AN EXPERIMENTAL INVESTIGATION INTO THE RELATIONSHIP BETWEEN PITCH-INTERVAL AND CONTOUR IN MELODY PROCESSING

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OR, WHAT BEETHOVEN KNEW ABOUT MUSIC PERCEPTION

BUT DIDN'T TELL

TABLE OF CONTENTS

		Page
ACKNOWLEDGEMENTS		i.
SUMMARY		ii.
LIST OF TABLES		iii.
LIST OF FIGURES		vi.
ABBREVIATIONS		viii.

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CHAPTER ONE: Approaches to understanding music perception.

1.1	Introduction	1
1.2	Psychophysical approaches	5
1.3	Absolute pitch studies	8
1.3.1	The possession of Absolute Pitch	9
1.3.2	The retention of Absolute Pitch	13
1.4	Multidimensional scaling approaches	16
1.5	Expectation and melody perception	21
1.6	Grouping mechanisms in music	26
1.7	Relationships in melodies	31
1.7.1	Musicological approaches	40
1.7.2	Psychological approaches	42
1.8	Summary and directions	47

CHAPTER TWO: Methodology.

2.1	Introduction	49
2.2	General methodology for Experiments 3 to 8	50
2.3	Selection of subjects	52
2.3.1	Differences between musicians and non-musicians	53
2.3.2	Musical ability	54
2.3.3	Aptitude vs Experience	55
2.4	Melodies used in the experiments	57
2.4.1	Beginnings of melodies	58
2.4.2	Range of intervals used	59
2.4.3	Tonality of melodies	60
2.4.4	Repetition of notes	60

2.4.5	Higher-order structures	61
2.4.6	Rhythm of melodies	61
2.4.7	Pitch-interval comparison melodies	62
2.4.8	Contour comparison melodies	63
2.5	Pitch-interval and contour	64
2.6	Interval between melodies in each trial	66
2.7	Use of an error detection paradigm	69
2.8	The choice of reaction time as a dependent variable	70
2.8.1	The use of reaction time as a dependent variable	70
2.8.2	The meaning of reaction time	72
2.8.3	Error rates and speed accuracy trade-off	74
2.8.4	The use of reaction times in the thesis	75
2.9	Summary	79

CHAPTER THREE: Testing the methodology.

3.1	Introduction	80
3.2	Experiment 1: Method	84
3.2.1	Subjects	84
3.2.2	Task	84
3.2.3	Design	86
3.2.4	Counterbalancing of subjects	86
3.2.5	Melodies	87
3.2.6.	Procedure	89
3.3	Results	93
3.4	Discussion	95
3.4.1	The laterality question	96
3.4.2	General points arising from Experiment 1	97

CHAPTER FOUR: Pitch-interval and contour in novel melodies transposed on the second hearing; the effect of length.

4.1	Introduction	101
4.2	Experiment 2: Method	108
4.2.1	Subjects	108
4.2.2	Task	108
4.2.3	Design	110

4.2.4 Melodies 110

4.2.5 Interval between first playing and comparison trial 115

4.2.6 Scoresheets 116

4.2.7 Procedure 116

4.3 Results 120

4.3.1 Criterion 1 122

4.3.2 Criterion 2 123

4.4 Discussion 126

4.4.1 Overall results 126

4.4.2 15-note melodies 128

4.4.3 General discussion 130

CHAPTER FIVE: Pitch-interval and contour in novel melodies transposed on the second hearing; investigating the task x length interaction.

5.1 Introduction 133

5.2 Experiment 3: Method 139

5.2.1 Subjects 139

5.2.2 Task 139

5.2.3 Design 140

5.2.4 Counterbalancing of subjects 140

5.2.5 Melodies 141

5.2.6 Distribution of alterations 142

5.2.7 Procedure 143

5.3 Results 146

5.3.1 Overall results 147

5.3.2 Serial position effects 150

5.3.3 Melodies of 3, 5, 7 and 9-notes 151

5.3.4 Overview of results for 3,5,7 and 9 note melodies 152

5.3.5 Melodies of 11,13 and 15-notes 154

5.3.6 Overview of results for 11,13, and 15-note melodies 156

5.4 General discussion 158

CHAPTER SIX: The salience of the tonal centre investigated through direct comparison of two different pitch-interval tasks.

6.1	Introduction	161
6.2	Experiment 4: Method	167
6.2.1	Subjects	167
6.2.2	Task	167
6.2.3	Design	168
6.2.4	Counterbalancing of subjects	168
6.2.5	Melodies	168
6.2.6	Procedure	170
6.3	Results	171
6.3.1	Experiment 4 only	171
6.3.2	Experiments 3 & 4	172
6.4	Discussion	175
6.4.1	Experiment 4	175
6.4.2	Comparison of Experiments 3 & 4	176
6.5	Introduction	183
6.6	Experiment 5: Method	185
6.6.1	Subjects	185
6.6.2	Task	185
6.6.3	Design	186
6.6.4	Counterbalancing of subjects	186
6.6.5	Melodies	186
6.6.6	Procedure	189
6.7	Results	191
6.8	Discussion	192

CHAPTER SEVEN: Implications of the results of Experiments 2, 3 and 4.

7.1	The study of melody processing	194
7.2	Pitch-interval and contour as cognitive codes	198
7.3	Musicological implications	202
7.4	Conclusion to Chapter 7	206

CHAPTER EIGHT: Pitch-interval and contour in novel melodies untransposed on the second hearing.

8.1	Introduction	207
8.1.1	Tests of melodic memory	210
8.1.2	Non-transposition in music	211
8.2	Experiment 6: Method	215
8.2.1	Subjects	215
8.2.2	Task	215
8.2.3	Design	216
8.2.4	Counterbalancing of subjects	217
8.2.5	Melodies	217
8.2.6	Procedure	220
8.3	Results	224
8.4	Discussion	226

CHAPTER NINE: Pitch-interval and contour in familiar melodies.

9.1	Introduction	235
9.2	Experiment 7: Method	241
9.2.1	Subjects	241
9.2.2	Task	241
9.2.3	Design	242
9.2.4	Counterbalancing of subjects	243
9.2.5	Melodies	243
9.2.6	Procedure	245
9.3	Results	248
9.4	Discussion	250

CHAPTER TEN: The relationship between pitch-interval, contour and key distance.

10.1	Introduction	256
10.2	Experiment 8: Method	268
10.2.1	Subjects	268
10.2.2	Task	268
10.2.3	Design	269
10.2.4	Counterbalancing of subjects	269
10.2.5	Melodies	269

10.2.6	Procedure	271
10.3	Results	274
10.4	Discussion	275

CHAPTER ELEVEN: Conclusions.

11.1	Summary of results	284
11.2	Issues arising I	290
11.2.1	The role of contour in music processing	290
11.2.2	The nature of the tonal centre	306
11.2.3	Relationship with other areas in cognitive psychology	320
11.3	Issues arising II	325
11.3.1	Generalisations from the experimental results	325
11.3.2	Relationship between music and music perception	332

CHAPTER TWELVE: Contour -- new directions? 339

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REFERENCES 349

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APPENDICES		**364**
Appendix 1:	**Experiment 1**	**364**
Appendix 2:	**Experiment 2**	**366**
Appendix 3:	**Experiments 3 & 4**	**372**
Appendix 4:	**Experiment 6**	**387**
Appendix 5:	**Experiment 7**	**389**
Appendix 6:	**Experiment 8**	**394**

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SUMMARY

The relationship between pitch-interval (precise intervals between notes) and contour (sequence of ups and downs) in melody processing was considered in eight experiments. Each experiment consisted of subjects listening to a number of melody pairs, the second in each pair serving as a comparison to the first. Depending upon the condition, subjects were required to attend to the pitch-interval or contour relationships in the first melody and to detect an alteration in that relationship in the comparison melody. A reaction time measure served as the dependent variable.

The methodology was tested in Experiment 1. Experiments 2,3 and 4 showed the relative salience of pitch-interval and contour to be a function of both melody length and serial position. Contour was found to be more salient for short melodies and at the beginnings of melodies, whereas pitch-interval was more salient for longer melodies and for later serial positions. In these experiments, the melodies heard were novel and their comparisons transposed. The results were interpreted in terms of the listeners' need to establish a tonal centre for the encoding of pitch-interval information which may not be necessary for the encoding of contour information. Until a tonal centre can be established contour is the more salient aspect of a melody. Pitch-interval and contour might therefore be of differing importance depending upon the current availability of a tonal centre during melody processing.

Experiment 5 investigated the effect of alteration size and no significant effects were found. Experiment 6 showed that when transposition effects are controlled for such that the comparison melodies were heard in the same key as the first melody, the pitch-interval relationships were more salient than the contour relationships but contour was still available to the listener. Experiment 7 showed pitch-interval to be more salient than contour when melodies were familiar. Thus both Experiments 6 and 7 show pitch-interval to be more important when a tonal centre is more readily available to the listener. Contour is still available, but less essential under these conditions.

Experiment 8 showed pitch-interval but not contour to be affected by key-distance, again showing pitch-interval encoding to be dependent upon a tonal centre which is not necessary for contour.

The experiments thus show contour always to be available but to be more or less important depending upon the availability of pitch-interval information which is in turn dependent upon the availability of a tonal centre. The relationship between pitch-interval and contour thus changes according to the salience of a tonal centre. Any condition which serves to make a tonal centre more available (particularly non-transposition or familiarity) also makes pitch-interval more available.

Contour is independent of a tonal centre and thus becomes more important in the total percept when tonality is confusing or unpredictable. This has implications for both the understanding of the cognitive processing of melodies and for the understanding of the role of contour in music itself.

LIST OF TABLES

		Page
3.1	Experiment 1: Design.	86
3.2	Experiment 1: Counterbalancing of subjects.	86
3.3	Experiment 1: Task x Ear x Hand ANOVA.	93
3.4	Experiment 1: Mean RTs for each Task/Ear/Hand condition.	93
3.5	Experiment 1: Task x Serial Position ANOVA.	94
3.6	Experiment 1: Mean RTs for each Task/Serial position condition.	94
4.1	Experiment 2: Design.	110
4.2	Experiment 2: Mean percentage accuracy scores for each Task/Length/Speed condition.	122
4.3	Experiment 2: Task x Length x Speed ANOVA (Criterion 1).	122
4.4	Experiment 2: Mean percentage accuracy scores for each Task/Length/Speed condition (Criterion 2).	123
4.5	Experiment 2: Task/Length x Speed ANOVA (Criterion 2).	123
4.6	Experiment 2: Mean percentage accuracy scores for each Task/Speed/Position condition for 15-note melodies (Criterion 1).	124
4.7	Experiment 2: Task x Speed x Position ANOVA for 15-note melodies.	124
5.1	Experiment 3: Design.	140
5.2	Experiment 3: Counterbalancing.	140
5.3	Experiment 3: Distribution of alterations for each melody length.	140
5.4	Mean reaction times for each Task/Length condition.	146
5.5	Task x Length ANOVA.	146
5.6	Experiment 3: Percentage accuracy scores for each Task/Length condition.	147
5.7	Experiment 3: Task x Length ANOVA (percentage accuracy data).	147

5.8 Summary of results of Task x Serial Position ANOVAs for 5,7 and 9-note melodies. 152

5.9 2-way Task x Position ANOVA for 5-note melodies (RT data). 152

5.10 2-way Task x Position ANOVA for 7-note melodies (RT data). 152

5.11 2-way Task x Position ANOVA for 9-note melodies (RT data). 152

5.12 Summary of results of Task x Serial Position ANOVAs for 11, 13 and 15-note melodies. 154

5.13 2-way Task x Position ANOVA for 11-note melodies (Percentage accuracy data). 154

5.14 2-way Task x Position ANOVA for 13-note melodies (Percentage accuracy data). 154

5.15 2-way Task x Position ANOVA for 15-note melodies (Percentage accuracy data). 154

6.1 Experiment 4: Design. 168

6.2 Experiment 4: Mean RTs for each Task/Length condition. 171

6.3 Experiment 4: Task x Length ANOVA (RT data). 171

6.4 Experiment 4: Mean percentage accuracy scores for each Task/Length condition. 172

6.5 Experiments 3 & 4: Comparison of mean RTs for each Task/Length condition. 172

6.6 Experiments 3 & 4: Comparison of percentage accuracy scores in each Task/Length condition. 172

6.7 Experiments 3 & 4: Experiment x Length ANOVA for P-I tasks (RT data). 173

6.8 Experiment 5: Design. 186

6.9 Experiment 5: Mean reaction time in each task/alteration condition. 191

6.10	Experiment 5: Task x Alteration size ANOVA (RT data).	191
8.1	Experiment 6: Design.	216
8.2	Experiment 6: Counterbalancing.	216
8.3	Experiment 6: Mean RTs for each Task/Length condition.	224
8.4	Experiment 6: Task x Length ANOVA (RT data).	224
9.1	Experiment 7: Design.	242
9.2	Experiment 7: Mean RTs for each Task/Position condition.	248
9.3	Task x Position ANOVA (RT data).	248
10.1	Experiment 8: Design.	269
10.2	Experiment 8: Mean RTs in each Task/Key condition.	274
10.3	Experiment 8: Task x Key ANOVA (RT data).	274

LIST OF FIGURES

		Page
3.1	Task x ear x hand interaction (Experiment 1).	93
3.2	Task x serial position interaction (Experiment 1).	94
4.1	Task x length interaction (Experiment 2, Criterion 1).	122
4.2	Task x length x speed interaction (Experiment 2, Criterion 1).	123
4.3	Task x position interaction (Experiment 2, Criterion 1).	124
4.4	Task x speed x position interaction (Experiment 2, Criterion 1).	125
4.5	Effect of position on task for moderate melodies only (Experiment 2, Criterion 1).	125
5.1	Task x length interaction (Experiment 3, RT data).	146
5.2	Task x length interaction (Experiment 3, Percentage accuracy data).	147
5.3	Task x position interaction for 5-note melodies (Experiment 3, RT data).	152
5.4	Task x position interaction for 7-note melodies (Experiment 3, RT data).	152
5.5	Task x position interaction for 9-note melodies (Experiment 3, RT data).	152
5.6	Task x position interaction for 11-note melodies (Experiment 3, Percentage accuracy data).	154
5.7	Relationship between task and position for 13-note melodies. (Experiment 3, Percentage accuracy data).	154
5.8	Relationship between task and position for 15-note melodies. (Experiment 3, Percentage accuracy data).	154
6.1	Relationship between task and length (Experiment 4, RT data).	172
6.2	Comparison of RT data from Experiments 3 & 4 (Pitch-interval data).	172
6.3	Comparison of RT data from Experiments 3 & 4 (Pitch-interval data).	172
6.4	Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (5-note melodies).	173
6.5	Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (7-note melodies).	173
6.6	Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (9-note melodies).	173
6.7	Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (11-note melodies).	173

6.8	Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (13-note melodies).	173
6.9	Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (15-note melodies).	173
8.1	Relationship between task and length (Experiment 6).	224
9.1	Task x position interaction (Experiment 7).	248
10.1	The circle of fifths.	261
10.2	Task x key condition interaction (Experiment 8).	274

ABBREVIATIONS

There are a number of abbreviations used in the figures. These are as follows:

P-I	Pitch-interval
CON	Contour
LH	Left Hand
RH	Right Hand
LE	Left Ear
RE	Right Ear
RT	Reaction Time
ms	milliseconds
MOD	Moderate

Unless specified otherwise the following symbols refer to:

———————————— Pitch-interval

-------------------- Contour

Musical examples: Musical examples of experimental melodies are always written out in the correct key. Other examples are in the correct key only if a score was available.

CHAPTER ONE

1.1 INTRODUCTION

It is said that, on her deathbed, Gertrude Stein was asked by her lifelong friend, Alice B. Toklas, "Oh Gertrude, what's the answer?" to which Miss Stein, formidable and incisive to the last, snapped "Never mind that, what's the _question_?".

Those wishing to understand music perception might learn from this vignette the virtue of being specific when asking questions, and to make it absolutely clear what the questions are before attempting to answer them.

All of an individual's reactions to music present too complex a system to be studied as a whole and to be realistic, empirical studies of music must be of well-defined components of the process. However, separating out the system may not always be an appropriate experimental technique, as _naturalistic_ music perception does not involve the processing of just pitch values, or just a contour, or just a rhythm, but the processing of a complex whole to which each element contributes more or less.

Given the complexity of music itself, the nature of _melody_ perception is the topic of consideration in the thesis. There are three main premises which underpin the methodological and conceptual stance taken. First, naturalism is considered to be of perhaps greatest importance. That is, general principles concerning melody perception are aimed at, and are investigated using 'typical' melodies. The experimental circumstances under which listeners hear melodies are always likened to natural listening situations.

Second, the link between musicology and psychology is considered in some detail, as it is supposed that there must be a link -- a strong link -- between the two.

Both premises stem from the fact that since music is a cultural product, compositional processes are linked to the very nature of music perception, as one, at least up to a point, should determine the other. It is also more important to investigate cases which reflect a listener's more usual experience than to investigate the way listeners might process atonal sequences, or tonal sequences that are notably unrealistic. By investigating the nature of typical melody processing, by using typical melodies, then more general principles about melody processing can be formulated.

The third premise is that the question "What makes a melody a melody?" is an important one to ask. In all types of music, melodies, usually in the form of themes or motifs, appear and reappear during the course of that piece. Often, these are not exact replications but are clearly related in the listener's judgment. The nature of these judgments shows which sorts of information the listener extracted from the melody on the first and subsquent hearings.

Music consists of tones and the most simple example of a series of related tones is a melody. Thus, the understanding of music perception might start with understanding the perception of simple, unrelated tones. However, it is likely that melody perception concerns additional processes to those involved in the perception of single tones. This first chapter reviews some of the approaches taken to the study of melody,and tone, perception, and each of these approaches are assessed in terms of their importance to the conceptual approach of the thesis.

Most current approaches to the understanding of melody perception fall somewhere between the extreme elementarism of Helmholtz (1885) and the extreme Gestaltism of von Ehrenfels (1937). Many of the studies to be reviewed in this chapter contribute to the understanding of melody perception, differing from the stance taken throughout the thesis, usually by being too atomistic.

This first chapter reviews some of the approaches taken to tone and melody perception and their relationship to the way melody perception is approached in the thesis outlined. It is not intended as a comprehensive review, which can be found, for example in Deutsch (1982c).

The first two topics to be reviewed are the psychophysical aspects of tone perception and the retention and identification of pitch. Melodies consist of notes possessing particular frequencies and so hence the capacity to retain and identify absolute pitch values also forms a topic to be reviewed.

The concept of pitch in both these topics is essentially unidimensional. Other views treat 'pitch' from a more cognitive -structural standpoint, taking account of the variety of relationships between notes of which the listener is aware. These approaches are also considered, starting with multidimensional scaling approaches to pitch perception. Studies of expectation in melody and music perception are then considered, which again take account of the interaction between the listener and the cognitive environment, showing how information theory can be applied to music processing.

Studies of grouping mechanisms in music are then considered, followed by a final section which discusses more naturalistic issues, bringing the topics of the thesis into focus.

The aim of this chapter is to review approaches to melody perception that are increasingly aligned to the approach taken in this thesis, starting with the psychophysical approach which is diametrically opposite to the stance taken, to the study of relationships in melody processing, which is directly the concern here.

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1.2 Psychophysical approaches

There are four main issues which concern the psychophysical researcher. These are, the nature of loudness, timbre, duration and pitch; the fourth is the particular topic reviewed here.

Helmholtz (1885) suggested that the nature of melodic perception could only be elucidated through complex analysis of the structure of the soundwave. However, there a number of anomalies which the psychophysical approach brings out and these make its application to the view of pitch taken in this thesis doubtful.

The central concern of the psychophysicist is to relate the objective, physical characteristics of a sound (in the case of pitch studies,the frequency of a note -- plus overtones in some cases) to its subjective interpretation. The main criticism of this approach from the point of view of this thesis is that the 'objective' is considered at all -- as Davies (1978) points out, the subjective is all-important in the study of the cognitive processing of melodies. Davies says:

> "...it should be apparent, therefore, that a person's response to a piece of music will be more fruitfully explored in terms of what he or she subjectively hears, rather than in terms of the music sound. The basic building blocks of music thus consist not of simple physical events, but of people's responses to these events" (p47).

An example of the way the relationship between the objective and the subjective nature of pitch has been studied by psychophysicists is that of the 'subjective' octave. It has been found that the distance between notes necessary for them to be labelled by the listener as an octave is slightly greater than the precise, objective distance where one note should be exactly double the frequency of the other (for example, Ward 1954; Sundberg & Lindqvist, 1973).

There is also other evidence to show that there are differences between 'subjective' and 'objective' pitch scaling (for example, Stevens & Volkman, 1940; Stevens & Galanter, 1957; Schneider, *et al* 1982). However, from the view taken in this thesis the objective is of no interest; the subjective is all-important. Thus, studies dealing with objective pitches and their subjective interpretation are of interest only from a general point of view, the main issue being seen as the nature of the subjective interpretation itself.

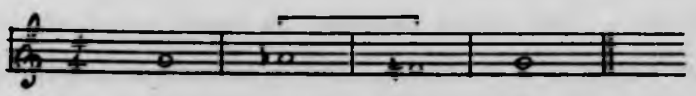
However, there are important aspects of psychophysical approaches which apply in very general terms to melody perception. They do not generally determine <u>what</u> happens in melody perception, but provide boundaries and show the limits of the perceptual system (Risset, 1978). Psychophysical studies can give the experimenter interested in melody perception broad limits in which to experiment.

For example, there is some evidence which shows that interval judgments are most accurate when the pitch of the notes heard lies somewhere between 60Hz and 4000Hz, which is also roughly the range of frequencies present on a piano (Guttman & Pruzansky, 1962).

Other work shows that there is a 'dominance area' for pitch between about 500Hz and 2,000Hz. This means that a complex tone, made up of a number of partials as well as a fundamental frequency, is likely to have its subjective frequency ascribed to some value between 500Hz and 2,000Hz. This might be the fundamental frequency, or a partial, of a tone (Plomp, 1967; Ritsma, 1967).

There are useful 'back-up' findings, then, that a psychophysical approach can supply to the experimenter interested in more cognitive aspects of melody perception. However, two criticisms limit its application to melody perception, even though it seeks to explain the interpretation of pitch events which are the basic units of melody. These criticisms have been recently put by Shepard (1982) who says that psychophysical approaches take no account of the context in which notes might be heard, and do not account for the multitude of subjective factors that the listener might bring to the situation. These undoubtedly have an important effect in melody perception.

Even in simple interval perception context can have a surprising effect. For example, the interval physically equal to an equally tempered major second can sound very much larger in the following context:



This is where the first (upper) of the two notes is a flattened supertonic and the second (lower) is a leading note. This interval sounds greater than a major second under these circumstances, especially when heard in the context of a Neapolitan sixth.

In summary, then, psychophysical approaches to pitch are not relevant to the study of melody perception where subjective factors are all-important. However, psychophysical studies can contribute to general issues in melody perception by setting limits within which melody perception must take place. Rasch & Plomp (1982) have recently suggested that it is difficult to decide which are the issues that the psychophysician should study in order to contribute to music perception. For melody perception, the subjective is considered to be of far greater importance than any objective properties of tones.

1.3 Absolute pitch studies

A melody is made up of a series of tones, thus the study of the nature of absolute pitch retention might be considered to be of some importance in understanding melody perception.

There are two main areas of concern here. First, the study of subjects who possess the ability to name a note in terms of its absolute frequency (known as 'Absolute Pitch' (AP)) -- do these people have greater ability at melody perception than people who do not possess this skill? Second, the study of pitch retention in the population as a whole -- does this relate to melody perception?

Each of these topics will be considered below.

1.3.1 The possession of Absolute Pitch (AP)

The ability to name a note in terms of its absolute frequency is generally termed Absolute Pitch (AP). This ability is variously praised and mocked as a skill in itself. Here, the relationship, if one exists, between this skill and melody perception is of interest.

Many uses of this skill have been suggested, for example Siegel (1976) suggested that AP helps to play an instrument in tune. However, practically, it is more likely that pitch discrimination is more important than AP itself. In addition, the player has to actually do something in order to correct him/herself if out of tune, and this implies skills of a different type, concerned with the practical problems involved in playing an instrument.

Similarly, Neu (1947) claimed that AP was nothing more than a fine degree of pitch discrimination. However, it is hard to see how naming a note is related to discrimination. Pitch discrimination is usually much more fine than the differences between normal scale steps; thus naming a note might be an entirely different task to discriminating pitch values that are much closer than those found in most musical situations.

Oakes (1951), found that AP was independent of the ability to discriminate pitch differences and this view has been recently stressed by Sloboda *(in press)*.

AP may not, therefore, be linked to pitch discrimination. Does pitch discrimination, then, relate to melody perception itself? Again, this link is not clear. For example, Deutsch (1969) reports findings by Wing (1948) and Trotter (1967) of subjects with good pitch discrimination skills whose melody perception was not very good at all. Of course, these may be just anomalies, but it makes the point that pitch discrimination does not necessarily relate to melody perception, which again may involve different processes.

AP, then, is not related to pitch discrimination, which in turn is not related to melody perception. It is worth considering why there is no such link.

There are several theories as to the origin of AP, the most plausible of which is that AP might be unlearned (for example, Abraham 1901). That is, the ability to retain absolute pitch values and to recognise notes as being the same frequency when heard on different occasions (without, of course, being able to put a name to these notes -- this part of the skill can only be learned) is fairly widespread at birth but is quickly lost. Pick (1979) considers why AP is lost, pointing out that the environment does not encourage a sense of AP.

A child, listening to a melody sung by its mother, would not know whether it is in the same key or a different key to when it was previously sung; father might also sing the same song, again at different pitch levels. So the ability to recognise a melody as being invariant even though it is heard in different keys is clearly important as far as the child's appreciation of music is concerned. Hennessy *et al* (1983) have recently shown that this ability emerges very early on.

A sense of relative pitch, then, is of much greater importance than a sense of absolute pitch. Relationships between notes are far more important than discrete pitch values. What, however, is really meant by relative pitch? This is one of the main concerns of the thesis and is discussed throughout. For now, relative pitch might be considered as awareness of relationships between notes rather than awareness of absolute frequency values.

Experiments have shown that absolute pitch is not correlated with relative pitch (for example, Ward 1954; Baggaley 1974), again demonstrating that there is no relationship between absolute pitch and the skills that are probably more important to melody perception itself.

Many studies of AP have shown how, even in experiments designed to investigate AP in those that possess the skill, 'distractors' have to be included between trials in order to stop subjects from inferring relationships between notes and thus reverting to 'relative' rather than absolute pitch as a source of reference (for example, studies by Abraham (1901), Mull (1925), Hartman (1954), and Hurni-Schlegel & Lang (1978) have all used distractors in order to prevent this from happening).

Thus, the tendency to infer relationships between notes is so great that possessors of AP infer relationships between notes even when, supposedly, they should have no need to do so. How much greater this tendency, then, in those of the population who do not possess this skill?

There have been many attempts to train AP (for example, Brady 1970; Cuddy 1968 & 1970). These all show that AP is hard to achieve and quickly disappears unless training is kept up. Cuddy's study (1970) is interesting as it shows that of two methods used to train AP, the method where only a few reference points were given led to better performance than where all note names were given. This can be interpreted as suggesting that when subjects are given a few reference points, they are better able to name notes in terms of their absolute frequency because they use these reference points as their basis and work out the notes they hear <u>relative</u> to this framework. When all note names were given, that is, listeners were trained by rote-learning, the names of all notes with which they were presented, performance was worse. Thus, when training took place on a completely absolute basis, performance was not as good as when some sorts of relative judgments could be made. This again shows the preference for some sense of relative, over completely absolute, pitch.

In summary, it can be said that AP is of little use in melody perception; relative pitch is much more important than AP and possessors are generally no better at melody perception than non-possessors (although, of course, good musicianship may contribute to both, and so AP might occur with good melody perception, but not be a necessary cause of it).

Relative pitch, though, is not totally relational in the sense that Kohler (1938) conceived of relational information; the conception of relative pitch in the thesis is not as a purely relational element, and so any approach to pitch which considers it as a totally relative phenomenon are also at variance with the ideas to be presented here.

1.3.2 The retention of absolute pitch

True AP is found in relatively few people. However, it has been found that most people can hold the absolute frequency value of a note in memory for quite some time, in some cases up to five minutes (Rakowski, 1972). Thus, non-possessors of AP can be thought of as possessors for short periods, for a restricted number of notes.

The concern of this section is to assess whether the retention of absolute pitch in memory is related to the perception and processing of melodies in general. This line of research has been followed by a number of researchers, in particular Deutsch (reviewed in Deutsch, 1982a).

The nature of the retention of absolute pitch initially sprang from studies of short-term memory such as those of Waugh & Norman (1965) and Broadbent (1958) Earlier work had shown that the retention of pitch deteriorated as a function of time (for example, Koester, 1945; Bachem, 1954). Wickelgren's work (1966, 1969) also suggested that pitch deteriorated in memory both as a function of time and intervening input. Deutsch (1970) suggests that Wickelgren confounded time delay with intervening material, and so set out to clarify this problem.

Deutsch studied the storage of pitch in a large number of experiments, using essentially the same experimental paradigm (in particular Deutsch, 1969, 1970, 1972a,1973, 1975a,1978a;more recently summarized in Deutsch 1982a). The standard procedure was to play subjects a note and then after a five-second pause, to play a 'probe' tone which was either different or the same as the first in terms of its absolute frequency. The task was to judge whether or not the first and the probe tones are the same in terms of absolute frequency. The main feature of these experiments is what happens in the five-second pause. The results show that, when nothing is presented in the five-second interval -- that is, it is silent -- then performance was 100%. This shows that pitch values can be retained over short periods if there is no intervening information.

However, when this interval is filled there are different effects. When the five-second interval is filled with information such as numbers, then little disruption takes place. If, however, the interval is filled with other tones, then performance drops markedly. This effect is particularly pronounced if the interval consists of tones that are close in pitch to the standard tone and probe tone.

The results of most of these experiments suggest that the presence of other tones is highly disruptive to the retention of absolute pitch information; the fact that notes that are closer in pitch are more disruptive than those that are further away in pitch suggests that even when subjects are asked to ignore these intervening tones, they tend to infer relationships between notes and thus find it difficult to retain the absolute nature of a note in memory whilst they are hearing other notes. It is logically easier to infer relationships between notes that are close than those that are far apart. However, the performance levels achieved show that even when intervening tones are heard, subjects are still able to retain the absolute nature of a note in memory. This is an important finding in relation to the thesis and relates to the hypothesis that relative pitch is not entirely relational; this will be developed later.

Deutsch's studies show that listeners infer relationships between notes whenever possible; thus the study of the retention of absolute pitch information suffers from the same problem as studies of the nature of AP reviewed above. That is, relationships between notes are of paramount importance and, wherever possible, listeners will infer relationships between them. Melody perception depends upon relationships between notes and so situations where subjects are asked to attend to discrete, absolute tones are so unusual that subjects try, as it were, to 'make a melody' out of the notes they hear, even if they are supposedly unrelated.

