 | 432 | 1.000 | 276 | –137 | 399 | –171 | –297 |
| D ... ... | 232 | 264 | –107 | 1.000 | 042 | 353 | 088 | –023 |
| E ... ... | 504 | 558 | 426 | 083 | 1.000 | –106 | –270 | 188 |
| F ... ... | 300 | 446 | –002 | –150 | 233 | 1.000 | 381 | –595 |
| G ... ... | 373 | 573 | 636 | 005 | 535 | 146 | 1.000 | –555 |
| H ... ... | 480 | 564 | 511 | –068 | 406 | 556 | 685 | 1.000 |

TABLE C10

Graphical solution for Boys.
(Diagonal and above) Cosines of Angles between Reference Vectors: Matrix $\Lambda'\Lambda$
(Diagonal and below) Correlations between Primary Factors: Matrix $R_{pq}$
(Decimal points omitted)

Factor

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| A ... ... | 1.000 | –486 | –345 | –727 | –095 | 401 | 376 | –103 |
| B ... ... | 570 | 1.000 | 100 | 268 | 050 | –083 | –408 | 151 |
| C ... ... | –019 | –128 | 1.000 | 127 | 038 | –547 | 201 | 498 |
| D ... ... | 767 | 426 | –217 | 1.000 | –137 | –016 | –568 | –091 |
| E ... ... | –108 | –196 | 187 | 024 | 1.000 | –508 | –042 | –121 |
| F ... ... | –517 | –421 | 419 | –413 | 607 | 1.000 | 018 | –437 |
| G ... ... | 325 | 494 | –359 | 584 | –099 | –377 | 1.000 | 226 |
| H ... ... | –225 | –343 | –149 | –094 | 436 | 492 | –254 | 1.000 |

TABLE C11

**Oblique Transformation Matrix Λ for 9 factor biquartimin solution for girls. (Decimal points omitted)**

Factor

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| I ... ... | 109 | 096 | 046 | 368 | 118 | 036 | 081 | 052 | –003 |
| II ... ... | 295 | 598 | –262 | –361 | –181 | –105 | 117 | 334 | –196 |
| III ... ... | 597 | –453 | –058 | –022 | –120 | –009 | 311 | –110 | 057 |
| IV ... ... | 074 | 271 | 590 | –730 | 203 | –044 | 149 | –129 | 129 |
| V ... ... | 378 | –220 | 385 | 149 | –171 | –066 | –367 | 182 | 283 |
| VI ... ... | –305 | 079 | 458 | 229 | –198 | –293 | 496 | 192 | 156 |
| VII ... ... | –064 | 117 | –086 | 071 | –726 | 808 | 413 | 253 | 456 |
| VIII ... ... | 483 | 533 | 052 | 346 | –150 | 146 | –556 | –818 | –045 |
| IX ... ... | –258 | 054 | –459 | –040 | 529 | –472 | 010 | –231 | 792 |

TABLE C12

**Oblique Transformation Matrix Λ for graphical solution for girls. (Decimal points omitted)**

Factor

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| I ... | 322 | 081 | 165 | 157 | 113 | –054 | –050 | –060 | 020 | –068 |
| II ... | –497 | 779 | 416 | –211 | –222 | –162 | –001 | 121 | –251 | 027 |
| III ... | –347 | –497 | 623 | 067 | –121 | –091 | 086 | 360 | 136 | 068 |
| IV ... | 202 | 045 | 086 | –750 | 411 | 249 | 299 | –096 | –230 | 107 |
| V ... | –449 | 129 | –164 | –077 | 411 | 170 | –330 | –219 | 098 | 283 |
| VI ... | –143 | –028 | –128 | –250 | –404 | 630 | 156 | 474 | 034 | 547 |
| VII ... | –186 | 161 | 110 | 004 | –363 | –505 | 592 | –013 | –121 | 052 |
| VIII ... | –264 | 230 | 094 | 386 | –216 | 121 | 375 | –752 | –041 | 182 |
| IX ... | 401 | 188 | –488 | –355 | 440 | –337 | 103 | –005 | –891 | 100 |
| X ... | 023 | –077 | –318 | –146 | 226 | –302 | –515 | 066 | –209 | 743 |

TABLE C13

Rotated Oblique Factor Matrix V for 8 factor biquartimin solution for girls. (Decimal points omitted)

