CHAPTER 7

THE THIRD STUDY

Chapter Overview

Chapter 7 presents the results of the third psychometric study, which involved subjects selected for their extreme musical talent compared with their age peers. The results showed that the Study 3 subjects were significantly superior on both of the sensitivity to autocorrelation tasks, and on the Luria model dimensions of successive and executive synthesis. Music experience was not a significant factor in explaining this superiority. The findings suggested that aspects of musical talent can be accounted for by a high level of ability on executive synthesis to coordinate the interaction of the two encoding dimensions. Further analysis indicated that abilities on simultaneous synthesis can explain individual differences in the perception of structure in pitch fluctuations, viz., the extent to which fractal structures are perceptible.

Section 7.1 outlines the research questions that arise from the previous two studies, particularly from Study 2. *Section 7.2* describes the experimental situation. The third section presents qualitative descriptions of some of the subjects. *Section 7.4* lists the experimental hypotheses, and *Section 7.5* details the analysis of the data. The final section discusses the results with regard to the literature and the results from Study 2.

7.1 Formulation of the research questions

Individual differences in the musical aptitude or potential of young children are commonly reported by music teachers. Some children apparently realise their extreme potential to become performing prodigies. Feldman (1993) states that "the prodigy is a child (typically younger then 10 years old) who is performing at the level of a highly trained adult in a very demanding field of endeavour" (p. 188). This definition, Feldman argues, has advantages over other descriptions in the literature by emphasising performance over psychometric potential, and recognising that the prodigy is a "human phenomenon which can only occur with the support and assistance of other human beings" (p. 188). Certainly prodigies enjoy some attention from the mass media and the dramatic arts, e.g., Peter Schaeffer's *Amadeus*. The thrust of many such depictions is that extreme musical ability is a mystery. Feldman suggests that "the study of prodigies therefore offers an opportunity both better to understand the nature and limitations of the concept of psychometric intelligence and to offer a unique avenue into some of the least understood aspects of intellectual development" (p. 189).

McPherson (1995) suggests that Gagne's potential-actualisation model for giftedness and talent is readily applicable to children with high levels of music abilities, particularly in educational contexts. Musical giftedness is analogous to music aptitude, which can only manifest as musical talent through successful interaction with other internal and external factors including personal motivation, skilled teaching, and committed inter-personal support from family and peers.

Again it should be noted that within the Luria model, domain specific experience is moderated by and contributes to the level of information processing abilities within that domain. For example, the relationship of attention to musical aptitude is moderated through enculturation (Clarke & Krumhansl, 1990) [Chapter 3]. Whereas musical aptitude is conceptualised here as an individual difference variable, Sloboda (1991) argues that musical aptitude is a general population attribute. "Almost every member of a culture is a musical expert, but the expertise is usually hidden and tacit" (p. 157). It is general music experience while young that creates the expertise, and formal music instruction which reveals it. Sloboda suggests that the skill levels of musical prodigies are not unique, and explains musical prodigiousness as an "obsession" for practice and musical thinking. How children with no reported musical tuition acquire perfect pitch, Sloboda admits, cannot be explained. Shuter (1968) acknowledges that musical training does improve scores on musical ability tests, but points to evidence that the development of prodigies far exceeds the standard achieved by normal people who undertake extensive musical instruction.

However, some attempt must be made to account for the greater musical experience of the highly musical subjects. The contribution of interactive environmental factors such as music education history could be investigated by several different types of analysis. A direct approach would be to quantify the subjects' music educational experience and compute correlations between music educational experience and performance on the sensitivity to autocorrelation structure tasks. The contribution of music experience to the sensitivity to autocorrelation structure would be indicated by the degree of correlation. Another strategy would be to compare the sensitivity to autocorrelation structure scores of sub-samples of normal and musical subjects matched on levels of ability on simultaneous, successive and executive synthesis. Here the effect size of significant differences would provide some indication of the contribution of experience to performance on these tasks. A contrasting approach would be to compare the individual information processing abilities of highly musical subjects with similar music education histories.

The results from Study 1 and Study 2 show that individual differences in certain aspects of musical ability can be partially explained in terms of the information processing dimensions of simultaneous, successive and executive synthesis. This in turn suggests that an investigation of the information processing abilities of subjects with demonstrably high musical ability could provide further evidence to support or refute such an explanation. For example, Elliot, Platt and Racine (1987) found that tuning of both successively and simultaneously presented intervals was superior by musically experienced subjects, although DeWitt and Crowder (1987) found that musicians were more sensitive to octave fusion. Expert musicians show greater sensitivity to onset delays (Wuthrich & Tunks, 1989), suggesting a superiority in successive processing. Musicians also display superior interval judgement in atonal contexts (Tsuzaki, 1991), indicating ability on simultaneous processing at the mnestic level. It could be expected, then, that subjects with extreme musical ability would show stronger relationships between abilities on simultaneous and successive synthesis and measures of musical perception, compared with normal subjects.

Furthermore, in the Luria model, expertise is characterised by high levels of focussing and planning, involving the first and third functional units. Crummer *et al* (1988) found differences in the P3 event-related potential between musicians and non-musicians, suggesting that musicians make more effective use of long-term music memory in processing new music stimuli. Birbaumer *et al* (1994) showed that differences in the perception of music between musical experts and musically unsophisticated listeners manifests as a higher dimensional complexity of the EEG traces from the prefrontal regions of musical sophisticates. In sum, subjects with extreme musical ability should show a stronger relationship between abilities on executive synthesis and measures of musical perception compared with normal subjects. This comparison, together with that above, is the focus of the <u>first research question</u>: Do subjects with high musical ability have higher abilities on the Luria model dimensions of information processing?

Two matters concerning test applicability and subject matching need to be considered when addressing this question. First, previous studies by Karnes and McCallum (1983), and

Schofield and Ashman (1987) have shown that the Luria model tests are particularly suitable for use with intellectually gifted children. Furthermore, Snart, Das and Mensink (1988), and Geake (1994) argue that the multidimensionality of the Luria model has been able to account for asynchronous abilities across domains within a generally gifted group. Second, any comparison between highly musical and normal subjects will need to be controlled for maturity effects. Hassler *et al* (1987), for example, found changes in the preferred information processing strategies of musically able children after the onset of puberty.

The results from the previous study also suggest that measures of perception of autocorrelation structure could contribute to the explanation of individual differences in music perception. Of particular relevance here are the findings of Monahan *et al* (1987) that musicians were superior to non-musicians on perception of contour tasks. In Study 2 the two variables which consistently reached significance were the root-mean-square-difference or error-in-estimation (RMSD) on the *Scale Estimation of Smoothing Test*, and the number of correct responses (NGOOD) on the *Change of Smoothing Test*. Confirmation that sensitivity to autocorrelation structure plays a role in music perception could be sought by comparing scores on these variables between subjects with extreme musical ability and subjects in Study 2. Hence the <u>second research question</u>: Are subjects with high music ability more sensitive to autocorrelation structure in fBm tone series?

A positive relationship between music ability and sensitivity to autocorrelation structure could also support the use of these new instruments as measures of auditory perception. Shuter-Dyson and Gabriel (1981) note that: "If a music test has any validity at all, recognised musicians can be expected to make higher scores than persons of average or low ability" (p. 12). Further, they suggest that a test which can also discriminate "between the more and the less able members of a highly talented group can be considered to have superior validity" (p. 12).

The *Scale Estimation of Smoothing Test* in particular may be suitable to investigate individual differences in the music information processing abilities of extremely musical children. It was argued in the previous chapter that the smoothing coefficient A provides a measure of signal-to-noise ratio of the generated tone series. Highly correlated tone series with low smoothing coefficients have high signal-to-noise ratios, i.e., are mostly signal, whereas tone series with high smoothing coefficients and low correlation have low signal-to-noise ratios, i.e., are mostly noise. This presents a way of testing the rival models for the perception of complex auditory contours described in Chapter 4. Voss and Clarke (1975, 1978) suggest that a characteristic of the pitch fluctuations of real music is a spectral density function $1/f^{\beta}$ where $\beta = 1$. In *Section 6.2* it was noted that Turner (1992) gives $A \approx 4.5$ as the smoothing coefficient required to produce tone series which have a spectral density coefficient $\beta = 1$. Voss and Clarke argue that listeners prefer fBm tone series with $\beta = 1$ because human perceptual systems are optimally sensitive to fractal structures. Study 1 provided some support for this position. Further evidence would be provided in this third study if subject performance were superior on tone series with $A \approx 4.5$ to performance on tone series with A low or A high.

In contrast, Gilden *et al* (1993) argue that perception of complex auditory contours is essentially bipartite. Complex contours may be analysable into fractal structures, but human perception recognises only signal and noise. Given that Study 2 established that the autocorrelation structure of fBm tone series is psychologically penetrable, it is possible here to compare Gilden *et al*'s perceptual model with that of Voss and Clarke. Under a bivariate model, tone series with low values for smoothing coefficient A, where signal to noise ratio is high, should be more easily perceived. Sensitivity should decline with increasing values of A, with the structure of tone series with high smoothing coefficients being most difficult to perceive, since noise would become more prominent than signal. In other words, there should be a positive relationship between perceptual response and the value of A, similar to that found by McMullen (1974) and McMullen and Arnold (1976). Such a relationship, if found, would support the perceptual models of Gilden *et al,* whereas maximal sensitivity for middle values of A would be consistent with the fractal model of Voss and Clarke. A third research question is, then: Is there a relationship between perceptual sensitivity and strength of the autocorrelation structure? The *Scale Estimation of Smoothing Test* would be the more suitable instrument for this investigation, since it requires a direct rating of stimulus characteristics rather than detection of a change.

7.2 Experimental situation

In this third study, subjects were selected as demonstrating extreme musicality either through performance at professional level while still very young, and/or selection into advanced music training programs such as those of conservatories, and/or success at formal public music exams at a superior level to their age peers, and/or learning music at a rate well in advance of their peers. In all cases selection was made either by the subject's music teacher or program director. In Freeman's (1974) study of musical and artistically talented children, subjects were selected on performance ability by specialist music teachers. "The opinions of such people are customarily used as validation in assessing tests of musical ability" (p. 5). The music teachers of subjects in this third study consistently conceptualised music ability along two dimensions: 1. speed of learning, and 2. sensitivity to musical performance. Here Vernon's construct of speed as an underpinning agency of cognitive ability may need to be reconsidered. But, as one leading piano teacher explained: "Musicality is not just quick fingers; many students display high dexterity. But no amount of diligent practice can create musicality." Whereas music teachers commonly use the term "musicality" in their assessments and discussions regarding students, it must be acknowledged that their conceptualisations are partly subjective. Shuter (1968) reports low correlations between Seashore tests and music teachers' ratings of musicality. However, as the results from Study 2 suggest, tests such as the Seashore battery may measure achievements in music learning rather than potential for future musical development. In any case, none of the music teachers or program directors involved had any hesitation or difficulty in nominating suitable students. And if speed of learning is a central selection criteria, then a fourth research question arises: Do subjects with high music ability show higher rates of learning on novel musical tasks such as those presented in this research?

To nominate suitable students as potential subjects for this study, two music education institutions and a number of private music teachers in Sydney and Canberra were approached. The number of subjects that were finally selected for this study was limited (N = 29). The institutions were the Sydney Conservatorium High School, which selects students on both musical and academic ability (5 subjects from Year 7), and the Canberra School of Music's *Young Music Outreach Program* (3 subjects). The music teachers included a faculty member of the School of Music, Sydney University (2 subjects), a consortium of private music teachers, *Bay Music*, in Sydney (8 subjects), the head music teachers of two non-government schools in Sydney which feature strong music and gifted education programs (5 subjects), and two private music teachers in Canberra (5 subjects). One subject was previously known to the researcher.

The parents of nominated students were sent a letter through the student's music teacher explaining the aims and procedures of the research. The responses from the parent(s), teachers and students were notable for their enthusiasm towards and interest in the research outcomes. All participants received a report summarising the results of the research within two months of testing. Except for the Sydney Conservatorium High School students who were tested at the school, participants were tested in their homes at a convenient time. The researcher ensured that potential distractions, especially noise, were absent from the testing situation, and that the furniture was comfortable for the subject. Both the tests for perception of autocorrelation structure and the Luria model adaptive battery were undertaken on a portable lap-top computer supplied by the researcher. All subjects indicated that they were at least comfortably familiar with computer usage; all subjects had personal computers in their homes. The testing was undertaken in one session of about one hour, with an interview on the subject's musical background affording a break between the two computer-based batteries. Subjects were advised that, due to the adaptive nature of most of the Luria model tests, success on an item would be "rewarded" by an increase in difficulty of the following item. Eventually, the level of difficulty would exceed the subject's ability. Some subjects commented afterwards that this was a novel experience for them. Nevertheless, most subjects commented favourably on the tests, particularly the Luria model battery. The MEK tests were considered unnecessary with these subjects.