It must be remembered that the intervening sequences generally used by Deutsch were atonal in nature and so the results may not generalise to 'typical' melody perception.

In general, Deutsch's experiments show that memory for absolute pitch values is poor when heard within even a remotely melodic context (i.e. there are other tones present). The tendency to infer relationships even under these circumstances shows how much more strong this tendency might be when notes are heard in explicitly tonal contexts, and this is the next topic of consideration.

1.4 Multidimensional scaling approaches

Multidimensional scaling approaches deal with theories of how relationships between notes heard in an explicitly tonal context might be represented. This approach to music perception is more closely aligned to that taken in the thesis as it concerns the representation of relationships within a tonal context; however, both of these aspects are viewed rather differently in the thesis, and this will be made clear below.

A standard technique in multidimensional scaling studies (for example, Krumhansl 1979) is to play subjects a set of reference tones, either in the form of a scale or a tonic triad, which establishes a tonal context. Pairs of tones, over a large number of trials, are then played to subjects; they are asked to rate these on similarity. Thus, subjects might be played a pair that are an octave apart, a fifth apart, a second apart and so on. By analysing these similarity ratings, the types of relationships between notes of which listeners are aware can be assessed.

It is commonly found (for example, Shepard 1982) that listeners will rate notes that are an octave apart as being more similar than notes that are closer in terms of physical pitch values. This is true also for relationships of a fifth and other strong relationships. This shows that listeners are aware of higher-order relationships which can then be formalised.

The aim of multidimensional scaling studies is to discover the relationships between notes heard in an explicity tonal context of which the listener is aware, and to represent them as points on a geometric structure. Shepard (1982) serves as a typical example here.

Multidimensional scaling is a powerful technique for elucidating the relationships between notes of which listeners might be aware.

As far as the question "How are notes represented in an explicit, unchanging context?" is concerned, multidimensional scaling can provide an answer. However, the question itself is not the most interesting and appropriate to melody perception, from the point of view of this thesis. The Stein/Toklas problem is nowhere more apparent than here.

The link between multidimensional scaling and the studies carried out in the thesis breaks down on two specific conceptual differences, which will be discussed below. However, before that, a general comment on multidimensional scaling studies should be made.

It is clear that the dimensions isolated by Shepard (1982) are of primary importance in understanding the cognitive structures that a listener might use in the interpretation of pitch relationships. However, multidimensional scaling techniques are so powerful that a danger might be that more and more rather less important dimensions are isolated and the relationship between these dimensions and more naturalistic issues in melody perception might become more and more distant. The application of the findings of such sophisticated experimental techniques in general issues in melody perception may not always be appropriate.

Additionally, multidimensional studies present the listener with an explicitly tonal context and notes are presented in pairs rather than in any extended stimulus like a melody, which is too far removed from the real nature of music perception and that is where the conceptual stance taken here contrasts with the multidimensional scaling approach to music perception. The thesis acknowledges, like multidimensional scaling approaches, that relationships between notes are all-important; however, it differs in the following ways.

First, and most importantly, multidimensional scaling approaches only consider pitch relationships (intervals); there are other relationships between notes which may be important, and these will be discussed later.

Second, the tonal context with which multidimensional scaling studies are concerned is fixed by the experimenter. As far as the thesis is concerned there are two important questions to be considered with relation to this. The first is "How is this tonal context achieved by the listener under more naturalistic circumstances?". Davies (1979) makes it clear that under natural listening conditions, the listener is not given an explicit tonal context in which to place all subsequent tonal material. Thus this technique lacks realism.

The second criticism, or difference, between multidimensional scaling and the stance taken in the thesis is that it cannot explain the finding of Krumhansl (1979) that the relationships between notes seem to be related to some contextually established tonal centre.

This tonal centre is some sense of the tonic of a key at any one point, around which all other notes pivot. It is the establishment and nature of this tonal centre which sets apart the ideas considered to be of greatest importance in the thesis from multidimensional studies. It is worth noting that the <u>methodological</u> approach taken in the thesis bears no relationship at all to multidimensional scaling techniques in themselves.

The example given in the section on psychophysical studies, of the major second when heard in the specific context given, applies equally here. The objection raised was that psychophysical approaches cannot take account of this phenomenon; neither can multidimensional scaling studies, which cannot, at present, take account of particular relationships within a specific key of this type.

The next approach to melody perception to be considered can explain more fruitfully the nature of this phenomenon, as it considers in greater detail the nature of <u>current</u>, rather than specific and unchanging, context in melody perception and music perception more generally. It is thus considered, in the terms of this thesis, to be more naturalistic, which is the primary goal.

Multidimensional scaling studies, however, do move more towards realism than the psychophysical studies and the studies of pitch reviewed earlier, as they take some account of context and are concerned explicitly with relationships between notes.

1.5 Expectation and melody perception

In general, studies of expectation seek to investigate music, and melody, perception by applying the principles of information theory as originally expounded by Shannon & Weaver (1949). Studies of pattern perception are particularly appropriate to melody perception (for example, Garner 1974). Garner's theories have been broadly taken into the study of melody perception, for a melody is a good example of a pattern.

For example, Crozier (1974) applied information theory to melody perception by quantifying the different dimensions of music (for example,harmony, rhythm, pitch and so on). Thus, the greater the amount of information contained in each of these dimensions, the more complex the melody, or piece of music.

Applications of information theory to melody and music processing have made considerable contributions. For example, many models of music processing take some account of serial order. It has been emphasised earlier that the essence of even a simple melody is change over time, and this is implicit in serial order studies; serial order therefore should be an important concern in melody processing.

Models proposed by Simon & Sumner (1968), Restle (1970), and Martin (1972) all possess some concept of serial order which is central to their approach to melody perception. Simon & Sumner, for example, propose that transposition is a case where melodies possess the same serial order but where there are a different set of tones However, a number of factors have been found which affect the ease with which a melody can be recognised in transposition (for example, Cohen 1975; Cuddy & Cohen 1976). These include, contour, tonal strength and other factors.

Thus, serial order concepts are insufficient in themselves to explain transposition in melodies. Transposition, although not discussed in this chapter, is a very important aspect of listening under natural circumstances; although Davies (1979) suggests that, under normal circumstances, listeners do not know whether a melody has or has not been transposed, there are some important, natural circumstances under which listeners are aware that a transposition has or has not taken place. These will be discussed later.

A further example of the applications of information theory to music perception has been in the work of Meyer (1956, 1967; Rosner & Meyer, 1982) which presents a fusion between aesthetics and music. It is suggested that music processing continually involves anticipation of what is to follow, based on what has already been heard. Thus, current context is of great importance, and the nature of change over time in music is implicit in this approach to melody perception.

In Meyer's approach, expectancies which are highly predictable (that is, are of low information value) become uninteresting, whereas music that never fulfils expectations (that is, is of high informational value) is ultimately frustrating.

However, there are problems in applying information theory to taste and preference in this way. Novelty and complexity both affect listener's preferences (Berlyne 1974). In a naturalistic situation, one listener may never had heard a particular Mozart symphony before, but be conversant with Mozart's style; a second listener may be a Mozart expert and know the particular symphony well; a third listener may never have heard a Mozart symphony before. Each of the three listeners will bring different types of expectancies to the situation, and these will all have an effect in the listener's comprehension of the music.

The example above presents a fundamental problem in information theory-type approaches to music perception and this was epitomised sixty-two years ago by Bissell (1921):

> "...there is one universal fact of mental life that is of utmost importance as a basis of expectation, that is habit..." (p17).

Each piece of music has different complexity to every listener and this complexity itself will change with increasing familiarity. This question of 'subjective complexity' (Hargreaves, 1983) is a very serious one for this type of approach to melody processing.

Thus, information theory-type approaches to melody processing and music processing more generally, are considered to be appropriate to naturalistic situations; however, they are often thwarted by the fact that each different listener will bring different cognitive structures and expectations to any particular listening situation. Green & Courtis (1969) have criticised information theory approaches to music processing as well as other organised signals because they cannot take full account of the structures that the listener brings to the situation, although attempts are made to assess these structures in much of the work within this area.

For example, a recent study by Carlsen (1981) shows how expectations in music vary according to cultural milieu and musical experience.

Carlsen played subjects of differing musical experience and cultural milieu two-note sequences and asked them to continue singing as if these were the first two notes of a melody, emphasising that they were to sing what was expected, rather than what was interesting.

It is not so much the results of the study that are interesting but the way in which the experiment was carried out -- by asking subjects to continue singing from the opening motifs given. Thus, this methodological approach seeks to tap melody comprehension <u>as it actually occurs</u>, which is one of the aims of the thesis presented here. This again relates back to the very nature of music, and the importance of change over time. Very many interesting things are going on <u>while</u> melodies are heard, which deserve investigation.

The results of Carlsen's study are themselves interesting; he found that some melodic beginnings generated very strong expectancies (that is, almost all subjects continued these sequences in the same way); in addition, different beginnings generated different expectancies.

Carlsen also found differences across cultures, but not major effects for training. This shows how exposure to music of different cultures makes a difference to the types of sequences that would be predicted; however, it also shows how musical experience, within a culture, seems to have little effect under the circumstances.

In summary, expectancy approaches to melody and music processing, despite its drawbacks, would seem to be appropriate to understanding music processing in naturalistic situations. Notwithstanding the particular problem of 'subjective complexity', this approach takes account of current context in music perception, and is much more appropriate as a methodological approach which can be used to answer the question "What makes a melody a melody?" which is an important concern of this thesis.

There is a general trend in cognitive psychology towards taking account of ever-changing context and assessing the contribution made by the subject to the situation (for example, Neisser 1976). This approach is entirely appropriate to music perception, as the structures that a listener can bring to a situation are extensive, if a little subject-specific. The importance of change over time is probably more important in music perception than any other cognitive process.

However, attempts to quantify music as, for example, Crozier has done, suggest a misconception of music of considerable importance; separating out all the elements of a melody, or piece of music, does not reflect natural listening skills, another important focus in this thesis.

1.6 Grouping mechanisms in music

The study and elucidation of grouping mechanisms in music processing is particularly relevant to the work to be presented. Throughout, the conceptual, rather than the methodological, links are considered, but though the methodological approach to grouping mechanisms bears little similarity to the current methodology, the thoughts underlying grouping mechanisms, and the possible underlying reason for their existence, bear some similarities to the ideas presented in the thesis. For the present, grouping mechanisms themselves will be considered.

Many good recent reviews of grouping mechanisms are available (for example, Bregman 1981; Deutsch 1982b; Sloboda (in press)). The third in particular deals with possible evolutionary reasons for the existence of grouping mechanisms in music.

The primary topics are the ways, and under what sorts of circumstances, listeners will group tone sequences together, and attribute one group of sounds as one source, and another group of sounds as another source. Clearly this relates to one of the central questions outlined earlier -- that of what makes a melody a melody. The way listeners group sounds together sheds light on how one melody or theme might be differentiated from another in general terms. Gestalt principles (Wertheimer, 1923) are particularly important in the study of grouping mechanisms, particularly the principles of proximity and common fate. Proximity is particularly important and takes on a different, and slightly unusual, role in music perception.

It has been found (for example, Deutsch 1975b;Butler 1979) that the listener will tend to group sounds together if they are close in pitch; this tendency overrides almost all other tendencies. In the 'octave illusion' (Deutsch 1975b) subjects hear different notes dichotically. A high note is heard in one ear and a note an octave lower in the other. This is followed by the same notes, but going into the alternative ear -- so that the ear that heard the higher note now hears the lower note. This whole procedure is then repeated several times and the results show that listeners tend to ascribe all the higher notes to one ear, and all the lower notes to the other.

This demonstrates that the tendency to group by pitch proximity overrides the tendency to group by location. Butler (1979) has shown the tendency to group by pitch proximity to be very robust, even when there are timbral differences between notes ascribed to the same source, as well as location differences.

However, it is clear that listeners also group by differences in timbre alone,otherwise it would be difficult under some circumstances to tell the solo instrument from the orchestra in some concertos, and to tell a singer apart from a huge orchestral backing (for example, Sundberg 1982).

Grouping in music can, then, occur on the basis of timbre, loudness or location; the most interesting type of grouping, from the point of view of the thesis, is on the basis of pitch proximity. This has two distinct and contrasting implications for melody perception and shows how a melody might be heard as a unified whole and differentiated from another.

When notes lie in close pitch proximity there is a tendency to assign them to the same source -- thus a melody is more likely to be considered _as_ a melody if the pitch relationships consist mostly of small intervals. At the other extreme, notes that are actually part of the same source, but are a long way apart in terms of the pitch relationships, the listener tends to regard as two separate sources. This kind of 'pitch streaming' has been a topic of much research (for example, Bregman & Campbell 1971; van Noorden 1975; Bregman 1981). The nature of pitch streaming can be seen described in detail in Bregman (1981).

The tendency to group in terms of pitch proximity can address realistic questions raised by music itself and it is this that makes the relationship between the study of grouping mechanisms and the approach taken in this thesis closer than any of the other topics reviewed this far. For example, Dowling (1973) has demonstrated how two familiar, interleaved melodies can be more readily recognised and separated if they are further apart in pitch. Greater pitch separation, then, allows the subject to separate the melodies into two separate streams which cannot be done when they overlap in pitch. This has direct implications for the way music composed in this way might be perceived.

The technique of writing a melodic line which rapidly alternates between high and low lotes, or at least between notes that are quite separated in pitch, is quite widespread in music. It is best shown in the contrapuntal solo string writing of J.S. Bach. This music, although coming from only one instrument, sometimes sounds to the listener as two separate melodic lines. This, of course, was the intention of the composer. Composers use, then, the tendency to group notes together in terms of pitch proximity in order to produce the desired effects in their music and examples can be seen in both Deutsch (1982b) and Sloboda (in press).

Thus, grouping mechanism studies directly address problems in music, and make music perception approachable, at least on a very general basis. Studies of this kind can also address grouping mechanisms in more general terms, showing how a melody, or theme, or instrument, can be identified from the background; the figure/ground question is particularly appropriate in music perception due to the variety of things going on at the same time. The way one of these can be identified as 'figure' and the rest as 'ground' is a particularly interesting problem in music perception. Timbre differences obviously help in distinguishing a solo instrument from the backing orchestra but it is interesting to note how the composer will help this process by writing music that is different in nature to the orchestral music.

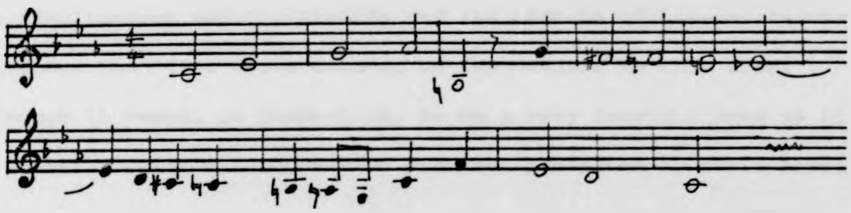
A good example of this on a small scale is the first movement of Mozart's clarinet quintet. The string quartet (accompaniment) starts with a very sedate, slow theme. The clarinet 'creeps' in, but quickly rises above the string quartet, playing different material. Thus the listener can discriminate figure from ground on the basis of timbre, pitch proximity or by more wholistic differences in material.

It is interesting to note that during the rise of the concerto in music history, from the concerto grosso, the difference between the music composed for the accompanying group and the nature of this group itself, in comparison to the solo instrument(s), dichotomised rapidly. In Bach's concerti grossi both instruments used and the music played in the solo instruments (the soli) were very similar to the backing group (concertini). Thus, there might be a solo group of two violins, viola da gamba and 'cello, and a backing group consisting of the same instruments but a larger number of them. The music played by both groups would also be very similar in nature.

In later concertos, the solo instrument is usually easily distinguished, timbrally, from the rest of the orchestra, but in addition, the music written for the solo instrument is different <u>in kind</u> from that written for the orchestra -- for example, there is no difficulty in discriminating figure from ground at the beginning of Tchaikovsky's First Piano Concerto!

The most interesting aspect of the way that the solo instrument and the accompanying group have become more and more dichotomised in music is that the relationship between compositional techniques and cognitive processes can be seen relatively easily. In order for the listener to discriminate figure and ground, the composer writes music that allows this to be done easily. Compositional processes and music itself depend upon each other in important ways, and it will be one of the main aims of the thesis to bring out this relationship.

The cognitive processing of fugues presents an interesting problem for figure/ground differentiation, as there really is no figure and ground -- all voices of a fugue are equally the figure. The problems of following a six-part fugue are therefore formidable and, for example, the fugue from Bach's Musical Offering is one of this type. The theme itself involves 11 of the 12 notes of the chromatic scale:



However, the notes are all close to one another and so the principle of pitch proximity can be seen to be particularly important in following this fugue in order to allow the listener to extract as much as possible. Following the fugue might, however, be made easier by orchestrating it so that grouping can also occur on the basis of timbre. It is interesting to note that Webern made an orchestral arrangement of this fugue. However, Webern arranged it so that each voice was played on a variety of instruments; thus, following an instrument would not be a way to simplify the problem presented by this fugue. Grouping by pitch proximity would also be no help because by sharing themes between instruments, the theme often jumps octaves.

It is unlikely, therefore, that many listeners can make any real sense of this arrangement but it is an interesting example of the sorts of problems studies of the cognitive processing of melodies could eventually address.

The problems involved in following several melodic lines at any one time is remarkably uninvestigated in music perception. A study by Sloboda & Edworthy (1981) concerns the processing of two simultaneous melodic strands and the effects of key-relatedness but other than this there seem to be few studies in this area, although it seems, on inspection, to be a very fruitful area as it is directly related to cognitive problems presented by music itself.

There are other, recent studies which search for more general principles about melody processing, again addressing the question "What makes a melody a melody?". In particular, studies made by Chew *et al* (1982) and Welker (1982) both investigate the nature of the abstraction of musical themes from melodic variations.

This type of study is paralleled in studies in other areas of cognitive psychology, particularly those of Franks & Bransford (for example, Franks & Bransford, 1971). In this experiment, subjects are asked to derive a geometric prototype from geometric variations. Translated to music, a prototype becomes a theme and variations become thematic variations. In studies of this kind the types of things that make a melody a melody, such as pitch relationships, or the contours, can be assessed and their importance to the total percept formalised.

However, it is not clear how far aspects of other types of cognitive psychology, particularly the methodological approaches taken, can be applied to music processing and comprehension. It is not really possible to compare the perception of geometric shapes to melody perception, unless the methodology is adapted to take account for the huge difference between the two. This is done to some extent in the studies reported above.

Another link between the thesis and grouping mechanism studies is that they describe what listeners do rather than suggesting, perhaps prematurely, how people might do it. It is essential to make the questions clear before the answers are attempted. The thesis is rather more concerned with what listeners might do, than with how they might do it. Pylyshyn (1972) makes the point that before mechanisms can be proposed by which information might be represented, it is necessary to establish what is represented. In terms of the search for realism in music processing this must be considered to be of utmost importance.

1.7 Relationships in melodies

All the approaches to tone, or melody, perception have thus far been concerned with the investigation of the pitch event in one form or another (usually in terms of pitch relationship, which are intervals). However, in the search for realism in the approach to music perception there are other types of relationships which should be considered.

Before these are discussed in greater detail a substantial contribution to understanding the encoding of interval relationships should be considered. Deutsch's work has also included studies of intervals, rather than the pitches in melodies. Deutsch (1969) proposed a neurological model in which pitch relationships are abstracted in order to internalise invariant interval relationships which in turn allows melodies to be recognised in whichever key they are heard. This model has been developed in more recent work (for example, Deutsch 1980; Deutsch & Feroe 1981; more recently reviewed in Deutsch 1982a), and deals with possible mechanisms involved in the processing of structured sequences and other overtly musical and realistic tasks.

However, the model that Deutsch proposes takes little account of the importance of change over time, as it contains an implicit assumption that all intervals heard are encoded in exactly the same way. Therefore, contextual effects and other important effects that are exclusive to melody perception are not taken account of. Deutsch draws an analogy between vision, comparing transposition in music to the work on vision in cats by Hubel & Wiesel (1962). It is hard to see the connection, as the primary features of music are so different to visual perception; this analogy is therefore very tenuous.

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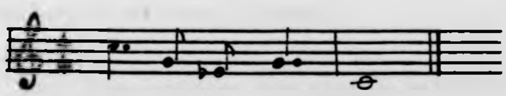
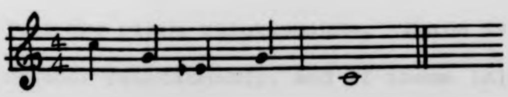
Deutsch's model takes little account of context and cannot, for example, account for the finding that some melodies are more easily recognisable when transposed than others (for example, Cohen 1975; Cuddy & Cohen 1976). Deutsch's model accounts for how melodies might be represented before establishing what is represented.

In music, themes (like melodies) appear and reappear over the course of the music; sometimes these reappearances are exactly the same in every way, but usually themes reappear in a slightly altered form. However, the listener is often aware that these themes are musically related; thus the question "What makes a melody a melody?" is a difficult one to answer, because themes that are in fact not exact repetitions will be recognised as being similar.

For example the theme below (A):



is clearly related to this theme (B):

which is related to this theme (C):

which is also related to the next theme (D):

which is in turn related to the first theme.

These variations represent transformations under different levels of invariance. (B) is a transformation of (A) in which the pitch values are kept the same, but the rhythm is altered; (C) is a variation of (B) where the rhythm and contour are preserved but the actual pitch values have been altered. (D) is related to (C) in that the pitch values are the same but the rhythm has been altered. (D) is related to (A) in that they both possess the same contour and rhythm but where the pitch values themselves have been altered.

This demonstrates how simple melodies can be related even though they are not exactly the same and also demonstrates that music consists of different types of relationship between notes, not just the pitch relationship. There is the rhythmic relationship, the contour relationship, and if theme (A) was played with two different sets of accompanying chords it could be established that the harmonic relationship is also important.

In addition, it is clear that all these different relationships go together to create the total percept and so separating them out represents an unnatural state of affairs for the listener (hence the earlier criticisms of expectancy studies which strive to quantify each of the relationships between notes).

The strength of the tendency to call a theme the same theme, or to call two themes related, is an index of the salience of the relationship(s) which have remained invariant on subsequent hearings. This in turn shows which of the types of relationship (pitch, contour, rhythm, harmony) was the most important relationship on the first hearing.

Thus when listening to real music, listeners represent the relationships between notes in a variety of ways, each of which may be more or less salient depending on the circumstances. The essentials of a melody are firmly rooted in change over time, therefore it is not necessary to assume that each of the relationships might be equally salient under all circumstances. At some points in a melody the pitch relationships might be most important, at other points the contour might be more more important, at others the rhythm and harmony might be more important. Music perception is definitely not the fixed system that some research assumes and the work of Jones (1978) particularly suggests that different note relationships vary in importance over time.

Experiments by Idson & Massaro (1978) and Kallman & Massaro (1979) investigate melody perception by manipulating some of the relationships between notes (octave, pitch and contour) but the 'melodies' produced sound so unlike those normally heard by subjects that it is difficult to see how the results might generalise to more natural circumstances. As Davies (1979) points out, manipulation of all the relationships in a melody does not make the results obtained from such large distortions logically necessary.

To investigate all these types of relationship clearly presents too large a problem, and thus two of the relationships between notes are considered in the thesis in detail. These are pitch (interval) relationships and the contour relationship.

The pitch relationship has been considered in earlier sections of this chapter where it was stressed that the dichotomy between absolute and relative pitch is perhaps an artificial one. The particular context which appears to be important in the interpretation of interval information seems to have a somewhat more absolute quality. Thus, this type of relationship between notes will be referred to as 'pitch-interval', which bridges the gap between the purely absolute and the purely relative, neither of which is entirely appropriate under the circumstances.

The contour relationship is the relationship between notes in terms of the direction of movement, or the shape, of a melody or theme regardless of the actual pitch-interval sizes. It is viewed slightly differently by differing groups of researchers, and this is discussed below. Contour relationships are of interest to both the musicologist and the psychologist, for rather different reasons.

1.7.1 Musicological approaches

Musicological approaches to contour tend to view it as a rather wholistic and global characteristic of music, considering it as being the 'shape' of a melody, theme, or larger unit of music. Some approaches to contour approach it in a more atomistic way, but in general melodic contour is considered as the sequence of movement of a melody or piece of music, with less emphasis on the pitch-interval relationships than a purely pitch-type description would entail.

Adams (1976) considers contour to be 'shape', 'configuration' or 'outline' and gives details on many of the approaches to melodic contour taken in musicological studies. Some studies view contour in a very global way, as simply the predominant configuration of a melody such as an arch-type shape, or a bow, which clearly does not take account of precise between-note differences (for example, Hood, 1971).

Other approaches are more specific and attempt to draw graphs of the melodic contour which takes account of the direction of movement of each successive note, and the _amount_ of change (for example, Herndon, 1974). However, this seems so specific as to be hardly differentiable from pitch-interval, in that it takes account both of direction of movement and amount of movement.

Other approaches have taken a much more simple view of contour, viewing it as the sequence of ups and downs in a theme where there are three main components -- up, down, or same. This is the starting point for Hoshovs'kyj's work, (for example, Hoshovs'kyj, 1965) although it is ultimately more complex. This appears to be a more fruitful view of contour as it clearly differentiates it from pitch-interval; however, it is possible to hold different views about contour and not degrade it as the different views of pitch-interval are extensive but do not degrade the importance of the relationship.

The main aim of musicologists is to classify melodies by different contours, rather than to look for psychological evidence that contour might be important in melody perception, however.

Adams (1976) questions whether contour has any status as an analytically independent aspect of music, but the nature of musicological evidence itself shows that contour seems to be an important aspect of many different types of music, which in turn suggests some sort of psychological reality for contour.

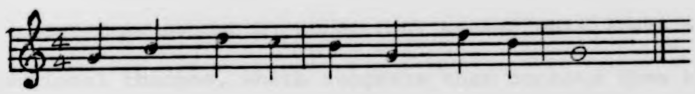
Contour replication (on a more wholistic basis) is important in jazz improvisation (Coker, 1964). Herzog (1937) suggests that contour invariance is perhaps the strongest influence in melodies which have otherwise been varied in some way.

Studies of the song 'Barbara Allen' (Kolinski, 1968; Seeger, 1966) show how the melody of this name has cropped up in various forms in many different cultures and it is interesting to note that many of these reoccurrences are contour-preserving rather than being exact repetitions.

Musicological evidence, then, suggests that contour is an important feature of melodies which are different but are somehow unified, that is, contour invariance is important even when other types of relationships might be different. This, in itself, suggests that contour is in some way salient to the listener. However, this is not the concern of the musicologist, but of the psychologist. Does contour have any psychological reality?

1.7.2 Psychological approaches

The view of contour differs between psychologists in much the same way as it does between musicologists. Deutsch (1982a) clearly views contour as a global characteristic of a melody, or piece of music. However, it is somewhat difficult to see why, given that her view of pitch is atomistic in the extreme.

Dowling (1982) considers contour in a much more specific way, as the sequence of ups and downs in a melody regardless of interval size. For example, the melody below can be expressed in terms of pitch-interval:

or contour:

This is the view of contour taken in the thesis, partly for the reason that this rather extreme view separates it clearly from pitch-interval (which is not done in some of the musicological approaches to contour). In order to investigate the psychological salience of contour, a somewhat extreme view is necessary, initially, in order to separate it from pitch-interval.

Many psychological studies of contour have taken this specific view of contour. Simon, for example (1972) suggests that melodies with simple contours (few direction changes) are easier to remember than those with lots of contour changes because they are lower in informational content. This attempt to quantify contour or any other relationship has already been criticised as being unrealistic. Rosser (1967) found that the recognition of six tones was made increasingly simple when the contour was made more simple. Divenyi & Hirsh (1974 & 1975) found that recognition of melodies improved when melodies with unidirectional contours were heard than when contours were more complex. Ortmann (1933) had earlier found the same thing.

This research shows that simple contours make melody perception (or short tone-sequence perception) easier when there are few directional changes, which suggests that contour does have some sort of psychological reality. However, some research has found that simple contours make melodies harder to remember than more complex ones. For example, Dowling & Bartlett (1981) in pilot studies found that unidirectional and V-shaped contours produced qualitatively different results to melodies with more complex contours. They found subjects had difficulty in retaining pitch-interval information when there were relatively few contour changes. Results are equivocal however, since other findings (for example, Taylor 1976) suggest that contour complexity has no effect on melody recognition.

All these studies attempt, in varying degrees, to quantify the contour relationship which, it has been previously suggested, is an unnatural situation. Pitch-interval and contour are undoubtedly related, and in order for the importance of contour to be elucidated situations must be devised in which natural sounding melodies are heard, where pitch-interval <u>and</u> contour are heard together, allowing the salience of each type of relationship to be assessed. It is likely, given the ever-changing nature of a melody, that sometimes contour will be particularly salient, while at other times pitch-interval might be of greater importance. One of the aims of the thesis is to investigate the relative salience of pitch-interval and contour in melody perception.

In doing so, the methodology used is taken from music itself, as the link between psychology and music is one that must be maintained if realism is to be introduced into studies of music perception.

The earlier example of thematic variation where rhythm, or contour, or pitch-interval is invariant but where other relationships change, is now narrowed down to just pitch-interval and contour. Throughout many different types of music thematic variation is introduced by preserving the contour but changing the precise pitch-interval relationships. The strength of the perceived relation between themes is an index of the salience of that particular relationship on the first hearing. Thus, the ease with which changes in either of these relationships are detected is also an index of the salience of that relationship. This is the essence of the methodology to be used throughout the thesis; it is derived from music itself.

However, there is an important problem in this type of approach and that is caused by the very nature of pitch-interval and contour themselves, and therefore cannot be avoided. That is, that a contour is implicit within pitch-interval values (a contour can be abstracted from pitch-interval values) but pitch-interval is not implicit in contour in the same way.

It is difficult, therefore, to manipulate pitch-interval and contour equivalently because of their differences; the only way this has really been achieved successfully is by Davies & Yelland (1977) where subjects were asked to draw contours of melodies. Thus naturalism is maintained by presenting both pitch-interval and contour at the same time and neither are manipulated in extreme ways.

However, Davies & Yelland's study clearly views contour as an abstraction from the precise pitch-interval values, which is not the view taken in this thesis. The aim is to assess the psychological reality of contour in the processing of 'typical' melodies. In doing so, subjects are asked to look for pitch-interval or contour invariance in specially composed melodies, which are composed as 'typical' melodies.

It is recognised that melody processing occurs on the basis of pitch-interval and contour, and that it is unnaturalistic to separate out these elements in this way. Thus, in asking subjects to look for contour or pitch-interval invariance, they are asked to turn their attention towards either of the elements in perhaps a slightly unnatural way. It is not thought that listeners can attend to one to the exclusion of the other, however.