Factor

| Test | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup ... ... | 223 | 184 | 150 | 134 | 033 | –210 | –097 | 073 |
| 2. LetterSer ... ... | 099 | 234 | –110 | –033 | 221 | –149 | 121 | 259 |
| 3. Raven'sPM ... ... | 109 | 222 | –111 | –031 | 415 | –231 | –043 | 109 |
| 4. Reasoning ... ... | –040 | 158 | 168 | 081 | –028 | 298 | 002 | –010 |
| 5. WdSquares ... ... | –172 | 172 | –146 | 035 | 362 | 055 | 025 | 014 |
| 6. ArithReas ... ... | 056 | 060 | –226 | 157 | 268 | –062 | 060 | 220 |
| 7. RdgVocab ... ... | 145 | –079 | 013 | 431 | 113 | –021 | –042 | –017 |
| 8. Sp.of Rdg ... ... | 113 | 057 | –012 | 615 | –289 | 074 | –015 | –023 |
| 9. RdgGenSig ... ... | 121 | –126 | –045 | 473 | 030 | 149 | –036 | –043 |
| 10. RdgDetails ... ... | 011 | –085 | –030 | 471 | 038 | –133 | –064 | 110 |
| 11. RdgInfer ... ... | 018 | 185 | 006 | 545 | –018 | 036 | –120 | –191 |
| 12. MatchWds ... ... | –085 | –071 | –088 | 146 | 057 | 037 | 266 | 322 |
| 13. TripletNos ... ... | –019 | 413 | –006 | –009 | 002 | 034 | –022 | –027 |
| 14. LetterList ... ... | –014 | 031 | 046 | –064 | 138 | –009 | 187 | 328 |
| 15. FiveLett ... ... | 038 | 256 | 133 | –147 | 246 | 125 | 016 | 038 |
| 16. RapidSpell ... ... | 291 | 211 | 227 | 017 | –246 | –003 | 256 | –077 |
| 17. Singing ... ... ... | 183 | 120 | –054 | 171 | 036 | 145 | –021 | –265 |
| 18. HapSpeech ... ... | –014 | 016 | 016 | –112 | –102 | 077 | 481 | 141 |
| 19. IllGroup ... ... | 181 | –142 | –026 | –019 | –049 | 026 | 362 | 244 |
| 20. SentComp ... ... | 150 | –247 | 389 | –045 | 162 | 104 | –012 | 039 |
| 21. Conseq ... ... ... | 083 | –244 | 221 | 134 | 302 | –145 | –072 | 052 |
| 22. WdNumber ... ... | –069 | 005 | 472 | 064 | –119 | 042 | 008 | 049 |
| 23. MemWds ... ... | 005 | 027 | 517 | –060 | 027 | –051 | –005 | –050 |
| 24. VisLetSpan ... ... | 576 | –083 | –108 | 059 | 057 | –129 | –014 | –004 |
| 25. AudLetSpan ... ... | 534 | 003 | –062 | 152 | –142 | –020 | 051 | –088 |
| 26. ListVocab ... ... | –057 | –248 | 012 | 357 | 034 | 019 | 210 | 141 |
| 27. ListGenSig ... ... | –100 | –115 | –021 | 385 | 030 | 168 | 137 | 031 |
| 28. ListDetails ... ... | –196 | –185 | –044 | 338 | 156 | –123 | 184 | 116 |
| 29. ListInfer ... ... | –075 | –072 | 130 | 357 | 024 | 062 | 040 | –094 |
| 30. ListShTalk ... ... | –277 | –013 | 097 | 160 | 145 | –179 | 235 | 154 |
| 31. ListSponSp ... ... | –066 | –067 | 007 | 281 | 094 | 326 | 001 | –101 |
| 32. ListBoysT ... ... | –088 | –079 | 236 | 160 | 292 | –134 | –051 | –127 |
| 33. ListGirlsT ... ... | –016 | –005 | 178 | 191 | 183 | 026 | 019 | –107 |
| 34. STEP List ... ... | 059 | 033 | 056 | 426 | 075 | 127 | –091 | –194 |

TABLE C14

Rotated Oblique Factor Matrix V for 9 factor biquartimin solution for girls. (Decimal points omitted)

| Test | Factor A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup ... | 117 | 266 | 075 | 131 | 183 | −289 | −121 | −008 | 046 |
| 2. LetterSer ... | 068 | 454 | −109 | −007 | 076 | −128 | 078 | 231 | −077 |
| 3. Raven'sPM ... | 117 | 461 | −051 | −045 | 145 | −058 | −086 | 082 | −316 |
| 4. Reasoning ... | −080 | 216 | 036 | 085 | −014 | 076 | 017 | 016 | 426 |
| 5. WdSquares ... | −082 | 351 | −057 | 027 | −011 | 229 | 009 | 068 | −227 |
| 6. ArithReas ... | 089 | 266 | −140 | 185 | −009 | 062 | −000 | 257 | −190 |
| 7. RdgVocab ... | 162 | −018 | 022 | 426 | 109 | 032 | −064 | −012 | −053 |
| 8. Sp.of Rdg ... | 090 | −029 | −025 | 647 | −075 | −025 | −014 | 010 | 138 |
| 9. RdgGenSig ... | 128 | −093 | −091 | 472 | 059 | 100 | −047 | −015 | 157 |
| 10. RdgDetails ... | −008 | −039 | 020 | 492 | 073 | −071 | −122 | 103 | −121 |
| 11. RdgInfer ... | 088 | 155 | 103 | 538 | −068 | 156 | −104 | −124 | −200 |
| 12. MatchWds ... | −053 | −055 | −037 | 208 | −064 | 052 | 215 | 358 | 003 |
| 13. TripletNos ... | −045 | 474 | −040 | −008 | −040 | −029 | −001 | −022 | 062 |
| 14. LetterList ... | 001 | 204 | 103 | −014 | −057 | 014 | 133 | 358 | −035 |
| 15. FiveLett ... | 054 | 435 | 109 | −156 | 007 | 104 | 017 | 068 | 073 |
| 16. RapidSpell ... | 339 | 123 | 227 | 029 | −068 | −038 | 333 | −069 | 003 |
| 17. Singing ... | 253 | 098 | −065 | 135 | −008 | 180 | 040 | −222 | −007 |
| 18. HapSpeech ... | 060 | 019 | 007 | −071 | −054 | 049 | 523 | 148 | 067 |
| 19. IllGroup ... | 207 | −084 | −041 | 028 | −014 | −021 | 356 | 248 | 100 |
| 20. SentComp ... | 161 | −169 | 354 | −060 | 105 | 072 | −031 | 044 | 133 |
| 21. Conseq ... | −007 | −109 | 067 | 095 | 436 | −210 | −117 | −078 | 150 |
| 22. WdNumber ... | −046 | −038 | 541 | 087 | −099 | 039 | 000 | 088 | −014 |
| 23. MemWds ... | 007 | 018 | 507 | −077 | 104 | −053 | 009 | −083 | −012 |
| 24. VisLetSpan ... | 575 | −033 | −105 | 046 | 070 | −083 | −013 | −013 | −095 |
| 25. AudLetSpan ... | 583 | −050 | −011 | 154 | −093 | 026 | 088 | −041 | −100 |
| 26. ListVocab ... | −006 | −214 | 044 | 389 | 055 | 068 | 181 | 152 | −024 |
| 27. ListGenSig ... | −022 | −089 | 019 | 408 | −044 | 207 | 129 | 094 | 018 |
| 28. ListDetails ... | −209 | −113 | −109 | 345 | 287 | −106 | 151 | 027 | 009 |
| 29. ListInfer ... | −062 | −084 | 071 | 344 | 147 | 033 | 052 | −117 | 099 |
| 30. ListShTalk ... | −301 | 073 | 034 | 172 | 278 | −172 | 212 | 046 | −018 |
| 31. ListSponSp ... | 042 | −034 | 060 | 280 | −129 | 374 | 011 | 017 | 049 |
| 32. ListBoysT ... | −106 | −009 | 141 | 105 | 387 | −094 | −051 | −236 | −027 |
| 33. ListGirlsT ... | −006 | 056 | 100 | 158 | 223 | 020 | 034 | −150 | 066 |
| 34. STEP List ... | 068 | 049 | −016 | 396 | 129 | 090 | −070 | −191 | 125 |
| 35. SchArith ... | −075 | 352 | −025 | −007 | −118 | 300 | −085 | 276 | −254 |
| 36. SchRdg ... | 097 | 014 | −031 | 271 | −061 | 068 | 055 | 244 | −035 |
| 37. SchComp ... | 051 | −093 | −009 | 195 | −020 | 036 | −010 | 251 | 048 |