In order to compare data with Study 2 results, subjects from Study 3 were approximately matched in age range. Whereas the Study 2 subjects ranged in age from 10 years 1 month to 12 years 11 months, mean age 11 years 4 months, the slightly less restricted range of 10 - 14 years was used in the selection of subjects for Study 3 to achieve an adequate sample size. The mean age of the Study 3 sample was six months older at 11 years 10 months, with a range from 10 years 0 months to 14 years 2 months.

No other demographic criteria, such as gender, socio-economic status, or ethnic background were used in the selection. The sample comprised 12 boys and 17 girls. Three families contributed more than one subject; there were two pairs of siblings and one triple. Some eight subjects participated in designated school programs for academically gifted children. Nearly all subjects played at least two instruments, with 22 studying piano as either a first or second instrument. [For the following discussion, the convention in music education of referring to non-piano studies as "instrumental" shall be adopted.]

7.3 Qualitative data

It is not claimed that all 29 subjects were prodigies as defined by Feldman, but at least four subjects would meet his criteria. As the statistics presented below do not do justice to the extraordinary musical achievements of some of the subjects in this study, this section presents several brief profiles of Study 3 subjects which highlight their extreme music ability. Pseudonyms are used for anonymity.

At 13 years of age, and after only six years of music study, Peter has already achieved many of the goals towards becoming a celebrated pianist. He holds a Licentiate in Music from the AMEB, the highest award, which he gained with Distinction, the highest possible level. He has performed concertos by Poulenc and Kabelevsky with the Melbourne and Queensland Symphony Orchestras. At a recent international piano competition in Italy he won the award for the most outstanding young performer. During the Sydney Festival, January 1995, Peter was a featured artist in the *Mostly Mozart Series* at the Sydney Opera House, performing a piece by Shostakovich for four hands.

The other pair of hands was provided by Angela, who had just turned 13. Angela holds an Associate in Music with Distinction in piano, and performed a Bartok concerto with the Sydney Symphony Orchestra in February 1995. Angela also enjoyed success in many sections at the Italian international piano competition, and is a regular prize winner at the City of Sydney Eisteddfod. Angela also plays violin, and gained a Distinction in her only AMEB exam in violin, 5th Grade, which she took at age 11. She is a consistent "top 10" student at school, coming 3rd in her Year in mathematics. This is in contrast to Peter, for whom school work is "a second priority".

As did Angela, Kim gained an Associate in Music at age 12, and will be sitting for her Licentiate in 1995. As a student at Sydney Conservatorium High School, Kim studies a second instrument, violin. In the span of one school year she reached Level 5 on violin, in contrast to her age peers who reached Levels 1 or 2. At primary school work she described herself as "average", without mentioning that English was her second language.

For Lizie, age 10, violin is her first instrument, although she maintains a comparable standard on piano. Her first AMEB exam in violin was 8th Grade, the highest Grade level, for which she gained a High Distinction. She is sitting for her first piano exam, 8th Grade, in 1995. A Suzuki Method student since 4 years old, Lizie has won numerous eisteddfod and competition prizes. She has toured Germany and Austria as the leader of the Nouveau Youth Orchestra, and has performed both the Bruch violin concerto and a Haydn piano concerto with professional orchestras. She recently won an Elizabethan Trust Scholarship for violin with an audition score of 100%. At school Lizie participates in the GATS program, and topped her Year in mathematics and language.

Another Suzuki method student, Emily, 11 years old, began violin at age 5. She has completed Suzuki Book 6, a comparable standard to AMEB Grade 7. She plays in her school orchestra, and in a string quartet. Emily also plays piano at AMEB 4th Grade after four years of study, as well as the full range of recorders, and is an accomplished singer. Like Lizie, Emily was top of her Year at school, her best subjects being mathematics, French and Japanese.

In order not to be left behind by his two older siblings, Saul, nearly 11, started Suzuki violin at just 3 years old. He has completed Suzuki Book 5, a comparable standard to AMEB Grade 6. Saul plays in both the junior and senior orchestras at his school. He also learns piano, and has a strong desire to play the drums. Mathematics is his best subject at school.

In contrast, Eric, aged 10, dislikes school mathematics. "I get frustrated with the teachers." Science is his favourite subject. Eric has been composing on the piano since age 7. He now studies with composer Larry Sitsky at the Canberra School of Music. Eric describes his composing thus: "I fiddle around with the notes; I remember compositions, I don't have to write them down. Then I put bits with other bits."

Two subjects had high achievements in dance. Margot, aged 14, plays the violin in a professional string quartet, as well as in her school orchestra. She began Suzuki studies aged 4 years. Margot is also an accomplished ballerina. She will be sitting for her Royal Academy of Dance Intermediate, the penultimate level, in 1995.

The majority of the subjects in this sample, however, were neither so accomplished, nor had been studying music from such an early age. Their selection seems to have been based on remarkable progress as beginners. For example, after three and a half years study on 'cello Cassie, aged 12, will sit for 6th Grade exams in 1995. A piano student of the Canberra School of Music *Young Music Program* for three years, James, now aged 13, took up the clarinet eight months ago, and is now ready for a 3rd Grade exam. Ruth, aged 12, has a similar profile: she will sit for clarinet Grade 3 after nine months tuition. Franz, aged 13, has reached AMEB 5th Grade after three years of learning the saxophone. Although in Year 7, he plays both alto and baritone saxophones in the Touring Band, the Senior Concert Band and the Senior Stage Bands at his selective high school. Faye, turning 12, plays the harp, having reached Suzuki Level 6 on piano in five years. She was a national finalist in the 1994 *Tournament of Minds*.

Although not formally interviewed, it was evident that the parents were very supportive, financially, logistically and personally, of their children's music education. Interestingly, not one parent indicated that their own musical ability was anything above average. This observation supports Figgs' (1980) results that musical ability (or lack thereof) regressed to the mean across generations, thus providing counter evidence to the hypothesis that musicality is genetically transmittable. Such evidence is consistent with Beament (1977) who argues from a biological perspective that ability in perception of musical sounds is evolutionally neutral, in contrast with the perception of non-musical sounds which has evolutionary advantage. Thus, Beament argues, musicality is not genetic but the consequence of serendipitous variation. As Gross (1993) argues, giftedness "shows no respect" for gender, social class or ethnicity.

The age in months (AGE) of each of the subjects was recorded. McPherson (1993) found that for music students of a comparable age to those in Study 3, early exposure to music education was a significant factor which affected both their AMEB exam success and their ability to improvise. Length of study was also important for performance at formal music assessment. The years of piano study (PSTUDY), years of instrumental study (INSTUDY), and year of first exposure to music education (MUEDYEAR) were also recorded for analysis.

7.4 Experimental hypotheses

The four research questions raised in *Sections 7.1* and *7.2* were formulated into four experimental hypotheses for statistical analysis.

Hypothesis 3.1: That Study 3 subjects will show superior performance on (a) the *Scale Estimation of Smoothing Test* and (b) the *Change of Smoothing Test* to Study 2 subjects.

Hypothesis 3.2: That Study 3 subjects will have superior abilities on (a) simultaneous synthesis (b) successive synthesis, and (c) executive synthesis compared with Study 2 subjects.

Hypothesis 3.3: That the rate of learning while undertaking (a) the *Scale Estimation of Smoothing Test* and (b) the *Change of Smoothing Test* will be higher for Study 3 subjects than for Study 2 subjects.

Hypothesis 3.4: (a) That performance on the *Scale Estimation of Smoothing Test* will be superior for middle values over extreme values of the smoothing coefficient;
(b) That performance on the *Scale Estimation of Smoothing Test* will be superior for low values and decrease for higher values of the smoothing coefficient.

7.5 Analysis of quantitative data

All data were analysed with *SPSS for Windows* [Appendix J]. Significances are generally reported at the 99% confidence level to reduce the possibility of Type II error. MANOVA procedures were used to investigate effects on a number of criterion variables as a set in testing Hypotheses 3.1, 3.2 3.3 and 3.4.

Preliminary analysis

The data sets from Study 2 and Study 3 were combined and the set of six Luria model marker tests reduced to three orthogonal dimensions using component analysis with Varimax rotation. The three components were interpretable within the model [Table 7.01]. Component 1 with loadings of the two marker tests for executive synthesis *Size Attention Test* (SIZE) and *Letter/ Number Attention Test* (NUMLET) reflected executive synthesis (exec). The loadings of the two marker tests for successive synthesis, *Number Recall Test* (NUMBER) and *Word Recall Test* (WORD) on Component 2 indicated that this component reflected successive synthesis (suc). The loadings of the two marker tests for simultaneous synthesis, *Inverted Shapes Test* (INVERT) and *Paper Folding Test* (PAPER) on Component 3 indicated that this component reflected simultaneous synthesis (sim). Compared with the component structure without the Study 3 data [Table 6.03], the high loadings of INVERT and WORD on Component 1 suggests that the *Inverted Shapes Test* and *Word Recall Test* were undertaken by Study 3 subjects with strategies which utilise close attention to features, rather than just direct spatial manipulation or just rote memorisation respectively. It should be noted that it is mainly the attentional aspects of executive synthesis that are operationalised in this battery. The high loading of NUMLET on Component 2 indicates the similarity of processing required for the *Letter/ Number Attention Test* to that for the *Number Recall Test* and *Word Recall Test*, which was also seen in the Component structures recovered in Study 1 and Study 2. Bartlett factor scores were calculated for further analysis, and partitioned into high (sim1, suc1, exec1), medium (sim2, suc2, exec2) and low (sim3, suc3, exec3) scores on each of the three components.

	Component 1	Component 2	Component 3
INVERT	**.53**	-.002	**.72**
PAPERF	.11	.34	**.87**
NUMLET	**.67**	**.51**	.24
SIZE	**.83**	.29	.22
NUMBER	.19	**.88**	.18
WORD	**.50**	**.67**	.17

Table 7.01 Component structure of combined Luria model marker tests for Study 3 and Study 2

For the Study 3 subjects, scores on the same variables as used in Study 2 for measuring performance on the *Scale Estimation of Smoothing Test*, viz., the root-mean-square difference between the smoothing coefficient A and its estimation (RMSD), and on the *Change of Smoothing Test*, viz., the number of correct responses (NGOOD), were computed. The distributions of these two variables were checked for normality [Appendix J]. Criteria for normality of distribution for a small sample $N \approx 30$ are coefficient of skewness < 1.11 and coefficient of kurtosis < 5.21 at the 99% confidence level (Stevens, 1986). The distributions of both RMSD and NGOOD closely approximated normal distributions [Table 7.02].

sensitivity to autocorrelation structure	test variable	coefficient of skewness	coefficient of kurtosis
Scale Estimation of Smoothing	RMSD	.46	2.5
Change of Smoothing Test	NGOOD	.06	2.8

Table 7.02 Coefficients of skewness and kurtosis of sensitivity to autocorrelation structure variables

A one-sample t-test showed that the difference for AGE between Study 3 subjects and the mean for Study 2 was not significant ($p = .054$, two-tailed). Pearson correlations with AGE were not significant at the 99% confidence level for any of the Study 3 test variables, including the experience-related variables of PSTUDY, INSTUDY and MUEDYEAR [Appendix J].

A check of the subjectivity of the teacher nominations was made with reference to the years of music study undertaken and the level of public music examination reached by their nominees. Public music examinations are conducted throughout Australia by the Australian Music Examinations Board (AMEB). McPherson (1993) has documented the usual rate of progress by AMEB music examination candidates in clarinet and trumpet across examination Grades 1 to 7 [Table 7.03]. Students typically commence instrumental studies around age 9 - 10 in Year 4 or 5, sit for their first AMEB exam, usually Grade 1, at age 12 - 13 in Year 6 or 7, and reach AMEB Grade 6 or 7 in their senior years of secondary school at age 17 - 18. An index of usual progress on instrumental examinations (INSTAMEB) was calculated as the ratio of AMEB Grade divided by years-of-study to achieve it. In the case of clarinet and trumpet, INSTAMEB ≈ 0.8, i.e., students typically progress through AMEB Grades at a rate of slightly less than one Grade level per year of study. McPherson notes that piano and violin students often start at a younger age, and study for more years than wind players before taking their first exam. Also, there is an additional Preliminary Grade before Grade 1 for piano. Consequently, a similar progress ratio for piano (PAMEB) of AMEB Grade divided by years-of-study was estimated at about 0.6.