The recognition of contour invariance, even though precise pitch-interval relationships have been changed, is an important part of the perception of thematic unity and probably occurs in realistic situations. Therefore the experimental technique is based on this realism, even though it presents some methodological problems, which will be considered in the following chapter.

1.8 Summary and directions

In music, themes appear and reappear in altered forms and yet listeners are often aware that they are related in some way. This shows the listener is aware of the relationships between notes and the fact that some relationships are invariant whilst others change.

In natural circumstances, all the relationships between notes are heard and processed simultaneously, and each may be more or less important in the total percept. The essence of music is change over time and thus one type of relationship may be more important, or salient, at one point in a piece of music whilst at another point a different type of relationship may be more important. Music itself suggests this.

Music is a cultural product and so observation of what actually happens when people are listening to music is very important. Experimental techniques based on typical musical experiences are more likely to reveal general principles about music processing than those that concern rather unusual conditions such as the processing of atonal sequences or the perception of single intervals or notes.

Two relationships between notes are considered in the thesis -- those of pitch-interval and contour. These are rather different types of relationship and it is likely that each may be more or less important to the listener under different circumstances. It is these circumstances that the thesis investigates, as well as how the relationship between pitch-interval and contour changes while a melody is heard.

Realism is an important aim and listeners are asked to listen to melodies that are broadly typical of melodies that would be heard under natural circumstances. In addition, listeners do not normally know <u>where</u>, in terms of tonal space, a piece of music will start, even if it is familiar. They do not know, for example, the absolute frequency of the first note. Thus, in the experiments reported here listeners are not generally 'prepared' for a stimulus as is done in some music research. (For example, in many tests of melodic memory subjects are given reference notes before each test starts). The aim throughout the thesis will be to reflect, in the experimental technique and materials used, a typical listening situation in order to address more realistic issues in melody perception.

In particular, the thesis will explore what relationships between notes are important to the listener; whether these change over the course of a melody and hence address the initial issue of what are the essential characteristics of a melody.

CHAPTER TWO

2.1 INTRODUCTION

In the last chapter, the differences between contour and pitch-interval were outlined; it is considered that they might both be important elements in melody perception, and might both be represented in some way. However, they are also very different with contour referring merely to the sequence of ups and downs but with pitch-interval concerning the amount of change in terms of absolute interval sizes.

Pitch-interval and contour are clearly different, thus the investigation of their relative importance poses several problems. The following chapter discusses some of the problems involved and presents a detailed methodology of the experiments to be reported. Apart from Experiments 1 and 2, the methodology for each experiment is essentially the same; this will be described in detail in the following sections. Further details of Experiments 1 and 2 will be found in their appropriate chapters (Chapters 3 & 4).

The last chapter emphasised the importance of presenting listeners with natural sounding melodies, thus in each of the experiments reported in the thesis, subjects are asked to listen to melodies and to direct their attention towards either the pitch-interval or the contour relationships. However, under natural circumstances it is likely that both are salient to some degree and so asking subjects to turn their attention towards the pitch-interval or contour is simply a way of assessing the salience of the relationship to the listener.

In each of the experiments subjects perform at least one pitch-interval and one contour task. In all cases a simple melody is heard. After a short pause a comparison melody is heard which, for the pitch-interval task, shares the same pitch-interval values but possesses one pitch-interval alteration. The task is to detect this alteration. In a contour task an initial melody is heard in the same way but subjects are asked to attend to the contour of this melody. The comparison melody shares only the same contour (although there are broad similarities, see discussion later); there is one contour alteration at one point in these comparison melodies and the task is again to detect this alteration and to press a button as quickly as possible. The reaction time is, then, a measure of the salience, or availability, of the pitch-interval or contour information at any point in a melody.

The reaction times obtained are not discussed in terms of the possible sub-processes which might be performed by the listener.This is in contrast to the more general use of reaction time data. For this reason, a detailed methodology is necessary. In the following pages a general methodology is given. The issues to be discussed in further detail are underlined.

2.2. General methodology for Experiments 3 to 8

In each experiment subjects, all musicians, were required to listen to specially composed melodies. These melodies were generated through a tone-generator attached to an LSI-11 minicomputer. The melodies were recorded on computer files where the frequency and duration of notes were specified in cycles per second and millisecond respectively. All melody files could be called up into a more general experiment-controlling program. Separate melody files were created for each experiment.

Subjects participated in a number of trials in each condition in each experiment, and the order of the trials was randomised separately for each subject in each of the conditions. The computer was set to run through the trials in this order before the experiment began.

Subjects always practised the task to be performed before each condition began, using specially-composed practice trials. The procedure for the practice trials was the same as for the experimental trials. In each experimental trial subjects were asked to listen to a melody of a specified length. This melody was heard binaurally through headphones at a loudness of approximately 80dB (the same for both ears). Subjects were asked to attend to the <u>pitch-interval or contour</u> of the melody.

After a 5-second pause a second melody was heard (either transposed or not, depending upon the experiment) which shared either the same <u>pitch-interval</u> values or the same <u>contour</u> throughout except that this comparison melody usually possessed one pitch-interval or contour alteration at one point; the task was to <u>detect this alteration</u> and to <u>press a button</u> as quickly as possible. Each trial proceeded in the same way and subjects initiated each successive trial using a foot pedal attached to the computer.

At the end of each block of trials, which usually constituted one experimental condition, a computer print-out specified:

(a) the number of each trial;

(b) the serial position of the note in which the button was pressed;

(c) the time in milliseconds from the start of that note to the moment of response.

The experiments were conducted in a laboratory in which there was little ambient noise. Only the subject and the experimenter were present in the laboratory.

The above presents a brief overview of the procedure used in Experiments 3 to 8. More specific details will be given in the appropriate chapters. The central methodological points (underlined) will be discussed below.

2.3 Selection of subjects

Subjects were required to have studied at least one musical instrument for a minimum period of five years and, in addition, were required to be currently taking lessons and participating in at least one musical activity (particularly orchestral playing). In any study of music processing there are several problems confronting the experimenter in the selection of subjects. These can be encapsulated in three specific questions:

(1) Are there qualitative, or merely quantitative, differences between musicians and non-musicians? Thus, can findings from experiments using only musicians be generalised to the population as a whole?

(2) What is meant by musical ability and how might it affect the outcome of particular experiments?

(3) How is musical aptitude related, if at all, to musical experience?

All three questions were considered before a subjects pool was decided upon,and will be considered below.

2.3.1 Differences between musicians and non-musicians

Some studies of music processing, particularly laterality studies, have found qualitative differences between musicians and non-musicians (for example, Bever & Chiarello, 1974; Johnson, 1977). Other laterality studies have fround no such differences (for example, Franklin, 1977).

A study by Hargreaves & Colman (1981) found that subjects' aesthetic responses to music varied considerably depending on musical training. Musicians tended to describe music 'objectively', that is, referring to structural points about the music (embodied aspects of the music) whereas non-musicians tended to note 'affective' aspects of the music (referring more to designative aspects of the music).

However, this does not in itself suggest that musicians and non-musicians process music differently -- musicians may perceive affective meaning in music but consider objective analysis more important, whilst non-musicians may perceive structure in music but be unable to describe it adequately.

Other studies suggest that differences between musicians and non-musicians may be quantitative, rather than qualitative. Sloboda & Edworthy (1981) found that when non-musicians were presented with a response measure which they could easily understand, the difference in performance levels between musicians and non-musicians was small. More recently Cuddy (1982) reports:

> "...in much of our work with pattern in tone sequences we have found the untrained listener to respond qualitatively in the same manner as the trained listener..." (p3).

Carlsen (1981) found no effect for musical training in his study of the expectancies created by different melody beginnings. Thus, studies specifically concerned with melody processing suggest that differences between musicians and non-musicians may be small and only quantitative in nature. This leads directly to the second question.

2.3.2 Musical ability

What is the nature of musicianship? Does the ability to play a musical instrument mean that one will score highly on a test of musical ability, or is music ability something different?

Of most importance is the possible relationship between musical ability and performance on the experimental task. Shuter-Dyson's (1981) extensive survey of musical ability shows that the measurement and assessment of musical ability is fraught with the same difficulties as intelligence measurement -- factor analysis reveals controversy over the nature of the ability itself, and different testsare differentially loaded for different factors.

Therefore assessing musical ability with tests might not be a guide to performance on the precise experimental task. For this reason subjects were not assessed in this way.

2.3.3 Aptitude vs Experience

Perhaps the most important question to ask is whether skill at playing a musical instrument and experience of music contributes towards performance in musical tasks.

Gaede *et al* (1978) found that laterality effects for aptitude were more important than experiential factors. Shuter-Dyson (1982) suggests that there is a broad distinction between musical aptitude and musical experience, and that aptitude might be of greater importance than experiential factors.

It is clear from most music perception experiments that subject groups are separated by experiential factors -- 'musicians' are subjects who play musical instruments, 'non-musicians' are those who do not. This, as any practising musician will report, implies nothing about aptitude, which may be the greater factor.

This definition, however, is convenient, and is the one used in the experiments to be reported in the thesis.

The answers to the three questions suggest that differences between musicians and non-musicians may be small, and that playing an instrument in itself suggests little about aptitude.

Thus, in the studies reported here the subject pool decided upon were practising 'musicians' who satisfied the criteria outlined at the beginning of this section. The main reason for this choice was that it was thought that musicians would be more confident in their responses and of their listening skills (non-musicians often report inability to perform a task even before they have attempted it) and to perform at a higher level which would, however, not be qualitatively different from responses made by non-musicians. Indeed, the problems of separating 'musical' from 'non-musical', as described above,makes any theory of qualitative differences difficult to uphold.

The 'average ability' of man (Blacking, 1971) is closer to the view taken here -- that man possesses an inherent 'musicality' which is somewhat independent of musical training.

Subjects were not screened before the start of the experiments for ability at the task to be performed, as is sometimes done (for example, Brown & Butler, 1981; Taylor, 1976; Deutsch, 1970). It is suggested that practices such as these may affect the result and any models suggested, based on the results, might be models of 'competent'melody processing only,rather than a more general model applying to subjects who are not very good at the task to be performed as well as those that are selected on the basis of pre-experiment screening.

Subjects were screened, however, for any hearing difficulties and were excluded from the experiment if they possessed any pronounced hearing difficulties.

All subjects satisfied the minimum criterion for musical experience (see the beginning of the section) but the range of experience was large -- from subjects just above the criterion to semi-professional. None of the subjects were fully professional.

2.4 Melodies used in the experiments

A large number of melodies were composed for use in the experiments and all of the melodies can be seen in Appendices 1 - 6. For each experiment a number of sets of melodies were composed, ranging from 2 - 14 sets, depending on the experiment.

For each set of melodies, comparison melodies were composed which were of two types -- pitch-interval or contour. The nature of the comparison melodies will be dealt with in a later section;

the present section concerns the nature of the constraints placed on the composition of the initial, original melodies.

One of the central purposes of the thesis is to create realism in the laboratory, that is, to reflect, experimentally, a listener's 'typical' melody experience. For that reason 'typical' melodies are desired. All the constraints placed on the composition of these melodies were a result of this central purpose. For all the original melodies these contraints were the same. These will be outlined below.

2.4.1. Beginnings of melodies

Bissell's (1921) extensive study of the opening of over 2,000 pieces of music covering a wide range of musical styles suggests that the most common opening sequence, by far, centres around the tonic triad -- 96% of openings, in fact, begin with one of the three notes from the tonic triad, with this note being the fifth or the tonic more commonly than the third. Bissell also considered the notes following the opening note and found that the first notes following were also very likely to be based on the tonic triad in some way.

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These findings were observed in the composition of the melodies used in the experiments -- almost all melodies began with notes based on the tonic triad.

2.4.2 Range of intervals used

Several cross-cultural studies (Ortmann, 1926; Fucks, 1962; Merriam, 1964; Dowling, 1967; Deutsch, 1978b) show that the occurrence of an interval in music in inversely related to its size -- thus the smaller an interval, the more frequent its occurrence. Bissell (1921) points out that the interval of a 4th is slightly less likely than the interval of a 5th, which appears to be the only anomaly in the general observation.

Experimental work (for example, Deutsch 1974; Olson & Hanson, 1977) shows that larger intervals may be more difficult to encode; it is not clear, however, whether it is the infrequency of these intervals that makes tnem difficult to encode (that is, their non-occurrence makes them difficult to encode) or whether it is their size itself, (that is, the task itself is difficult, perhaps in physiological terms). For the purposes of the thesis this does not matter; either way, smaller intervals should occur more frequently if a typical melodic experience is to be represented in the melodies.

Records were kept of the occurrence of intervals of each size in the melodies composed. In general, the smaller an interval the more frequent its occurrence; intervals larger than a 5th were fairly rare.

Taylor's (1972) extensive survey of the encoding of intervals in and out of musical context suggests a very complex relationship between interval and serial position -- different intervals are perceived more less easily as a function of their serial position. It was not possible, however, to observe Taylor's findings and compose melodic sequences; it was considered better to compose tuneful, typical melodies at the expense of ignoring some of the more specific and perhaps less important findings about interval encoding.

2.4.3 Tonality of melodies

By definition there are very few melodies in existence that are atonal; the melodies composed for the experiments were either strongly or moderately tonal (with a feel for a tonal centre). Before each experiment, one or two observers were asked to assess, informally, the tonality of each of the melodies to be used. They were reported to be of varying degrees of tonality, and weakly tonal melodies were rejected.

2.4.4 Repetition of notes

Cuddy & Lyons (1981) and Cuddy (1982) suggest that when a melody ends on the same note on which it started, recognition is easier, particularly when transposed. The melodies composed for the experiments reported in the thesis ended on either the tonic, the dominant, the subdominant or the mediant, all of which are important notes in any key. Melodies never ended on the supertonic, submediant or leading note.

In addition, no more than one repetition of a note was permitted in any one bar of a melody.

2.4.5 Higher-order structures

Structural devices based on the tonic triad and the scale, perhaps the most simple devices, are commonly found in simple melodies. Thus many of the melodies used in the experiments possess these structures.

In general, there were few constraints placed on the nature of the melodies composed. The most important 'constraint' was that they sounded like normal melodies and not artificial or odd. This was considered to be of paramount importance.

2.4.6 Rhythm of Melodies

In all experiments every note of every melody was exactly the same length (500ms) except for the last note which, depending upon melody length, was one second or two seconds long. In all cases the last note was lengthened so that it completed a bar. This was done in order to give the melodies a greater melodic plausibility.

Very occasionally a rule was broken in order to confer greater melodic sense. When all melodies had been composed they were assigned to either a 'pitch-interval comparison' or a 'contour comparison' condition. For each melody a comparison melody was composed which was to be used in either a pitch-interval or a contour task. There were additional constraints placed on the composition of these comparison melodies.

2.4.7 Pitch-interval comparison melodies

Each pitch interval comparison melody (apart from those to be used as catch trials), whether transposed or not, possessed one pitch-interval alteration in one serial position in the melody. There were several constraints placed on the nature of this alteration.

(a) The alteration was never smaller than a semitone and never larger than a third different to the original value of a note (relative to the key in which the comparison melody was written).

(b) The alteration was not normally outside the tonality of the melody; that is, the alteration was just as plausible, within the key, as the original note had been. This rule was observed for all experiments except Experiments 1 & 7, where the alterations were sometimes outside the tonality of the melody. This was necessary because few melodies were use in these experiments and so a lot of alterations had to be found. The range of alterations possible was small given constraint (c) below.

(c) Pitch-interval alterations always preserved the contour of the original melody, except in a very few cases where the nature of the melody did not allow this.

(d) For each set of comparison melodies, half on average possessed alterations that were higher than the original note (relative to the new key) and half possessed alterations that were lower than the original.

2.4.8 <u>Contour comparison melodies</u>

Each contour comparison melody that was to be used in an experimental trial possessed only the same contour but different intervals from the melody for which it was a comparison melody. In one serial position there was a contour alteration such that a note went up instead of down or *vice versa*. The constraints placed upon these contour comparison melodies was as follows:

(a) They were composed in such a way that apart from where the alteration occurred, the actual interval between notes did not vary by more than a third either greater or smaller than the equivalent interval in the first melody. Thus, although the intervals in the comparison melodies were different, they were kept, within broad limits, similar in size to the original intervals.

(b) The contour alterations were not outside the tonality of the melody and the resulting melody was just as tonal as the original. Throughout the whole of the comparison melodies the tonality was generally neither stronger nor weaker than the original melodies.

(c) For each set of comparison melodies composed half on average possessed alterations that went up instead of down, and half possessed alterations which went down instead of up.

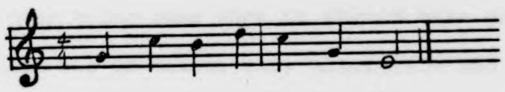
In most of the experiments (Experiments 2,3,4,5,7 & 8) the comparison melodies were heard in a different key to the original melody. When this occurred the transpositions always appeared at a higher pitch level than the original.

The melodies, when composed, were all placed on computer files. The range of frequencies used varied from 196 Hz (G below middle C) to 1175Hz (D two octaves above middle C), except for a few cases.

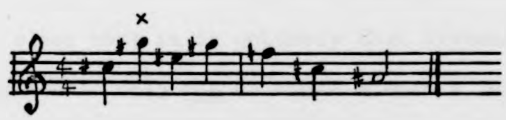
2.5 Pitch-interval and contour

The differences between pitch-interval and contour were demonstrated in the first chapter. In each experiment subjects were asked to perform at least one pitch-interval and one contour task and the melodies described in the previous sections were used for these tasks.

In the pitch-interval tasks they were asked to attend to the pitch-interval relationships of a melody. After a short pause a melody was heard in either the same or a different key, and this melody was the same as the first except that (in most cases) there was a pitch-interval alteration relative to the new key. For example, the subject might hear the melody below:

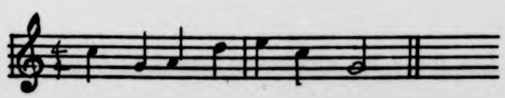


After a pause the comparison melody heard was as follows:

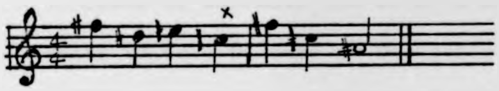


The task was to detect this alteration and to press a button as quickly as possible.

For the contour task subjects were asked to attend to the contour of a melody -- the sequence of ups and downs. For example, the subjects might be asked to attend to the contour of the melody below:



After a pause another melody was heard, either transposed or not, which shared only the same contour. For example,



This comparison melody usually possessed one contour alteration -- a note going down when it should have gone up or *vice versa*. The task was to detect this alteration and to press a button as quickly as possible.

It is clear that these tasks are very different and it is also clear that it is unlikely that listeners can turn their attention to only <u>one</u> of these elements, which are present in all melodies. Both contour and pitch-interval are part of the whole comprehension of a melody.

By asking subjects to attend to pitch-interval or contour the listener is merely asked to direct his or her attention towards one of these elements. It is not claimed, however, that listeners can turn their attention to one of the elements to the <u>exclusion</u> of the other.

2.6 <u>Interval between melodies in each trial</u>

There are two main variables to be considered in the setting of the intra-trial interval. These are:

(i) The effect of time delay on the decay of pitch information.

(ii) The effect of interference from other tones.

In order to estimate the effects of the two variables it is necessary to turn to some of Deutsch's earlier, more methodological work, which was reviewed in Chapter 1. For the purposes of this chapter, the methodological points are of most interest and these are that both time delay and the number of intervening tones effect the retention of pitch information.

In the experiments reported in Chapters 3,5,6,8,9 & 10, the interval between the end of the first melody and the start of the comparison melody is kept constant at five seconds. Thus, within any melody length, both the time interval and the amount of intervening information is kept constant. For example, a melody with an alteration on the fourth note would proceed as follows:

First melody	Interval	Second melody
1 2 3 4 5 x	5 seconds	1 2 3 4 5 x

The time interval between the first hearing of the note and its subsequent interval is 5 seconds + (time taken for 4 notes to play). The number of 'intervening' tones is four. This is the same for an alteration in any serial position.

However, for different length melodies, there is an almost unavoidable confounding of time interval with the number of intervening tones. For a 9-note melody, for example, the time interval between a note and its subsequent alteration is 5 seconds + (time taken for 8 notes to play); the number of intervening tones is 8.

The range of melody lengths investigated in this thesis, in particular those used in Experiments 3 & 4, is large and so the application of any technique which would keep the time interval between melodies constant over a wide variety of lengths would be almost impossible; the problem of the different numbers of intervening tones is, of course, wholly impossible if the processing of melodies of differing lengths is the topic under investigation.

Thus the interval between the first playing of a melody and its comparison is always kept constant at 5 seconds. This is done in all experiments except Experiment 2 where the introduction of melodies of different <u>speeds</u> created special problems; these will be dealt with in Chapter 4.

The general confounding of intervening material and time interval would predict that performance on longer melodies would be lower than performance on short melodies; this is the case throughout the thesis (apart from Experiment 7, where melodies were learned and so performance levels were higher). However, this is relatively unimportant as the thesis is concerned, throughout,with the comparison of levels of <u>salience</u> of pitch-interval and contour relationships. It is the relationship between the two, and not the absolute performance level, that is the topic of interest.

2.7 Use of an error detection paradigm

When subjects detected a pitch-interval or a contour alteration, they were required to press a button as quickly as possible. The assumptions behind what is going on in terms of cognitive activity between the onset of the stimulus and the moment of response is discussed in the next section; however, the use of an error detection paradigm requires some explanation in itself.

On hearing the first melody the listener retains a memory trace and it is the nature of this memory trace that the experiments are devised to investigate. On the second hearing this trace is compared with the melody now being heard, note-for-note in terms of either pitch-interval or contour (or, more realistically, both -- see the next section). The speed with which an alteration can be detected reflects the strength of the memory trace in terms of the type of information being investigated in the experiment. This suggests, in turn, the salience of the melody in terms of pitch-interval or contour on the first and second hearing.

Subjects are asked to detect an alteration in a specific type of relationship designated beforehand by the experimenter (either pitch-interval or contour). By this method, the criterion for incorrectness is clear; if subjects had been asked to judge whether a melody was the the same or not, the would have to continually assess the melody at a number of different levels throughout the whole of each melody. In that performance in music perception experiments is often very low, error-detection was chosen in order to enhance performance and to make the tasks as simple as possible.

2.8 The choice of reaction time as a dependent variable

Reaction times,as generally referred to in the psychological literature, are not entirely the same as they are used in this thesis. Reasons for this will become clear below. Before the use of a reaction time measure is considered in detail, more general and important aspects of reaction time measures must be taken into consideration. These are:

(i) The use of reaction time as a dependent variable.

(ii) The meaning of reaction time.

(iii) Error rates and the speed/accuracy trade-off.

Each of these factors are important in the selection of reaction time as a dependent variable and will be dealt with below.

2.8.1 The use of reaction time as a dependent variable

The use of reaction time as a variable in the investigation of substantive issues in cognitive psychology is widespread; in addition, the study of reaction time as a methodology in itself is an issue of some importance and it is necessary to note some of the more important issues raised by the methodological work, especially the possible existence of a speed/accuracy trade-off, to be discussed later.

Pachella (1974) states that reaction time as a dependent variable is often used by default- for unobservable cognitive activities, there simply isn't very much else to measure. Cognitive events must, at least, take time (Deese, 1969).

An important point that Pachella makes is that the use of <u>time</u> as the unit of measurement lends reliability to the data obtained, as it is undeniably a meaningful unit. In addition, time is resilient to arbitrary rescaling and, indeed, should not under most circumstances, be rescaled. Thus, in statistical analysis, particularly in the analysis of variance, any interactions obtained are likely to be that much more reliable and not artefacts of scaling methods which can introduce or eliminate interactions depending on the method used.

One purpose of the experiments described in the thesis is to investigate the nature of melody processing <u>as it actually occurs</u>; as Pachella points out, the only property of mental events that can be studied direct, in the intact organism, while these events are taking place, is their duration. This, again, points towards the use of reaction time paradigm.

There is a further important reason for the use of a reaction time measure, which is discussed in the introduction to Chapter 5. Williams (1975) carried out a study which has important implications for the effects of time delay between the onset of a stimulus and the moment or response, and this also suggests the use of a reaction time measure.

2.8.2 The meaning of reaction time

Reaction time is generally considered as the minimum amount of time required to make a correct response to a stimulus. This, in itself, is not an operational definition; the long and varied history of reaction time research has been greatly concerned with the nature and explanation of the cognitive events going on during this short period of time.

Basically, approaches to the nature of reaction time has fallen into two trends; one, following Donders (1868) sees reaction time as the total amount of time taken for the subject to perform a number of discrete stages of processing, with each stage beginning only after the last has been completed (recent examples include Sternberg, 1969a & b, 1975; Schweikert, 1978). This approach is still being followed.

However, these models were criticised relative early on (for example, Woodworth 1938; Woodworth & Schlosberg 1954). In direct contrast to the 'stage' models there have been many approaches to the study of reaction time which consider cognitive processes as continuous and rather more flexible, rather than as discrete, separate events. (For recent reviews of the most significant contributions in this area see Grice *et al*, 1982; Miller, 1982).

These models, although fundamentally contrasting in the way that they view cognitive processes, both seek to explain almost every millisecond in terms of some either discrete or parallel process. However, reaction time can also be used as a general index of task difficulty. This is particularly true of experiments which seek to address substantive issues in cognitive psychology rather than researching reaction time as a methodological issue *per se*.

It is also particularly true of experiments where reaction times are high. For example, Claxton (1980) points out that in Collins & Quillian's (1969) classic semantic memory experiment reaction times are between 1 and 1½ seconds. This is undoubtedly caused by the difficulty of the task; however, apart from a 75ms difference between conditions, they do not discuss where the rest of the time goes.

However, as far as Collins & Quillian's study is concerned, the activities taking place for the full second, or second-and-a-half, although interesting, are not central to their arguments. Moreover, it is the difference between the reaction times that is important. Reaction times are used in this same way in the experiments reported in the thesis, except that it is important to note that slower reaction times do not imply a steady accumulation of information. In contrast, they suggest relative unavailability of information.

2.8.3 Error rates and speed/accuracy trade-off

Most reaction time experiments achieve very low error rates, sometimes as low as 2% - 3%, which is usually achieved after practice at the task to be performed. In general, it is important to keep error rates down because a reaction time is, by definition, a correct response.

Pachella (1974) points out that even small fluctuations in error rates may affect results because of the existence of a trade-off between speed and accuracy (for example, Pew 1969; Pachella *et al*,1968; Rabbitt & Vyas, 1970). As the speed of reaction increases so error rates rise. This phenomenon has been extensively studied by, in particular, Rabbitt (for example, Rabbitt & Rogers, 1977, 1979). The value of practice is for the subject to assess his/her own performance and reach some optimum level of performance where they are neither making too many errors or responding too slowly.

However, returning to Collins & Quillian's study, they found that as reaction times rose, so error rates also rose. Therefore, in contrast to there being a speed/accuracy trade-off, both reaction time and number of errors were indices of the difficulty of the task. They discuss reaction time in preference to error rates as these are ultimately more revealing than the error rates.

When reaction times are used in the way Collins & Quillian use them and when there is a rise in error rates <u>with</u> slowing of reaction times, then the speed/accuracy trade-off may not be as crucial. In the experiments reported in the thesis, error rates are variable but it is always the case that as error rates rise, so reaction times slow.

However, it is not the case that all reaction time studies have resulted in low error rates. Keele (1973) reports a study by Fitts & Seeger (1953) where error rates were 20% for some conditions. Pachella (1974) cites an experiment carried out by himself where error rates were nearly 24%. Thus, even in situations where there might be a speed/accuracy trade-off, error rates are sometimes quite high and may substantially affect results.

2.8.4 <u>The use of reaction times in the thesis</u>

Reaction times have rarely been used in the study of <u>melody</u> perception, if at all. There are some studies concerning interval perception, using discrete intervals as stimuli (for example, Balzano 1978, 1982) and in the perception of single tones (Moss, *et al*, 1970). There are two central reasons for this, the first is that, typically, melody perception experiments result in high error rates and second, in an error-detection paradigm involving melodies, altered notes <u>appear</u> (even if they objectively do not) to occur at unpredictable intervals. Both these problems will be discussed briefly.

Experiments by Cohen (1975) give error rates of 70% in some conditions and some of the error rates in White's (1960) study of distorted melodies produced error rates of 85% in some conditions. More recently work by Cuddy (1982) gives error rates of 65% in some conditions.

Thus high error rates are common in melody perception experiments; this would be important if the speed/accuracy trade-off applied to the data obtained in the thesis. However, it has already been pointed out that error rates rose as reaction times slowed, and so high error rates, which are almost unavoidable in music perception experiments are not so crucial in this case.

The problems of responding to unpredictable events may be more important. Rabbitt (1981) points out that in real life people often have to respond to continuous rather than discrete signals. In the experiments reported in the thesis the melodies heard are viewed as continuous events. Rabbitt & Vyas (1980) comment on the fact that there has been little investigation into how people respond to sequences which occur at unpredictable intervals, a situation which appears to occur in the experiments reported in the thesis.

Rabbitt & Vyas carried out an investigation of this type of problem. They varied the time interval between the response task and the onset of the next signal from trial to trial, thus making the onset of each stimulus unpredictable. They found that apart from when very short time intervals occurred this time interval had little effect on the nature of the responses. Thus, in the experiments to be reported in this thesis, the unpredictability of the alterations in melodies is thought to have little effect.

Although no specific inferences will be made on the nature of the cognitive processes occurring between the onset of the stimulus (an altered note) and the moment of response (pressing the button), the reaction time is considered as a measure of the strength of availability of the information about which subjects are asked to make judgments. Reaction times are not broken down in any way but significant differences are commented upon.

For example,in a pitch-interval task, subjects are asked to attend to the pitch-interval relationships in a melody (see section 2.5 on pitch-interval and contour). After a pause they hear another melody, with which they must compare each subsequent note on the basis of pitch-interval. The speed with which an alteration can be detected suggests, ultimately, something about the availability of that information at that point, both in the memory trace and as the current melody is being processed. This in turn suggests the salience of that relationship.

In a similar way subjects are asked to compare contours of melodies heard in the same way. The speed with which this can be done reflects the salience and strength of this type of relationship at that moment (remember that it is unlikely that subjects attend to one or the other, but much more likely that they are attending both pitch-interval and contour).

In essence, then, significant differences in reaction times ultimately suggest that the type of relationship producing the significantly faster reaction times is, at any point, the more salient of the two.

Finally, some comment is necessary on the treatment of the raw data obtained. Reaction times are not excluded on the basis of their deviation from mean reaction times as fast or slow reaction times were considered to be possibly the most interesting and important. Thus, all reaction times of less than 2,000ms were taken and included in the results. Responses made after this, and anticipatory responses (those less than 160ms), were rejected. All other reaction times were included.