TABLE C15

Rotated Oblique Factor Matrix V for graphical solution for girls. (Decimal points omitted)

| Test | Factor A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. LetterGroup ... | 021 | 348 | 036 | –046 | 120 | 208 | –022 | –120 | –126 | –026 |
| 2. LetterSer ... ... | 036 | 556 | 163 | –100 | 017 | –077 | –063 | 008 | –212 | –023 |
| 3. Raven'sPM ... | 124 | 450 | 206 | 011 | 053 | –036 | –114 | –148 | –050 | –133 |
| 4. Reasoning ... | 144 | 290 | –190 | –166 | 171 | –124 | 202 | –182 | –329 | 078 |
| 5. WdSquares ... | 245 | 268 | 094 | 094 | –058 | –153 | 051 | –164 | 013 | –168 |
| 6. ArithReas ... | 074 | 376 | 152 | 142 | 015 | –194 | –215 | –041 | –004 | –058 |
| 7. RdgVocab ... | 245 | –019 | 077 | 252 | 158 | –084 | –214 | –113 | 083 | 026 |
| 8. Sp.of Rdg ... | 021 | 039 | –037 | 324 | –073 | 009 | –186 | –031 | 039 | 189 |
| 9. RdgGenSig ... | 237 | –025 | 029 | 274 | 155 | –202 | –096 | –131 | –007 | –053 |
| 10. RdgDetails ... | 148 | –108 | –029 | 325 | 018 | 111 | –234 | –063 | 200 | –083 |
| 11. RdgInfer ... ... | 157 | 029 | 103 | 412 | –155 | 104 | 003 | –223 | 245 | –018 |
| 12. MatchWds ... | 098 | 194 | 130 | 061 | –053 | –066 | –049 | 155 | 038 | –110 |
| 13. TripletNos ... | –022 | 439 | –082 | –123 | –070 | –043 | 094 | –124 | –281 | 205 |
| 14. LetterList ... | 010 | 330 | 073 | –141 | 071 | –020 | –125 | 077 | –036 | 052 |
| 15. FiveLett ... ... | 113 | 435 | 082 | –219 | 135 | –068 | 175 | –206 | –211 | –048 |
| 16. RapidSpell ... | –081 | –047 | 452 | –112 | –113 | 154 | 207 | 176 | 005 | 145 |
| 17. Singing ... ... | 110 | –041 | 319 | 175 | –064 | –133 | 245 | –145 | 007 | –153 |
| 18. HapSpeech ... | 091 | –077 | 360 | –163 | –150 | –082 | 144 | 362 | –080 | 046 |
| 19. IllGroup ... ... | 006 | –005 | 320 | –103 | 049 | –168 | –059 | 305 | –078 | 075 |
| 20. SentComp ... | 183 | –143 | 026 | –174 | 427 | 041 | –081 | –110 | 061 | –001 |
| 21. Conseq ... ... | 461 | –081 | –159 | –087 | 508 | –035 | –221 | –111 | –152 | –046 |
| 22. WdNumber ... | 012 | –086 | –111 | –111 | 087 | 383 | –043 | –046 | 234 | 197 |
| 23. MemWds ... | 169 | –135 | –052 | –227 | 213 | 341 | –044 | –072 | 098 | 166 |
| 24. VisLetSpan ... | –166 | 045 | 505 | 106 | 117 | –136 | –125 | 019 | 028 | –083 |
| 25. AudLetSpan ... | –242 | –045 | 588 | 185 | –081 | –036 | 032 | 058 | 149 | –050 |
| 26. ListVocab ... | 304 | –200 | 144 | 240 | 060 | –065 | –100 | 097 | 192 | –119 |
| 27. ListGenSig ... | 271 | –093 | 126 | 270 | –049 | –061 | 067 | –009 | 170 | –187 |
| 28. ListDetails ... | 516 | –192 | –069 | 151 | 096 | –066 | –135 | 126 | –022 | –088 |
| 29. ListInfer ... ... | 393 | –206 | –143 | 101 | 172 | –088 | –132 | –039 | –041 | 204 |
| 30. ListShTalk ... | 479 | –015 | –021 | –003 | –013 | 177 | 092 | 132 | –022 | –201 |
| 31. ListSponSp ... | 209 | –052 | 117 | 240 | 003 | –134 | 170 | –193 | 163 | –233 |
| 32. ListBoysT ... | 555 | –189 | –062 | 014 | 261 | 114 | –115 | –146 | –001 | –167 |
| 33. ListGirlsT ... | 427 | –074 | 025 | 017 | 192 | –010 | 077 | –127 | –058 | –080 |
| 34. STEP List ... | 343 | –023 | 007 | 221 | 127 | –102 | 069 | –229 | –046 | –072 |
| 35. SchArith ... ... | 118 | 428 | 066 | 102 | 009 | –194 | –056 | –233 | 087 | –260 |
| 36. SchRdg ... ... | 042 | 142 | 113 | 157 | 057 | –152 | –196 | 012 | 065 | –019 |
| 37. SchComp ... ... | 042 | 084 | –027 | 077 | 186 | –164 | –270 | 003 | 027 | 021 |