Age	AMEB grade	Years of music study
10-11	1-2	2
11-12	2-3	3
12-13	3-4	4
14	4-5	5
15	5	6
16	6	7
17	6-7	8

Table 7.03 Instrumental music examination performance by age
(McPherson, 1993)

The ratios for exam progress, PAMEB and INSTAMEB, were then computed for Study 3 subjects after first converting non-AMEB gradings, such as Conservatorium Levels and Suzuki Books, to their equivalent AMEB Grade level:

$$\text{INSTAMEB} = \text{1995 AMEB Instrumental Grade} / \text{INSTUDY}, \qquad (7.1)$$

$$\text{PAMEB} = \text{1995 AMEB Piano Grade} / \text{PSTUDY}. \qquad (7.2)$$

For those subjects of the Study 3 sample who undertook instrumental studies (N = 22), mean INSTAMEB = 1.58. A two-tailed one-sample t-test showed that the mean INSTAMEB was significantly higher than the estimated value for typical music students from McPherson's data [Appendix J, Table 7.04]. For those subjects of the Study 3 sample who undertook piano studies (N = 18), mean PAMEB = 1.19. A two-tailed one-sample t-test showed that the mean PAMEB was significantly higher than the estimated value for typical music students from McPherson's data [Appendix J, Table 7.04]. Most Study 3 subjects progressed at rates greater than one AMEB Grade per year. These results suggest that the music teacher criterion of speed-of-learning was applied consistently in the selection of these subjects.

		Study 3 subjects (Grades/year)	Normals (Grades/year)
Instrumental	INSTAMEB	1.58	0.8
Piano	PAMEB	1.19	0.6

Table 7.04 Rates of progress through AMEB Grades for Study 3 subjects

Hypothesis 3.1: That Study 3 subjects will show superior performance on (a) the *Scale Estimation of Smoothing Test,* and (b) the *Change of Smoothing Test* to Study 2 subjects.

To compare the sensitivity to autocorrelation structures of Study 3 subjects (MOZART = 1) with Study 2 subjects (MOZART = 0), a 2-group MANOVA was undertaken with MOZART as the independent variable and RMSD and NGOOD as dependent variables [Appendix J]. The multivariate effect for MOZART was significant (Wilk's $\lambda = .918$, $p = .001$, $\eta^2 = .082$). The univariate effects are reported in Table 7.05, the means are reported in Table 7.06.

DV	F	df	significance p	effect size η^2
RMSD	11.26	1,157	.001	.067
NGOOD	6.63	1,157	.011	.041

Table 7.05 Significant univariate effects of Study 3 membership and sensitivity to autocorrelation structure variables

		Study 3	Study 2
Scale estimation	RMSD	2.44	3.06
Correct responses	NGOOD	13.97	11.82

Table 7.06 Comparison of Study 3 with Study 2 means of sensitivity to autocorrelation structure variables

The mean value for RMSD of Study 3 subjects was significantly lower (better) than the mean RMSD in Study 2 [Table 7.06]. Performance on the *Scale Estimation of Smoothing Test* by Study 3 subjects was superior, and thus the null hypothesis associated with Hypothesis 3.1 (a) should be rejected. The mean number of correct responses NGOOD by Study 3 subjects on the *Change of Smoothing Test* was also significantly superior to that in Study 2 [Table 7.06]. It follows that the null hypothesis associated with Hypothesis 3.1 (b) should also be rejected.

A selection of labels for the extreme values of the smoothing coefficient A = 1 and A = 9 are reported in Table 7.07, along with RMSD scores, and partition of scores on the Luria model tests. It was thought that Study 3 subjects might make better use of discriminating labels than did the subjects in Study 2. Some 59% of Study 3 subjects entered labels which, presuming they carried their conventional meaning, were categorised as useful for the task of scalewise discrimination (example cases 1, 2, 8; counter example cases 4, 9). This compares with 36.2% of subjects with useful labels in Study 2. Although many labels were similar to those in Study 2 (example cases 1, 2, 3), a characteristic of the Study 3 labels was the use of music terminology (example cases 5, 6, 7, 10) and aesthetic descriptions (example case 8).

case	A = 1 label	A = 9 label	A ZERO	RMSD	sim3	suc3	exec3
1	close to	far apart	0	1.92	1	1	3
2	close	jumpy	0	1.83	1	3	1
3	flat	free	10	3.31	3	2	1
4	robots	falling	10	4.20	3	3	3
5	chromatic	jumpy	0	2.36	1	1	1
6	semitone	lengthy	0	2.23	3	2	2
7	minor	jumpy	3	1.78	1	1	1
8	mysterious	excited	1	3.22	2	1	3
9	fast	unsure	10	3.34	1	3	2
10	untuneful	pointless	0	1.65	3	1	3

Table 7.07 Responses of Study 3 subjects to *Scale Estimation of Smoothing Test*

Additionally, it was conjectured that the response to the item with A = 0 (AZERO) by Study 3 subjects might be more accurate than in Study 2. The AZERO responses of both studies were categorised into five groups: 'accurate' where AZERO = 0; 'close' where 0 < AZERO ≤ 1; 'same-half-scale' where 1 < AZERO ≤ 5; 'other-half-scale' where 5 < AZERO < 10; and 'other-end' where AZERO = 10 [Table 7.08]. The response to this item by Study 3 subjects was compared with the Study 2 data. A Contingency Table analysis showed the differences between the grouped responses to the A = 0 item to be significant ($\chi^2 = 17.37$, p = .0016). A larger proportion of Study 3 subjects used a scale extreme to estimate this item, and a larger percentage correctly estimated the item at zero than the proportion of Study 2 subjects who made similar responses.

As accurate data were gathered on the date when each of the Study 3 subjects began their music studies (MUEDYEAR), the possibility that performance on the sensitivity to autocorrelation structure tests may, at least in part, be related to music experience was tested by a pair of partial

Response	AZERO	Study 3 (percentage)	Study 2 (percentage)
accurate	AZERO = 0	54.2	40.5
close	0 < AZERO ≤ 1	12.5	18.3
same half scale	1 < AZERO ≤ 5	16.6	18.3
other half scale	5 < AZERO < 10	0.0	12.7
other scale end	AZERO = 10	16.7	10.3

Table 7.08 Comparison of Study 3 with Study 2 responses to AZERO item

correlations between MUEDYEAR, controlled for AGE, and each of RMSD and NGOOD [Appendix J]. Neither were significant [Table 7.09]. This is consistent with the argument that individual differences in abilities at pitch perception can be explained by variance in music aptitude or potential, which is independent of music experience.

Correlations were also computed between years of instrumental study (INSTUDY), years of piano study (PSTUDY), rates of AMEB Grade progress (INSTAMEB, PAMEB), and each of RMSD and NGOOD [Appendix J]. Only the correlation between PSTUDY and RMSD was significant [Table 7.09]. Noting that RMSD is an error term, this indicates a positive relationship. Here is some evidence for a relationship between perceptual skills and music education experience. In this particular situation, it could be noted that the *Scale Estimation of Smoothing Test* was designed to engage the quasi-spatial processing dimension of simultaneous synthesis, and Demorest (1994) reports a study in which the spatial skills of young children were enhanced after a program of learning the keyboard.

Music experience		RMSD	NGOOD
instrumental study	INSTUDY	.14	-.03
piano study	PSTUDY	-.60*	-.27
first year of music study	MUEDYEAR †	-.01	.09
AMEB grade progress	INSTAMEB	-.33	-.12
AMEB grade progress	PAMEB	-.29	.003
	(† controlled for AGE)	* p < .01	

Table 7.09 Correlations between music experience and sensitivity to autocorrelation structure

Hypothesis 3.2: That Study 3 subjects will have superior abilities on (a) simultaneous synthesis, (b) successive synthesis, and (c) executive synthesis compared with Study 2 subjects.

To compare the information processing abilities of Study 3 subjects with those of subjects in Study 2, a 2-group MANOVA was undertaken with MOZART as the independent variable and the component scores of sim, suc and exec as dependent variables [Appendix J]. The multivariate effect was significant (Wilk's $\lambda = .627$, $p < .001$, $\eta^2 = .373$). The univariate effects are reported in Table 7.10, the means are reported in Table 7.11.

DV	F	df	significance p	effect size η^2
sim	3.57	1,151	.061	.023
suc	19.79	1,151	<.001	.116
exec	46.10	1,151	<.001	.234

Table 7.10 Univariate effects of Study 3 membership and Luria model component scores

		Study 3	Study 2
Executive synthesis	exec	.997	-.233
Successive synthesis	suc	.702	-.164
Simultaneous synthesis	sim	.313	-.073

Table 7.11 Comparison of mean Luria model component scores between Study 3 and Study 2

The mean scores of the Study 3 subjects were higher than those of the Study 2 subjects on each of exec, suc and sim [Table 7.11]. The effect size of 23% on exec highlights the importance of executive synthesis to the information processing abilities of the Study 3 subjects. Ability on successive synthesis contributes a further 11% to the variance between the two groups. Ability on simultaneous synthesis seems not to be as critical. A possible explanation is that this dimension of coding is subsumed by executive synthesis in Study 3 subjects. Whereas the null hypothesis associated with Hypothesis 3.2 (a) should not be rejected, there is clear evidence that the null hypotheses associated with Hypotheses 3.2 (b) and (c) should be rejected.

As in Study 2, possible relationships between the three information processing dimensions and performance on the two sensitivity to autocorrelation structure tests were investigated with a series of two-tailed correlations between each of sim, suc and exec, and each of RMSD and NGOOD. However, due to several characteristics of these data, such an undertaking was not straightforward. First, the component scores sim, suc and exec were computed for the combined

Study 2 and Study 3 samples. Thus the correlations were first computed for this combined sample [Table 7.12]. All were significant. This highlights a central feature of this thesis: that the three dimensions of information processing are required for each of these perceptual tasks.

		RMSD	NGOOD
Executive synthesis	exec	-.25**	.28***
Successive synthesis	suc	-.25**	.22**
Simultaneous synthesis	sim	-.33***	.19*

* p < .05   ** p < .01   *** p < .001

Table 7.12 Correlations between sensitivity to autocorrelation structure and Luria model component scores for combined Study 2 and Study 3.

The addition of the Study 3 subjects apparently increased the levels of correlation over those achieved by the Study 2 subjects alone [Tables 6.08 and 6.13]. This result can be explained with reference to the distribution of means of the various music ability measures in Study 2, e.g., Tables 6.10, 6.16, 6.17, 6.24 and 6.25, where scores dropped noticeably for subjects with the lowest levels of information processing abilities. That is, the performances of the lowest ability subjects contributed more to the correlations in Study 2 than did the performances of their more able peers. Here, for the combined sample, the addition of very able subjects provided a greater contrast between the high and low ends of the range.

However, although the correlations in Table 7.12 are generally much stronger than those in Tables 6.08 and 6.13, a direct comparison is not possible. The component structure in Study 3 [Table 7.01] is different from the component structure in Study 2 [Table 6.03]. Consequently, the Bartlett component scores sim, suc and exec are not strictly equivalent across the two studies. But, even allowing that such scores are conceptually similar, such correlations for the separate Study 3 and Study 2 samples cannot be directly compared since the Study 3 subjects have significantly higher scores on the Luria model dimensions. Consequently, a sub-sample (N = 75) of subjects from Study 2 were matched with the Study 3 subjects on their partitioned scores (high, medium and low) on simultaneous (sim3), successive (suc3) and executive (exec3) synthesis. The correlations between sim, suc and exec and RMSD and NGOOD were then computed for this matched sub-sample of Study 2 subjects [Table 7.13]. The strength of the results in Table 7.13 is somewhat compromised by the less than perfect matching of the sub-sample due to the uneven distribution of Study 3 subjects across the partition cells [Appendix J]. For example, there was a high proportion of Study 3 to Study 2 subjects in the exec3 (high) and the suc3 (high) partitions, while there were no Study 3 subjects in the exec3 (low) partitions.

Nevertheless, several comparisons can be noted. First, the correlations for the matched sub-sample were lower than those for the whole of the Study 2 sample [Tables 6.08 and 6.13]. Given that the information processing abilities of the sub-sample were somewhat higher than that of the whole sample, this result is consistent with the distribution of means of the various music ability measures in Study 2 noted above, viz., that differences were greatest for subjects with the lowest levels of information processing abilities, particularly for subjects with the lowest levels of executive synthesis. Second, and consistent with this interpretation, the significant correlations in Study 2 of <u>sim</u> x RMSD and <u>suc</u> x NGOOD were also significant in the matched sub-sample, but <u>exec</u> x NGOOD was not. Third, all of the correlations for the matched sub-sample were much lower than those for the combined sample. While this is consistent with the interpretation above of the combined sample correlations, it must be noted that these results could be influenced by the uneven distribution of subjects across the categories used for matching.

An uneven distribution of subjects across the Luria model partitions was apparent in the attempt to compare the correlations of the matched sub-sample with those of the Study 3 sample. The Study 3 sample was both small in size (N = 29), and restricted in range, having component scores bunched towards the top of the <u>sim</u>, <u>suc</u> and <u>exec</u> range. It seemed unlikely, then, that correlations using the Study 3 sample alone could reach significance. This indeed was the case [Table 7.13]. Here was a situation where absence of evidence should not be interpreted as evidence of absence. Consequently, a comparison of the correlations in Study 2 and Study 3 between the three information processing dimensions and the two measures of sensitivity to autocorrelation structure could not be made. A replication study using a larger sample of young, highly able musical subjects is recommended [Chapter 8].