The data were always considered in two ways; both mean reaction times and percentage accuracy (calculated as the number of reaction times produced as a percentage of the total number possible in any condition) scores were taken. No data transformations were performed for the analysis of variance, the statistical technique used throughout. (For reasons for this see Keppel, 1973).

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2.9 Summary

In this chapter the methodological approach taken in the thesis has been considered in some detail, with the major points being discussed more specifically. More detail of specific procedures is given in each of the experimental chapters, especially where this deviates from the methodology given here. This will be particularly apparent for Experiments 1 and 2.

CHAPTER THREE

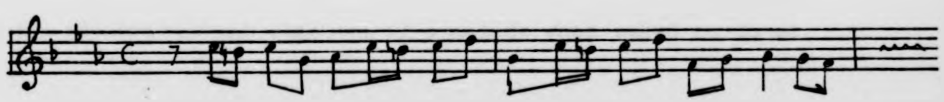
3.1 INTRODUCTION

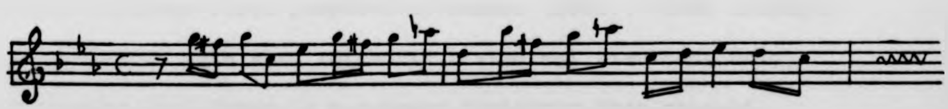
The thesis is concerned with the relative salience of pitch-interval and contour and when contour might be more salient than pitch-interval or *vice versa*, it does not fully endorse the idea that only pitch-interval values are important in melody perception.

One way to investigate the differences between the processing of pitch-interval and contour is to ask subjects to attend to each of these elements separately,as outlined in Chapter 2. The first experiment, which can be considered as a pilot study, tests the experimental procedure to be followed throughout the thesis. It aims to discover whether, when requested to do so, subjects can turn their attention towards the pitch-interval values and the contour of a melody. A secondary purpose of this experiment is to test for any laterality effects which may occur.

Work on music processing and hemispheric differences was carried out by Kimura (1961, 1964, 1967) and Milner (1962). Both of these researchers suggested that the right hemisphere was more suited to dealing with musical material than the left hemisphere. This hypothesis was supported by the data, and stems from the idea that the left hemisphere is concerned with language and serial, analytic tasks, and the right with 'non-language', especially spatial, tasks (for example, Levy-Agresti & Sperry,1968). Much of this early work, however, tended to view music as an almost unidimensional stimulus, with little regard for the complexity and diversity present in even a simple melody.

The assumption that music, with all its complexity might be mediated by only one cerebral hemisphere under all circumstances, and regardless of musical training, is probably erroneous. For example, different elements of music might be differentially mediated by the cerebral hemispheres. This view was put forward in particular by Gates & Bradshaw (1977a & b). They suggest that when, for example, a person listens to a fugue, both the pitch-interval values and the contour are important. Tonal answers are contour-preserving but do not preserve the precise interval values. For example, Fugue II from Book I of the 48 Preludes and Fugues (the Well-tempered Klavier) by Bach has first and second voices as follows:

First voice:

Second voice:



Tonal answers do more than just preserve contour -- they are usually musical paraphrases which, on the whole, preserve contour. Gates & Bradshaw suggest that pitch-interval <u>and</u> contour are important in comprehending fugues, and suggest that these two elements might be differentially mediated by the cerebral hemispheres, with pitch-interval information being mediated by the left hemisphere because it is serial in nature, and contour being mediated by the right hemisphere because it is a more wholistic and even perhaps spatial element of a melody of theme. If such laterality effects are present, then it is important to control for them in any experimental investigation of the processing of pitch-interval and contour.

In this first experiment, any possible laterality effects are controlled for,though the laterality question is not a central concern. The central concern is to determine whether or not subjects can direct their attention towards the contour and the pitch-interval elements of a melody when asked to do so.

Laterality effects are controlled for by using a dichotic listening paradigm first proposed by Kimura (1961). When messages are presented to both ears (dichotic listening) simultaneously, it is thought that there is a greater certainty that stimuli going into one ear will travel to the contralateral ear than when monaural stimulation occurs. In addition, Darwin (1974) suggests that ear/hemisphere cross-over occurs to an even greater degree when messages going to the unattended ear are similar in some way to that going into the attended ear.

In this pilot experiment, subjects were required to learn the pitch-interval values and the contour of a melody on different occasions. After learning they were required in each experimental trial, to detect changes in either of these features in comparison melodies, depending on the task being performed. Half of the time the melodies were heard in one ear and half of the time in the other. Random frequencies were presented to the unattended ear in order to enhance ear/cortex cross-over (Darwin, 1974). The response measure taken was a reaction time. In addition, the hand of response was controlled for. Subjects were asked to press a button as quickly as possible when they detected either pitch-interval or contour alterations in the comparison melodies which they heard.

EXPERIMENT ONE

3.2 METHOD

3.2.1. Subjects: 16 subjects participated in two experimental sessions. Every subject was a musician who had been learning at least one musical instrument for a minimum of five years during the period immediately prior to the experiment.

3.2.2. Task: Subjects took part in two sessions, one of which will be referred to as pitch-interval, the other as contour.

In the pitch-interval task subjects were required to listen to a melody ten times. The melody was 13 notes long and was always heard in the key of F major. The melody was heard monaurally, five times in one ear and five times in the other (counterbalanced across subjects). They were required to attend to the pitch-interval relationships in this melody, and to learn them.

After the learning phase, subjects participated in 24 experimental trials. In each trial, the original melody was heard again in the same key. After a five second pause, the same melody was heard in the same key.

This comparison melody usually possessed one pitch-interval alteration at one point in the melody. The task was to detect this alteration and to press a button as quickly as possible. In 20 trials the comparison melody possessed an alteration, in 4 trials the comparison melody was exactly the same as the original melody and was thus a catch trial.

The melodies were always heard monaurally, and ear of presentation was controlled for, as was the hand of response (see Design section below). Random frequencies were played into the unattended ear throughout the experiment (except for the learning phase).

In the contour session, subjects were required to learn the contour of the same melody over ten learning trials. The melody was always heard in the key of F major.

The experimental trials proceeded in exactly the same way as for the pitch-interval task, but in each trial subjects were required to compare the contour of the learned melody with the contour of another melody sharing only the same contour. Most of the comparison melodies possessed one contour alteration. The task was to detect this alteration and to press a button as quickly as possible. There were again 20 trials of this type, and four trials where the comparison melody shared the same contour as the original melody throughout. These were catch trials.

Again the melodies were always heard monaurally, and ear of presentation and hand of response were controlled for (see Design section below). Random frequencies were heard in the unattended ear throughout the experiment, with the exception of the learning phase.

3.2.3. Design: there were 4 nested factors - Task (pitch-interval/contour); Ear (left/right); Hand (left/right), and position of alteration within comparison melody (from serial position 2 to serial position 12). The design was as set out in Table 3.1. The fourth factor, the position of the alteration within the melodies,was randomised as the order of the 24 trials was randomised for each subject.

3.2.4. Counterbalancing of subjects:

Learning phase: Half of the subjects began by hearing the melody in the left ear, half in the right. The order was then reversed for the second five learning trials. In the second session, the order of ears was reversed from what it had been for that subject in the previous session.

TASK	P-I(24)				CONTOUR(24)			
EAR	LEFT(12)		RIGHT(12)		LEFT(12)		RIGHT(12)	
HAND	LEFT (6)	RIGHT (6)	LEFT (6)	RIGHT (6)	LEFT (6)	RIGHT (6)	LEFT (6)	RIGHT (6)
EXPERIMENTAL TRIALS	5	5	5	5	5	5	5	5
CATCH TRIALS	1	1	1	1	1	1	1	1

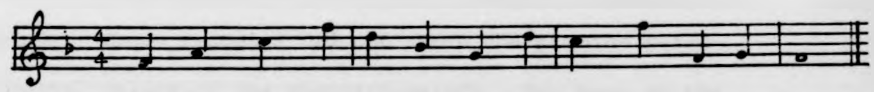
Table 3.1 Experiment 1: Design.
( ) = number of trials.

SUBJECT No.	TASK ORDER	EAR ORDER	HAND ORDER
1, 9	P-I, C	L, R	L, R
2, 10	P-I, C	L, R	R, L
3, 11	P-I, C	R, L	L, R
4, 12	P-I, C	R, L	R, L
5, 13	C, P-I	L, R	L, R
6, 14	C, P-I	L, R	R, L
7, 15	C, P-I	R, L	L, R
8, 16	C, P-I	R, L	R, L

Table 3.2 Experiment 1: Counterbalancing of subjects.

Experimental phase: the 24 trials were blocked in four groups or 6 trials, one group for each ear/hand condition. Counterbalancing of the blocks was as described in Table 3.2. The order of the 24 trials, however, was randomised separately for each subject. Each ear/hand block consisted of 5 experimental trials and 1 catch trial. The position of each catch trial within an ear/hand block was also randomised.

3.2.5. Melodies: one standard melody was composed as follows:



Two sets of comparison melodies were composed, one for the pitch-interval task (A) and one for the contour task (B).

(A) Pitch-interval

Twenty variations on the melody were composed, each of which possessed one pitch-interval alteration. This alteration was by either a semitone or larger. An example of one of these comparison melodies can be seen below.

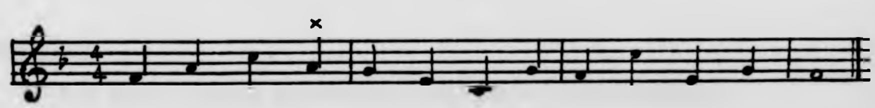
The twenty alterations were distributed throughout the twenty melodies in the following way:

Serial position	2	3	4	5	6	7	8	9	10	11	12
No. alterations	2	2	2	1	2	2	2	1	2	2	2

There were no alterations on the first or the last notes. There were also four catch trials in this part of the experiment, and for these the original melody was used.

(B) Contour

Twenty variations on the melody were composed, each of which shared only the same contour as the original melody. These melodies did not share the precise pitch-interval values of the standard melody. For each of the 20 melodies, there was one contour alteration at one point in the melody. An example can be seen below.



The twenty alterations were distributed throughout the twenty melodies in the following way.

Serial position	2	3	4	5	6	7	8	9	10	11	12
No. alterations	2	2	2	2	2	1	2	2	2	2	1

There were no alterations on the first or the last notes.

In addition to these twenty melodies, four melodies were composed which shared the same contour as the standard melody throughout. These were used as catch trials in the experiment. An example can be seen below.

All the melodies used in this experiment can be seen in Appendix 1.

A series of random frequencies was generated within the same range as the melodies themselves and were recorded on a Tandberg reel-to-reel tape recorder. These were played in the unattended ear throughout the experiment, except for the initial learning phase.

3.2.6. Procedure

For each of the tasks (pitch-interval and contour) the order of the 20 experimental trials was randomised for each subject. These were then divided into four blocks of five trials and placed in the appropriate cell (see Tables 3.1 and 3.2). In addition, one catch trial was placed within each block, and the position of this trial was randomised for each of the subjects in each of the conditions. For the contour task, the order of the catch trials was also randomised, as each catch trial was different. When the 24 trials had been arranged in this way for each of the subjects, the experiment proceeded as follows.

Pitch-interval Task

1. Each subject heard the standard melody 10 times monaurally, 5 times in each ear. The subject was asked to attend to, and learn, the pitch-interval relationships in this melody. The melody was always heard in F major.

2. After the learning phase, the subject practised the experimental task over 4 practice trials (specially composed).

3. In each experimental trial, the standard melody was heard, always in F major. After a five-second pause, the melody was heard again but usually possessed one pitch-interval alteration. On detecting this alteration the subject was required to press a button as quickly as possible.

4. The melody was always heard monaurally. During the experimental phase, random frequencies within the same range of the melodies were heard in the unattended ear.

5. Subjects controlled the starting of each trial with the button used for responses.

6. The order of the ear and hand conditions was presented as described in Table 3.2, and the order of the twenty experimental trials was randomised, as described earlier.

7. There were four catch trials where the comparison melody was an exact repetition of the standard melody. There was one catch trial for each of the ear/hand blocks. Melodies described in Melodies A were used in this part of the experiment.

Contour Task

1. Each subject heard the standard melody 10 times monaurally, 5 times in each ear. The subject was required to learn the contour of the melody. The melody was always in the key of F major.

2. After the learning phase, the subject practised the experimental task over four practice trials.

3. In each experimental trial the procedure was exactly the same as for the pitch-interval task except that subjects were

required to compare the contour of the comparison melody with that of the standard melody and to detect alterations in the contour at one point in the comparison melody. On detecting this alteration, the subject was required to press a button as quickly as possible.

4. The experiment proceeded in exactly the same way as the pitch-interval task. The order of the ear and hand conditions was presented as described in Table 3.2, and the order of the 20 experimental trials was randomised for each subject.

5. There were 4 catch trials where the contour of the comparison melody was exactly the same as the standard melody. There was one catch trial in each of the ear/hand conditions, and as well as the position of the catch trial being randomised, the order of the four catch trials was randomised for each subject separately, as the catch trials were different. Melodies described in Melodies B were used in this part of the experiment.

The melodies were heard at a level of 80db with random frequencies being heard at a lower level, 60db. The melodies were filed on flexible disks where the frequency of a note and its length were specified. The melodies were generated by a Farnell DSG oscillator attached to a microcomputer.

The microcomputer controlled the measuring of the reaction time as well as the generation of the melodies.

3.3 RESULTS

A mean reaction time was calculated for each subject in each of the conditions. Collapsing across position of alteration, the fourth factor, and considering only the task (pitch-interval/contour), ear (left/right), and hand (left/right) conditions, a 3-way analysis of variance was carried out. The results can be seen in Table 3.3.

(Note: The lowest number of reaction times produced for any condition was 3, and so the 3 fastest RTs for each condition were taken in this analysis).

There are no significant main effects, no significant 2-way interactions, but a significant 3-way interaction between the three factors Task x Ear x Hand. The means for each of the conditions can be seen in Table 3.4 and the interaction can be seen illustrated in Figure 3.1 *Post hoc* analysis (Tukey's a) reveals a critical value of 32ms for significance at the 0.05 level and a value of 44.8ms for significance at the 0.01 level.

A second 2-way analysis of variance was carried out collapsing across ear and hand conditions, considering only the task (pitch-interval/contour) and serial position of alteration (serial notes 2 to 12) factors. There was

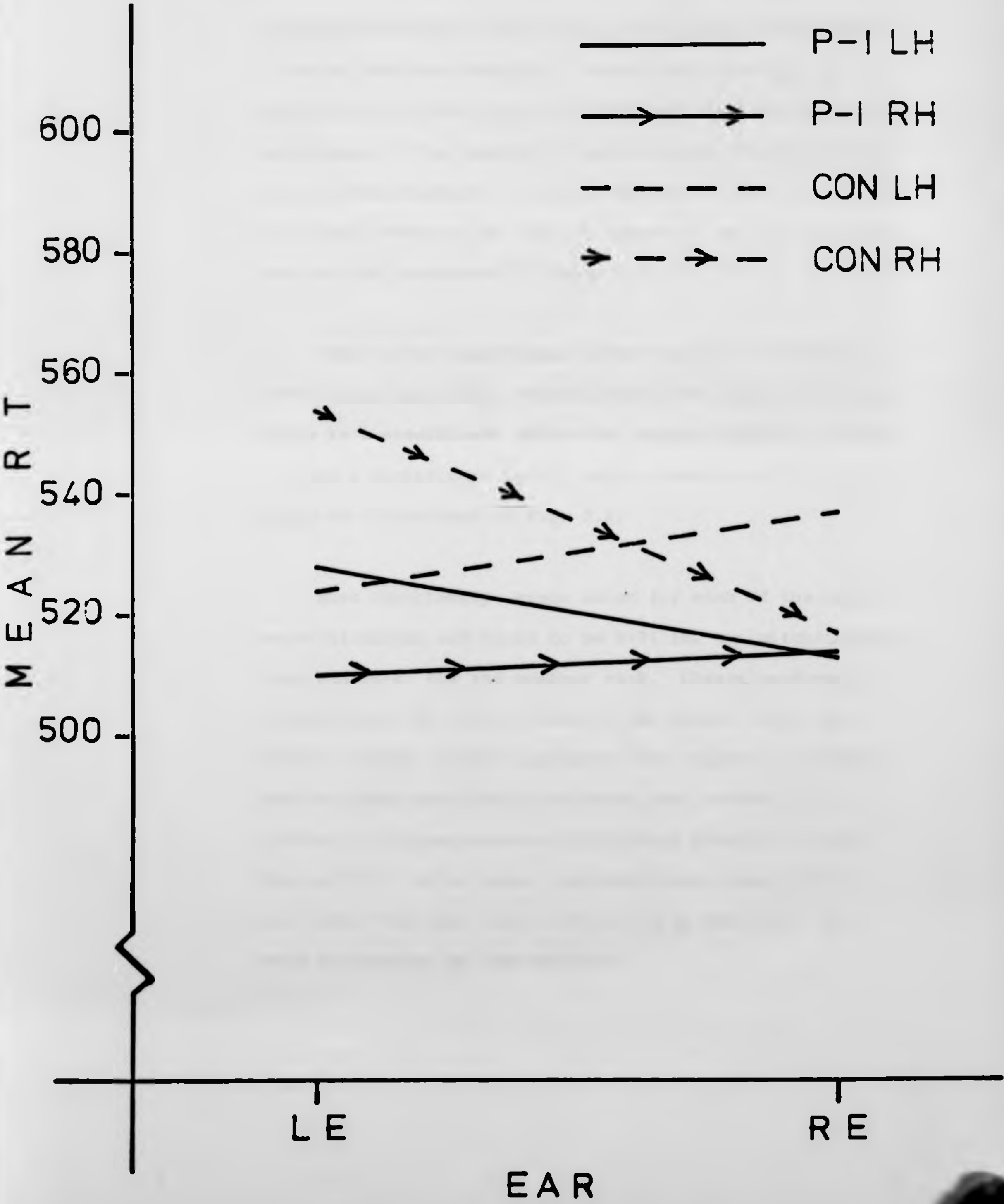
SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	35224371·9	1	35224371·9		
ERROR (WITHIN SUBJECTS)	709460·2	15	47297·3		
TASK	9129·4	1	9129·4	0·88	0·36
ERROR (TASK)	155514·2	15	10367·6		
EAR	2458·8	1	2458·8	0·47	0·5
ERROR (EAR)	78063·4	15	5204·2		
TASK x EAR	273·2	1	273·2	0·07	0·8
ERROR (TASK x EAR)	57362·4	15	3824·2		
HAND	70·5	1	70·5	0·01	0·9
ERROR (HAND)	77898·1	15	5193·2		
TASK x HAND	1505·6	1	1505·6	0·25	0·6
ERROR (TASK x HAND)	91529·5	15	6102·0		
EAR x HAND	1976·6	1	1976·6	0·31	0·6
ERROR (EAR x HAND)	95083·0	15	6338·9		
TASK x EAR x HAND	9265·1	1	9265·1	5·01	$<0·05$
ERROR (TASK x EAR x HAND)	27733·1	15	1848·9		

Table 3.3 Experiment 1: Task x Ear x Hand ANOVA

CONDITION			MEAN REACTION TIME (ms)
P-I	LEFT EAR	LEFT HAND	528
P-I	LEFT EAR	RIGHT HAND	510
P-I	RIGHT EAR	LEFT HAND	513
P-I	RIGHT EAR	RIGHT HAND	514
CONTOUR	LEFT EAR	LEFT HAND	524
CONTOUR	LEFT EAR	RIGHT HAND	554
CONTOUR	RIGHT EAR	LEFT HAND	537
CONTOUR	RIGHT EAR	RIGHT HAND	517

Table 3.4 Experiment 1: Mean RTs for each Task/Ear/Hand condition.

FIGURE 3.1 Task x ear x hand interaction (Experiment 1).



insufficient data to carry out a 4-way Task x Ear x Hand x Serial Position analysis. A mean reaction time was calculated for each subject in each of the task/position conditions. (For details of distribution of alterations see Melodies section of Methods section). The results of the 2-way ANOVA can be seen in Table 3.5 and the means for each of the conditions in Table 3.6.

There is no significant effect for task (although the F value approaches significance, see Table 3.5), but there is a significant effect for serial position. There is also a significant task x serial position interaction which is illustrated in Fig. 3.2.

Most importantly, error rates for each of the tasks were calculated and found to be 9•7% for the pitch-interval task and 16•4% for the contour task. Chance performance levels should be 25% for each of the tasks, given the amount of time in which subjects were allowed to respond and the range over which responses were counted as correct. This performance level would predict an error rate of 75%. It is clear that both error rates are far lower than this and so it is likely that both tasks were performable by the subjects.

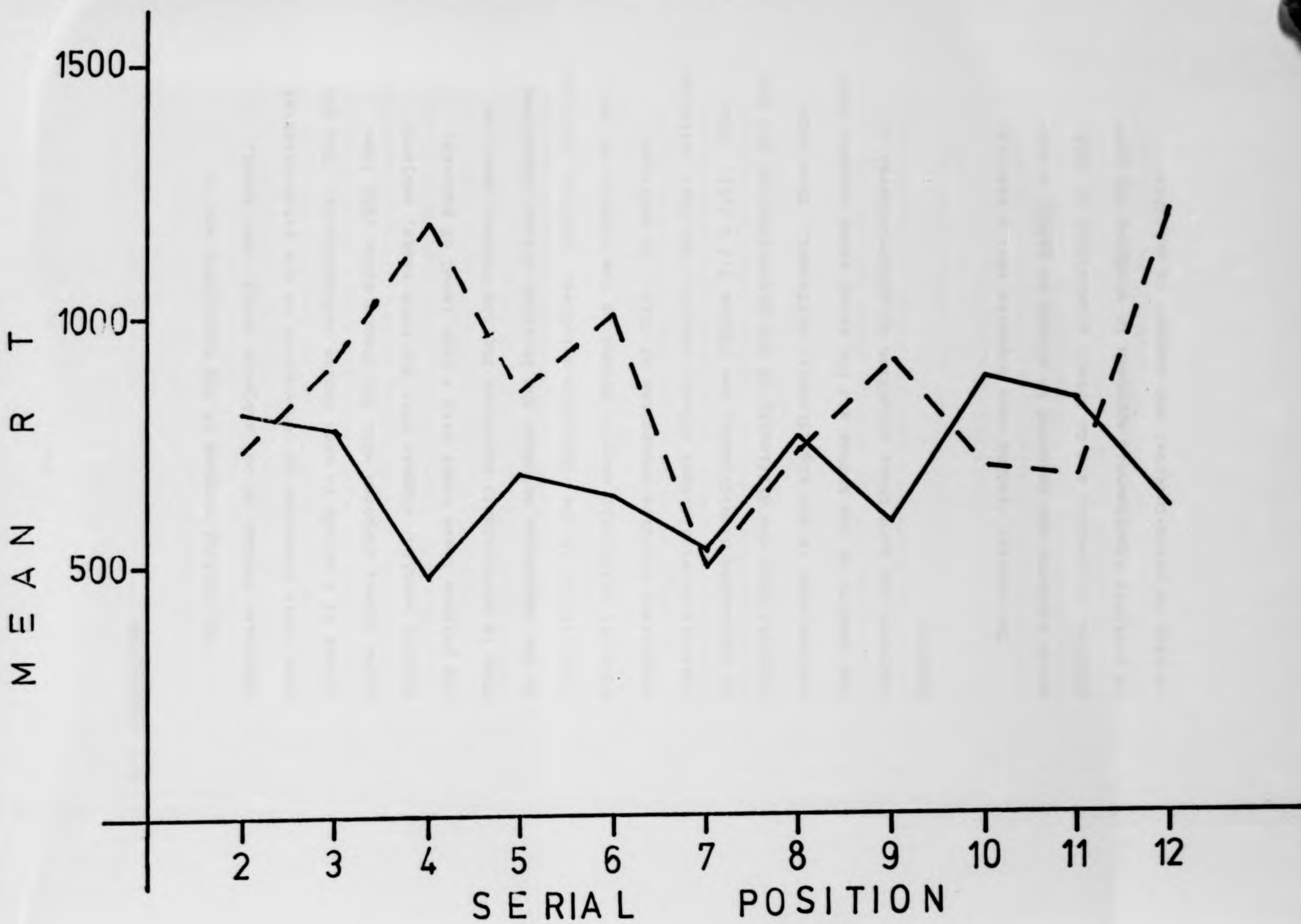
SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	7739400	15	515926		
TASK	2808600	1	2808600	4·219	0·052
ERROR (TASK)	9985380	15	665692		
SERIAL POSITION	3781960	10	37196	2·470	<0·01
ERROR (SERIAL POSITION)	22967250	150	153115		
TASK x SERIAL POSITION	8596790	10	859679	6·491	<0·001
ERROR (TASK x SERIAL POSITION)	19864800	150	132432		

Table 3.5 Experiment 1: Task x Serial Position ANOVA

SERIAL POSITION	P-I (ms)	CONTOUR (ms)	MEAN (ms)
2	808	731	770
3	775	916	846
4	479	1186	833
5	685	848	767
6	640	999	820
7	527	490	509
8	758	730	744
9	585	906	746
10	878	696	787
11	829	670	750
12	609	1199	904
MEAN	688	852	

Table 3.6 Experiment 1: Mean RTs for each Task/Serial Position condition.

FIGURE 3.2 Task x serial position interaction (Experiment 1).



3.4 DISCUSSION

The central purpose of the experiment was to determine whether or not subjects could, when asked, turn their attention to the contour or the pitch-interval values of a melody to some degree independently. The low error rates, compared with the chance error rate (see Results section) suggest that for both tasks, subjects can perform these tasks with a high level of success. This is particularly important for the contour task, as in the comparison melodies the interval values themselves were altered in the comparison melodies. However, subjects found it relatively easy to attend to the contour of the comparison melodies regardless of this. In addition, there is no significant effect, overall, for task (although it approaches significance, see Tables 3.3 & 3.5). This suggests that the difficulty of the pitch-interval and the contour task is not significantly different. Thus both the results of the ANOVAs and the error rates suggest that subjects can turn their attention to pitch-interval or contour.

The central finding thus suggests that a task in which subjects are required to attend to either pitch-interval or contour and to detect alterations in each is a viable experimental approach to studying the processing of pitch-interval and contour in melodies.

This technique will therefore be used in most of the following experiments.

There are other results obtained from this experiment which warrant further discussion. First, the results from the 3-way task x ear x hand ANOVA (Table 3.3) will be discussed with respect to the laterality paradigm; the second part of the discussion will consider the more general implications of the findings from the 2-way ANOVA (Table 3.5).

3.4.1 The laterality question

A 3-way Task x Ear x Hand ANOVA revealed no significant main effects, no significant 2-way interactions but a significant 3-way interaction, which can be seen in Fig. 3.1.

However, *post hoc* analysis shows that the only permissible pairwise comparisons which are significant are between the pitch-interval and contour tasks for the right hand with melodies heard in the left ear, and again between pitch-interval and contour for the left hand with melodies heard in the right ear. For both of these comparisons the pitch-interval task is performed significantly faster than the contour task. Thus the significant interaction may be due to superiority in the pitch-interval task in some of the conditions. Certainly the data is not strong enough to address the laterality question as set out by Gates & Bradshaw (1977a) as suggested in the introduction, that is that pitch-interval might be better processed by the left hemisphere and contour better processed by the right hemisphere.

Although the results obtained in Experiment 1 cannot address the laterality question, it was included initially as it was considered that contour and pitch-interval might be differentially mediated by the cerebral hemispheres. However, as the results do not suggest the presence of any such effects, all subsequent experiments will involve a simple binaural presentation of melodies.

3.4.2 General points arising from Experiment 1

Centrally, there was no significant effect for task and so the experimental technique has been validated to some extent, as described earlier.

The 2-way ANOVA (Table 3.5) shows that there is a significant effect for serial position of alteration. Inspection of Fig. 3.2 shows that the effect for serial position is rather obscure in the present experiment.

There is no single trend which can describe the results obtained. However, of greatest importance to the thesis is the interaction between task and serial position. Again Fig. 3.2 does not clearly reveal the nature of this interaction, but in most general terms it can be suggested that serial position has a differential effect on the processing of pitch-interval than contour even when the melody was actually the same for both the pitch-interval and the contour task. Therefore there might be differences in the way that pitch-interval and contour are processed and encoded; furthermore, the results suggest that sometimes contour is more salient than pitch-interval, whereas at other points pitch-interval is more salient than contour (see Fig. 3.2).

One problem with this first experiment is that the same melody was used throughout; thus some of the results may have been due to idiosyncrasies of that particular melody. This will be avoided in future experiments and a wider range of melodies will be used.

Pitch-interval and contour, then, appear to have different levels of salience at different points in a melody; this finding points the way to subsequent experiments where a variety of different conditions are investigated where contour and pitch-interval may have more or less salience. These will be investigated in the following experiments. The experimental procedure used will be similar to that used in the present experiment.

As a final methodological point, it was pointed out in the introduction that the unavoidable problem in experimentation on contour processing *per se* is that it is necessary to alter pitch-interval in order to alter contour whereas it is not necessary to alter contour in order to alter pitch-interval. Thus, in the pitch-interval task described here the comparison melody possessed one alteration at one point; for the contour task, it was necessary to alter many of the pitch-interval values so that the comparison melody becomes a different melody. Thus the problem for the listener might become one of 'picking out' the contour from all the new pitch-interval values. If this was the case, then it would be predicted reaction times would slow down progressively with increasing serial position in the contour task. This might be predicted as contour is generally considered to be an abstraction from pitch-interval (for example, Davies & Yelland, 1977). Table 3.6 does not show the predicted trend.

The main purpose of Experiment 1 was to test an experimental technique where subjects are specifically requested to turn their attention towards pitch-interval or contour, and it was found that both tasks can be performed equally well. The way that pitch-interval and contour interact in this experiment present an interesting phenomenon which will be investigated in subsequent experiments.

CHAPTER FOUR

4.1. INTRODUCTION

The proposition that contour plays an important role in melody processing, and music processing in general, was highlighted in the first chapter. Much recent research suggests that contour might play an important role in the processing of melodies. How and why is not made altogether clear.

The research most relevant to this issue is that of Dowling and co-workers (Dowling & Fujitani, 1971; Dowling, 1978; Dowling & Bartlett, 1981; Bartlett & Dowling, 1980; Dowling, 1982). This work will be reviewed in some detail here.

Dowling & Fujitani (1971) suggested that contour is an important organisational feature in music. The repetition of themes and phrases at different pitch levels, where the interval sizes are altered but where the contour is preserved is an extremely common compositional device. Dowling & Fujitani (1971) carried out an experiment in which subjects heard a 5-note melody, then, after a pause, heard a comparison melody which was either transposed or untransposed. In addition to the transposition factor, the comparison tasks were of three types (performed by different groups of subjects). Subjects were required to distinguish between same and different melodies, between same melodies and ones with only the same contour and between melodies with the same contour and different ones.