TABLE C16

9 Factor Biquartimin solution for Girls.
(Diagonal and above) Cosines of Angles between Reference Vectors ($\Lambda'\Lambda$)
(Diagonal and below) Correlations between Primary Factors: Matrix $R_{pq}$.
(Decimal points omitted)

Factor

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| A ... ... ... | 1.000 | 065 | 091 | 025 | −263 | 169 | −348 | −313 | −211 |
| B ... ... ... | 294 | 1.000 | −021 | −192 | −102 | 071 | −150 | −224 | −086 |
| C ... ... ... | 116 | 187 | 1.000 | −125 | −165 | −001 | 060 | 045 | −101 |
| D ... ... ... | 387 | 451 | 279 | 1.000 | −232 | 133 | −232 | −190 | 037 |
| E ... ... ... | 547 | 430 | 352 | 570 | 1.000 | −773 | −265 | −319 | 070 |
| F ... ... ... | 326 | 269 | 295 | 356 | 813 | 1.000 | 108 | 099 | −062 |
| G ... ... ... | 351 | 207 | 060 | 352 | 343 | 190 | 1.000 | 576 | 209 |
| H ... ... ... | 441 | 399 | 192 | 398 | 535 | 379 | −195 | 1.000 | −038 |
| I ... ... ... | 164 | 097 | 107 | 000 | 059 | 071 | −218 | 221 | 1.000 |

TABLE C17

Graphical solution for Girls.
(Diagonal and above) Cosines of Angles between Reference Vectors: Matrix $\Lambda'\Lambda$
(Diagonal and below) Correlations between Primary Factors: Matrix $R_{pq}$.
(Decimal points omitted)

Factor

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| A ... | 1.000 | −250 | −509 | −197 | 451 | −102 | −039 | 007 | −340 | −243 |
| B ... | 356 | 1.000 | −014 | −188 | −064 | −163 | 160 | −316 | −440 | 020 |
| C ... | 486 | −051 | 1.000 | 216 | −476 | −004 | 319 | 141 | 428 | −327 |
| D ... | 080 | 675 | 001 | 1.000 | −456 | −129 | −054 | −339 | 552 | −324 |
| E ... | 020 | 756 | −092 | 851 | 1.000 | −101 | −459 | −218 | −413 | 071 |
| F ... | −093 | −063 | 219 | 282 | 047 | 1.000 | −021 | 086 | 428 | 150 |
| G ... | 033 | 713 | −256 | 759 | 897 | −067 | 1.000 | −173 | −156 | −240 |
| H ... | 032 | 770 | −186 | 855 | 887 | 070 | 843 | 1.000 | 057 | 130 |
| I ... | 297 | 671 | −278 | 228 | 535 | −531 | 613 | 466 | 1.000 | −235 |
| J ... | 510 | 634 | 239 | 569 | 599 | −140 | 606 | 525 | 540 | 1.000 |

APPENDIX D

## RELIABILITY CO-EFFICIENTS

| Test | Type of coefficient | Value of coef-ficient | N | S.D. of raw score | No. of items in test |
|---|---|---|---|---|---|
| 1. Letter Grouping ... ... | Test-retest ... ... | .89 | 38 | 9.16 | 30 |
| 2. Letter Series ... ... | Test-retest ... ... | .94 | 32 | 9.22 | 25 |
| 3. Progressive Matrices (1938), Total Score ... | Kuder-Richardson | .87 | 100 | 8.15 | 60 |
| 4. Reasoning ... ... ... | Test-retest ... ... | .74 | 27 | 3.42 | 30 |
| 5. Word Squares ... ... | Kuder-Richardson | .73 | 100 | 3.05 | 15 |
| 6. Arithmetic Reas. ... ... | „ | .58 | 100 | 2.19 | 17 |
| 7. Reading Vocab. ... ... | „ | .89 | 100 | 5.82 | 30 |
| 8. Speed of Reading ... ... | Test-retest ... ... | .86 | 30 | 4.45 | 30 |
| 9. Reading for Gen. Significance ... ... | Kuder-Richardson | .67 | 100 | 2.66 | 14 |
| 10. Reading to Note Details | „ | .72 | 100 | 3.15 | 19 |
| 11. Reading for Inference ... | „ | .72 | 100 | 2.50 | 12 |
| 12. Matching Words ... ... | „ | .91 | 100 | 7.15 | 30 |
| 13. Triplet Numbers ... ... | Test-retest ... ... | .51 | 36 | 5.80 | 25 |
| 14. Letter List ... ... ... | Test-retest ... ... | .56 | 41 | 9.92 | 27 |
| 15. Five Letters ... ... ... | Kuder-Richardson | .84 | 100 | 3.80 | 15 |
| 16. Rapid Spelling ... ... | „ | .74 | 100 | 2.50 | 11 |
| 17. Singing ... ... ... | Corrected odd-even sentence correlation | .38 | 100 | 3.90 | 3 sent. |
| 18. Haphazard Speech ... | „ | .53 | 100 | 4.74 | 5 sent. |
| 19. Illogical Grouping ... | „ | .69 | 100 | 6.30 | 6 sent. |
| 20. Sent. Completion ... ... | Kuder-Richardson | .80 | 100 | 4.31 | 25 |
| 21. Consequences ... ... | „ | .68 | 100 | 3.05 | 20 |
| 22. Word-Number ... ... | „ | .75 | 100 | 3.04 | 15 |
| 23. Memory for Words ... | „ | .74 | 100 | 3.90 | 20 |
| 24. Letter Span I ... ... | „ | .73 | 100 | 2.51 | 17 |
| 25. Letter Span II ... ... | „ | .70 | 100 | 2.29 | 19 |
| 26. List Vocabulary ... ... | „ | .79 | 100 | 4.98 | 30 |
| 27. List for Gen. Significance | „ | .56 | 100 | 2.27 | 14 |
| 28. List to Note Details ... | „ | .64 | 100 | 2.77 | 18 |
| 29. List for Inference ... | „ | .62 | 100 | 2.35 | 13 |
| 30. List to Short Talk ... | „ | .44 | 100 | 2.37 | 15 |
| 31. List to Spon. Speech ... | „ | .29 | 100 | 2.19 | 17 |
| 32. List to Boys' Talk ... | „ | .56 | 100 | 2.55 | 15 |
| 33. List to Girls' Talk ... | „ | .71 | 100 | 2.91 | 14 |
| 34. S.T.E.P. Listening ... | „ | .80 | 100 | 5.91 | 38 |