Study 2 matched		RMSD	NGOOD
Executive synthesis	exec	-.09	.14
Successive synthesis	suc	-.01	.20*
Simultaneous synthesis	sim	-.25**	.05

* p < .1 ** p < .05

Study 3		RMSD	NGOOD
Executive synthesis	exec	-.19	-.02
Successive synthesis	suc	-.09	-.25
Simultaneous synthesis	sim	-.05	.12

Table 7.13 Correlations between sensitivity to autocorrelation structure and Luria model component scores for the matched Study 2 sub-sample and the Study 3 sample

Nevertheless, it should not be assumed that within the Study 3 sample there was not some variance in the information processing strategies employed by these subjects on the sensitivity to autocorrelation structure tasks. Such individual strategies presumably utilised individual

Family	Subject	Age year.month	RMSD percentile	NGOOD percentile	sim p'tile	suc p'tile	exec p'tile
A	1	11.10	78.8	24.4	64.5	78	96
A	2	10.0	88.2	42.0	83.5	82.5	28.5
B	1	14.2	91.5	79.4	59.5	65	90
B	2	12.4	53.2	22.9	81.5	44.5	82.5
B	3	10.11	52.3	50.4	38	82	41.5
C	1	12.5	38.0	79.4	65	92	83
C	2	10.3	53.0	99.2	38.5	93	75

Table 7.14 Scores of Study 3 siblings as percentiles of the combined Study 2 and Study 3 scores of the sensitivity to autocorrelation structure tasks and the Luria model components

strengths on particular processing dimensions. Such a possibility is illustrated by a comparison of the scores on sim, suc and exec, and RMSD and NGOOD, of the three sets of siblings among the Study 3 subjects [Table 7.14]. In order to compare raw scores with component scores, all scores in Table 7.14 have been computed as percentiles of the combined Study 2 and Study 3 data.

In all three families, the siblings were raised together. In families A and B, all siblings received similar (Suzuki) music instruction from an early age. Inspection of Table 7.14 shows a notable variance in the scores on the sensitivity to autocorrelation structure variables between same-family siblings, consistent with the argument that levels of musical expertise cannot entirely be explained by either formal or informal music instruction. Rather, such individual differences in perceptual abilities can be explained by the notable variance in scores on the three information processing dimensions, consistent with Beament (1977) and Figgs (1980), who argue that the distribution of musical aptitude is serendipitous.

Conversely, the variance of information processing scores in Table 7.14 for similar levels of sensitivity measures highlight the importance of individual strategies. That is, similar cognitive behaviour can result from the application of different combinations of information processing dimensions. This is a feature of the Luria model [Chapter 2]. An extension of this analysis to the rest of the Study 3 subjects revealed that all had either high ability on successive synthesis (similar to subjects A2, B3, C2), high ability on executive synthesis (similar to subjects A1, B1, B2), or high ability on both (similar to subject C1). This in turn suggests that, in achieving their high level of musical performance, musical children may employ either or both of two distinct learning styles, which Biggs and Kirby (1980) label 'shallow' and 'deep'. The first is based largely on successive synthesis (e.g., remembering musical pieces, copying a teacher's performance), while the other is more dependent on executive synthesis (e.g., attending to interpretive nuances, reflecting on self-performance).

Hypothesis 3.3: That the rate of learning while undertaking (a) the *Scale Estimation of Smoothing Test* and (b) the *Change of Smoothing Test* will be higher for Study 3 subjects than for Study 2 subjects.

The *Scale Estimation of Smoothing Test* consisted of 20 items. The rate of learning on this task was defined as the change in performance on five sequential sets of four items, item performance being measured by the absolute difference between the smoothing coefficient A and the subject estimation (AD1 - AD5).

The learning rates of the Study 3 and all of the Study 2 subjects on the *Scale Estimation of Smoothing Test* were compared with a 2-group MANOVA with MOZART as the independent variable and the set of AD1 to AD5 as the dependent variables [Appendix J]. The multivariate effect for MOZART was significant (Wilk's λ = .895, p = .012, η^2 = .105). Roy-Bargman Stepdown F-tests were significant for AD1 and AD2 [Table 7.15]. The first step-down effect is identical to the univariate effect (Bray & Maxwell, 1982).

The Study 3 subjects were superior on the first group of four items, and, controlling for this difference, were also superior on the second group of items. This trend was not continued, however, suggesting that the rate of learning of the Study 3 subjects was superior only at the beginning of the task. This was sufficient, nevertheless, for Study 3 subjects to maintain consistent superiority in performance [Figure 7.01]. On balance, there is sufficient evidence to reject the null hypothesis associated with Hypothesis 3.3 (a).

DV	F	df	p	Study 3 mean	Study 2 mean
AD1	5.50	1,136	.020	8.43	10.46
AD2	7.11	1,135	.009	6.84	9.92
AD3	1.72	1,134	.192	8.02	10.53
AD4	0.13	1,133	.717	7.71	9.94
AD5	0.76	1,132	.384	6.93	9.61

Table 7.15 Stepdown effects and comparison of means between Study 3 and Study 2 for *Scale Estimation of Smoothing Test* learning

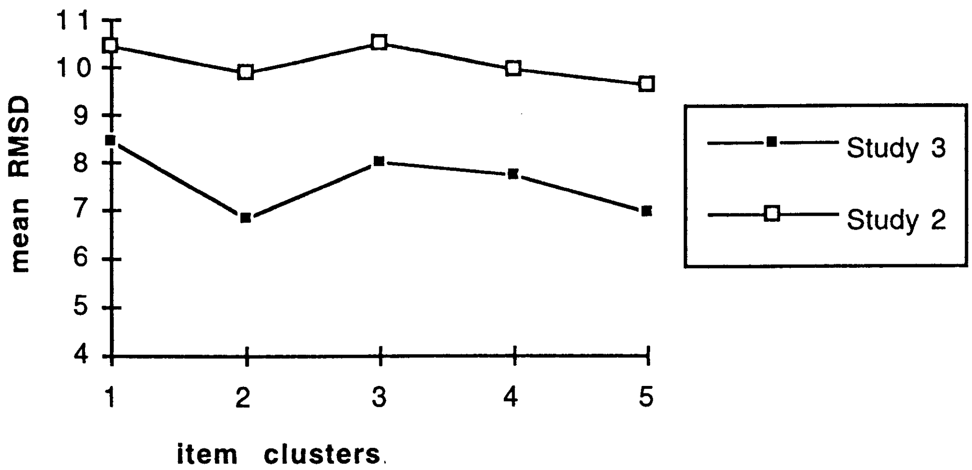

Figure 7.01 Comparison between Study 3 and Study 2 subjects on learning on the *Scale Estimation of Smoothing Test*

The *Change of Smoothing Test* consisted of 33 items, three of which were controls where A did not change. The rate of learning on this task was defined as the change in performance on six sequential sets of five items, with the three control items not considered (GG1 - GG6). Item performance was recorded as either being correct or not. It should be noted that the range of differences in A for the two concatenated tone series was progressively shrunk from item 1 to item 33, in order to make the task progressively more difficult. Thus a unchanging level of performance as measured here could indicate that the increasing degree of difficulty was sufficient to offset effects of improvement through learning.

The learning rates of Study 3 and Study 2 subjects on the *Change of Smoothing Test* were compared with a 2-group MANOVA with MOZART as the independent variable and GG1 to GG6 as the set of dependent variables [Appendix J]. Here the multivariate effect was not significant, so Roy-Bargman Stepdown F-tests are not reported. Nevertheless, the data suggest a better initial response by the Study 3 subjects. The success rate of Study 3 subjects declined from 63% to 25% compared with the success rate of Study 2 subjects, which declined from 51% to 25% [Table 7.16]. It could be noted, however, that the decrease in the item-group means suggests that, as designed, this task became progressively more difficult, perhaps towards the finish too difficult, with a similar basement effect for both groups [Figure 7.02]. But since absences of an effect cannot be compared, there is insufficient evidence to reject the null Hypothesis 3.3 (b).

DV	Study 3 means	Study 2 means
GG1	3.17	2.55
GG2	2.82	2.25
GG3	2.72	2.26
GG4	2.17	1.86
GG5	1.79	1.63
GG6	1.24	1.26

Table 7.16 Comparison of means between Study 3 and Study 2 for *Change of Smoothing Test* learning

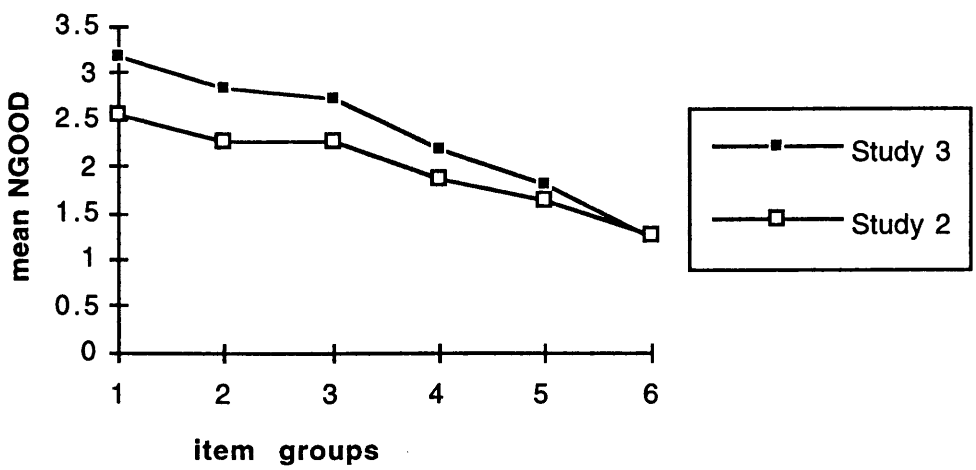

Figure 7.02 Comparison of Study 3 with Study 2 subjects on learning on the *Change of Smoothing Test*

Although the evidence is not strong, these findings are consistent with the interpretation above that Study 3 subjects employ executive synthesis to a greater extent than their age peers. Here, Study 3 subjects seem to have employed more appropriate strategies from the outset, which suggests that these subjects have higher levels of planning ability, an aspect of executive synthesis.

Hypothesis 3.4: (a) That performance on the *Scale Estimation of Smoothing Test* will be superior for middle values over extreme values of the smoothing coefficient;
(b) That performance on the *Scale Estimation of Smoothing Test* will be superior for low values and decrease for higher values of the smoothing coefficient.

These hypotheses were tested with the RMSD scores from Study 3. These data were collapsed into three groups according to the value of the smoothing coefficient. For the *Scale Estimation of Smoothing Test,* the range of the smoothing coefficient was scaled so that $0 \leq A \leq 10$. To test the hypothesis, the values of A were grouped into low, middle and high sub-ranges (labelled S3-LO, S3-MID and S3-HI). The three groups needed to be of a similar size. The range of the middle group was first determined around the critical value of $A = 4.5$, the approximate value for fractal form; for S3-MID, $A = 4.5 \pm 1.5$, i.e., $3 < A < 6$. It followed that S3-LO, the group for which the low values of A resulted in a high signal-to-noise ratio, was then of equal size, $0 \leq A \leq 3$, while for S3-HI, $6 \leq A \leq 10$. The absolute difference (D) between subject scale estimations and A on each item were then grouped accordingly. Subject means on S3-LO, S3-MID and S3-HI were compared with Least-Square-Difference (LSD) tests [Table 7.17], as Scheffe post hoc tests for significant differences are too conservative for small sample sizes (Stevens, 1986). Additionally, a two-tailed correlation between A and D was computed for the scores of each subject.

As D is an error term where low values indicate high performance, evidence in support of Hypothesis 3.4 (a), the Voss and Clarke model, would consist of a downward curvilinear (inverted U) pattern of means of D, i.e., S3-LO > S3-MID < S3-HI. This would be reinforced by a non-significant correlation of D with A. Evidence in support of Hypothesis 3.4 (b), the Gilden, Schmuckler and Clayton model, would consist of a monotonic increasing pattern of means of D, i.e., S3-LO < S3-MID < S3-HI. This would be reinforced by a significant correlation of D with A.