The results indicate that the task where subjects had to distinguish between exact same and same contour melodies was particularly difficult when melodies were heard in transposition. This did not occur when melodies were untransposed; this finding thus suggests that melodic contour might be particularly important when melodies are novel and are heard in transposition. In addition, melodies used by Dowling & Fujitani were only 5 notes long which, in terms of a melody, is very short. Thus the results suggest that, at least, in <u>brief</u>, novel, transposed melodies, contour is particularly important.

In a later study, Dowling (1978) found that subjects found it very difficult to distinguish between 'exact same' and 'same contour' comparison melodies when these were transposed, again with the same confusion not occurring when melodies were untransposed. However, he found that confusion did not occur to such a great extent when the comparison melodies were atonal than when they were tonal. All the original melodies were tonal in this experiment.

Subjects found it easier to distinguish between contour-preserving melodies when they were atonal.

However, this experiment was designed to assess the role of contour and interval in melody perception and is it likely that some other factor, at a much more general level, came into play when subjects were asked to compare melodies where one is tonal and the other is not. It is suggested here that the distinction between atonal and tonal melodies takes place along a much more gross, and different, level to the precise encoding of interval <u>or</u> contour. The harmonic implications of a tonal melody are so different to atonal ones that listeners might use this, rather than note-for-note comparisons. The results of this experiment led Dowling to suggest some interdependence of interval and contour in the light of the effect described above.

In Chapter 2 it was suggested that interval and contour do not exist independently -- of course they are inter-dependent. However, this does not exclude the possibility that under certain conditions either of these relationships may be more or less salient. The ease with which the listener can direct their attention towards either of these elements reflects their salience. It is not a case of one or the other, but one of different levels of salience of each.

Dowling's findings that confusion between 'exact same' and 'same contour' did not occur when melodies were untransposed might possibly be caused by the fact that interval values are more salient, or contour values are less salient, under these conditions. This question will be considered in Chapter 8.

Dowling (1978) suggests that:

> "the contour is an abstraction which can be remembered independently of pitch and interval sizes" (p346).

However, if this is the case, why did 'same contour' comparisons create more confusion when melodies were transposed than when untransposed? This suggest that sometimes contour is <u>not</u> an abstraction, but a level of relationship between notes that is more, or less salient at any point. Dowling explains this finding in terms of the subjects' misunderstanding of the task. However, it is likely that this phenomenon reflects the fundamental difference between pitch-interval and contour which will be brought out in this thesis.

The following experiment investigates the role of pitch-interval and contour in novel, transposed melodies. Dowling & Bartlett (1981) suggest that research with novel melodies indicates that contour plays a dominant role (dominant over precise interval information) while precise interval information contributes little, if anything, to performance on tasks within a short-term memory paradigm. However, they do not elucidate as to why this should be so.

Much of Dowling's work suggests that contour is particularly important when novel melodies are heard in transposition. The following experiment tests this hypothesis by asking subjects to attend to the intervals or contours of melodies in different tasks and to compare these elements with comparison melodies sharing the precise interval values or the same contour only. They were required to detect changes in either pitch-interval or contour and it is hypothesised that, under these conditions, contour would be more salient than pitch-interval.

It was mentioned above that the melodies used by Dowling & Fujitani were brief, and that this in itself might be of some importance. There is much evidence (to be reviewed later) to suggest that the processing of pitch-interval information takes place more efficiently when a tonal centre can be established. This tonal centre is a sense of a tonic, or point (frequency) about which the melody is, at any point, centred. This tonal centre is essentially a sense of the key that the melody is in at any point.

If a tonal centre needs to be established for the accurate processing of interval relationships, then it is possible that five notes are not enough, especially when heard in transposition, to establish a tonal centre. Longer melodies may make a tonal centre clearer. Thus, in the following experiment melodies of two lengths are heard -- 5 and 15 notes in length respectively. It is suggested that contour might be more salient for the short melodies but pitch-interval would be more salient than contour for the 15 note melodies. It is questionable what, if any, <u>melodic</u> information is derived from short, novel, transposed melodies. In longer melodies, it may be that the notes themselves make a tonal framework in which to place the notes of that melody, which may in turn affect the importance and salience of pitch-interval relationships.

Two further variables will be investigated in this experiment. The first is the effect of the speed of presentation of melodies and the second is serial position of the alterations to be detected.

As this experiment serves to introduce a number of hypotheses to be investigated more fully in subsequent chapters a simple scoresheet method of response was used rather than the reaction time method used in all other experiments. Subjects were given a scoresheet which numbered the notes to be heard in each trial. They were asked to mark the serial position of the note that they considered had been altered (by either pitch-interval or contour) in the comparison melody in each trial. This method is very similar to that used in some of the published tests of melodic memory (for example Seashore 1960; Bentley 1966). For each melody heard, every note is given on the score sheet in terms of 1, 2, 3 ...n where n is the number of notes in the melody.

EXPERIMENT TWO

4.2 METHOD

4.2.1 Subjects: 30 subjects participated in 2 experimental sessions. Every subject was a musician who had been learning at least one musical instrument for a minimum of five years during the period immediately prior to the experiment.

4.2.2 Task: Subjects took part in 2 experimental sessions, one of which will be referred to as pitch-interval, the other as contour.

In the pitch-interval task, subjects were required to listen to a series of 48 different melody pairs, half of which were 5 notes long and half of which were 15 notes long. In each trial a melody was heard in the key of C major. Subjects were required to attend to the pitch-interval relationships of this melody. After a short pause (to be discussed later), subjects heard the same melody transposed to the tritone (F sharp major). This comparison melody possessed one pitch-interval alteration in this new key. The task was to detect this alteration and to mark its serial position on a score sheet.

For both the twenty four 5- and 15-note melodies, there were 18 trials where the comparison melody possessed one alteration and 6 trials where the comparison was an exact transposition. These transpositions were catch trials.

In the contour session subjects again listened to a series of 48 melody pairs, half of which were 5 notes long and half of which were 15 notes long. In each trial a melody was heard in C major. After a short pause another melody was heard, transposed to F sharp major. This comparison melody usually possessed one contour alteration with relation to the first melody. The task was to detect this contour alteration and to mark its serial position on a scoresheet.

Again, for both the 5-note and the 15-note melodies there were 18 trials in which the comparison melody possessed one contour alteration. For 6 trials the contour of the comparison was exactly the same as the first throughout. These were catch trials.

For both the pitch-interval and contour sessions the order of the 48 trials was randomised. The same sequence of trials was used for all subjects (because of the scoresheet method of response).

4.2.3 Design: there were three nested factors -- task (pitch-interval/contour), length of melody (5/15 notes), and speed (2 notes per second/4 notes per second). The design can be seen in Table 4.1. A fourth factor, serial position of alterations within the comparison melody, was randomised across all conditions.

There were an equal number of trials in each of the conditions. The order of the 48 pitch-interval trials was randomised, and this order was used to construct a scoresheet which was used for all subjects. This same order of 48 trials was used for the contour section of the experiment (the same scoresheet was used).

4.2.4 Melodies: two sets of 48 melody pairs were composed. One set was to be used in the pitch-interval task, the other in the contour task. The sets were designed as follows.

(A) Pitch-Interval

Twenty-four melodies were composed in the key of C major. Each melody was 5 notes in length. For each

TASK	P-I (48)				CONTOUR (48)			
LENGTH	5(24)		15(24)		5(24)		15(24)	
SPEED	F(12)	M(12)	F(12)	M(12)	F(12)	M(12)	F(12)	M(12)
EXPERIMENTAL TRIALS	9	9	9	9	9	9	9	9
CATCH TRIALS	3	3	3	3	3	3	3	3

Table 4.1 Experiment 2: Design.

( ) = number of trials. F = Fast (4 notes/sec).
M = Moderate (2 notes/sec).

melody a comparison melody was composed in the key of F sharp major. Eighteen of these comparison melodies possessed one pitch-interval alteration at one point in the melody. For example, the melody below:

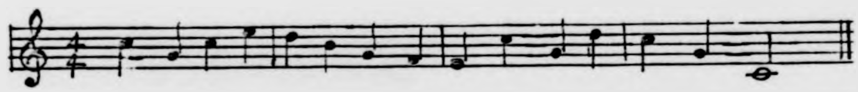
possessed a comparison melody as follows:

Throughout the 18 melodies the alterations were distributed as follows:

Serial position	1	2	3	4	5
No. alterations	0	6	6	6	0

For the remaining 6 melodies, a comparison melody was again composed in the key of F sharp major which was an exact transposition throughout. These were used as catch trials.

Twenty-four 15-note melodies were composed in the key of C major. For each melody, a comparison melody was composed in the key of F sharp major. Eighteen of these comparison melodies possessed one pitch-interval alteration at one point in the melody. For example, the melody below:



possessed a comparison melody as follows:

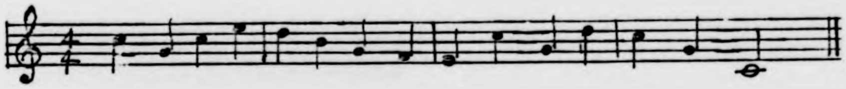
Throughout the 18 melodies the alterations were distributed as follows:

Serial position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. alterations	0	2	2	2	0	0	2	2	2	0	0	2	2	2	0

For the remaining 6 melodies, a comparison melody was again composed in the key of F sharp major which was an exact transposition throughout. These were used as catch trials.

<u>(B) Contour</u>

Twenty-four 5-note and twenty-four 15-note melodies were composed in the same way as for pitch-interval above. Each of the melodies was in the key of C major. A comparison melody was written for each of the 48 melodies in the key of F sharp major.

For the twenty-four 5-note melodies 18 possessed comparison melodies which shared the same contour except that there was an alteration at one point. For example the melody below:

possessed a comparison melody as follows:

Throughout the 18 melodies the alterations were distributed as follows:

Serial position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. alterations	0	2	2	2	0	0	2	2	2	0	0	2	2	2	0

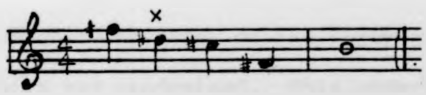
For the remaining 6 melodies, a comparison melody was again composed in the key of F sharp major which was an exact transposition throughout. These were used as catch trials.

(B) Contour

Twenty-four 5-note and twenty-four 15-note melodies were composed in the same way as for pitch-interval above. Each of the melodies was in the key of C major. A comparison melody was written for each of the 48 melodies in the key of F sharp major.

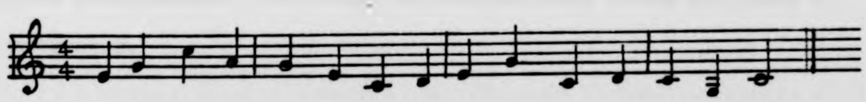
For the twenty-four 5-note melodies 18 possessed comparison melodies which shared the same contour except that there was an alteration at one point. For example the melody below:

possessed a comparison melody as follows:

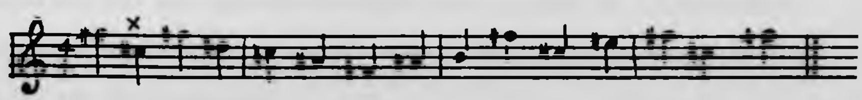


For the other comparison melodies, the contour was the same as the first melody throughout. These were catch trials. The distribution of the alterations was exactly the same as for the pitch-interval melodies (A) above.

For the twenty-four 15-note melodies 18 of the comparison melodies possessed one contour alteration at one point in the melody. For example, the melody below



possessed a comparison melody as follows:



For the other 6 comparison melodies the contour was exactly the same as the first melody throughout. The distribution of the alterations was exactly the same as for the pitch-interval melodies (A) above.

All the melodies used in this experiment can be seen in Appendix 2.

The melody pairs were assigned to the conditions described in Table 4.1. They were assigned randomly to the fast and the moderate speed conditions. When all the melody pairs had been assigned the order of the forty-eight 5-note and 15-note melody pairs was randomised. This order was the same for both the 48 pitch-interval and the 48 contour melody pairs, except that the speed variable was different for both. Only the sequence of melodies in terms of length was the same for the contour and the pitch-interval tasks.

The 48 pitch-interval melody pairs (A) were recorded onto a Tandberg reel-to-reel tape recorder at the specified speed. The melodies were recorded from an electric piano and were played by the experimenter, the speed of the melodies being dictated by a metronome.

Odd-numbered trials (melody pairs) were played on a piano register and even-numbered trials were played on a harpsichord register in order to facilitate differentiation between melody pairs by the listener.

In each trial both melodies were preceded by a warning signal, the note A at 880Hz. There was a 1 second pause between the warning signal and the start of each melody. There was also a five second pause between the end of one trial (the end of the comparison melody) and the start of the next trial (the warning signal for the next trial).

4.2.5. Interval between first playing and comparison trial

The interval between the first playing of a melody and its comparison is different from all other experiments reported in the thesis, so will be discussed here rather than in the methodological chapter (Chapter 2). The time interval between the first playing of a melody and its comparison was designated such that the interval between a note and its subsequent alteration was constant across both melody lengths and both speeds. This meant that the interval between first and second hearing of the melody in each trial was slightly different.

This was considered to be more satisfactory than allowing the interval to remain constant and the inter-alteration time to vary, in order to make each trial as similar as possible.

The main reason for this was that the melodies were played at different speeds. As this is not done in subsequent experiments, the time interval between the end of the first melody and the start of the next is kept constant. The time interval with respect to other experiments is discussed in greater detail in the methodological chapter (Chapter 2).

4.2.6 <u>Scoresheets</u>: The same scoresheet was used for the pitch-interval and the contour task (see Design section earlier). The scoresheets specified:

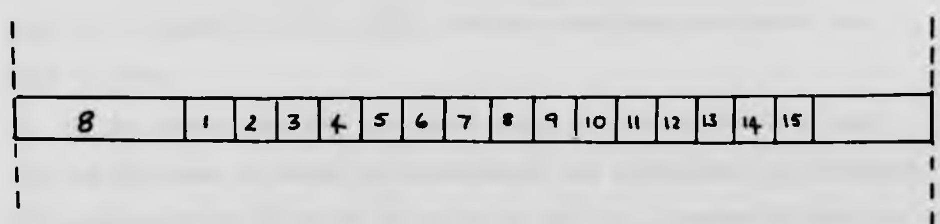
1. The number of the trial from 1 to 48.
2. The number of notes in the melody for each trial.

Subjects thus knew the length of each melody prior to the start of the trial. They did not know whether the melody was to be played at a moderate or a fast speed.

4.2.7 <u>Procedure</u>: The order of the two experimental sessions, pitch-interval and contour, was counterbalanced across subjects. The order of the trials in each section was initially randomised (see Design section) and then all subjects carried out the trials in the same random order. The instructions for each session were typed out and were as follows:

<u>Pitch-interval task</u>

"The experiment in which you are about to participate aims to investigate some of the constraints which may exist on our memory for tonal sequences. You will see a scoresheet in front of you which looks like this:



On the left the number of the trial is given. In each trial you will be hearing two nearly identical 5- or 15-note melodies, and the numbers to the right of the trial number tell you how many notes there will be in each melody. There is a space to the right of these numbers which will be used occasionally. The experiment will proceed as follows:

1. You will hear a high-pitched warning signal. After a short pause you will hear either a 5-note or a 15-note melody. You will know how long the melody is to be by looking at the score sheet. You should listen to the melody and try to remember it as well as you can.

2. After a pause you will hear another warning signal, after which you will hear another melody. The second melody (which we can call the comparison melody) will be different from the first in two ways:

1. It will be in a different key.

2. One note of the melody <u>may</u> be altered by a semitone or more. The alteration will not make the melody any less melodically viable than the first.

3. When listening to the comparison melody you are asked to follow the numbers (so that the first note corresponds to number 1, the second to number 2, etc), and circle the note that you think has been altered.

4. If you cannot specify the exact note, but think you have some idea of the area in which the alteration was contained, use brackets. For example, 1 2 3 (4 5 6 7) 8 9 10 11....suggests that you

think that the alteration occurred somewhere between notes 4 and 7, although you are not exactly sure. Please be as accurate as you can.

5. There will not always be an error, so if you think that the comparison melody was the same as the first then write 'No error' or 'NE' in the space to the right of the scoresheet.

6. The first and the last notes of the comparison melodies will never be altered.

7. At the end of the trial, you will have a very short while to make up your mind. Always make some response, even if you think you are only guessing.

8. The next trial will proceed very quickly and will be exactly the same as the first. There are 48 trials in all".

Contour task

"The experiment in which you are about to participate aims to investigate some of the constraints which may exist on our memory for tonal sequences. You will see a scoresheet in front of you which looks like this:

8	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	

On the left the number of each trial is given. In each trial you will be hearing two similar 5- or 15-note melodies, and the numbers to the right of the trial number tell you how many notes there are in each melody. There is a space to the right of each set of numbers which will be used occasionally. The experiment will proceed as follows:

1. You will hear a high-pitched warning signal. After a short pause you will hear either a 5-note or a 15-note melody. You will know in advance the length of the melody by looking at the score sheet. You should listen to the melody and try to remember the <u>melodic contour</u> (the sequence of ups and downs) as well as you can. The notes themselves are of no importance -- what <u>is</u> important is the sequence of ups and downs.

2. After a pause you will hear another warning signal, after which you will hear another melody in a different key. This melody will be different from the one that you heard first, but will be similar in that it <u>shares the same melodic contour as the first</u>, although the melody itself may be different. At one point in the second melody there may be a deviation in melodic contour such that a note that went up in the first melody goes down in the second or *vice versa*. Your task is to detect this change in direction and to indicate which note changes direction in the second melody.

3. When listening to the second melody you should follow the numbers (so that the number 1 corresponds to the first note, the number 2 to the second, and so on) and circle the note that you think has been altered on the second playing.

<u>DO NOT CHEAT BY MAPPING OUT THE CONTOUR ON THE PAPER.</u> <u>THIS IS VITAL.</u>

4. If you cannot specify the exact point where the note changed direction, then draw brackets around the area where you thought the deviation occurred. For example, 1 2 3 (4 5 6 7) 8 9 10 11 .... suggests that you thought that the deviation occurred somewhere between the fourth and seventh note, but that you can be no more

1. You will hear a high-pitched warning signal. After a short pause you will hear either a 5-note or a 15-note melody. You will know in advance the length of the melody by looking at the score sheet. You should listen to the melody and try to remember the melodic contour (the sequence of ups and downs) as well as you can. The notes themselves are of no importance -- what is important is the sequence of ups and downs.

2. After a pause you will hear another warning signal, after which you will hear another melody in a different key. This melody will be different from the one that you heard first, but will be similar in that it shares the same melodic contour as the first, although the melody itself may be different. At one point in the second melody there may be a deviation in melodic contour such that a note that went up in the first melody goes down in the second or *vice versa*. Your task is to detect this change in direction and to indicate which note changes direction in the second melody.

3. When listening to the second melody you should follow the numbers (so that the number 1 corresponds to the first note, the number 2 to the second, and so on) and circle the note that you think has been altered on the second playing.

DO NOT CHEAT BY MAPPING OUT THE CONTOUR ON THE PAPER. THIS IS VITAL.

4. If you cannot specify the exact point where the note changed direction, then draw brackets around the area where you thought the deviation occurred. For example, 1 2 3 (4 5 6 7) 8 9 10 11 .... suggests that you thought that the deviation occurred somewhere between the fourth and seventh note, but that you can be no more

specific about this.

5. There is not always an alteration in melodic contour, and the first and the last notes are never altered.

6. At the end of the trial you will have a very short while to make up your mind. If you feel that there has been no alteration write 'No error' or 'NE' in the space to the right of the score sheet.

7. You must always make a response, even if you are only guessing.

8. The next trial will proceed very quickly and the procedure is exactly the same for each trial. There are 48 trials in all".

All subjects were instructed in exactly the same way. Each of the two sessions lasted approximately 20 minutes. Subjects listened to the tape from start to finish and had no control over the starting and stopping of the tape. Each trial followed five seconds after the end of the last one.

4.3. RESULTS

Subjects were allowed to make two different types of response -- they could either circle the actual note that they felt had been altered or, if they were unsure as to the actual note that had been altered, they could bracket the area of the melody that they thought contained the alteration (see Procedure section). Two data criteria were devised in order to take account of both types of response.

1. If subjects had actually circled only one note they were scored 1 point for every correct response and zero for any other response.

2. If subjects had bracketed an area of the melody on the score sheet or, alternatively, if they had circled a note which was near to the actually altered note (but was, however, wrong) subjects were scored from 5 to 0 depending upon how far the response was from the actual alteration.

In cases where one note was circled subjects were scored 5 if they had circled the actually altered note (which would have scored one point under criterion 1 above); 4 if they were one note away on either side; 3 if two notes away, and so on.

When a number of notes had been bracketed, the following procedure was adopted. The central point of a bracket was taken as the most positive response (the position the subject considered the most likely to be the altered note). This centre point was then taken *as if* it had been a single circled note as in criterion 1 above. The distance from this central point to the actual alteration was then scored from 5 to 0 depending on how far away these two points were. For example, the response below would score 2 points:

```
                          Actual alteration
                              x
1  2  3  4 (5  6  7  8  9) 10  11  12  13  14  15
                  x
             Taken as response
```

In cases where an even number of notes had been bracketed the mid-point between two notes was taken as the most accurate response, and the distance was calculated from here. A maximum bracket size of 9 notes was permitted; larger brackets were counted as incorrect and scored zero.

This method of scoring was called criterion 2. Both scoring systems overlap and the results from both criteria were considered.

Collapsing across serial position of alteration there were 8 conditions -- 2-task (pitch-interval/contour) x 2-length (5-note/15-note) x 2-speed (fast/moderate). A mean score was calculated for each of the subjects in each of the 8 conditions and each score was converted to a percentage of the total possible score for each of the conditions. This procedure was followed for both criterion 1 and criterion 2.

4.3.1 Criterion 1

The mean percentage scores for each condition can be seen in Table 4.2. A 3-way task x length x speed ANOVA was carried out and the results can be seen in Table 4.3. There is a significant effect for task, a significant effect for length and a significant effect for speed. These effects are qualified, however, by a 2-way task x length interaction which can be seen in Fig. 4.1. This shows that the percentage accuracy was higher for contour than pitch-interval for the 5-note melodies, but the reverse was true

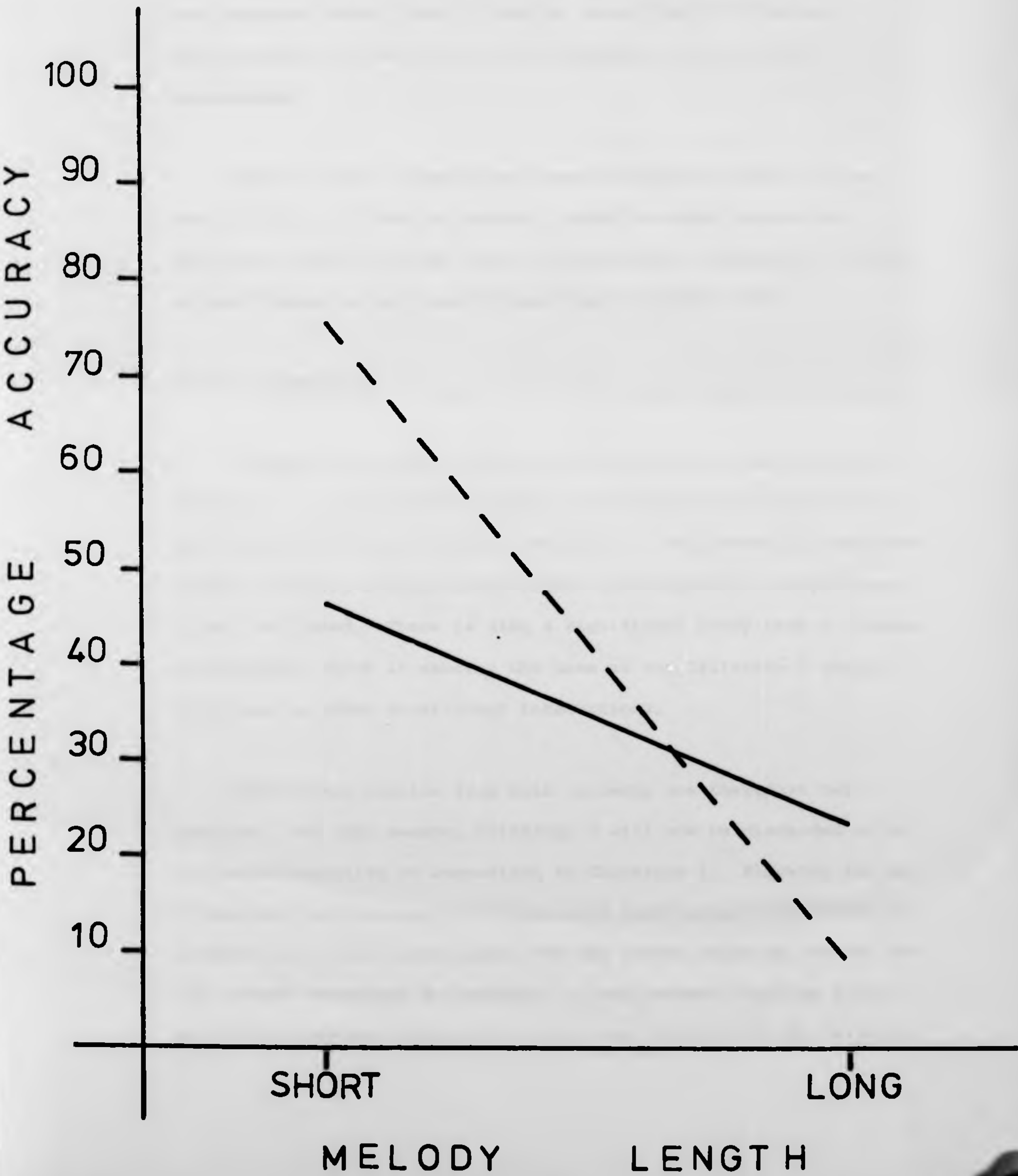
TASK	P-I		CONTOUR	
LENGTH	5	15	5	15
FAST	44·4	12·7	68·2	4·2
MODERATE	49·0	33·6	83·4	14·7

Table 4.2 Experiment 2: Mean percentage accuracy scores for each Task/Length/Speed condition. (Criterion 1).

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	360762·6	1	360762·6		
ERROR (WITHIN SUBJECTS)	39145·5	29	1349·9		
TASK	3549·7	1	3549·7	7·63	<0·01
ERROR (TASK)	13483·4	29	465·0		
LENGTH	121275·1		121275·1	420·49	<0·001
ERROR (LENGTH)	8364·0	29	288·4		
TASK x LENGTH	27413·4	1	27413·4	93·06	<0·001
ERROR (TASK x LENGTH)	8542·7	29	294·6		
SPEED	9817·6	1	9817·6	57·56	<0·001
ERROR (SPEED)	4946·0	29	170·6		
TASK x SPEED	0·1042	1	0·1042	0·00	0·98
ERROR (TASK x SPEED)	4839·5	29	166·9		
LENGTH x SPEED	501·7	1	501·7	2·56	0·12
ERROR (LENGTH x SPEED)	5684·9	29	196·0		
TASK x LENGTH x SPEED	1680·1	1	1680·1	10·53	<0·01
ERROR (TASK x LENGTH x SPEED)	4628·5	29	159·6		

Table 4.3 Experiment 2: Task x Length x Speed ANOVA (Criterion 1).

FIGURE 4.1 Task x length interaction (Experiment 2, Criterion 1).



for the 15-note melodies. Both differences are significant and were assessed using Tukey's Honestly Significant Difference; exact values will be given in the discussion section where appropriate.

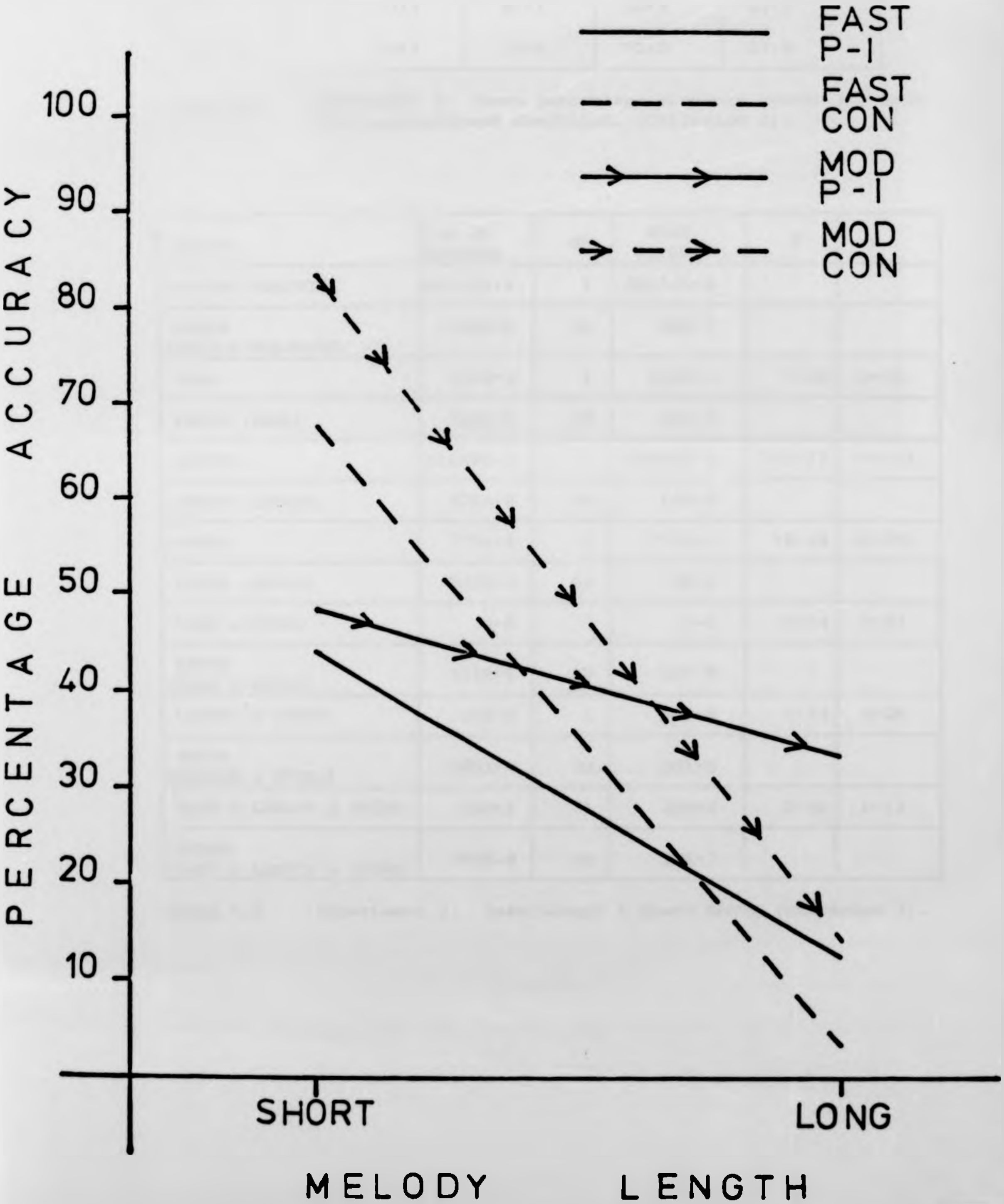
There is also a significant 3-way interaction which can be seen in Fig. 4.2 This is a task x length x speed interaction and most simply it can be seen that length has differential effects on pitch-interval and contour depending on melody speed.