## Appendix E

# THE TECHNIQUE OF FACTOR ANALYSIS

FACTOR analysis is a technique for studying the interrelationships between variables, and has been used extensively in studying relationships between different kinds of mental tasks. Common observation indicates that people differ greatly in their performance on such tasks; some know many more words than others, some have a much better memory than others, some can spell better than others. Such performances, and many others, can be measured by developing appropriate tests, and the relationships between these performances can be established by correlating the results of persons on the various pairs of tests. When only three or four tests are involved, it is relatively easy to interpret the relationships (usually expressed in the form of correlation co-efficients) between the various tests or groups of tests; when the number of tests is large, it is virtually impossible to interpret the mass of interrelationships as presented in a table or matrix of correlation co-efficients. Factor analysis seeks to establish a simpler and more easily grasped framework for expressing the complex of interrelationships among such tests, and thus for describing the ways in which people differ in their mental behaviour.

It is the aim of factor analysis to describe the relationships between variables in as economical or parsimonious a manner as possible; it attempts to explain the correlations between a number of variables in terms of a smaller number of variables or dimensions or explanatory constructs. It might demonstrate, for instance, that the correlations between six tests, such as addition, subtraction, multiplication, division, vocabulary and reading comprehension can be accounted for by two basic variables or constructs, which might be taken to represent computational ability and verbal ability. If this were so, each person's performance could be adequately described by a number score and a verbal score, instead of the original six scores. By indicating whether tests are measuring much the same ability or different abilities, factor analysis is of great assistance in the development of test batteries. It shows how a wide range of mental abilities can be tested economically by a few relatively "pure" tests of those abilities, and how duplication of measurement and thus of testing time and effort can be avoided.

Factor analysis has been most fruitfully employed as an experimental technique in the psychological investigation of individual differences in abilities and personality, where the aim has been to identify and describe the fundamental variables underlying mental behaviour. It is a useful technique for exploratory studies of a new field, where little is known about the basic variables or the structure of their relationships. In the 1930's, for example, large batteries of tests of quite different mental tasks were assembled and applied to large groups of students, and the correlations between the tests were analysed to determine whether they could be adequately accounted for by a smaller number of underlying variables. It was found that most of the variation among the tests could be described in terms of a few broad variables, such as ability to comprehend verbal relations, ability in numerical tasks, ability to think spatially, memory ability and so on. When the broad outlines of a field have been established in this way, factor analysis has been employed in more detailed investigations of these broad areas of behaviour, in an attempt to identify the basic types of thinking or behaving which occur in these fields. Within the field of memory, for example, hypotheses have been developed about the different types of memorizing that people are called upon to undertake—memorizing pairs of unrelated words, sequences of letters or digits, meaningful material, material presented in auditory or visual form, and so on. Tests have been constructed to measure these hypothesized abilities, and the correlations between the tests for a particular group of persons have been factor analyzed to determine whether the hypotheses could be confirmed, or whether they needed further refinement.

From the results of numerous factor studies, a comprehensive picture of the main types of mental activity has been developed. Well established factors (known as "reference factors") have been incorporated into systematic frameworks, which are used as bases for investigating newly hypothesized factors. When a new factor is proposed to account for a particular kind of mental task, the need for the new factor and its place in the overall pattern of mental abilities can be systematically investigated by applying tests designed to measure this factor along with tests selected to measure standard "reference factors," and factor analysing the resulting table of inter-correlations. It might be asked, for example, whether the variation in the performance of people on tests of listening comprehension could be adequately described in terms of known sources of variation—reference factors—or whether it was necessary to postulate a listening factor or listening ability to account for this variation. In this way, new factors can be verified and incorporated into the existing framework, and the picture of mental abilities extended.

Various procedures are used to determine or "extract" the factors which will account for a given correlation (or covariance) matrix. In conformity with their theories about the nature of mental activity, British psychologists have tended to follow methods which involve, as a first step, the extraction of a general factor in which all tests in a battery are represented, and then the identification of group factors corresponding to sub-groupings of similar tests. The American approach to factor analysis, developed largely by Thurstone, makes no initial assumption about the need for a general factor but seeks to determine the minimum number of factors indicated by the correlations. This is achieved with the aid of mathematical techniques such as centroid analysis, multiple-group analysis or principal axes factor analysis, which are used to "factorize" the correlation matrix, the ultimate aim being to determine a new set of factors which will successively account for as much of the variation in test scores as possible, and which will together account almost completely for the original correlations except for minor discrepancies or small "residual" amounts. In all of these methods, it is necessary to estimate the "communality" of each test, which is that portion of its self-correlation which is associated with other tests in the battery.