Inspection of Table 7.17 shows that twelve of the 29 subjects had a downward curvilinear pattern of means, supporting Hypothesis 3.4 (a) and the Voss and Clarke model (labelled VC). Eight subjects had a monotonic increasing pattern of means, in support of Hypothesis 3.4 (b) and the

case	S3-LO	S3-MID	S3-HI	LSD	Pearson r	model
1	1.07	0.97	2.65	1 < 3, 2 < 3	.001	VC
2	1.10	1.82	1.05		.60	none
3	0.57	1.15	2.77	1 < 3, 2 < 3	.004	GSC
4	4.08	2.09	2.40		.125	VC
5	0.65	1.42	3.19	1 < 3, 2 < 3	.000	GSC
6	3.20	2.17	1.93		.52	none
7	2.18	2.45	2.49		.76	GSC
8	1.47	1.62	1.43		.70	none
9	5.25	1.51	3.42	1 > 2	.35	VC
10	1.41	1.20	1.42		.81	VC
11	1.61	1.75	2.54		.105	GSC
12	1.90	0.90	1.06		.15	VC
13	0.70	1.53	2.49		.012	GSC
14	1.52	1.81	1.20		.78	none
15	0.48	1.05	1.40		.040	GSC
16	1.03	2.13	1.69		.40	none
17	1.68	1.61	1.22		.90	none
18	2.07	1.13	2.36		.21	VC
19	3.14	2.30	2.05		.38	none
20	1.91	1.74	1.28		.27	none
21	2.81	2.41	2.54		.95	VC
22	2.54	1.26	2.56		.94	VC
23	1.68	1.13	2.19		.69	VC
24	1.11	1.91	1.95		.091	GSC
25	1.22	1.31	0.66		.51	none
26	2.95	2.77	2.96		.69	VC
27	1.98	2.54	3.00		.18	GSC
28	4.78	1.11	1.59	1 > 2, 1 > 3	.022	VC
29	3.63	1.07	3.02	1 > 2 < 3	.81	VC

VC = perceptual model of Voss & Clarke, means are downwards curvilinear

GSC = perceptual model of Gilden, Schmuckler & Clayton, means are monotonic increasing

Table 7.17 Means of *Scale Estimation of Smoothing Test* scores grouped for high, middle and low values of smoothing coefficient, with correlations between means and smoothing coefficients and suggested perceptual models

Gilden, Schmuckler and Clayton model (labelled GSC). A further nine subjects had patterns of means which were either upward curvilinear or monotonic decreasing. Two explanations for this distribution of patterns can be suggested: this response is a random variable, or, this response is an individual difference variable.

The second suggestion was tested with a 3-group MANOVA with MODEL (VC = 1, none = 2, GSC = 3) as the independent variable and sim, suc and exec as the dependent variables [Appendix J]. The multivariate effect was not significant. The univariate effect for sim was significant at the 90% confidence level ($F(2,26) = 2.84$, $p = .077$, $\eta^2 = .179$). The means are reported in Table 7.18. The score on sim for VC was higher than for GSC. LSD post-hoc tests showed that the difference in the means between VC and GSC was significant at the 95% confidence level.

	fractal	no model	signal-noise
simultaneous synthesis	.56*	.34	-.06*

* LSD post hoc

Table 7.18 Mean component scores on simultaneous synthesis for fractal and bipartite perceptual models

Subjects whose performance on the *Scale Estimation of Smoothing Test* was best for the middle values of the smoothing coefficient, where the pitch series could exhibit fractal form, had higher measures on simultaneous synthesis than subjects whose performance on the *Scale Estimation of Smoothing Test* was best for the low values of the smoothing coefficient, where the pitch series could exhibit a maximal signal to noise ratio. These results indicate that the variance in subject responses as a function of smoothing coefficient are a consequence of individual differences. Nearly 18% of the variance of such differences is accounted for by ability on simultaneous synthesis.

These findings show that both models of perception are supported - whether one or the other is adopted depends on the information processing strengths of the individual. Subjects with low ability on simultaneous synthesis use bipartite perception to process complex auditory contours, whereas subjects with high ability on simultaneous synthesis are more sensitive to self similarity in auditory structures. There is evidence, therefore, to reject both the null hypotheses associated with Hypothesis 3.4 (a) and Hypothesis 3.4 (b) contingent upon the information processing abilities of the subjects who undertake the *Scale Estimation of Smoothing Test.*

These findings highlight the importance of individual differences in perceptual tasks. In experimental settings, this implies that generalisability may be compromised without an adequate sample size. Gilden *et al* used only five subjects in gathering data for their bipartite model. Voss and Clarke's sample size is unreported.

A summary of the findings of *Section 7.5* with respect to the research Hypotheses 3.1 to 3.4 is provided in Table 7.19.

Research Hypotheses supported	Research Hypotheses rejected
3.1 (a) (b), 3.2 (b) (c), 3.3 (a) (b), 3.4 (a) (b)	3.2 (a) 3.3 (b)

Table 7.19 Summary of Study 3 hypothesis testing

7.6 General discussion

The third study was designed, in part, to validate the findings of the previous studies through the administration of the same psychometric battery to subjects with high music ability. The testing of Hypothesis 3.1 (a), (b) and (c) addressed the first research question: Do subjects with high musical ability have higher abilities on dimensions of information processing? This question was answered in the affirmative for the information processing dimensions of successive and executive synthesis. The importance of successive synthesis in music perception was seen in the earlier results from Study 1 and Study 2, as well as in the literature reviewed in Chapter 3 (e.g., Allik *et al*, 1989; Barsz, 1988; McAdams, 1987; Monahan *et al*, 1987; Sorkin, 1990; Warren *et al*, 1991; West *et al*, 1987; Wuthrich & Tunks, 1989). The results here support evidence from Monahan *et al* (1987), and Elliot *et al* (1987), that ability in serial pattern recognition is consistently higher in music experts than in novices. Such evidence justifies the assumption in this research that ability in music perception is an important contributor to music ability in general.

The importance of executive synthesis in music perception was also seen in the earlier studies, consistent with the literature reviewed in Chapter 3 (e.g., Andrews & Dowling, 1991; Boltz, 1991; Clarke & Krumhansl, 1990; Dowling, 1990; Jones, 1992; McAdams, 1987; Morgan & Brandt, 1989). The large effect size of over 23% indicates the importance of executive synthesis to the information processing strategies of Study 3 subjects. In the Luria model, executive control is a responsibility of the third functional block associated with the pre-frontal cortex. This psychometric evidence for the importance of executive synthesis to music ability is consistent with electroencephalographic evidence that musical expertise involves cerebral organisation in the frontal lobes (Birbaumer *et al*, 1994; Hantz *et al*, 1992; Janata & Petsche, 1993).

Executive processes, as described by Luria, include the integration of separately encoded information. Webster and Richardson (1994) argue that musical thinking involves both grouping perceived sounds and 'colouring' this information with affective content. To account for their early dedication to music, it would seem plausible to suggest that the Study 3 subjects must receive considerable positive affective feedback from their musical endeavours to maintain their motivation for focussed and demanding musical study, while rejecting or ignoring many of the contemporary temptations to children of this age group are exposed. Schofield and Ashman (1987) note that information processing in gifted children more resembles adult processing. This could be explained by a superior regulatory function of executive synthesis where attentional processes are directed inwards (Crawford, 1986; McCallum *et al*, 1988).

Whether or not any of these particular individuals will succumb to the "mid-life crisis" of prodigious adolescent performers, observed by Bamberger (1982), remains to be seen. Bamberger argues that there is a shift in cognitive processing strategies after puberty away from an integrated approach. It seems unlikely that such a broad claim takes into account the individual differences in information processing strategies of adolescents found with research using the Luria model (e.g., Walton, 1983). Certainly, executive integration seems important for the information processing capabilities of Study 3 subjects at this age. Jones (1992), for example argues that it is through attention that the different perspectives of performers and listeners are shared. This has particular salience for Study 3 subjects who, given their successes at music learning, sitting music examinations and performing at concerts described in *Section 7.3*, are both expert performers and listeners.

Given the argument of Pogonowski (1989), that it is through integrative processes that executive control creates expectancies, these results are also consistent with evidence presented by Adachi and Carlsen (1994) that young musical children have high abilities at creating appropriate musical expectancies. A superior ability by Study 3 subjects to create appropriate expectancies may explain the results related to Hypothesis 3.3 (a) and (b) which addressed the <u>fourth research question</u>: Do subjects with high music ability show higher rates of learning on novel musical tasks, such as those presented in this research? This question does not address the general music learning characteristics of the Study 3 subjects. The comparison with normal progress through AMEB Grades, the reported criteria of selection by music teachers, and the subjects' case histories provided sufficient evidence for the superior music learning ability of this group. If psychometric confirmation of this assessment was to be sought, then an experiment with a repeated measures design undertaken over some time would be required. Here the research question focussed on the application of superior music learning ability to a novel quasi-musical task. The results showed that the significant differences for the Study 3 subjects were found at the beginning of each task. This could suggest that Study 3 subjects use their superior abilities on executive synthesis to more rapidly generate expectancies or plans that rely on their strengths on either simultaneous or successive encoding. Such an interpretation is consistent with McAdams (1987), who argues that executive synthesis resolves cognitive conflict between simultaneous and sequential grouping processes. Certainly the Study 3 subjects, none of whom seemed to be musical recluses, made a highly effective use of their music practice time to master new works.

Also, most of these subjects were very successful at school, typically being placed in the top 10% of their Year. Around half of the subjects were selected for school-based programs catering for academically gifted children, or attended selective schools. The majority nominated mathematics as their best subject - several had come top of their Year in mathematics and/or gained distinctions in national mathematics competitions. This observation is consistent with the strong relationship found in Study 2 between ability at music perception and school mathematics performance. It also supports the above argument that both music cognition and general intellectual activities share common dimensions of information processing.

These considerations point to one limitation of Study 3: the computer-adaptive Luria model battery operationalises executive synthesis mainly as inward-directed attention or cognitive control, with *Letter/Number Attention* and Stroop-type marker tests. There would be advantages in future studies to understanding the information processing strategies of subjects such as those involved here if other aspects of executive synthesis were to be operationalised, particularly the generation of expectancies (e.g., Balch, 1981; Boltz, 1989; Serafine, 1988), and planning, as in the PASS model (e.g., Das & Heemsbergen, 1983; Das *et al*, 1994; Naglieri *et al*, 1990). A more sensitive measurement of abilities on executive synthesis may also inform its relationships with the encoding dimensions, particularly simultaneous synthesis. The high cross-loading of the *Inverted Matrices* marker test for simultaneous synthesis on the component reflecting executive synthesis suggests that, within the Luria model, simultaneous processing and cognitive control are integrated at the highest level under executive synthesis. Such a suggestion may explain the low difference in mean scores on simultaneous synthesis between Study 3 and Study 2 subjects.

Nevertheless, individual differences in simultaneous synthesis were important for explaining the results related to Hypothesis 3.4 (a) and (b). The <u>third research question</u> was concerned about a possible relationship between perceptual sensitivity and the strength of the autocorrelation structure of the pitch sequence being perceived. Two perceptual models were proposed: one that involved fractal perception following Voss and Clarke (1975, 1978); the other involved signal-noise or bipartite perception following Gilden *et al* (1993). There was evidence to support both models of perception. The key variable was ability on simultaneous synthesis. Subjects with low ability on simultaneous synthesis only use bipartite perception to process complex auditory contours, possibly because they lack the ability to encode fine quasi-spatial detail. Subjects with high ability on simultaneous synthesis can process such detail, and thus are able to appreciate form over more than two levels of scaling, i.e., they have the cognitive ability to encode fractal form. This finding is of considerable importance to the general thrust of this thesis: even in a seemingly homogeneous group of subjects selected by agreed criteria there is a wide range of individual cognitive differences. This has implications for experimental reporting. For example, this finding may explain why, in the McMullen and Arnold (1976) study, the relationship between redundancy and perceived complexity did not reach statistical significance with a sample size similar to that in Study 3.

This finding may also inform the conjecture that temporal correlation occurs within pitch sub-streams and is then combined (Barsz, 1988; Sorkin, 1990). This model would predict that there would be no relationship between D and levels of A, because as A increases from zero to larger values, more sub-streams would become available for use. As the majority of differences between the mean values of D for each of the three levels of A were non-significant, there may be some support here for this assumption. The prominence of individual differences, however, is consistent with the equivocal evidence found for this relationship (Barsz, 1988).

The individual difference results reported here are implicitly contingent upon the positive answer found to the second research question: Are subjects with high music ability more sensitive to autocorrelation structure in fBm tone series? This question was addressed by the testing of Hypothesis 3.2 (a) and (b). These individual difference results may also explain the low effect sizes, less than 7%, reported in the results related to Hypothesis 3.2. Alternately, these results could be consistent with the findings of Bigand (1990) which supported the perceptual abstraction of the two forms of melodic structure theorised by Jackendoff (1991) (also Lerdahl & Jackendoff, 1983): 'reduced structure' and 'prolongational structure' [Chapter 3]. These results from Study 3 could be interpreted as indicating that subjects may be more sensitive to one or other of these structural forms, depending on their individual abilities on successive and simultaneous processing (Snart, Das & Mensink, 1988). Moreover, three separate analyses failed to provide significant evidence for a contribution of music experience to the superior sensitivity to autocorrelation structure of the Study 3 subjects. Whereas many aspects of musicality are dependent upon music experience, the perception of coherence in pitch series is apparently not; rather, such perception is best accounted for as an information processing task.