4.3.2 Criterion 2

The mean percentage scores for each condition can be seen in Table 4.4. A 3-way task x length x speed ANOVA was carried out, and the results can be seen in Table 4.5. This shows a significant effect for task, a significant effect for length and a significant effect for speed. There is also a significant 2-way task x length interaction, which is exactly the same as for Criterion 1 above. There are no other significant interactions.

The overall results from both criteria are therefore very similar. For this reason, Criterion 2 will now be discarded as it is length-sensitive in comparison to Criterion 1. Allowing the use of brackets and scoring 5 to 1 for each trial means that almost any response will score some points for the 5-note melodies but not for the 15-note melodies; in addition, it was assumed that the middle point of a bracket might be the most sure response in any trial --

FIGURE 4.2 Task x length x speed interaction (Experiment 2, Criterion 1).



TASK	P-I		CONTOUR	
LENGTH	5	15	5	15
FAST	73•1	41•1	80•9	22•7
MODERATE	80•5	57•0	92•0	33•9

Table 4.4 Experiment 2: Mean percentage accuracy scores for each Task/Length/Speed condition. (Criterion 2).

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	868325•4	1	868325•4		
ERROR (WITHIN SUBJECTS)	13986•9	29	482•3		
TASK	1859•3	1	1859•3	7•28	<0•05
ERROR (TASK)	7403•5	29	255•3		
LENGTH	110596•3	1	110596•3	752•27	<0•001
ERROR (LENGTH)	4263•5	29	147•0		
SPEED	7774•8	1	7774•8	78•49	<0•001
ERROR (SPEED)	2872•4	29	99•0		
TASK x SPEED	4•8	1	4•8	0•04	0•83
ERROR (TASK x SPEED)	3158•9	29	108•9		
LENGTH x SPEED	268•8	1	268•8	1•33	0•26
ERROR (LENGTH x SPEED)	5851•9	29	201•8		
TASK x LENGTH x SPEED	260•4	1	260•4	2•56	0•12
ERROR (TASK x LENGTH x SPEED)	2948•8	29	101•7		

Table 4.5 Experiment 2: Task/Length x Speed ANOVA (Criterion 2).

this need not have necessarily been the case. Criterion 1 is considered to be the most reliable data scoring system.

Thus, all subsequent discussion deals with data Criterion 1 only.

A further analysis was carried out on the long melodies only. For both the contour and the pitch-interval task, the alterations were evenly distributed throughout the extent of the melodies (see Melodies section earlier). The serial position of the alterations was considered in this second analysis.

The 15-note melodies were divided into three groups depending upon the serial position of the alteration within the comparison melody. These were designated position 1 (notes 1-5); position 2 (notes 6-10); and position 3 (notes 11-15). A mean score was calculated for each subject in each of the 12 task x speed x position conditions using data from Criterion 1 only. The scores were converted to a percentage of the total possible score for each of the 12 conditions.

The mean percentage scores for each of the conditions can be seen in Table 4.6. A 3-way task x speed x position ANOVA was carried out, and can be seen in Table 4.7. There is a significant effect for task, a significant effect for speed, and a significant effect for position. All interactions are also significant.

The 2-way task x position interaction is illustrated in Fig.4.3. Position has a differential effect on the pitch-interval task than the contour task, with the largest difference between the two being position 2. The significant task x speed x position interaction is

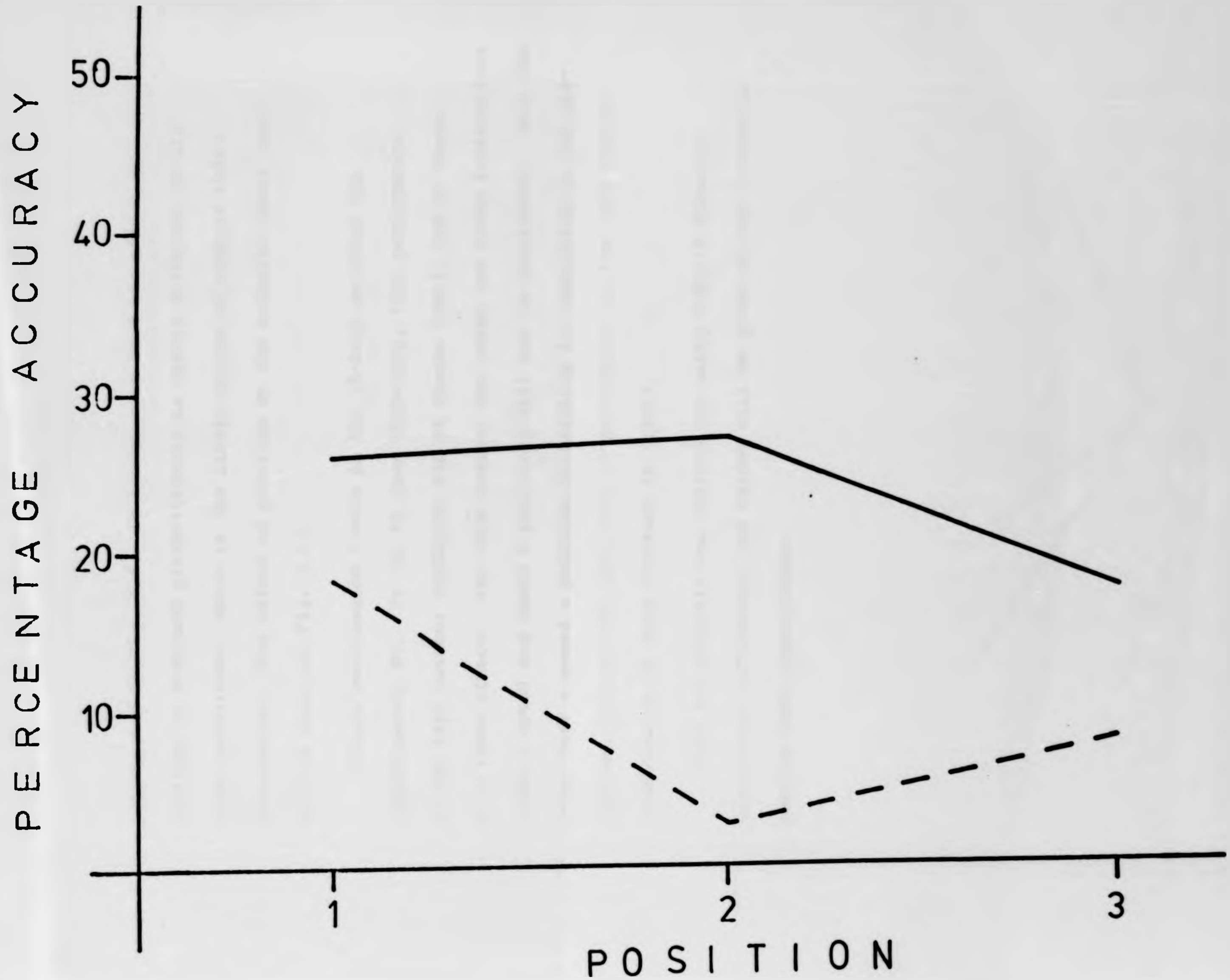
POSITION	1		2		3	
SPEED	FAST	MOD	FAST	MOD	FAST	MOD
P-I	17•7	34•1	5•0	48•5	12•1	22•0
CONTOUR	6•6	29•8	0	5•0	3•3	12•1

Table 4.6 Experiment 2: Mean percentage accuracy scores for each Task/Speed/Position condition for 15-note melodies. (Criterion 1).

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	96301•5	1	96301•5		
ERROR (WITHIN SUBJECTS)	40489•5	29	1396•2		
TASK	17056•9	1	17056•9	48•61	<0•001
ERROR (TASK)	10175•1	29	350•9		
SPEED	28551•2	1	28551•2	45•76	<0•001
ERROR (SPEED)	18092•8	29	623•9		
TASK x SPEED	2711•5	1	2711•5	11•82	<0•005
ERROR (TASK x SPEED)	6650•8	29	229•3		
POSITION	6140•6	2	3070•3	5•63	<0•01
ERROR (POSITION)	31636•9	58	545•5		
TASK x POSITION	5001•2	2	2500•6	7•05	<0•005
ERROR (TASK x POSITION)	20579•2	58	354•8		
SPEED x POSITION	3529•1	2	1764•5	5•60	<0•01
ERROR (SPEED x POSITION)	18273•4	58	315•1		
TASK x SPEED x POSITION	8774•3	2	4387•1	10•82	<0•001
ERROR (TASK x SPEED x POSITION)	25313•9	58	405•4		

Table 4.7 Experiment 2: Task x Speed x Position ANOVA for 15-note melodies. (Criterion 1).

FIGURE 4.3 Task x position interaction (Experiment 2, Criterion 1).



illustrated in Fig. 4.4. It can be seen that the effect of position on moderate pitch-interval is vastly different to all other conditions, which is the likely source of much of this interaction. The effect of position on the moderate speed tasks only is shown in Fig. 4.5.

Chance performance levels in the 15-note melodies was approximately 8%. It can be seen therefore, that performance in the fast contour condition was at chance level, and so there is a floor effect. For this reason, the other two 2-way interactions (task x speed and speed x position) will not be considered. Only the 3-way task x speed x position interaction is considered in the discussion, because the low level of performance on the fast contour condition is of some interest in itself.

Post hoc analysis was carried out using Tukey's Honestly Significant Difference, and values will be given in the discussion section where appropriate.

FIGURE 4.4 Task x speed position interaction (Experiment 2, Criterion 1).

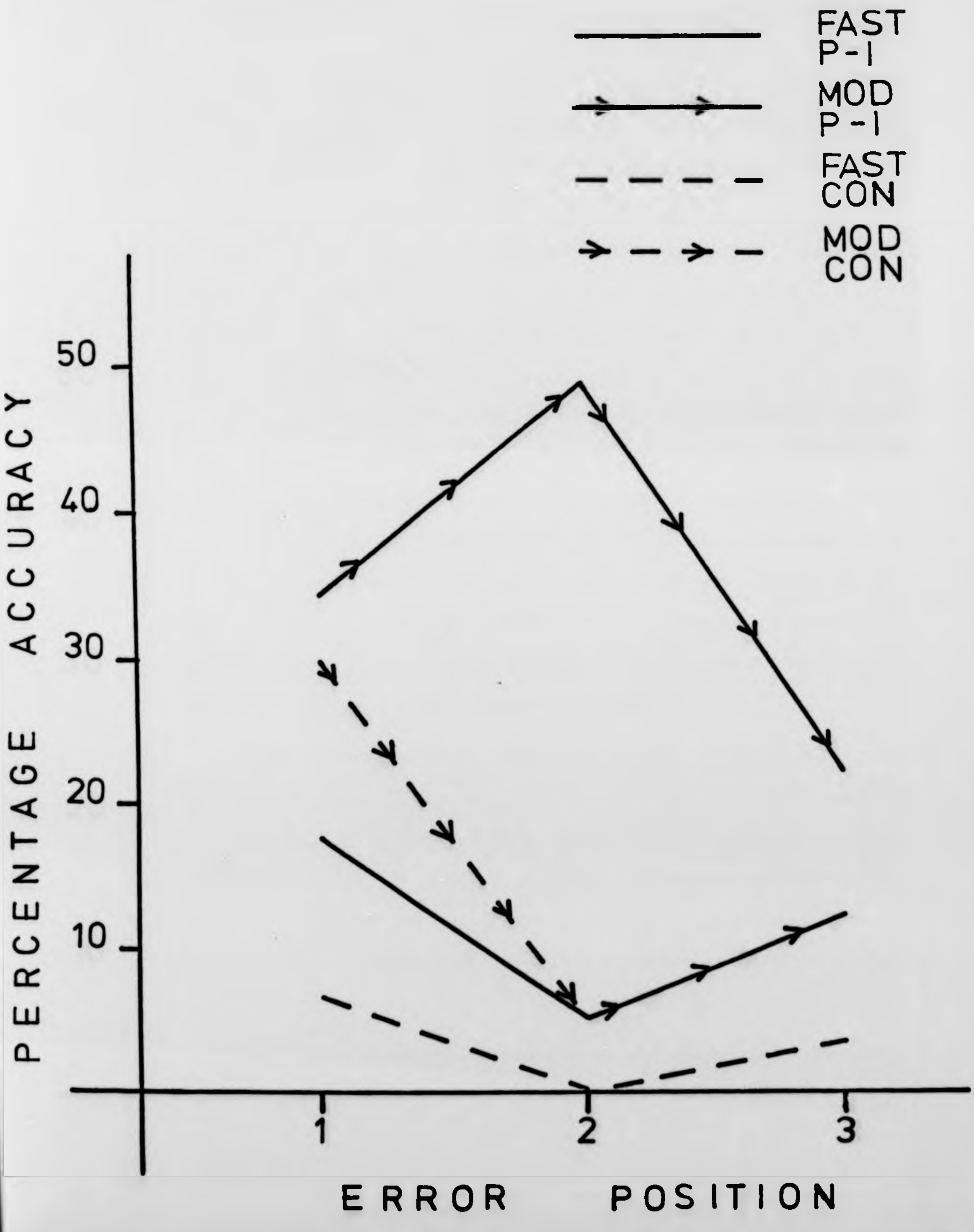
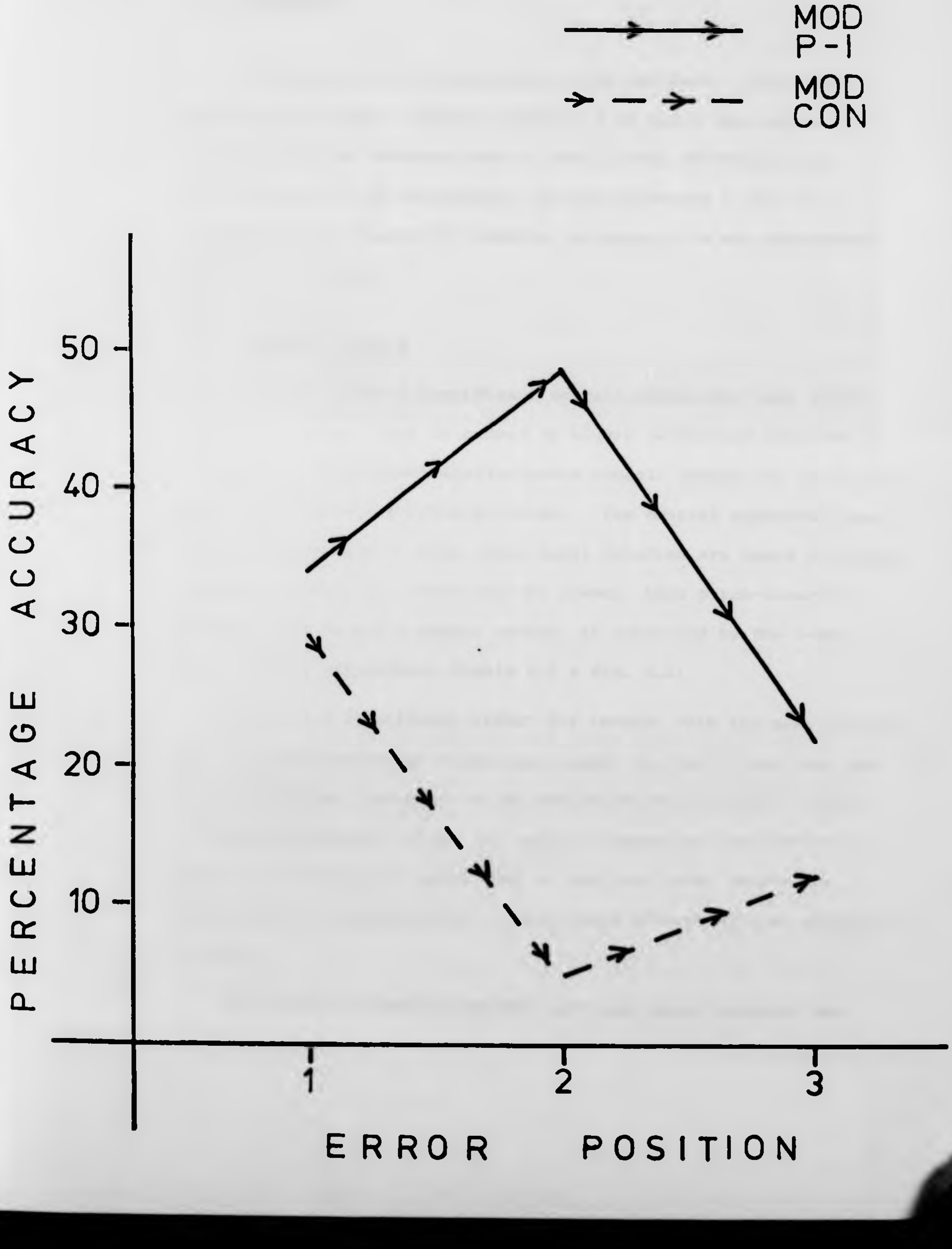


FIGURE 4.5 Effect of position on task for moderate melodies only (Experiment 2, Criterion 1).



4.4 Discussion

The results will be discussed in two sections. The first concerns the overall results (Tables 4.2 to 4.5); the second concerns only the response made to the 15-note melodies. For both sections of the discussion, results Criterion 1 will be considered (for reasons why results Criterion 2 is not considered, see Results section).

4.4.1 Overall Results

Table 4.2 shows a significant overall effect for task (pitch-interval/contour). This is caused by higher percentage response to contour than pitch-interval alterations overall (means are 42.6% for contour and 34.9% for pitch-interval). The central hypothesis has thus been supported -- that, when novel melodies are heard in transposition, contour is a more salient element than pitch-interval. However, this is not a simple effect, as evidenced by the 2-way task x length interaction (Table 4.2 & Fig. 4.1)

There is a significant effect for length, with the mean percentage alteration detection being much higher for the 5-note than the 15-note melodies (means are 61.3% and 16.3% respectively). There is also a significant effect for speed. Alterations were detected better at the moderate speed than at the fast speed (means are 45.6% and 32.4% respectively). These main effects will be returned to later.

The 2-way interaction between task and length supports the second hypothesis of the experiment. It was hypothesised that for the 5-note melodies contour would be more salient than pitch-interval whilst the reverse would be true for the 15-note melodies. Inspection of Fig.4.1 shows this to be the case. *Post hoc* analysis (Tukey's HSD) shows that the differences between pitch-interval and contour are significant for both lengths, but are contrasting in nature. For the 5-note melodies the contour alterations were detected at a higher rate than pitch-interval; for the 15-note melodies, the pitch-interval alterations were detected at a higher rate than the contour alterations (Tukey's HSDs are 17•83 for the 5-note melodies; 8•61 for the 15-note melodies; $p<0\cdot01$ for both comparisons).

Novel 5-note melodies then, heard in transposition, are more salient in terms of their contour relationships than in terms of their pitch-interval relationship. Fifteen note melodies, however, are more salient in terms of their pitch-interval relationships than their contour relationships. This will be discussed in more detail in Chapter 7.

Table 4.2 also revealed a significant 3-way task x length x speed interaction (Fig. 4.2). *Post hoc* analysis shows that all permissible pairwise comparisons are significant except between short (5-note) fast pitch-interval and short moderate pitch-interval (Tukey's HSD = 1•98; df = 2,29 ns). The equivalent comparison for long melodies (long, fast *v* long, moderate pitch) gives the largest HSD for all comparisons (Tukey's HSD = 9•07; df = 2,29, $p<0\cdot01$). It is likely that a large part of the interaction is caused by this contrast.

A possible interpretation of this interaction is that manipulation of speed improves performance on the pitch-interval task more than it does the contour task (speed has an overall significant effect). Fig. 4.2 shows that the effect of different speed is much more pronounced on pitch-interval than it is on contour. Hearing the melodies at the moderate speed improved pitch-interval processing quite noticeably; there is no such effect for contour. This suggests that the task of detecting alterations in a 15-note melody (and thus the task of processing a novel, 15-note melody) can be done quite adequately in terms of the pitch-interval relationships if the task is made more simple (in this case by playing melodies at a slower speed). No manipulation of speed, however, can aid the processing of 15 notes in terms of contour.

A 15-note melody may therefore have little salience in terms of its contour. This finding has implications for the way contour might be used in music, and this will be discussed in more detail in Chapter 7.

All the results obtained from this general analysis suggest that the salience of pitch-interval and contour relationships is in some way dependent upon melody length.

4.4.2 Fifteen-note Melodies

For the melodies as a whole, contour was processed better than pitch-interval. However, for the 15-note melodies alone, the reverse was the case. Table 4.7 shows a significant overall effect for task. This is caused by the higher percentage correct scores for the pitch-interval task than the contour task (means are 23•2% for pitch-interval; 9•5% for contour -- contour is therefore not much better than would be predicted by chance).

Table 4.7 also shows a significant effect for speed, and a significant effect for position. Figure 4.3 shows that the performance on the contour task was much worse than performance on the pitch-interval task, and that the effect of position was different for the two tasks (this illustrates the 2-way task x position interaction). *Post hoc* analysis shows a significant difference between position 1 and 2 & 3 for contour, but not between positions 2 and 3 (Tukey HSDs are 6•04; 2•0 and 0•04 respectively). Thus the most notable decay in contour processing occurs between positions 1 and 2 -- relatively early on in the melody.

For pitch-interval, however, there is no significant difference between positions 1 and 2, only between positions 1 and 3 & 2 and 3 (Tukey HSDs are 0•3; 3•7 and 3•4 respectively). The most significant drop in pitch-interval processing therefore occurs between positions 2 and 3 -- later on in the melody than contour.

There are significant differences between pitch-interval and contour in positions 2 and 3, but not position 1 (Tukey HSDs are 9•3; 3•6 and 2•4 respectively). Thus for 15-note melodies, in contrast to 5-note melodies, contour is never more salient than pitch-interval.

pitch-interval and contour are equally salient at the beginning, with pitch-interval becoming the more salient with increasing serial position. This will be discussed further in Chapter 7.

The effect of position can be seen in more detail in Figures 4.4 and 4.5. The most surprising result is that the difference between pitch-interval in positions 1 & 2 is significant (Tukey HSD= 3·9; df = 2,58; p<0·05), with the percentage correct responses being higher for position 2 than position 1. This can be seen illustrated more clearly in Figure 4.5.

4.4.3 General Discussion

There are several points that emerge from the experiment presented in this chapter. First, when melodies are heard in transposition and are novel, contour is a more salient element than pitch-interval. However, this is true only for short 5-note melodies. For longer 15-note melodies pitch-interval is more salient than contour. This suggests that length might in some way determine the relative importance and salience of pitch-interval and contour under the conditions described in this experiment.

The finding that for 5-note melodies the contour relationship is more salient than the pitch-interval relationship puts Dowling's finding (1978) into perspective. In Dowling's experiment subjects were easily confused between 'exact same' and 'same contour' comparison melodies when melodies were 5 notes long. This may be because for novel, transposed melodies, contour is a more salient element than pitch-interval.

Many studies have involved the transposition of melodies and short melodic sequences which are novel to the listener (Dowling & Fujitani, 1971; Dowling, 1978; Cuddy & Cohen, 1976; Cuddy *et al*, 1979; Attneave & Olson, 1971). It is an important methodological point to note that relationships other than the pitch-interval relationship may warrant investigation. Indeed, the pitch-interval relationship itself may not be the most interesting feature of these melodies.

For long 15-note melodies, pitch-interval was found to be more salient than contour. However, there was a floor effect for the contour task and so too much emphasis should not be placed on this result. However, the results obtained showed a significant difference (Table 4.6) for task.

Other findings from the experiment suggest that for 15-note melodies, there are different serial position effects for the contour and the pitch-interval tasks. This relates back to the interaction between task and serial position found in Experiment 1, but in this case the interaction is much clearer.

The general finding is that the salience of contour falls more rapidly with increasing serial position than does pitch-interval. A second, and important, finding is that the processing of pitch-interval in position 2 (notes 6-10) was significantly better than position 1 (notes 1-5). Processing was worse in position 3, but this may have been due to the great difficulty subjects had in performing the task at this point.

Thus pitch-interval processing improves after contour has been at its most salient; this is the general finding from the experiment reported here. Contour may be at its most important, its most _salient_, when the pitch-interval relationships are not as salient as they are at other points. This finding will be discussed and developed in Chapter 7, but a brief overview will be given here.

There is a good deal of evidence (to be discussed in Chapter 6) which suggests that pitch-interval relationships are more easily processed when the listener can locate some sort of tonal centre. When melodies are heard transposition, the only way this tonal framework, or centre, can be located is through the notes of the melodies themselves. It is logical to suppose that a few notes must be heard in order to determine this tonal centre. This argument will be developed later, however.

In addition, contour may not need a tonal centre in the same way that pitch-interval might; in some sense then, contour is more relational than pitch-interval which, although also relational, depends upon the determination of a tonal centre which is a set of interpretation of notes which can, ultimately, be ascribed to a set of physical frequencies. The differences between contour and pitch-interval may depend upon this difference. This argument will be developed throughout the thesis, and may underpin the difference and relationship between pitch-interval and.contour.

CHAPTER FIVE

5.1 INTRODUCTION

In Experiment 2, the relative salience of contour and pitch-interval were found to be dependent in some way upon melody length; in addition, it was found that serial position had an important effect on the relative salience of pitch-interval and contour, in particular with contour being salient at the beginning of melodies, with pitch-interval becoming more salient in the middle, rather than at the beginning of a melody. The following experiment investigates these findings in more detail.

Melodies of only two lengths were used in the previous experiment, and the central finding was a task x length interaction (Table 4.2). The main purpose of the next experiment is to investigate this interaction more fully.

While Experiment 1 used a reaction time paradigm, Experiment 2 due to its pivotal nature used a more simple score sheet method. The central finding from Experiment 2 was a task x length interaction obtained from data from scoresheet responses. As pointed out in Chapter 2, reaction time data is a highly robust and reliable form of data and is not easily transformable. For this reason, interactions obtained from reaction time data are much more likely to really exist then to be data artefacts (see Pachella, 1974). Thus, all experiments to be described from this chapter onwards revert to a reaction time measure, as interpretations of interactions are that much more secure.

Another reason why a reaction measure is thought to be preferable to other types of measure comes from results of an experiment carried out Williams (1975). In Experiment 2 the point at which subjects made their response was quite varied; they could make a response immediately upon detecting an alteration, that is, while the melody was still being heard, at the end of the comparison melody before the next trial started, or even after later trials had finished (this was attempted by some subjects, without much success). This variation might have important effects. In addition, this variation carries information which may well be important.

Williams' study brings the reader's attention to the problem of time intervals between the occurrence of an event and the report of that event, which in melody perception experiments implies the time interval between the moment a note is heard which requires some response, and the onset of that response. Clearly in Experiment 2 there was a fairly wide range of times in which a response could have been made.

Williams concerns himself with the effect of time delay on the reporting of pitches from different serial positions in atonal sequences of different lengths. In the experiment reported (1975), subjects were asked to listen to atonal sequences of 3, 5 and 7 notes in length. Immediately after hearing the sequence, they were asked to report on any of the notes in the sequence, the serial position of the note required being indicated by a row of lights in front of the subject. Subjects were asked to sing the required note, and the experimenter compared this sung note with the correct note, which he (Williams) played on the keyboard. The subject was scored 1 point if this response was correct, 0 if incorrect.

The three factors in the experiment were melody length, serial position of the note to be reported on, and the time delay between the end of the sequence and the reporting of the required note, which was 0•5, 1•5, 3, 5, 7•5 or 15 seconds. In relation to the first two factors, the factors of this experiment were very similar to the one to be reported next (Experiment 3).

The main results of this experiment are unimportant, but interactions obtained are potentially very important. It was found that even a very short time delay between the occurrence of the note and the report of that note affected the reporting of that note correctly; however, the interactions also suggest that the time delay differentially affected the recall of information from melodies of different lengths. If, for example, the subject was asked to recall the <u>last</u> note in the series immediately after presentation of the last note, then the recall would be approximately the same regardless of melody length. However, if a time delay of 3 seconds occurred before recall of the last note, then reporting of the last note from a 7-note sequence was affected more than the recall of the last note from a 3- or 5-note sequence.

In general, Williams found that the longer the time delay between the occurrence of the last note and the moment of response, the greater differential effect this had on the recall of the last note of different length sequences.

Thus, even a relatively short time delay (the longest one Williams used was 15 seconds) had differential effects on the recall of notes in the <u>same</u> serial position in melodies of different lengths. These results generalise to notes in other serial positions, and therefore have important implications for the topics under investigation in this thesis.

It is clear that Williams' experiment is concerned with the retention of <u>discrete</u> pitch values and is concerned with the serial position effect widely studied in the pychological literature (for example, Murdock, 1962). Taylor (1972) found the same type of serial position effect as reported in Murdock using melodies, but on the whole the 'serial position' phenomenon is not as relevant to <u>related</u> materials (for example, melodies) than it is to discrete, unrelated items, as the tones used in Williams' study.

However, the methodological points arising from Williams' study are considered to be important to the problem under investigation in this thesis; the effect of time delay on the retention of notes in different serial positions must be considered. For this reason, it was thought most appropriate to elicit a response from the subject <u>as soon as the event occurred</u> -- that is, subjects should respond as soon as an alteration was detected. The most simple way to achieve this is by use of a reaction time measure, and the assumptions behind the meaning of reaction time in the experiments reported here have been dealt with in detail in the methodological chapter (Chapter 2).

As stated earlier, the central purpose of the present experiment is to extend the hypotheses put forward in Chapter 4. This is done by investigating the processing and encoding of pitch-interval and contour over a wider range of melodies than those investigated in the previous experiment. As well as extending the experimental paradigm, reaction time measures are used instead of the scoresheet method used in Experiment 2.

In the following experiment, subjects were asked to listen to melodies of 3, 5, 7, 9, 11, 13 and 15 notes on different occasions, and to detect pitch-interval or contour alterations in comparison melodies for each melody length. It was hypothesised, following from Experiment 2, that contour would be more salient than pitch-interval for the shorter melodies -- reaction times produced to contour alterations would be faster for contour comparisons than for pitch-interval comparisons (see Chapter 2), and that pitch-interval would be more salient than contour for longer melodies (reaction times would be faster to pitch-interval alterations than to contour alterations).