The factors extracted by any of the above methods are unrelated to or independent of each other, and are actually only one of many possible sets of factors which will account for the original correlations. From a geometrical point of view, the original correlations among the n tests can be represented by the angular separations between n test vectors emanating from an origin into m-dimensional space, where m is the minimum number of dimensions required to account for the original correlations; the factors represent one of many possible sets of reference axes against which these vectors can be interpreted. The projections of the test vectors on each of the new axes give the "loadings" of each test on the new factors. However, as the new axes merely provide an arbitrary frame of reference, and as the addition of new tests to the battery is likely to alter their position appreciably, Thurstone and his followers claim that they must be rotated to a position which yields factors which are "psychologically meaningful."

The rotation of axes in this search for psychological meaning may take several forms. It has been customary to determine new positions for the axes by inspecting plots of the pattern of test points for each pair of axes, and noting which tests cluster together. Although still commonly employed, this approach has the disadvantage of requiring decisions of a subjective nature, and some success has been achieved in recent years with "analytic" methods of rotation, whereby certain functions of the factor loadings are maximized or minimized to yield a precise solution. But regardless of the method used to locate the new axes, an important question about the relationship between the finally accepted factors has to be faced. The factors are unrelated before rotation, and some investigators prefer that the rotated factors to which they give a psychological interpretation should also be unrelated or independent. Such factors are described as "orthogonal," as they are represented by axes which are at right angles with each other. Other factor analysts, however, do not insist on independent factors, as they consider that explanatory constructs like height and weight, for instance, do not have to be completely independent of each other to be useful concepts; they therefore allow for the possibility of correlated or "oblique" factors, represented by axes which are not at right angles to each other.

Thurstone's criterion of "simple structure," which was developed from the assumption that in every intellectual task there are some mental functions that are not involved, has proved to be a useful guide in rotating axes to positions which have psychological meaning. This requires that axes be placed through clusters of test points so that each test will have significant loadings on only one or two factors, and so that each factor will include a good number of tests with near zero loadings. The application of this principle shows whether a psychologically acceptable solution of this form can be attained, and allows the pattern of test points to determine whether the final factors are orthogonal or oblique. If they are oblique, the factors themselves are correlated, and the correlations among these primary factors can be analyzed to yield more comprehensive second-order factors.

The end result of the process of factorizing a correlation matrix and rotating the obtained factors is to provide a table which shows the loading of each test on each factor, i.e., the extent to which each test is represented in each of the factors identified. The psychological interpretation of each factor is undertaken by noting which tests have high loadings on the factor and which have zero or negligible loadings. Among the better known of the established factors are V (verbal comprehension), N (facility in manipulating numbers), Vz (spatial visualization), D (deduction), I (induction), M (memory) and W (word fluency); the main factors isolated in British studies have been g (general ability), v:ed (verbal educational) comprising both v (verbal) and n (number) abilities, and k:m, a practical—spatial—mechanical factor.

The factors identified in factor analytic studies are not distinctive mental faculties or entities in the mind, but mathematical constructs which describe and classify types of mental behaviour. They are thus influenced by and susceptible to the effects of training or schooling. The absence of a spelling factor in a primitive community would cause no concern; the presence of such a factor among teachers' college students in a civilized community would call for remedial instruction in spelling to reduce the range of individual differences and thus the effect of the factor.

APPENDIX F

# GLOSSARY OF TECHNICAL TERMS

## A. Terms associated with matrices and matrix notation

1. *Matrix*

A matrix is a rectangular or square arrangement of numbers in a table, usually represented in matrix notation by a single letter, thus:—

$$A = \begin{Vmatrix} 7 & 5 & 6 & 4 \\ 9 & 3 & 7 & 6 \\ 5 & 8 & 1 & 9 \end{Vmatrix}$$

A matrix has no specific arithmetical value.

2. *Correlation Matrix*

A correlation matrix is a square symmetric matrix in which the cell entries consist of the correlation co-efficients between the various pairs of tests, e.g.:—

R =

| | Test 1 | Test 2 | Test 3 |
|---|---|---|---|
| Test 1 | 1.00 | .65 | .48 |
| Test 2 | .65 | 1.00 | .37 |
| Test 3 | .48 | .37 | 1.00 |

3. *Factor Matrix*

A factor matrix is usually a rectangular matrix consisting of the loadings of each test in a battery on each of the factors extracted.

F =

| | Factor I | Factor II |
|---|---|---|
| Test 1 | .20 | .84 |
| Test 2 | .21 | .69 |
| Test 3 | .70 | .10 |
| Test 4 | .72 | .00 |

4. *Matrix Multiplication*

Under certain conditions, two matrices may be multiplied to give a product matrix. For example:—

$$\underset{A}{\begin{Vmatrix} 5 & 4 \\ 1 & 4 \\ 2 & 6 \end{Vmatrix}} \times \underset{B}{\begin{Vmatrix} 3 & 2 & 7 \\ 2 & 4 & 1 \end{Vmatrix}} = \underset{C}{\begin{Vmatrix} 23 & 26 & 39 \\ 11 & 18 & 11 \\ 18 & 28 & 20 \end{Vmatrix}}$$

The elements in the product matrix C are obtained by multiplying in turn each element of each row of matrix A by each element of each column of matrix B, and summing the products. For example, (5 x 3) + (4 x 2) = 23, (5 x 2) + (4 x 4) = 26, etc.