More importantly for this program of research, the superior performance of subjects with high music ability on both the *Scale Estimation of Smoothing Test* and the *Change of Smoothing Test* validates these instruments as measures of ability in musical perception, or at least, measures of abilities on information processing skills related to music perception. It is acknowledged that the design of these instruments involved some degree of compromise between controlling the time evolution of the fBm series and retaining some resemblance of music. There could be some peripheral variance, e.g., pitch range, or the occurrence of a particular interval (Tsuzaki, 1991), which some subjects with high levels of music perceptual ability could use to make the discriminations required in these tasks, rather than, or in addition to, sensitivity to autocorrelation structure as such. Consideration of individual abilities on the three information processing dimensions, such as with the groups of siblings, suggests that the superior perceptual strategies of these subjects are not uniform. Such variance in the perception of differences in fBm tone series by subjects with high music ability could be the subject of further research following this program.

Chapter summary

Chapter 7 described Study 3 (N = 29) involving subjects with demonstrated high music abilities. Profiles of some of these subjects were given. The subjects undertook the same battery of tests as in Study 2, except for the MEK. Comparisons with Study 2 results showed that the Study 3 subjects had superior information processing abilities, especially executive synthesis, which they employed in their superior perception of autocorrelation structure of fBm tone series. Several analyses indicated that there was no significant contribution of music education experience to the perception of autocorrelation structure. This study afforded an opportunity to test the rival models of auditory contour perception of Voss and Clarke, and Gilden, Schmuckler and Clayton. The results showed that the perception of auditory contour is a matter of individual differences in information processing abilities.

CHAPTER 8

REVIEW AND CONCLUSIONS

Chapter Overview

This final chapter reviews the evidence that individual differences in information processing, as proposed by the Luria model, can account for individual differences in abilities to perceive autocorrelation structure and other pitch pattern characteristics in music. The chapter has four sections. The first section presents an overview of the experimental results. *Section 8.2* discusses these results with respect to the literature reviewed in Chapters 2, 3 and 4. *Section 8.3* notes some of the strengths and limitations of this program of research. The chapter concludes with some recommendations for further research in *Section 8.4.*

This program of research was motivated by the question: Why mozart? The question is generic; the lower case "m" is deliberate. Many of the 'great' composers, e.g., Handel, Haydn, Beethoven and Mendelssohn, were music prodigies, playing the keyboard in their infancy, and beginning to compose around age 10 years (Storr, 1992). Nor is this an exclusive phenomenon of bygone eras, as the biographies of many of this century's composers, e.g., Prokofiev and Britten, would attest. This program of research investigated the proposition that individual differences in music ability can be explained as individual differences in abilities in information processing. As noted in Chapter 1, the term "music ability" is not a unidimensional construct; rather, music ability arises from the interaction of music aptitude and early music environment, and manifests in particular music activities such as listening, performing, improvising and composing.

The Luria model, as operationalised to account for individual differences in performance on school tasks such as reading, mathematics and formal reasoning, was used in this study to explain variance in abilities in some aspects of music perception. Luria's model proposes three mutually independent dimensions to the processing of information, simultaneous, successive and executive synthesis. Simultaneous synthesis involves encoding information in a quasi-spatial 'surveyable array' based on common interrelationships. Successive synthesis involves encoding information in a sequentially ordered linear chain. Executive synthesis involves the processes of attention, information integration, and cognitive control. An individual's information processing ability can be represented by scores on components representing these dimensions.

8.1 Overview of the research results

The research was undertaken over three psychometric studies, two with Year 5 and 6 children in government primary schools and a third with age-matched subjects with high music ability. A consistent theme of the literature on music cognition reviewed in Chapter 3 is that different aspects of music perception such as contour and pitch require different cognitive processes (e.g., Dowling, 1990). The first study (N = 151) sought to investigate relationships between the Luria model dimensions of information processing, established measures of musical ability, and the perception of musical contour inversion. A second concern of the literature, following a study of Voss and Clarke (1975,1978) [Chapter 4], is whether or not music exhibits self similarity or fractal form. Whereas it has been argued that the work of Voss and Clarke is methodologically flawed, particularly with regard to pitch fluctuations (Nettheim, 1992), the conjecture that music has ubiquitous appeal because its form is similar to that of Nature was sufficiently appealing to deserve a fuller investigation. Thus Study 1 also investigated relationships between the Luria model dimensions of information processing and the perception of fractal form in auditory contours as a replication and extension of the study by Voss and Clarke.

The Luria model dimensions were measured with a paper and pencil battery which has had substantial use in research over two decades by Fitzgerald (1978, 1990) and colleagues. Conventional music abilities were measured with the *Music Evaluation Kit* (MEK) Part I *Pitch Discrimination* and Part V *Patterns Recognition* (Bryce, 1979), developed by ACER. Perception of contour inversion was assessed with an original instrument designed as an auditory analogue of the *Fitzgerald Matrices B* marker test for simultaneous synthesis. In the replication of the Voss study, three fractional Brownian motion (fBm) tone series with contrasting spectral density function coefficients, white music with $\beta = 0$, brown music with $\beta = 2$, and fractal music with $\beta = 1$, were generated by a random multiplicative addition algorithm (Landini, 1992). The replication of the Voss study also used an affective response instrument based on Osgood's Semantic Differential to achieve a more sensitive measure of response to the three fBm tone series.

The results of Study 1 are summarised in Table 8.01. The Luria model marker tests were reduced by a principal components analysis to three components reflecting the three dimensions of simultaneous, successive and executive synthesis. About 12% of subjects achieved criterion on the MEK. Multivariate analysis revealed relationships between MEK performance and successive and executive synthesis. Only 5% of items on the perception of musical contour inversion task were answered at better than chance, indicating that this task was too difficult for these subjects due to its considerable information processing demands. This was interpreted as supporting the argument in Chapter 3 that musical contour encoding is undertaken by successive synthesis rather than its visual analogue which requires simultaneous synthesis. The results of the replication study showed general support for Voss and Clarke, although statistical significance was achieved only by those subjects with MEK criterion scores. For these subjects, there were significant correlations between scores on the successive synthesis factor and semantic differential preference ratings for fractal or 1/f music. These results demonstrate, as Luria emphasised, that the dimensions of information processing work in concert on any given perceptual task.

It was noted that if Voss' claim, that all music is 1/f-like, is correct then the perception of this property is not helpful in explaining differences between particular pieces of music. As the spectral density function is related through Fourier Transformation to the autocorrelation function, fBm series with different values of β have different levels of autocorrelation. Chapter 4 reviewed some of the literature positing autocorrelation as the process by which musical elements are created, e.g., at the primitive or pre-cortical level by Bregman's (1994) account of auditory streaming; at the cognitive or schematic level by Leman's (1994a) model of tone centering. There is also evidence for the perception of autocorrelation structure at the primitive pre-cortical level (Ando *et al*, 1989). The second study (N = 135) sought evidence for the perception of autocorrelation structure at the cognitive level. Study 2 aimed to investigate relationships between the Luria model dimensions of information processing, established measures of musical ability, school academic performance, music education experience, and the perception of autocorrelation structure in fBm tone series.

The Luria model dimensions were measured with a battery in new computer adaptive format devised by Fitzgerald *et al* (1995). Pitch pattern discrimination ability was measured by the MEK but, unlike in Study 1, scores were used to represent a continuous variable. The perception of

Hypoth	IV	Analysis	Dependent	Variables	
1.1	MUSAPT	MANOVA	sim null	suc null	exec null
1.2	MUSISCR	Pearson	r = .18 p=.042		
		Princ Comp	.33		
1.3	MUSAPT	ANOVA	MUSISCR $p = .005\ \eta^2 = .06$		
1.4	FRACSCR	t-test	WHITESCR p < .001	BROWNSCR p < .001	
1.5, 1.6	FRACSCR	Pearson	null	null	
1.7	MUSAPT	Pearson	FRACSCR	WHITESCR	BROWNSCR
	sim			r ≈ .2 p < .01	
	suc		r ≈ .7 p < .001		r ≈ -.7 p < .01
	exec				

Table 8.01 Summary of Study 1 results

autocorrelation structure was measured by two original instruments which employed fBm tone series with continuous values of β, generated by a random smoothing algorithm (Turner, 1992). The *Scale Estimation of Smoothing Test* required scale judgement (after Pentland, 1984); performance was measured by an error term. The *Change of Smoothing Test* required detection of the boundary between a concatenated pair of fBm tone series (after Serafine, 1988); performance was measured by the number of correct short latency responses.

The results of Study 2 are summarised in Table 8.02. As in Study 1, a three-component structure reflecting the Luria model was recovered from a principal components analysis. A replication of the Study 1 investigation into the relationship between the Luria model dimensions and performance on the MEK showed that, as suggested in the music cognition literature, all three

Hypoth	IV	Analysis	Dependent	Variables	
2.1	RMSD	Pearson	sim r=-.34 $p < .001$	suc	exec r= -.16 $p = .039$
		ANOVA	$p= .002\ \eta^2 = .13$	$p= .012\ \eta^2 =.09$	
		Princ Comp	-.71	-.38	
2.2	NGOOD	Pearson		r = .23 p=.001	r = .30 $p < .001$
		MANOVA		$p =.005\ \eta^2 =.08$	$p =.002\ \eta^2 = .10$
2.3	MEKTOT	Pearson	RMSD r = -.32 $p<.001$	NGOOD r = .25 p=.003	
2.4	MEKTOT	Pearson	sim r= .26 p= .003	suc r= .35 $p < .001$	exec r= .22 p= .010
		ANOVA		$p <.001\ \eta^2 =.12$	$p =.017\ \eta^2 = .05$
2.5	MUSEXP	MANOVA	RMSD null	NGOOD null	
2.5	MATH	Pearson	r = -.50 $p <.001$	r = .42 $p < .001$	
		MANOVA	$p < .001\ \eta^2= .27$	$p <.001\ \eta^2= .09$	
2.6	LANG	Pearson	r = -.45 $p < .001$	r = .40 $p < .001$	
		MANOVA	$p < .001\ \eta^2 =.23$	$p <.001\ \eta^2= .17$	

Table 8.02 Summary of Study 2 results

information processing dimensions are required in pitch and pattern perception. Multivariate analyses showed that performance on the *Scale Estimation of Smoothing Test* was related to abilities on simultaneous and successive syntheses, while performance on the *Change of Smoothing Test* was related to abilities on successive and executive syntheses. Sensitivity to autocorrelation structure was not related to music experience, supporting the construct of innate musical aptitude. Sensitivity to autocorrelation structure was strongly related to school performance in mathematics and English language, supporting observations by teachers of such relationships with music abilities. This shared variance can be attributed to common dimensions of information processing.

A possible limitation to the generalisability of the results from Study 2 lies in the restricted validity of fBm tone series to represent the characteristics of real music. To this end, a third study was designed to replicate Study 2 with age-matched subjects selected for their high levels of music ability. It was also suggested that such a sample would be suitable for comparing the perception of fractal form conjecture of Voss with the bipartite or signal-noise model of contour perception advanced by Gilden *et al* (1993).

Study 3 (N = 29) sought to investigate relationships between the Luria model dimensions of information processing and perception of autocorrelation structure, and learning rates on the perception of autocorrelation structure tasks. The performance of Study 3 subjects was compared with that of 'normal' subjects in Study 2. This third study also compared the two perceptual models posited for the perception of complex auditory contours. Subjects undertook the same computer-based tests as used in Study 2.

The results of Study 3 are summarised in Table 8.03. As in the previous studies, the Luria model marker tests, here for the combined samples from Study 3 and Study 2, were reduced to three components. The addition of the Study 3 subject scores changed the component structure; the component reflecting executive synthesis now accounted for the most variance compared with the Study 2 component structure in which the component reflecting successive synthesis accounted for the most variance. Compared with normal subjects, subjects with high music ability were superior on both tests for perception of autocorrelation structure, offering some validation for their use as tests for music perception. Subjects with high music ability were also superior on all Luria model marker tests, and particularly on component scores for successive and executive synthesis. Nearly 25% of the variance on executive synthesis was accounted for by membership of the high music ability group, supporting the important role for executive processes in music perception. The significant correlations between all three information processing dimensions and both of the perception of autocorrelation structure tasks indicated the superior role of executive synthesis for integrating attentional and encoding processes into highly effective strategies. It is the employment of such information processing strategies, rather than just a fortunate accumulation of music experiences, that enables some children to display superior musical aptitude. The evidence from this study, then, supported the 'common knowledge' of music teachers and practising musicians that there is more to musical potential or musical giftedness than can be explained by early music education alone. Multivariate analysis showed that Study 3 subjects were superior at the beginning of the sensitivity tasks, again consistent with a high ability on executive synthesis, and observed superiority in music learning in general.