A further topic under investigation was the effect of serial position on the detection of pitch-interval and contour alterations. In Experiment 2, it was found that the detection of contour alterations deteriorated rapidly with increasing serial position.

However, the detection of pitch-interval alterations improved from position 1 to position 2. This effect is further investigated in the following experiment. In addition to the investigation of the salience of pitch-interval and contour in melodies of different lengths, the effect of serial position on the encoding of pitch-interval and contour in each melody length is investigated. Melodies were composed such that alterations were distributed evenly to facilitate investigation of any serial position effects which might occur.

EXPERIMENT THREE

5.2 METHOD

5.2.1. Subjects: 10 subjects participated in 14 experimental sessions. Every subject was a musician who had been learning at least one musical instrument for a minimum of five years during the period immediately prior to the experiment.

5.2.2. Task: Subjects participated in 14 different tasks, 7 of which were pitch-interval and 7 of which were contour. In each of the pitch-interval sessions, they listened to 16 melody pairs (trials). In each session, the melodies were of only one length -- 3, 5, 7, 9, 11, 13 or 15 notes. In each trial a melody was heard in the key of C major. After a 5-second pause, the melody was heard again, transposed to F sharp major. This comparison melody usually possessed one pitch-interval alteration at one point in the melody. The subjects' task was to detect this alteration and to press a button as quickly as possible. There were 12 trials of this type for each of the melody lengths and 4 catch trials where the comparison melody was exactly the same as the first throughout.

In each of the 7 contour sessions, one for each melody length, subjects again heard 16 melody pairs (trials). In each trial a melody was heard and subjects were required to attend to the contour of the melody. The melody was always in the key of C major.

After a 5-second pause another melody was heard in the key of F sharp major. This comparison melody shared the same contour except that at one point there was an alteration with relation to the first melody. The task was to detect this alteration and to press a button as quickly as possible. There were 12 trials for each melody length like this. For the other 4 trials the comparison melody shared the same contour as the first melody throughout. These were catch trials.

5.2.3. Design: There were 2 nested factors -- task (pitch-interval/contour) and length (3, 5, 7, 9, 11, 13 and 15 notes). The design of the experiment can be seen in Table 5.1.

A third factor, the position of the alterations within the melodies, was different for each melody length, and will be described in the Melodies section. As far as was possible, the distribution of the alterations throughout the melodies for each length was kept uniform.

5.2.4. Counterbalancing of subjects: It was not possible to fully counterbalance the order of the 14 conditions because of the large number of conditions and the small number of subjects. The counterbalancing that was undertaken can be seen in Table 5.2. The order of the 16 trials within each of the 14 conditions was randomised separately for each of the subjects in each of the conditions.

TASK	P-I	CONTOUR
LENGTH	3 5 7 9 11 13 15	3 5 7 9 11 13 15
EXPERIMENTAL TRIALS	12 for each length	12 for each length
CATCH TRIALS	4 for each length	4 for each length

Table 5.1 Experiment 3: Design.

SUBJECT	ORDER FOR EACH LENGTH		ORDER OF LENGTHS						
1	P	C	3	5	7	9	11	13	15
2	C	P	3	5	7	9	11	13	15
3	P	C	5	7	9	11	13	15	3
4	C	P	5	7	9	11	13	15	3
5	P	C	7	9	11	13	15	3	5
6	C	P	7	9	11	13	15	3	5
7	P	C	9	11	13	15	3	5	7
8	C	P	9	11	13	15	3	5	7
9	P	C	11	13	15	3	5	7	9
10	C	P	11	13	15	3	5	7	9

Table 5.2 Experiment 3: Counterbalancing.

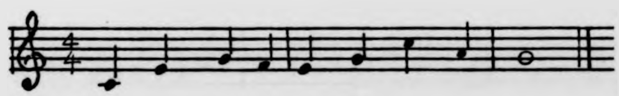
	SERIAL POSITION OF NOTE
MELODY LENGTH	(NUMBER OF ALTERATIONS)
3	1 2 3 (0 6 6)
5	1 2 3 4 5 (0 3 3 3 3)
7	1 2 3 4 5 6 7 (0 2 2 2 2 2 2)
9	1 2 3 4 5 6 7 8 9 (0 2 1 2 1 1 2 1 2)
11	1 2 3 4 5 6 7 8 9 10 11 (0 1 2 1 1 1 1 1 2 1 1)
13	1 2 3 4 5 6 7 8 9 10 11 12 13 (0 1 1 1 1 1 1 1 1 1 1 1 1)
15	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 (0 1 1 1 1 0 1 1 1 1 0 1 1 1 1

Table 5.3 Experiment 3: Distribution of alterations for each melody length.

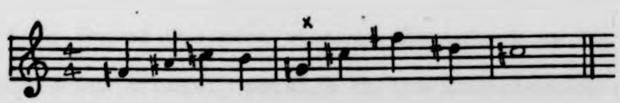
5.2.5. Melodies: 14 sets of 16 melody pairs were composed. Seven sets were to be used in the pitch-interval tasks and seven were to be used in the contour tasks. The sets were designed as follows:

(A) Pitch-Interval

For each of the melody lengths 3, 5, 7, 9, 11, 13 and 15 notes, 16 melodies were composed in the key of C major. For each of the melodies, a comparison melody was composed in the key of F sharp major. For 12 of the 16 comparison melodies for each length, the melody possessed one pitch-interval alteration in the new key. For example the melody below:



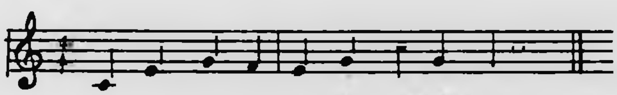
possessed a comparison melody as follows:



For the other 4 comparison melodies for each length, the melody was correctly transposed throughout. These were catch trials. Details on the distribution of the alterations within each set of melodies can be seen after section (B) below.

(B) Contour

For each of the 7 melody lengths, 16 melodies were composed in the key of C major. For each of the melodies a comparison melody was composed in the key of F sharp major. For 12 of the 16 comparison melodies the melody shared the same contour as the original melody except that at one point the contour was different. For example the melody below:



possessed a comparison melody as follows:

For the other 4 comparison melodies for each length the melody shared the same contour throughout as the first. These were catch trials. Details on the distribution of the alterations within each set of melodies can be seen below.

5.2.6 Distribution of alterations

The 12 alterations in each of the comparison melody sets were distributed throughout the serial positions of the melody as evenly as was possible. This distribution was the same for the pitch-interval (A) and the contour (B) sets. The distribution of alterations can be seen in Table 5.3.

All the notes of the melodies were 500ms in length except the last note. For the 3. 7, 11 and 15 note melodies the last note was 1,000ms in length, and for the 5, 9 and 13 note melodies the last note was 2,000ms in length. This was done so as to make the melodies sound melodically balanced (for further discussion see the Methodological chapter, Chapter 2). All melodies used in this experiment can be seen in Appendix 3.

5.2.7 Procedure: The order of the 14 conditions (see Table 5.1) was counterbalanced according to Table 5.2. Subjects attended the laboratory on 14 occasions, and participated in only one condition on each occasion. On seven occasions subjects performed a pitch-interval task, and on the other seven they performed a contour task. On each occasion melodies were of a different length.

Pitch-Interval Tasks

The procedure for each of the pitch-interval tasks (one each for 3, 5, 7, 9, 11, 13 and 15 note melodies) was as follows.

1. Subjects were given practice at the task they were to perform. There were 4 practice trials which were specifically composed as practice trials. The order of these trials was randomised for each subject in each of the conditions. The procedure for the practice trials was the same as for the experimental trials.

2. In each experimental trial, subjects heard a melody of the length prescribed for the occasion. The melody was always in the key of C major. Subjects were required to attend to the pitch-interval relationships in this melody.

3. After a 5-second pause the same melody was heard in the key of F sharp major. This melody usually possessed one pitch-interval alteration in the new key.

4. Subjects were required to detect this alteration and to press a button as quickly as possible when it had been heard. The reaction time was measured to the nearest millisecond.

5. Each trial proceeded in the same way. There were 16 trials for each of the melody lengths, comprising 12 experimental trials, where the comparison melody possessed one pitch-interval alteration and 4 catch trials where the comparison melody was an exact transposition of the melody throughout.

6. The order of the 16 trials was randomised for each of the subjects in each of the conditions.

7. Melody sets described in Melodies A were used in this part of the experiment.

Contour Tasks

The procedure for the contour task was exactly the same as that for the pitch-interval task.

1. After practice (using 4 specifically designed practice trials, the order of which was randomised for each subject), subjects participated in 16 experimental trials for each melody length. The procedure for the practice trials was the same as for the experimental trials.

2. In each experimental trial subjects heard a melody of the length prescribed for the occasion. The melody was always heard

in the key of C major. Subjects were required to attend to the contour of the melody.

3. After a 5-second pause, a comparison melody was heard in the key of F sharp major. This melody usually possessed one contour alteration.

4. Subjects were required to detect this alteration and to press a button as quickly as possible on detecting this alteration. The reaction time was measured to the nearest millisecond.

5. Each trial proceeded in exactly the same way. There were 16 trials for each of the melody lengths, comprising 12 experimental trials where the comparison melody possessed one contour alteration with relation to the first melody and 4 catch trials where the contour of the comparison melody was exactly the same as the first melody throughout.

6. The order of the 16 trials was randomised for each of the subjects in each of the conditions.

7. Melody sets described in Melodies B were used in this part of the experiment.

5.3 RESULTS

Mean reaction times were calculated for each subject in each of the 14 task/length conditions. These means were collapsed across serial position of alteration, which will be discussed later in this section.

The mean reaction times for 10 subjects in each of the task/ length conditions can be seen in Table 5.4. A 2-way task x length ANOVA was carried out and the results can be seen in Table 5.5. There is a significant effect for task, a significant effect for length and a significant interaction between task and length (Figure 5.1). Figure 1 shows that the effect of length on task is quite different; for the shorter melodies, contour reaction times are faster than pitch-interval, whilst for the longer melodies pitch-interval reaction times are shorter than the contour reaction times.

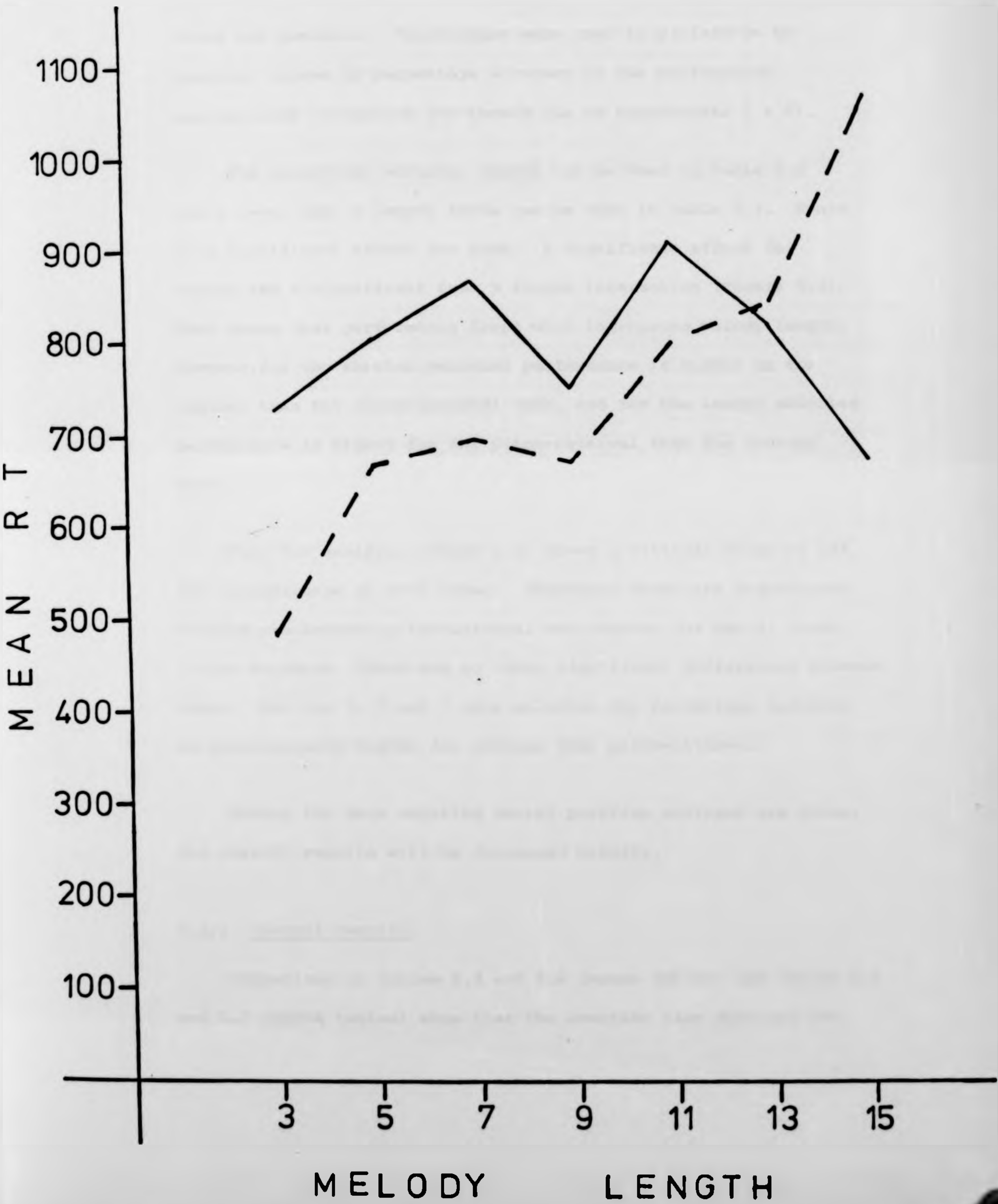
Post hoc analysis (Tukey's a) reveals a critical value of 65ms for significance at the 0•01 level. Therefore there are significant differences between pitch-interval and contour for 3, 5, and 7-note melodies (contour sig. faster than pitch-interval) and 15-note melodies (pitch-interval sig. faster than contour).

In addition, error rates were considered, as these were high, especially for the longer melodies. The number of reaction times produced by each subject in each of the task/length conditions was measured, and the percentage accuracy score was calculated from this. From this condition, a maximum of 12 reaction

TASK	LENGTH							
	3	5	7	9	11	13	15	MEAN
P-I	736	813	878	760	920	831	680	803
CONTOUR	489	677	702	681	810	855	1080	756
MEAN	613	745	790	721	865	843	880	

Table 5.4 Mean reaction times for each Task/Length condition.

FIGURE 5.1 Task x length interaction (Experiment 3, RT data).



times was possible. Percentages were used in preference to absolute scores as percentage accuracy is the performance measure used throughout the thesis (as in Experiments 1 & 2).

The percentage accuracy scores can be seen in Table 5.6 and a 2-way task x length ANOVA can be seen in Table 5.7. There is a significant effect for task, a significant effect for length and a significant task x length interaction (Figure 5.2). This shows that performance drops with increasing melody length; however, for the shorter melodies performance is higher on the contour than the pitch-interval task, and for the longer melodies performance is higher for the pitch-interval than the contour task.

Post hoc analysis (Tukey's a) gives a critical value of 18% for significance at 0·01 level. Therefore there are significant differences between pitch-interval and contour for the 3, 5 and 7 note melodies. There are no other significant differences between tasks. For the 3, 5 and 7 note melodies the percentage accuracy is significantly higher for contour than pitch-interval.

Before the more detailed serial position analyses are given, the overall results will be discussed briefly.

5.3.1 Overall results

Comparison of Tables 5.4 and 5.6 (means tables) and Tables 5.5 and 5.7 (ANOVA tables) show that the reaction time data and the times was possible. Percentages were used in preference to absolute scores as percentage accuracy is the performance measure used throughout the thesis (as in Experiments 1 & 2).

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Before the more detailed serial position analyses are given, the overall results will be discussed briefly.

5.3.1 Overall results

Comparison of Tables 5.4 and 5.6 (means tables) and Tables 5.5 and 5.7 (ANOVA tables) show that the reaction time data and the

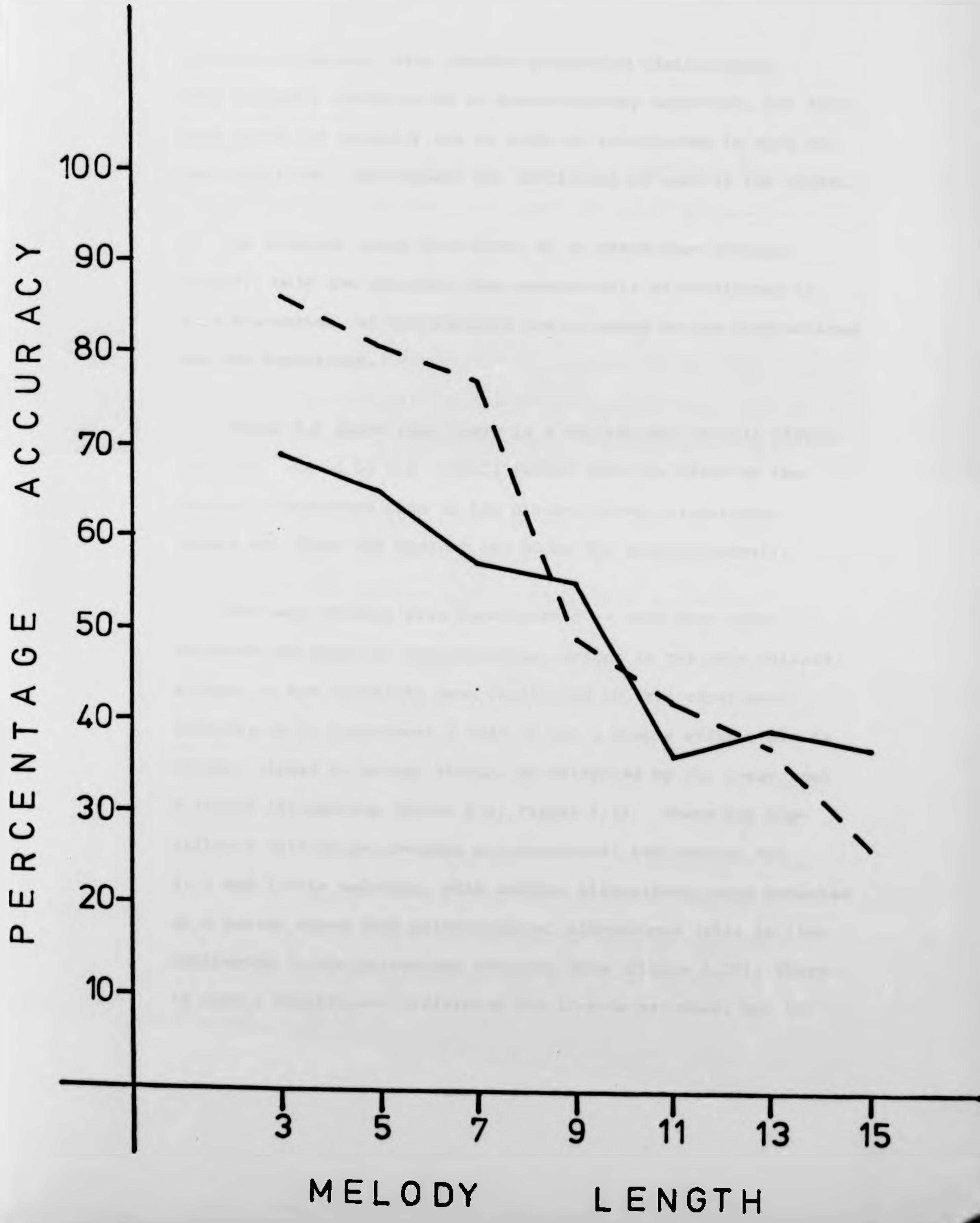
TASK	LENGTH						
	3	5	7	9	11	13	15
P-I	70	66	58	53	37	40	38
CONTOUR	87	82	78	50	43	38	27

Table 5.6 Experiment 3: Percentage accuracy scores for each Task/Length condition.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	210•1	9	23•3		
ERROR (WITHIN SUBJECTS)	430•6	117	3•7		
TASK	20•0	1	20•0	5•45	<0•05
ERROR (TASK)	79•4	9	8•8		
LENGTH	592•8	6	98•8	26•84	<0•001
ERROR (LENGTH)	170•1	54	3•1		
TASK x LENGTH	62•9	6	10•5	2•85	<0•05
ERROR (TASK x LENGTH)	181•1	54	3•4		

Table 5.7 Experiment 3: Task x Length ANOVA (percentage accuracy data).

FIGURE 5.2 Task x length interaction (Experiment 3, Percentage accuracy data).



percentage accuracy data possess pronounced similarities. This suggests that there is no speed/accuracy trade-off, but that both speed and accuracy are an index of performance in each of the conditions, and reflect the difficulty of each of the tasks.

As reaction times slow down, so do percentage accuracy scores. Only the reaction time measure will be considered in this discussion, as the emphasis was on speed in the instructions for the experiment.

Table 5.5 shows that there is a significant overall effect for task, caused by the overall faster reaction times to the contour alterations than to the pitch-interval alterations (means are 756ms for contour and 803ms for pitch-interval).

The main finding from Experiment 2 -- that when novel melodies are heard in transposition contour is the more salient element -- has therefore been replicated in this experiment. However, as in Experiment 2 this is not a simple effect, but is closely linked to melody length, as evidenced by the 2-way task x length interaction (Table 5.5, Figure 5.1). There are significant differences between pitch-interval and contour for 3, 5 and 7 note melodies, with contour alterations being detected at a faster speed than pitch-interval alterations (this is also replicated in the percentage accuracy data (Figure 5.2)). There is also a significant difference for 15-note melodies, but in this case the pitch-interval alterations are detected at a significantly faster speed than the contour alterations.

The other central finding from Experiment 2 has also been replicated in the present experiment. For 5-note melodies, contour alterations were detected at a significantly faster speed than pitch-interval, whilst the reverse was true for 15-note melodies. This implies that contour is more salient than pitch-interval for 5-note melodies under the experimental conditions and that pitch-interval is more salient than contour for 15-note melodies. This was found in Experiment 2 using a scoresheet response measure. When tighter control is placed over the time interval between the occurrence of the event (the alteration) and the moment of response (the pressing of the button), the same results are found as in Experiment 2.

In Experiment 2, only two melody lengths were used. The presence of a task x length interaction suggested that there should be some melody length between 5 and 15 notes for which contour and pitch-interval are equally salient. For the present experiment, the difference between pitch-interval and contour for 9, 11 and 13 notes is not significant, suggesting that for these melody lengths, pitch-interval and contour are equally salient. As no even-numbered melody lengths were used, this range might be extended to being between 8 and 14 notes.

It is suggested that the processing of novel, transposed melodies progresses along a contour--pitch-interval continuum where the relative salience of each type of relationship changes with increasing melody length. For shorter melody lengths, contour is considerably more salient than pitch-interval. For slightly longer melodies, pitch-interval and contour might be equally salient whereas for longer melodies, pitch-interval may be more salient than contour.

Of course, for longer melodies the limitations of short-term memory make performance very bad for both types of information but, as was stressed earlier in the thesis, it is the <u>relative</u> salience of pitch-interval and contour that is of most interest.

The possibility of a contour--pitch-interval continuum for the processing of novel, transposed melodies is investigated in more detail in the following section, which considers the effect of serial position on pitch-interval and contour. The results are first considered.

5.3.2 Serial position effects

Table 5.2 shows the distribution of alterations in the melodies of each length; this was the same for both the pitch-interval and the contour melody sets for any melody length. For each of the melody lengths, the melodies were divided into serial position groups of from one to five, depending upon melody length. These groups were position 1 (notes 1 - 3), position 2 (notes 4 - 6), position 3 (notes 7 - 9), position 4 (notes 10 - 12) and position 5 (notes 13 - 15). Each melody length was divided into these groups, and if the melody did not divide exactly by three, the last group was made up of the remainder after groups of three had been formed as far as possible.

A mean reaction time was calculated for each subject's responses to melodies in each of the serial position groups. This was possible for melodies of up to 9 notes in length; for the longer melodies there were fewer alterations per note (due to the longer melodies) and, in addition, performance was lower for these melody lengths. For the 11, 13 and 15 note melodies the percentage accuracy scores were considered instead. It was pointed out in the previous section that, as reaction times slowed, performance also fell in terms of percentage accuracy (compare Table 5.4 & 5.6; 5.5 & 5.7; Figures 5.1 & 5.2, which all illustrate this relationship). Both sets of data show remarkable similarities.

The 3, 5, 7 and 9-note melodies will be considered in one section, followed by the 11, 13 and 15-note melodies.

5.3.3 <u>Melodies of 3, 5, 7 and 9-notes.</u>

For the 3-note melodies a t-test gave a value of $t = 3{\cdot}78$; ($df = 9$; $p{\cdot}0{<}005$). The mean reaction times were 736ms for pitch-interval and 489 ms for contour. Thus reaction times for the contour task were significantly faster than those for the pitch-interval task.

For all other melody lengths, 2-way task x serial position ANOVAs were carried out, which can be seen summarised in Table 5.8. The results of the analyses can be seen in Tables 5.9, 5.10 and 5.11. There are significant effects for task for each length, position for each length, and significant interactions between task and position for each melody length. The interactions can be seen illustrated in Figures 5.3, 5.4 and 5.5.

Post hoc analyses (Tukey's a) reveal the values reported in Table 5.8. The nature of the interactions is such that position always has a significant effect for pitch-interval, with reaction times becoming significantly faster for each serial position, but having no effect for contour. In addition, contour reaction times are faster than pitch-interval for the earlier positions but not the later positions throughout.

5.3.4 <u>Overview of Results for 3, 5, 7 and 9-note melodies</u>

For all melody lengths, there is a significant effect for task, with contour alterations being detected at a faster speed than pitch-interval alterations for all melody lengths. The central finding is, therefore, that contour is more salient than pitch-interval when novel melodies are transposed for melodies of up to 9 notes in length. (Note: there is a significant difference between pitch-interval and contour for the 9-note

LENGTH	TASK	POSITION	INTERACTION	SIG.DIFFS. WITHIN TASKS	SIG.DIFFS. BETWEEN TASKS	CRITICAL VALUE AT 0.01 LEVEL (TUKEY's a)
5 NOTES	SIG (Table 5.9)	SIG	SIG (Fig. 5.3)	P-I 2<P-I 1	CONTOUR 1<P-I 1	292 ms
7 NOTES	SIG (Table 5.10)	SIG	SIG (Fig. 5.4)	P-I 2<P-I 1 P-I 3<P-I 1 P-I 3<P-I 2	CONTOUR 1<P-I 1 CONTOUR 2<P-I 2	245 ms
9 NOTES	SIG (Table 5.11)	SIG	SIG (Fig. 5.5)	P-I 2<P-I 1 P-I 3<P-I 1 P-I 3<P-I 2	CONTOUR 1<P-I 1 CONTOUR 2<P-I 2	249 ms

Table 5.8 Summary of results of Task x Serial Position ANOVA for 5, 7 and 9-note melodies.

X<Y = RTs in condition X significantly faster than RTs in condition Y.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	876744	9	97416		
ERROR (WITHIN SUBJECTS)	669412	27	24793		
TASK	1930000	1	1930000	77·9	<0·001
ERROR (TASK)	71128	9	7904		
POSITION	352540	1	352540	14·2	<0·001
ERROR (POSITION)	236142	9	26238		
TASK x POSITION	947656	1	947656	38·3	<0·001
ERROR (TASK x POSITION)	362142	9	40238		

Table 5.9 2-way Task x Position ANOVA for 5-note melodies. (RT data).

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	1662696	9	71410·7		
ERROR (WITHIN SUBJECTS)	3370000	45	74805·4		
TASK	1264300	1	1264300	16·90	<0·001
ERROR (TASK)	1106950	9	122995		
POSITION	1975270	2	987635	13·20	<0·001
ERROR (POSITION)	1608520	18	89362		
TASK x POSITION	1790810	2	895406	11·97	<0·001
ERROR (TASK x POSITION)	650770	18	36154		

Table 5.10 2-way Task x Position ANOVA for 7-note melodies. (RT data).

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	11822100	9	131356		
ERROR (WITHIN SUBJECTS)	1839960	45	40888		
TASK	708420	1	708420	17·33	<0·001
ERROR (TASK)	487058	9	54117·6		
POSITION	1443450	2	721724	17·65	<0·001
ERROR (POSITION)	471102	18	26172·3		
TASK x POSITION	550306	2	275153	6·73	<0·005
ERROR (TASK x POSITION)	881800	18	48988·9		

Table 5.11 2-way Task x Position ANOVA for 9-note melodies. (RT data).

FIGURE 5.3

Task x position interaction for 5-note melodies (Experiment 3, RT data).

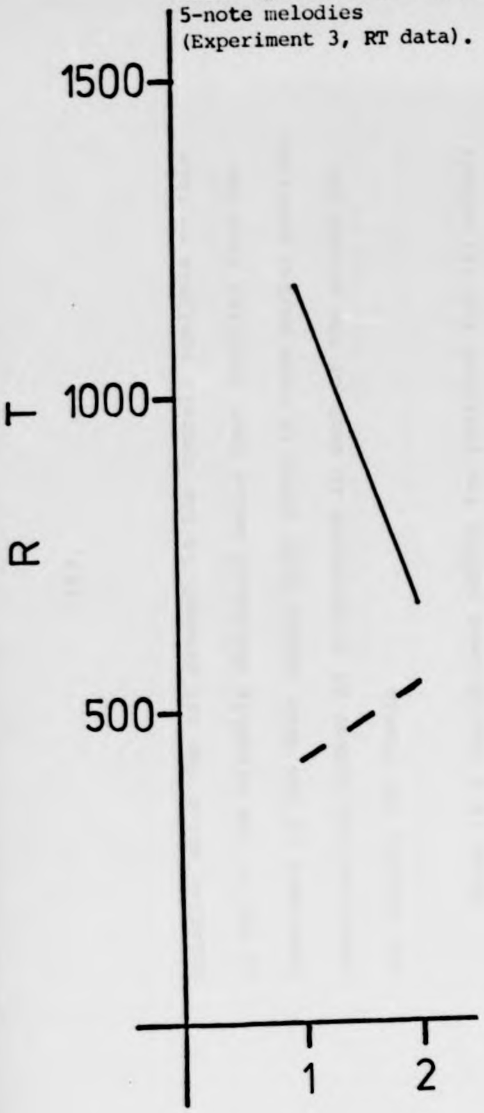


FIGURE 5.4

Task x position interaction for 7-note melodies (Experiment 3, RT data).