5. *Matrix Equation*

This is an equation which expresses a relationship between matrices, such as AB = C, A + B = B + A, etc.

6. *Diagonal Matrix*

A matrix with non-zero entries in the principal diagonal cells and zeros elsewhere is called a diagonal matrix.

$$D = \begin{Vmatrix} 3 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & .4 \end{Vmatrix}$$

7. *Transpose*

The transpose of a matrix is formed by writing the rows of the matrix as columns of the new matrix. The transpose of matrix A above is denoted as A′.

$$A' = \begin{Vmatrix} 7 & 9 & 5 \\ 5 & 3 & 8 \\ 6 & 7 & 1 \\ 4 & 6 & 9 \end{Vmatrix}$$

8. *Inverse*

The inverse of a matrix is a second matrix, which when multiplied by the original matrix, gives a matrix with unities in the diagonal cells and zeros elsewhere. Thus:—

$$\begin{Vmatrix} 1 & 2 & 3 \\ 4 & 9 & 12 \\ 1 & 5 & 13 \end{Vmatrix} \text{ x } \begin{Vmatrix} 5.7 & -1.1 & -.3 \\ -4.0 & 1.0 & 0.0 \\ 1.1 & -.3 & .1 \end{Vmatrix} = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{Vmatrix}$$

$$A \quad \text{x} \quad A^{-1} \quad = \quad I$$

Original matrix x inverse matrix = identity matrix

This relationship is analogous to the reciprocal relationship in ordinary algebra, e.g., $a \text{ x } \frac{1}{a} = 1$. A matrix has to be square and non-singular (i.e., with a determinant not equal to zero) in order to have an inverse.

9. *Determinant*

A determinant is a special form of notation used to denote a sum of product terms, with alternating algebraic signs. Thus the expression (as — br) can be represented as

$$\begin{vmatrix} a & r \\ b & s \end{vmatrix}.$$

A determinant differs from a matrix in that it is always a square arrangement of numbers with a definite numerical value.

10. *Order*

The order of a matrix or of a determinant indicates the number of rows and columns of the matrix. A matrix consisting of three rows and two columns of numbers would be of order 3 x 2.

11. *Minor*

Minors of a determinant are obtained by eliminating various rows and columns of the determinant. Elimination of the third row and third column of the third order determinant

$$\begin{vmatrix} a & r & x \\ b & s & y \\ c & t & z \end{vmatrix}$$

gives the two-rowed or second order minor $\begin{vmatrix} a & r \\ b & s \end{vmatrix}$; elimination of the first and third rows and the first and second columns gives the one-rowed or first order minor $| y |$.

12. *Rank of a Matrix*

The rank of a matrix is the order of the highest non-vanishing minor or determinant, and one of the problems in factor analysis is to determine this rank. For example, the matrix

$$\begin{Vmatrix} 2 & 3 & 4 \\ 4 & 3 & 2 \\ 3 & 3 & 3 \end{Vmatrix}$$

has only one-third order determinant, namely,

$$\begin{vmatrix} 2 & 3 & 4 \\ 4 & 3 & 2 \\ 3 & 3 & 3 \end{vmatrix}$$

which has a value of zero and thus vanishes.

(In expanded form, this determinant is expressed as

$$2 \times 3 \times 3 - 2 \times 3 \times 2 + 4 \times 3 \times 4 - 4 \times 3 \times 3 + 3 \times 3 \times 2 - 3 \times 3 \times 4 = 0).*$$

None of the two-rowed or second-order minors vanish, e.g.,

$$\begin{vmatrix} 2 & 3 \\ 4 & 3 \end{vmatrix} = -6, \begin{vmatrix} 2 & 4 \\ 4 & 2 \end{vmatrix} = -12,$$

and the rank of the matrix is thus 2. In factor analysis, this is taken to indicate that the inter-relationships among the numbers in the matrix (usually correlation co-efficients), can be accounted for in terms of two independent variables. The true rank of a correlation matrix based on experimental data is usually equal to the number of variables, but factor analysis seeks to determine some smaller rank which will account for the correlations to a very close approximation.

## B. Terms associated with the factorization of matrices

1. *Communalities*

The communality of a test is that part of its variance which it has in common with other tests in a test battery, and which is described as its common factor variance. It is usually represented by the symbol $h^2$. The remaining portion of a test's variance, $(1 - h^2)$, is unique to the particular test, and represents abilities involved in that test only (specific variance) and errors of measurement (error variance).

In experimental problems, the numerical value of the communality is unknown and has to be estimated for each test. Often the highest correlation obtained between each test and other tests in the battery is used as a first approximation.

The communality of a test can be computed from an orthogonal factor matrix by squaring the loading of the test on each factor and summing these squares.

2. *Principal Axes*

Reference axes located through a scattergram or swarm of points in a multivariate score distribution or through a pattern of test vectors so as to maximize the sum of the squared score or test projections on these axes are known as principal axes. The first or

*Methods of evaluating determinants are described in Thurstone's text (Thurstone, 1947).

major principal axis maximizes the sum of squares of these projections for the original data, and each subsequent principal axis maximizes the sum of squares of that part of the score or test configuration not accounted for by the principal axes already located. The principal axes, and the factors which they represent, are orthogonal (at right angles) to each other. They are determined algebraically by setting up a specific equation (known as the characteristic equation) for the particular matrix and finding the set of values which satisfy this equation.

3. *Eigenvalues*

The roots of a characteristic equation are called eigenvalues, latent roots or characteristic roots. They represent the variance of the original test standard scores (when considered as points in a space of as many dimensions as there are tests) along the principal axes, or the amount of common factor variance (or total test variance in some cases) which can be attributed to each principal axis. The eigenvalues of the matrix

$$\begin{Vmatrix} .906 & .438 & .072 \\ .438 & .891 & -.309 \\ .072 & -.309 & .650 \end{Vmatrix}$$

are 1.379, .809 and .259, or in matrix form

$$\begin{Vmatrix} 1.379 & 0 & 0 \\ 0 & .809 & 0 \\ 0 & 0 & .259 \end{Vmatrix}$$

When test communalities are inserted in correlation matrices, the sum of the eigenvalues is equal to the total common factor variance.