Hypoth	I V	Analysis	Dependent	Variables	
3.1	MOZART	MANOVA	RMSD $p = .001$	NGOOD $p = .011$	
3.2	MOZART	MANOVA	sim $p = .061$	suc $p < .000$ $\eta^2 = .12$	exec $p < .000$ $\eta^2 = .23$
3.3	MOZART	Stepdown MANOVA	RMSD T1 $p = .020$ T2 $p = .009$	NGOOD T1 $p = .011$	
3.4	VC or GSC	MANOVA	sim $p = .077$ $\eta^2 = .18$	suc	exec

Table 8.03 Summary of Study 3 results

Interestingly, evidence was found to support both contrasting models of auditory contour perception. Further analysis showed that this result was the outcome of individual differences on simultaneous synthesis; subjects with low abilities on simultaneous synthesis were limited to bipartite perception, whereas subjects with high abilities on simultaneous synthesis were able to process the complexities of fractal form.

8.2 General discussion and conclusions

This study considered several related questions. At the most general level: "What relationship exists between an individual's measure of information processing ability and his/her ability in music perception?" More specifically: "What relationship exists between an individual's measure of information processing ability and his/her abilities to process certain aspects of music signal information?" This in turn raised the question: "What particular aspects of information contained in a music signal are used to create particular music images and schemata?"

Modeling music perception as an information processing task involves demonstrations of, or at least plausible arguments for, causal links between a hierarchy of 'representational categories': signals (the acoustical or waveform representation of sound), images (the neural activity of aspects of the signal in the auditory system), schemata (information structures reflecting learned functional organisation) and mental representations (knowledge structures used for problem solving) (Leman, 1994b).

> *Signals are transformed into images, and images organise into schemata and are controlled by these schemata. By looking for correlations between responses of model, and ... data ... one may try to relate the response structure of the schemata to the space of mental representations* (Leman, 1994b: 204).

Or as Minsky (1981) puts it: "music theory is not only about music, but about how people process it" (p. 29). The results from this research suggest that the arguments for an information processing approach are reasonable (e.g., Krumhansl, 1992; Lufti, 1990; McAdams, 1987; Umemoto, 1990; Unyk, 1990; West, Cross & Howell, 1987). It could be noted that this approach relegates the dispute between 'music-as-sound' (e.g., Gibson, 1969; Krumhansl, 1992) and 'music-as-cognition' (e.g., Cook, 1994; Serafine, 1988) to a matter of limited focussing on two extremes of the one complex process. The process is hierarchical - information at one level is correlated or chunked into Gestalts which become the elements of the next higher level (e.g., Boltz, 1991; Godoy, 1994; Krumhansl, 1992). It was hypothesised that autocorrelational mechanisms are responsible for these grouping phenomena. Such a hypothesis is consistent with models of perception which are coarse-grained rather than continuous. Licklider (1951), for example, notes that the auditory mechanism is better understood as an autocorrelator than as a frequency analyser.

The level of processing under investigation here was the transformation of musical images into schemata. The musical stimuli in this research were either short phrases of single tones recognised as simple contoured patterns, or fBm tone series whose structures were perceived as complex contours. In contrast with the stable musical schemata from musical experience, the Gestalts required of subjects in the sensitivity to autocorrelation structure tasks could have little or no support from long term memory. Nevertheless, the direct estimation of strength of autocorrelation task could have similar demands for cognitive processing as determining whether a melody is major, minor or modal, while the response to change in autocorrelation task could have similar demands for cognitive processing as determining where a modulation has occurred or where a new phrase has begun. Certainly the subjects with higher music abilities across all three studies performed better on these tasks, supporting the argument for a music aptitude or potential which contributes to music ability through its interaction with music experience (Gordon, 1979, 1993; McPherson, 1995; Sergeant & Thatcher, 1974; Trehub, 1994; Walters, 1989).

Although the Luria model had not previously been used in the field of music, the hierarchical interplay of the two encoding dimensions to chunk or correlate information featured in the model provided a particularly salient description of the cognitive demands of music perception. Importantly, within a cyclic hierarchy of simultaneous and successive coding, perceptions at all levels are available "all-at-once". So it is with music, which makes sense over all time scales, from single notes through phrases to whole movements (Boltz, 1991). Also like speech, heard music is a once-only experience - there is no 'going back over' with temporal phenomena. Thus music information must first be processed in the order of its perception (e.g., Brown, 1988; McAdams, 1987; West *et al*, 1987; Wuthrich & Tunks, 1989).

This is seen in the results from all three studies where abilities on successive synthesis related to performance on every perceptual task. In Study 1, ability on successive synthesis related to success on the contour inversion task, and to the preference for fractal music by subjects with criterion scores on the MEK. In Study 2, ability on successive synthesis related to success on both of the sensitivity to autocorrelation tasks, and to performance on the MEK. In Study 3, the high music ability subjects had significantly higher component scores on successive synthesis than their peers in Study 2, consistent with previous evidence for superiority of serial processing by musical experts (Monahan *et al*, 1987).

These results inform the work of Dowling (1990, 1991, 1994a, 1994b) that pitch contour is an important contributor to the music perceptual Gestalt, but its relative importance diminishes with the musical experience of the listener, and the novelty of the tonal context of the musical phrase. More recent work has focussed on the relationships between pitch contour perception, working memory and cognitive control (Dowling, 1995a, 1995b; Dowling, Kwak & Andrews, 1995; Halpern, Bartlett & Dowling, 1995). In the Luria model, the capacity of working memory is related to strength on successive processing (Kirby & Das, 1990), while cognitive control is a function of executive synthesis (e.g., Das *et al*, 1994). The evidence from Study 1 and Study 2 indicates that the encoding of contour is undertaken primarily by successive synthesis. This explains why young children can accurately reproduce melodic contours without necessarily reproducing the correct pitch intervals. In the Luria model, cognitive development is asynchronous across the three information processing dimensions. Whereas successive synthesis is available from birth, simultaneous and executive syntheses develop from the child's interactions with the cognitive environment (Golden, 1987). Innate individual differences in capacities on these processing dimensions actualise in the music domain as asynchronous music abilities for the individual (Cuddy & Upitis, 1992), and variance in music abilities within the population.

There is also evidence from each of the studies that simultaneous synthesis is involved in music perception. In Study 1, abilities on simultaneous synthesis related to the limited success achievable on the contour inversion task. The mental manipulation of a successively encoded pitch contour required further processing of the contour into a simultaneous Gestalt. In Study 2, simultaneous synthesis related to performance on the MEK, consistent with the argument in Chapter 3 that simultaneous synthesis underpins the formation of schema for pitch (e.g., Bartlett & Dowling, 1988; Wuthrich & Tunks, 1989). Also in Study 2, simultaneous synthesis strongly related to success on the *Scale Estimation of Smoothing Test*, consistent with the further argument in Chapter 3 that simultaneous synthesis underpins the formation scale templates and pitch hierarchies (e.g., Cuddy, 1991; West & Fryer, 1990). This finding is consistent with previous evidence for a positive relationship between music aptitude and spatial processing abilities (Hassler *et al*, 1985, 1987; Karma, 1979, 1982). The Study 3 subjects had significantly higher scores on the marker tests for simultaneous synthesis, consistent with evidence by Elliot *et al* (1987) for superior 'vertical integration' of music information by music experts.

This is not to say that the Study 3 subjects were homogeneous in abilities on the information processing dimensions. Individual differences in simultaneous synthesis were shown, in Study 3, to explain apparently contrasting evidence for perception of complex auditory contours. On the one hand, there is evidence that music, as distinct from other auditory signals, has a characteristic 1/f power spectral function similar to fractal structures in the natural world (e.g., Boon *et al*, 1990; Gardner, 1978; Pickover, 1986; Voss & Clarke, 1975, 1978). The consequent autocorrelation function, being intermediary between highly correlated and completely uncorrelated, is conceptually consistent with analyses of music based on information theory where music is characterised by a balance of novelty and prediction (e.g., Berlyne, 1970; McMullen, 1974; McMullen & Arnold, 1976; Meyer, 1970). Musical form is characterised by self similarity over all time scales up to the length of the piece (Klimontovich & Boon, 1987; Voss, 1988), evidence for which includes statistical reductions which still retain a recognisable similarity to the original (Hsu, 1993; Pinkerton, 1956). There is evidence that fractal structure is directly perceivable (e.g., Gleick & Porter, 1991; Kersten, 1987; Pentland, 1984). On the other hand, the simultaneous organisation of sounds is not always integrative (Bregman, 1994). There is counter evidence that real music is not essentially fractal in form (Nettheim, 1992), and that in any case, fractal structure is not directly perceivable in complex auditory contours (Schmuckler & Gilden, 1993). Rather, the cognitive processing of complex contours involves bipartite perception of signal and noise (Gilden *et al*, 1993; Terhardt, 1991). Study 3 showed that this dichotomy is the result of individual differences on simultaneous synthesis. Subjects with low abilities on simultaneous synthesis discriminated best between complex contours with a prominent signal component; subjects with high abilities on simultaneous synthesis showed a perceptual preference for fractal contours. This suggests that subjects with high abilities on simultaneous synthesis are able to process the more complex quasi-spatial information that such musical signals contain. Such an interpretation might explain the ambivalent results of an earlier investigation into perception of macro and micro contours by Cohen *et al* (1989). They found that for some subjects, high macrocontour complexity did not always produce low performance in subjective coding of contour complexity. These results from Study 3 suggest that the question of the perceptual underpinnings for aesthetic preference needs also to be addressed in terms of individual differences. This might explain the variance in preference responses found by McMullen and Arnold (1976) to sequences of differing structural complexity.

In sum, the results of this research program show that the perception of musical structure requires both successive and simultaneous synthesis. As McAdams (1984) notes: "There are separate groups of criteria that determine the way one organises acoustic information sequentially and simultaneously. ... Sequential information is organised according to criteria of spectral continuity. ... Simultaneous information is organised according to criteria of coherence" (p. 318). The orthogonality of these two dimensions in the operationalised psychometric Luria model as applied to music is supported by evidence from Cuddy and Upitis (1992) that in brain damaged patients, pitch can be preserved while rhythm destroyed, and vice-versa. It was observations of this nature that originally led Luria to formulate his model. There is "some degree of neural independence for rhythmic and melodic processes. Within a given individual, therefore, certain perceptual components may be privileged over others in the individual's response to music. ... Moreover, strengths or weaknesses in one component may not be predictive of strength or weakness in another" (Cuddy & Upitis, 1992: 338). Individual differences in acuity of perception of pitch contour arise from individual strengths and weaknesses on these two dimensions of information processing.

Their integration into perceptual strategies is determined by executive synthesis. Halpern *et al* (1995) conclude that "expertise effects ... depend upon the task and the strategies it evokes' (p. 45). This was demonstrated in Study 3 where it seemed that this small sample of selected subjects could have generated a variety of strategies to deal with the sensitivity to autocorrelation tasks. This could be due to the marked superiority on executive synthesis of these subjects, which, for different individuals, possibly relies on different components of executive processing, including attention, cognitive control, integration of encoded information, integration of affective information, evaluation, the formation of expectancies and the formulation of plans.

Evidence for the attentional role of executive synthesis in music perception was provided in Study 1 and Study 2 by the relationship of executive synthesis with success on the MEK, consistent with other studies supporting a pivotal role for attention in music processing (e.g., Andrews, 1991; Boltz, 1991; Clarke & Krumhansl, 1990; Morgan & Brandt, 1989; Posner & Petersen, 1990; Unyk, 1990). The effect for the interaction of successive and executive synthesis on all Study 2 variables was consistent with Clarke and Krumhansl (1990) who suggest that attention, a necessary attribute for music perception, is the outcome of temporal organisation. The superior ability of the Study 3 subjects to concentrate on music learning and performance tasks could be explained by the self-regulatory role of executive synthesis, where attention is utilised for metacognition (Crawford, 1986).

Evidence for the cognitive control aspect of executive synthesis was provided in Study 2 by the relationship of executive synthesis with success on the *Change of Smoothing Test.* Here, executive synthesis was strongly related to making correct decisions over structural boundaries, following Bever (1988), and generally consistent with previous studies showing how attention creates expectancies which determine musical meaning from musical structure (e.g., Dowling, 1990; Janata & Petsche, 1993; Jones, 1992; Schmuckler, 1990; Smoliar & Mikulska, 1994). The first task for the music listener is to sort musical components into separate groupings (Deutsch, 1982). This cognitive ability to impose boundaries is, according to Minsky (1981, 1988), absolutely fundamental to the construction of meaning in music and in language. It has its roots in the evolutionary origins of human intelligence in a spatial environment, where the detection of boundaries is the primary objective of visual processing. Minsky's position is supported here by the strong relationship between success at making correct decisions concerning changes in autocorrelation structures and school performance in English language. Similar relationships between other measures of music aptitude and verbal abilities have been reported (Karma, 1979, 1982; Taylor, 1973). This is consistent with Shuter-Dyson and Gabriel (1981) who also argue that Gestalts formed from sequences of pitches have generative and perceptual rules which parallel those of language. It is also consistent with the results of laterality studies suggesting that tone series and verbal sequences are processed in a similar manner (Strong, 1992). It should be noted that this interpretation is not in conflict with Luria's observations that auditory processing is not unitary, and that music is processed separately to speech. Here the processing is being undertaken at a higher level where, as Luria evidences, modality is no longer relevant (Luria, 1973). Making sense of spoken or written language, and avoiding ambiguity, involves constant decision-making over lexical demography, e.g., grouping descriptive phrases with their contingent noun or verb and not with some other noun or verb in the same sentence. Similarly in music, a listener needs to impose structural delineators to make sense of compositional form, e.g., classical phrasing (short - short - long), or sonata form (theme - repeat - exposition - recapitulation). It is a well established school practice with young children to enhance the learning of serial verbal information by singing or chanting the target material (Wolfe & Hom, 1993).