4. *Eigenvectors*

The direction of a principal axis identified by an eigenvalue is specified by a corresponding eigenvector (or latent or characteristic vector) of the direction cosines for that axis, which enables the angles between the principal axis and each of the original test vectors to be determined. The direction cosines of the first principal axis in the above example (represented by the eigenvalue of 1.379) to the original test vectors are .638, .729, and −.246 respectively; the first eigenvector is thus

$$\begin{Vmatrix} .638 \\ .729 \\ -.246 \end{Vmatrix}$$

5. *Principal Axis Factor Loadings*

Principal axis factor loadings are the projections of the test vectors on the principal axes, (or the correlations between the test vectors and the principal axes), after the latter have been adjusted to take account of their different variances. These factor loadings are determined by multiplying the direction cosines in each eigenvector by the square root of the corresponding eigenvalue. In the above example, the factor loadings of the three tests on the first principal axis are .750, .856 and –.289. The sum of squares of these factor loadings is equivalent to the first eigenvalue, viz. 1.379.

6. *Residual Correlation Matrix*

This matrix indicates the amount of correlation between tests which has not been accounted for by the factors that have been extracted. The extraction of factors is usually continued until all of the residual correlations are zero or near-zero.

## C. Terms associated with the rotation of factors

1. *Unrotated orthogonal reference frame*

The unrotated orthogonal reference frame refers to the arbitrary set of reference axes resulting from the application of a centroid or principal axis or other type of analysis to the original correlation matrix. The projections of test vectors on these reference axes (in other words, the factor loadings of the tests) form what is often referred to as the *unrotated orthogonal factor matrix* (usually designated as F). These reference axes are at right angles to each other, and thus the corresponding factors are orthogonal, independent, or uncorrelated.

2. *Orthogonal rotation*

A rotation of the arbitrary orthogonal reference axes to a new position which does not involve any alteration in the angular separation of these axes is known as an orthogonal rotation or transformation. Reference axes (and thus factors) are orthogonal in both the original and the new axis system.

3. *Oblique rotation*

A rotation of the arbitrary orthogonal reference axes to a new position in which the reference axes are not necessarily at right angles is known as an oblique rotation or transformation of the axes. In an oblique factor matrix, the correlations between the factors may be non-zero.

4. *Transformation matrix*

A transformation matrix (usually designated as Λ) is a matrix of direction cosines indicating the direction of each axis in the new system in relation to each axis in the old system. Post-multiplication of an unrotated arbitrary orthogonal factor matrix (F) by a transformation matrix (Λ) gives a rotated factor matrix (V) of factor loadings or test projections on the new axes.

5. *Simple Structure*

This concept was introduced by Thurstone as a guide in rotating the arbitrary orthogonal reference frame to a unique position in which factors would have acceptable psychological meaning. It is developed from the idea that not all mental functions are involved in every intellectual task. The criteria for simple structure in a factor matrix are that there be at least one zero (or near-zero) loading for each test, that each factor column should contain as many zero loadings as there are factors, and that in every pair of factor columns, there be a good proportion of tests with zero loadings in both columns, several tests with zero loadings in one column but not in the other, and only a small number of tests with appreciable loadings in both columns. For a given unrotated orthogonal factor matrix, it may prove possible to rotate the matrix to *orthogonal simple structure* (in which the new axes are still at right angles to each other) or to *oblique simple structure* (in which the new axes are not at right angles to each other), or it may not be possible to attain simple structure at all.

6. *Positive manifold*

This refers to a particular form of simple structure solution in which all factor loadings are positive or zero, or negligibly negative. Such a solution is often achieved in the field of mental abilities as these are mostly positively correlated.

7. *Graphical methods of rotation*

In graphical methods of rotation, the new positions of the axes are located by inspection of the configuration of test points when these are plotted in relation to the arbitrary orthogonal co-ordinate reference axes. These methods usually employ two-dimensional configurations.

8. *Analytic methods of rotation*

In analytic methods of rotation, the new positions of the axes are determined by objective mathematical procedures. These procedures are designed to fulfil the conditions set up for a desired type of rotated factor matrix, usually one which meets the criteria for "simple structure." The quartimax method, for instance, maximizes the variance of all squared loadings of a factor matrix; the raw varimax method maximizes the within-factor variance of the squared factor loadings for a given factor matrix, while the normal varimax method maximizes the same function after the factor loadings have been adjusted to take account of differences in test communalities.

9. *Biquartimin method of rotation*

This analytic method of rotation to oblique simple structure minimizes over all factors both the sum of the cross-products and the sum of the covariances of the squared factor loadings. The normalized biquartimin method minimizes the same function after the factor loadings have been adjusted to take account of differences in test communalities. The aim of the biquartimin method is to maximize both the number of zero or near-zero entries in the rotated factor matrix and the number of significant factor loadings which occur in only one row and one column of the factor matrix.

10. *Primary factors*

The factors identified in the rotated factor matrix (V) are known as primary or first-order factors. Psychological interpretations are usually based on these factors.

11. *Second-order factors*

When the vectors representing primary factors are not orthogonal to each other, the primary factors are themselves correlated. The matrix of correlations between the primary factors can then be itself analyzed to determine whether these correlations can be adequately accounted for in terms of one or more *second-order factors*. Each second-order factor would usually subsume a number of primary factors. If the second-order factors were correlated, third-order factors could be extracted, and the process could be continued to give successively higher-order factors.

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