This line of argument underpins studies into the possible relationships between music and visual representations (e.g., Boon *et al*, 1990). In comparing memory for visual art works and music, Bartlett (1984) concludes "that sequences of [visual or acoustic] stimuli can be perceived as coherent events" (p. 246). Nevertheless, the results of these studies show that some caution must be exercised in the attempt to find marker tests for components of simultaneous or successive synthesis across modalities. Modal specificity does hold with processing at the primary zone level; the initial processing necessary for auditory contours is not the same as that initially required for visual contours. Previous attempts at visual-auditory analogues have, consequently, been less than wholly successful (Handel & Yoder, 1975).

For learning, the roles of successive synthesis in encoding for memory, and executive synthesis in using successively encoded information for the creation of expectancies, consistent with the implication-realisation model of Narmour (1990), have particular importance. The Study 3 subjects were superior at the beginning stages of the two sensitivity to autocorrelation structure tasks, suggesting that, consistent with their higher abilities on executive synthesis, they were able to more readily form relevant expectancies and hence form appropriate strategies. This is consistent with Cohen (1991) who found that musically experienced subjects could predict the tonic of Preludes and Fugues by Bach from the beginning four notes, and in contrast to Fiske (1987) and Madsen *et al* (1993) who suggest that the listening responses of inexperienced and experienced musicians are similar.

A strength of the Luria model is its grounding in neuropsychology. The psychometric results from this research are consistent with evidence from EEG studies that both hemispheres of the brain are involved in processing music (Autervaniemi *et al*, 1993; Hassler, 1990; Pribram, 1992), particularly the auditory cortices, an area Luria associates with successive synthesis, the right parietal areas, an area Luria associates with simultaneous synthesis, and the frontal lobes, an area Luria associates with executive synthesis (Janata & Petsche, 1993). Furthermore, the degree of involvement of these areas changes with learning (Crummer *et al*, 1988; Frisnia *et al*, 1988; Gardner *et al*, 1977). The large percentage of explained variance on executive synthesis by Study 3 subjects is consistent with evidence that musically expert subjects showed higher EEG activity in the frontal lobes, particularly on complex stimuli, than non-experts on simple periodic stimuli (Birbaumer *et al*, 1994). Again this highlights the individual nature of responses to music. Or as Birbaumer *et al* put it bluntly: "Complex music produces complex brain activity in complex people, simple music excites simple brain activity in simple people" (p. 3).

This statement points to an answer to the specific question: Why Mozart? Shuter (1968) reports an estimate of Mozart's IQ of around 150. From an analysis of Mozart's personal correspondence [extract below], Gardner (1982) describes Mozart's self-awareness of simultaneous processing during composing. From the results of Study 3 it could be conjectured that Mozart was an individual with extremely high abilities on successive, simultaneous and executive syntheses. He was also fortunate to have been born into a musical family, with a more than devoted father, and without the imposition of compulsory schooling to interrupt his grand tours. Nevertheless, his remarkable music ability depended, in part, on his ability to process information from musical signals. The results from the present research would support the further conjecture that Mozart could readily form musical gestalts from his superior perception of musical structure. Bregman argues that the form of good composition facilitates the auditory functioning of listeners. From the number of contemporary performers who rate Mozart's music as "perfect" despite the datedness of its cultural context, and given that Mozart is the most frequently performed composer world wide (Johnston, 1989), it would seem that Mozart, at some level of cognitive functioning, was aware of this. Such a claim would be consistent with Mozart's own meta-cognitive description:

> *... my subject enlarges itself, becomes methodised and defined, and the whole, though it be long, stands almost complete and finished in my mind, so I can survey it, like a fine picture*

or a beautiful statue, at a glance. Nor do I hear in my imagination the parts successively, but I hear them, as it were, all at once (Gardner, 1982: 358).

Perhaps this can explain the findings of Marsden (1987) that the cognitive processing required while listening to a Mozart string quartet is remarkably stable. He explains this in terms of the high level of complexity maintained throughout the composition.

In conclusion, the same information processing dimensions that underpin individual differences in cognitive abilities in other areas operate in the music domain. This explains the common teacher observation of relationships between music ability and other intellectual abilities, especially mathematics. Sergeant and Thatcher (1974) showed that the failure of earlier attempts to confirm this relationship were compromised by a disregard for the statistical principle that correlation is constrained by reliability. The results from Study 2 support Sergeant and Thatcher's re-analysis, at least for a positive relationship between musical ability and abilities at mathematics and language at the primary school level.

8.3 Strengths and limitations of the research

A particular strength of this research program was the use of three-factor operationalised Luria model to assess individual abilities on dimensions of information processing. The advantages of the Luria model for this research include its parsimony, its demonstrated generalisability in accounting for individual differences, its foundation in neuroscience, and particularly, its development outside of the area of music cognition. As a focus of this research was on a new approach to the assessment of musical aptitude, the stability of the Luria model component scores (Leasak *et al*, 1982; Fitzgerald, 1990) is of considerable importance, as is its established validity with school-age subjects (e.g., Biggs & Kirby, 1980; Hunt *et al*, 1976). The grounding of the model in findings from clinical neurology means that the investigator can be more confident in attributing causation as an explanation for significant correlations.

In contrast, several limitations characterise many previous models of music perception. First, such models are typically not parsimonious; some in fact, are exhaustively complicated, e.g., Schenkerian analysis. Second, some models hold no necessary generalisability for other areas of perception, e.g., the musical parser of Jackendoff (1991). This is an outcome of the circularity of using only music tests to understand music cognition (Karma, 1985). Third, many accounts are unable to explain the nature of individual differences in musical ability (e.g., Radford, 1994). This seems remarkable given the degree to which high ability is feted in the performing arts. Much recent research has gathered evidence which points to the importance of extensive musical training in improving perceptual performance (e.g., Sloboda *et al*, 1994a), despite commentators who emphasise the complexity of mental processes and representations necessary for music perception (e.g., Cuddy & Upitis, 1992).

A limitation of the three-factor operationalisation of the Luria model used here is that executive synthesis is measured only on marker tests for cognitive control. It was evident that subjects employed other aspects of executive processing, such as integration, evaluation and planning, in their perceptual responses. This suggests that in future studies of music information processing with the Luria model, some tests for these aspects of executive synthesis could be devised, or adopted from other psychometric batteries, e.g., the planning marker tests from the PASS operationalisation of the Luria model (Naglieri *et al*, 1990).

A general limitation to the strength of these results lies in the modest effect sizes reported, mostly less than 25%. That is, significant correlations rarely exceeded 0.5. According to Sergeant and Thatcher (1974) this is typical of studies into musical aptitude. These authors argue that such correlations are constrained by a ceiling of modest test validity and reliability, estimated around 0.4. Adjusting for such a ceiling raises the effect sizes to more impressive levels. Without several replication studies there can be no firm estimates of the validity and reliability of the sensitivity to autocorrelation tasks employed in this study. As a large number of music aptitude instruments were reviewed by Sergeant and Thatcher, it is likely that their results are quite general. It is possible, then, that the validity and reliability of these new tests could be constrained by a similar ceiling effect which would account for the significant but modest correlations reported above.

A potential limitation to generalisation in this research is that the music referred to is implicitly Western music. However, it was noted in Chapter 3 that the cognitive organisation of music in some West African and East European cultures was similar in many respects to that of Western music (Pressing, 1983), and self-similarity across time scales has been observed in Javanese music (McCardell, 1993). Cross-cultural comparisons using the Luria model showed similar dimensions of information processing among Indian (Das & Molloy, 1975), Native Canadian and Chinese (Das *et al*, 1994), and Australian Aboriginal (Klich & Davidson, 1984) children. Together, these results suggest that the conclusions of this research are likely to be applicable in other cultural contexts.

Another potential limitation is that the experimental stimuli were not presented in a real music context (Brown, 1988). The point has to stand, although experimental controls are difficult to impose in real music contexts (Monahan *et al*, 1987). An advantage of using fBm tone series was that the perceptual Gestalts formed were presumably not conventional music elements, therefore conferring no advantage of music learning for some subjects, especially those in Study 3. Brown argues further that such laboratory studies, typically using musically sophisticated subjects, do not inform our understanding of "the mental representations of music shared by a much broader population of listeners" (p. 221). In response, musically sophisticated subjects were used in the final study only after it had first been demonstrated that the Luria model was applicable to the mental representations of music shared by a much broader population of listeners.

A more serious limitation is that experimental stimuli could not be regarded as examples of real music. For example, the fBm tone series as generated had no variation in rhythm or dynamics. It could be remarked that neither does much contemporary popular music. As many of the cues for serial organisation in music are provided by rhythmic or dynamic emphasis (Monahan *et al*, 1987), the absence of rhythmic or dynamic variation would seem to make the perceptual task more, rather than less, exacting. Nettheim (1992) notes that in real music, rhythm does not follow an inverse power law, and therefore any combination of a 1/f distribution of rhythm with a 1/f distribution of pitch would be less music-like than a 1/f distribution of pitch on its own.

In this research the focus was exclusively on the perception of pitch fluctuations. Such a focus was based on the evidence that pitch is a privileged musical attribute in so far as its accurate perception explains more variance in music ability than does any other musical characteristic such as rhythm or dynamics (Beament, 1977; Gordon, 1979, 1993; Halpern, Bartlett & Dowling, 1995; McPherson, 1993; Walters, 1989). In Chapter 5, the pitch relationship between the output of Landini's (1992) algorithm and examples of real music was examined. The relationship was weak, adding further to the likely difficulty of discriminating fBm tone series. Nevertheless, the mean performance by Study 2 subjects on the scale estimation task was significantly better than chance.

The tasks employed in this research were not immune to the general criticisms which can be levelled at any testing procedure. For example, Serafine (1988) argues that the products of the analytic tools of music cognition have minimal cognitive reality. Such a position would hold that an instrument such as the MEK does not measure music ability; rather it simply reflects experience with tone tests. A strength of this research is that the independent measures of the Luria model battery do not leave such a claim unchallenged.

8.4. Recommendations for further research

Gordon (1993) argues that audiation is at the core of music ability. He recommends a three-level music curriculum based on individual differences of young children in their abilities to audiate. A first recommendation for further research is for an investigation of possible relationships between individual differences in audiation and abilities on the information processing dimensions of the Luria model. Use of the sensitivity to autocorrelation structure tasks in this context would also afford a replication of this study.

Pogonowski (1989) conceptualises executive control in music as a process of audiating alternate musical hypotheses in preparation for a musical plan, such as when improvising. As a second recommendation for further research, this suggestion could be directly tested through an investigation of individual differences in skills at improvisation and abilities on simultaneous, successive and executive syntheses.

The relationships found between music perceptual acuity and abilities in school mathematics and English language suggest, as Gardner (1993) himself acknowledges, that his seven intelligences are not necessarily independent. But, since common dimensions of information processing manifest only in specific domains, it would be prudent in educational contexts to maintain the notion of a separate music intelligence. A third recommendation for further research is to investigate relationships between individual differences in music intelligence and the other Gardner intelligences using the Luria model.

A fourth suggestion for further research concerns the superior disposition for learning by children with high music ability. A more sensitive investigation of this characteristic could be undertaken along the information processing dimensions of the Luria model by employing the psychometric approach of component learning curves suggested by Tucker (1955). Such an analysis may inform our understanding of the relationships between learning and music information encoding, and between learning and the creation of musical expectancies.

8.5 Concluding remarks

The motivating question for this research: "Why mozart?" is underscored by the more basic inquiry: "Why music?" Calvin (1994), in a review of the evolution of human intelligence, notes that the evolution of sequential processing followed a different path from the evolution of quasi-spatial reasoning leading to planning. These two dimensions of human information processing evolved in response to different kinaesthetic environmental selection pressures: slow sequences which permit response feedback, and fast sequences which require the formation of a total plan before enaction. Music and dance, as efferent behaviours which parallel these selection criteria, are the "by-products" of such evolved brains. It is by using their fundamental dimensions of information processing that these brains make sense of music.