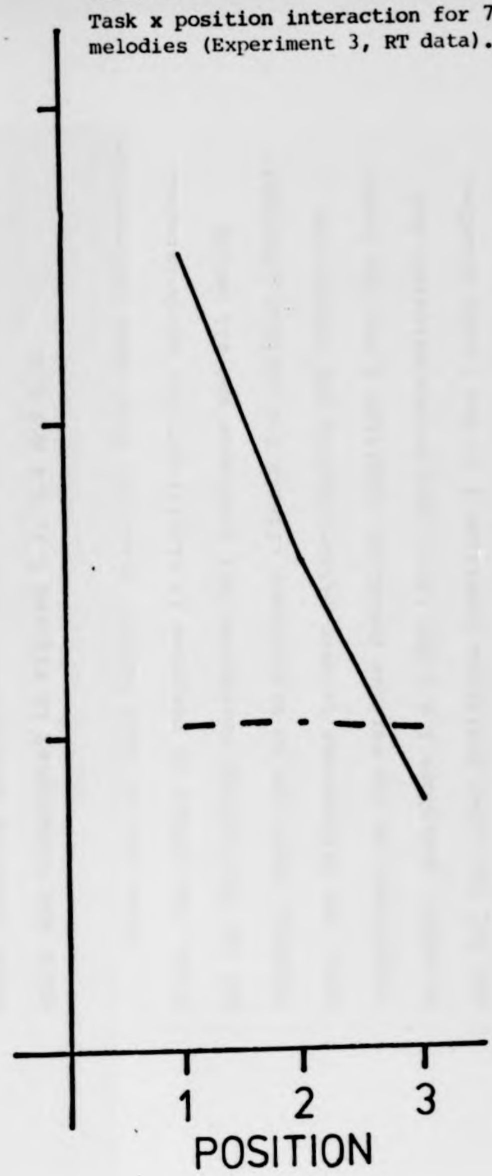
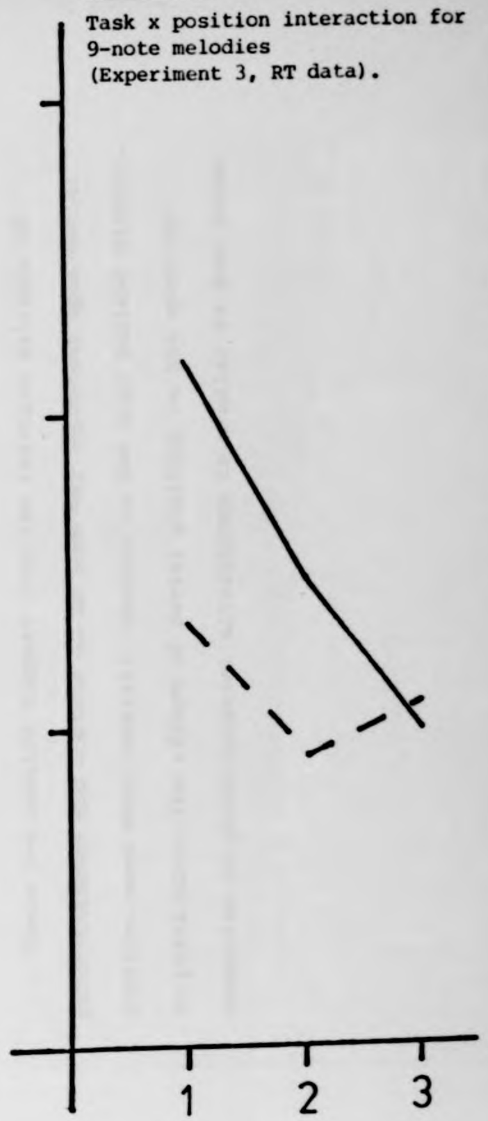


FIGURE 5.5

Task x position interaction for 9-note melodies (Experiment 3, RT data).



melodies which was not present in the overall analysis -- this is due to the slightly different means that resulted from the treatment of the data (means were given in each serial position group and the number of alterations in each of the groups was not exactly the same)).

There is a significant effect for position for all melody lengths, but of central interest are the significant task x serial position interactions found for each of the melody lengths, which are illustrated in Figures 5.3, 5.4 and 5.5.

There are two main effects resulting from these interactions. First, the effect of position is significant for pitch-interval but not for contour throughout all positions and all melody lengths; there are no significant effects for contour. Furthermore, the differences between pitch-interval and contour are significant in the earlier positions (position 1 for the 5-note melodies, positions 1 & 2 for the 7- and 9-note melodies) but not for the later positions (position 2 in the 5-note melodies, position 3 in the 7- and 9-note melodies).

These two results suggest that the relative salience of pitch-interval and contour is in some way dependent upon serial position even when, overall, contour is the more salient element. In particular, the effect of serial position on the speed of detection of pitch-interval alterations is similar to that found in Experiment 2 -- that the processing of pitch-interval relationships was performed better after a few notes had been heard than at the very beginning.

In general, the results show that the relationship between pitch-interval and contour changes throughout the extent of the melodies such that contour is more salient at the beginning of the melody, but with pitch-interval and contour becoming equally salient as the melody progresses. In particular this is due to the pitch-interval relationships becoming more salient in themselves, rather than the contour relationships becoming less salient, at least for melodies of up to 9 notes in length.

5.3.5 Melodies of 11, 13 and 15-notes

For each melody length, a task x serial position ANOVA was carried out using the percentage accuracy scores. It should be noted that performance on both pitch-interval and contour tasks was bad for the longer melodies and so the results will be discussed only in general terms.

The 2-way analyses of variance for the 11-, 13- and 15-note melodies can be seen in Tables 5.13, 5.14 and 5.15. The results from each analysis, and the significant *post hoc* comparisons, can be seen summarised in Table 5.12. The significant interactions and non-significant interations can be seen in Figures 5.6, 5.7 and 5.8. Task is significant only for 15-note melodies. Percentage accuracy scores are 40% for pitch-interval and

LENGTH	TASK	POSITION	INTERACTION	SIG.DIFFS. WITHIN TASKS	SIG.DIFFS BETWEEN TASKS	CRITICAL VALUE AT 0·01 LEVEL (TUKEY a)
11 NOTES	N.S. (Table 5.13)	SIG	SIG (Fig. 5.6)	P-I 2>P-I 4 CONTOUR 1>CONTOUR 4	CONTOUR 1>P-I 1 ONLY	33%
13 NOTES	N.S. (Table 5.14)	SIG	N.S. (Fig. 5.7)	NONE FOR P-I CONTOUR 5 > ALL OTHER POSITIONS	NO SIG.DIFFS.	37%
15 NOTES	SIG (Table 5.15)	SIG	N.S. (Fig. 5.8)	P-I 5 > P-I 1 P-I 5 > P-I 3 CONTOUR 1>CONTOUR 2 CONTOUR 1>CONTOUR 3	P-I 2>CONTOUR 2 P-I 5>CONTOUR 5	29%

Table 5.12 Summary of results of Task x Serial Position ANOVAs for 11, 13 and 15 note melodies.

X > Y = percentage accuracy in Condition X significantly higher than percentage accuracy in Condition Y.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	8890·4	9	987·8		
ERROR (WITHIN SUBJECTS)	38606	63	612·8		
TASK	2804	1	2804	3·40	0·1
ERROR (TASK)	6257·2	9	695·2		
POSITION	8548·2	3	2849·4	4·65	<0·05
ERROR (POSITION)	13441	27	497816		
TASK x POSITION	6450	3	2150	3·51	<0·05
ERROR (TASK x POSITION)	18907·7	27	700·3		

Table 5.13 2-way Task x Position ANOVA for 11-note melodies. (Percentage accuracy data).

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	25639·3	9	2848·8		
ERROR (WITHIN SUBJECTS)	85937	81	1061		
TASK	177·4	1	177·4	0·17	0·95
ERROR (TASK)	22703·5	9	2522·6		
POSITION	12713·8	4	3178·5	2·99	<0·05
ERROR (POSITION)	28614·3	36	794·8		
TASK x POSITION	8041	4	2010·2	1·90	0·25
ERROR (TASK x POSITION)	34619·2	36	961·6		

Table 5.14 2-way Task x Position ANOVA for 13-note melodies. (Percentage accuracy data).

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	17219	9	1913•2		
ERROR (WITHIN SUBJECTS)	77512•4	81	956•9		
TASK	5128	1	5128	5•50	<0•05
ERROR (TASK)	6445	9	716•1		
POSITION	9784•7	4	2446•2	2•62	<0•05
ERROR (POSITION)	30315•9	36	842•1		
TASK x POSITION	8674•4	4	2168•6	2•33	0•06
ERROR (TASK x POSITION)	38751•5	36	1076•4		

Table 5.15 2-way Task x Position ANOVA for 15-note melodies. (Percentage accuracy data).

FIGURE 5.6

Task x position interaction for 11-note melodies (Experiment 3, Percentage accuracy data).

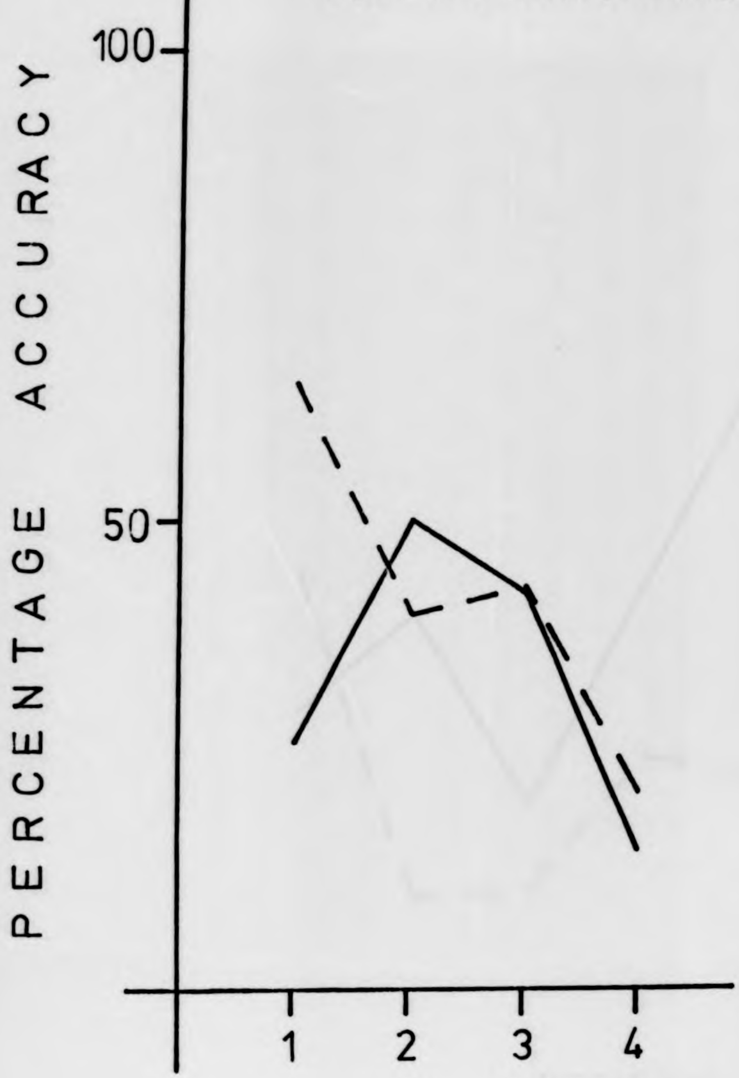


FIGURE 5.7

Relationship between task and position for 13-note melodies (Experiment 3, Percentage accuracy data).

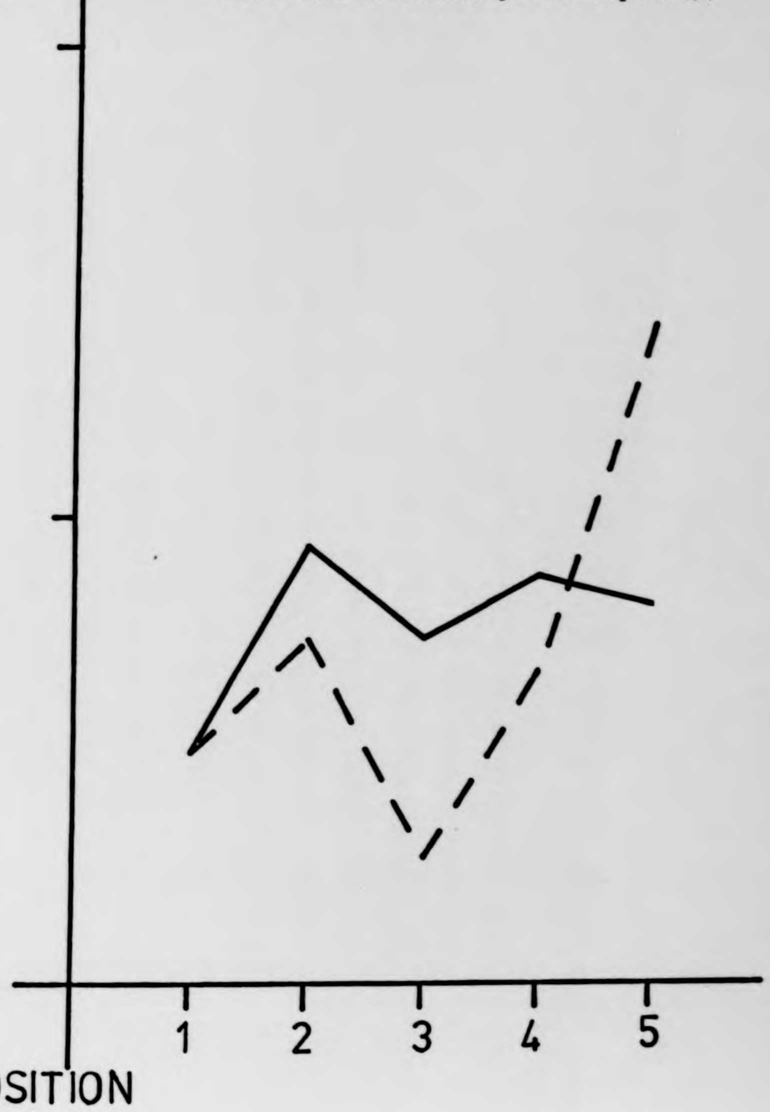
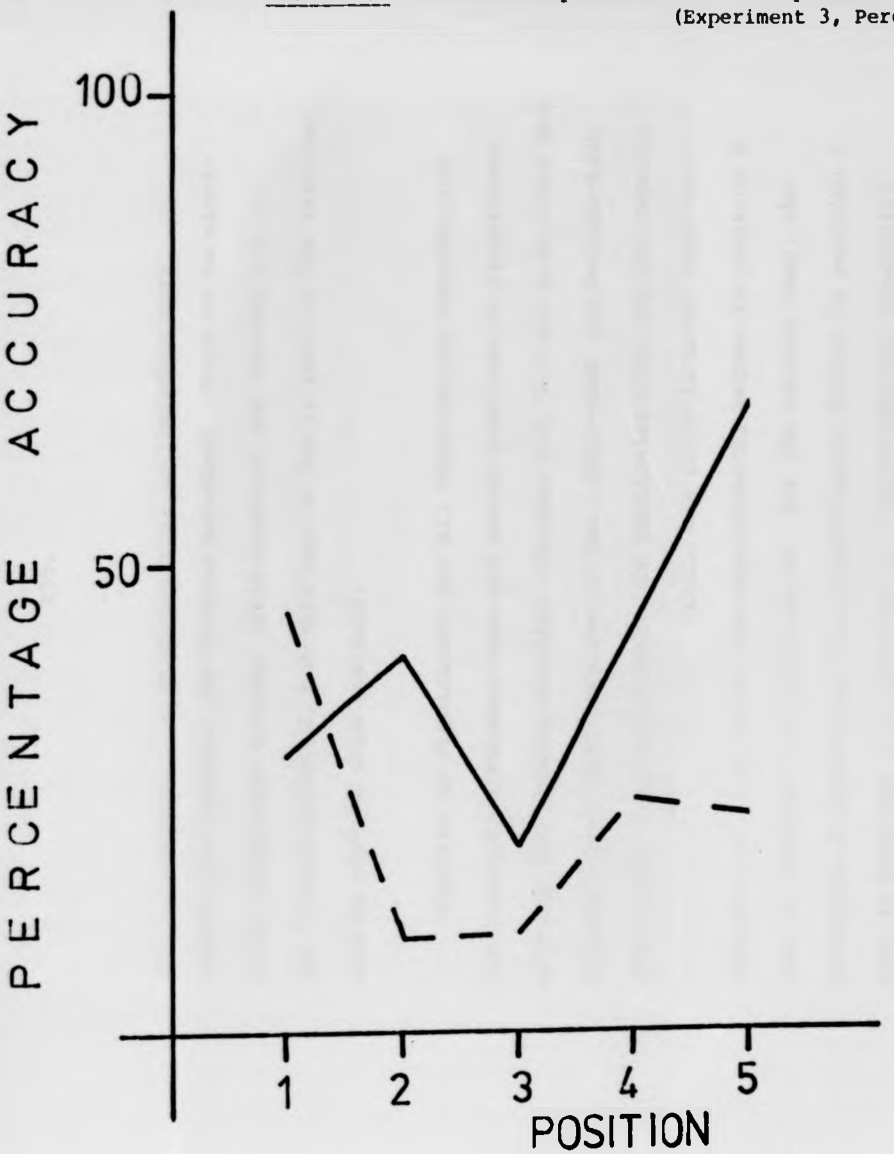


FIGURE 5.8 Relationship between task and position for 15-note melodies (Experiment 3, Percentage accuracy data).



23% for contour. Pitch-interval is therefore more salient than contour for 15-note melodies. There is no significant difference between pitch-interval and contour for 11- and 13-note melodies, but this may be due in part to the response measure used in this analysis.

Position is significant for all three melody lengths, but the interaction between task and serial position is significant only for the 11-note melodies (Figures 5.6, 5.7 and 5.8). *Post hoc* analysis shows that very few of the within-task and between-task comparisons are significant. Of particular note are the results for the 15-note melodies. Within the pitch-interval task the detection of alterations was significantly better in position 5 than in position 1 or position 3. For the contour task, the detection of alterations was significantly better in position 1 than in position 2 or position 3. Pitch-interval processing was better at the end of the melody, contour at the beginning.

The other main finding is that contour is <u>not</u> more salient than pitch-interval at the beginning of the 13- and 15-note melodies. This is only true of the 11-note melodies (see Table 5.12). For the 15-note melodies there are no positions where contour alterations were detected at a higher rate than pitch-interval; in contrast, there are two positions (2 and 5) where pitch-interval was detected at a higher rate than contour.

5.3.6 Overview of results for 11, 13 and 15-note melodies

As has been stressed earlier, responses to these longer melodies was poor and so too much emphasis will not be placed on the results. However, the central finding is that there is no significant task effect for 11 and 13-note melodies, but there is for 15-note melodies. For this melody length the pitch-interval alterations were detected at a significantly higher rate than the contour alterations. This is in direct contrast to the shorter melodies (3, 5, 7 and 9 notes in length) where contour was processed at a faster speed than pitch-interval (the reasons why the results criterion has been changed has been discussed earlier, when it was pointed out that both speed and accuracy reflect the difficulty of the tasks).

The lack of significant effect for task for the 11- and 13-note melodies supports the general finding in this experiment -- that for melodies of this length (and possibly shorter, particularly for 9-note melodies) contour and pitch-interval are equally salient. This will be discussed in more detail in Chapter 7.

The other results of interest for these longer melodies is that the relationship between pitch-interval and contour and serial position is different from the relationship for the shorter melodies. It is important to note that the processing of both pitch-interval and contour is worse for the longer melodies than the shorter melodies (as evidenced by the large significant effect for melody length (Table 5.4)), but, as has been stressed before, it is the relative salience of pitch-interval and contour that is of most interest.

For the 11-note melodies, contour is still more salient than pitch-interval for the first position. However, this is not so for the 13- and 15-note melodies. For the 13-note melodies there are no positions where contour or pitch-interval are processed significantly better than each other. For the 15-note melodies there are two positions (2 and 5) where pitch-interval is processed significantly better than pitch-interval, which is in complete contrast to the shorter melodies.

5.4 GENERAL DISCUSSION

The overall results of this experiment extend and support the hypotheses proposed in Chapter 4 (Experiment 2). When novel melodies are heard in transposition, then contour is a more salient element than pitch-interval for melodies up to about 9 notes in length (the results from the present experiment are equivocal). For longer melodies, pitch-interval and contour are equally salient until 15 notes, where pitch-interval is more salient than contour. These findings support the hypothesis of a contour--pitch-interval continuum, suggested earlier in this chapter.

The contour--pitch-interval continuum suggests that melody length might determine the relative salience of the contour and pitch-interval relationships; this in turn has implications for the relative importance of pitch-interval and contour relationships in composed music -- the length of a theme or melody might in some way determine the nature of the way that theme is processed, which in turn might suggest the nature of the memory trace of that theme. This idea will be further discussed in Chapter 7.

A further finding is that, even though overall for a particular melody length pitch-interval or contour might be the more salient element, there are very pronounced serial position effects, and these serial position effects change with increasing melody length. In summary, for melodies of up to 11 notes in length, contour is processed either significantly faster, or at a higher percentage accuracy than pitch-interval in the first (and sometimes second) serial position, but not in the later serial positions. For the 13- and 15-note melodies there is no such effect. For the 15-note melodies, there are two positions where pitch-interval was processed at a significantly higher rate than contour, which is a directly contrasting result.

In the shorter melodies this is mainly caused by the effect of serial position on the processing of pitch-interval relationships, which improves for every serial position for melodies up to 9 notes in length. The results are not as conclusive for the longer melodies. In terms of the contour--pitch-interval continuum proposed above, not only might the length of a melody determine the relative salience of pitch-interval and contour -- the serial position of a note (in particular for the shorter melodies) might also determine its contour or pitch-interval salience.

The contour--pitch-interval continuum, then, can be seen in terms of a fairly complex interaction between melody length and serial position of note, and will be discussed further in Chapter 7. In conclusion, it is thought that the importance of contour in short melodies and at the beginning of melodies might be caused by the underlying differences between the nature of pitch-interval and contour information. Contour is relational and therefore does not require the location of a 'tonal centre' (key) in the same way that pitch-interval might. Pitch-interval ultimately depends upon the accurate location of a tonal centre, which, when novel melodies are heard in transposition, can only be revealed by the notes of a melody themselves. Until this can be done, contour may be more important.

Thus there is an underlying cognitive explanation for the importance of contour in melody processing, and may account for why, and how, contour is an important element of a melody, as suggested by recent research (Cohen, 1975; Dowling, 1978). One of the levels at which a melody can be represented is that of contour, as suggested by Jones (1978). Contour representation is representation at a different level than pitch or pitch-interval. This idea will be developed in Chapter 10.

The results obtained in Experiment 3 have implications for the way composed music might be perceived, and musicological evidence will be proposed in Chapter 7.

The following experiment investigates the concept of the 'tonal centre' and the processing of pitch-interval information using a different type of pitch-interval task to the task reported in Experiments 2 & 3.

CHAPTER SIX

6.1 INTRODUCTION

In the preceding chapters, evidence was obtained which suggests that contour is more salient than pitch-interval for short, novel, transposed melodies. In addition, it was found that contour was relatively more salient than pitch-interval at the beginning of melodies under these conditions, with pitch-interval becoming relatively more salient as a melody progresses, up to the point when the task became too difficult (when melodies became too long).

The central reason for this was suggested as the need to establish some sort of 'tonal centre' -- the sense of a tonic or key -- for the accurate encoding of pitch-interval. This may not be necessary for the encoding of contour. The following experiment investigates this hypothesis more fully.

The concept of a 'tonal centre' introduces the importance of context in studies of music, most particularly melody, perception. Context is a widely studied topic in the general psychological literature and can be seen reviewed in Taylor (1972). Context studies generally find that context does have an effect on the perception of focal stimuli which is either deleterious or advantageous. Both quality and quantity of context are found to have some effect.

Specifically relating to melody perception, 'focal stimuli' are considered as discrete notes, or intervals,and 'context' is the presence of other notes surrounding these stimuli -- some sort of melodic framework. There is evidence to suggest that both the quality and quantity of this framework is important, and that ultimately this relates to the need to establish a tonal centre for the accurate reporting of, for example, a single interval within a melodic context.

Barnes (1960) found that context in fact had an adverse effect on the singing of single intervals. Siegel & Siegel (1977) found that trained musicians could identify intervals reliably and independently of context. Most research, however, suggests that interval perception takes place better when heard in some sort of melodic context. Taylor (1972), in an extensive study of the perception of melodic intervals in and out of context, found that most intervals were better perceived when heard in melodic context.

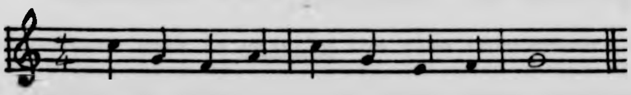
Some studies show that listeners are better able to detect interval alterations when melodies are tonal, rather than atonal (for example, Francès (1958); Dewar *et al* (1977)). A study by Cuddy *et al* (1979) shows how the perception of a melodic sequence is worse when embedded in an atonal sequence than in a tonal sequence when transposed. All these results point to the importance of the establishment of a tonal centre -- which must, logically, be more difficult to establish for atonal than tonal melodies.

The results of Experiments 2 & 3 have been interpreted as showing how the tonal centre becomes clearer as more notes are heard; the pitch-interval values become clearer as the tonal centre becomes established, and up to that point the contour relationship is more salient.

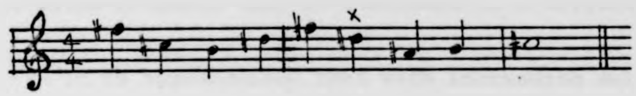
However, although performance on the pitch-interval task improved after the first few notes had been heard, performance again fell off rapidly towards the end of the longer melodies. This is probably due to the difficulty of the task itself. This is a particular problem in experiments concerning melody processing -- when melodies are heard which are of a realistic length, they become too difficult to retain in a short-term memory experiment where they have been heard only once previously. Task difficulty may therefore cloud important effects.

In the following experiment the establishment of a tonal centre in transposed melodies is investigated in further detail; however, a different pitch-interval task is set. As in Experiment 3, a wide variety of melody lengths are used and the original melodies heard are exactly the same as in Experiment 3. However, there is a major difference in the comparison melodies.

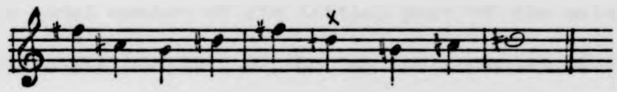
In Experiment 3 the melody below:



possessed a comparison melody as follows:



There is one altered note, relative to the new key, which then returns to the same key. In the following experiment the comparison melody is as follows:



There is one altered note but after the alteration has occurred the melody modulates to whichever key makes the alteration, in retrospect, correct with relation to the new key. Thus, after the alteration has occurred the whole melody is in a different key.

It is thought that this new task will lead to different sorts of responses, to be discussed later, and in order to eliminate the effect of increasing task difficulty due to increasing melody length, the responses from the following experiment are compared with those from Experiment 3.

Experiments 3 & 4 (following) thus share these similarities:- the contour task is <u>exactly</u> the same throughout; the pitch-interval is exactly the same up to the point where the alterations in the comparison melodies occur. But in Experiment 4 the melody in the pitch-interval task is continued in a different key.

It is hypothesised that with increasing melody length, the tonal centre will become clearer purely because more notes will be heard, which should establish a tonal centre. This hypothesis derives from the results of Experiments 2 & 3. For the shorter melodies, then, the listener will not be able to establish either the tonal centre of the initial part of the melody (before the alteration occurs) or the new tonal centre of the melody after the alteration has occurred. However, for the longer melodies, once the tonal centre has been located, a deviation from the tonal centre will be detected as such and so the listeners will have to reorientate themselves into the new key.

Thus it is predicted that for the shorter melodies there should be little difference between the reaction times produced in Experiment 4 and those to be produced in the following experiment. However, for the longer melodies a difference is predicted. The location of an initial tonal centre before the alteration occurs might affect the speed with which these new alterations are detected.

The effects of serial position are also of interest. The tonal centre cannot be established in the very early positions, so the technique used by the listener to detect an alteration might be quite different to the technique used for detecting alterations once a tonal centre has been established. Thus a comparison of reaction times for a number of serial positions within each melody length will be carried out. It is predicted that with increasing serial position the reaction times produced in this and the preceding experiment will diverge.

For both the melodies as a whole and for serial positions within each melody length, it is thought that the salience of the tonal centre with increasing melody length and serial position will have a differential effect on the reaction times produced in this experiment to those found in Experiment 3.

The following experiment is carried out in exactly the same way as Experiment 3, using the same melodies. The contour task is identical, serving as a comparison between subjects. The pitch-interval task is different and it is thought that this difference will have differential effects of the reaction times obtained between Experiments 3 & 4, which in turn reflects the salience, or otherwise, of the tonal centre.

EXPERIMENT FOUR

6.2 METHOD

6.2.1 Subjects: Ten subjects participated in 14 experimental sessions. Every subject was a musician who had been learning at least one musical instrument for a minimum of five years during the period immediately prior to the experiment.

6.2.2 Task: Subjects participated in 14 different tasks, 7 of which were pitch-interval and 7 of which were contour.

In each of the pitch-interval sessions, subjects listened to 16 melody pairs (trials). In each session the melodies were of only one length -- 3, 5, 7, 9, 11, 13 or 15 notes. In each trial, a melody was heard in the key of C major. After a five second pause the melody was heard again, transposed to F sharp major. This comparison melody usually possessed one pitch-interval alteration at one point in the melody. After this alteration occurred all intervals were preserved and so were the same as in the first melody. The task was to detect this alteration and to press a button as quickly as possible. There were 12 trials of this type for each of the melody lengths and 4 catch trials where the comparison melody was exactly the same as the first throughout.

In each of the 7 contour sessions, one for each melody length, subjects again heard 16 melody pairs. The procedure for the contour task was identical to that of Experiment 3 (see Procedure section of Chapter 5).

6.2.3 Design: There were 2 nested factors -- task (pitch-interval/contour) and melody length (3, 5, 7, 9, 11, 13 and 15 notes). The design of the experiment was exactly the same as for Experiment 3 (see Tables 5.1 & 6.1).

The third factor, the position of the alterations within the melodies, was different for each melody length, and was the same as Experiment 3 (see Table 5.3).

6.2.4 Counterbalancing of subjects: This was exactly the same for Experiment 3 (see Table 5.2). The order of the 16 trials within each of the 14 conditions was randomised separately for each of the subjects in each of the conditions.

6.2.5 Melodies: 14 sets of 16 melody pairs were composed. Seven sets were used in the pitch-interval task, 7 in the contour task. The sets were designed as follows:

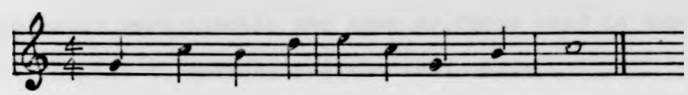
(A) Pitch-Interval

For each of the melody lengths 3, 5, 7, 9, 11, 13 and 15 notes, 16 melodies were composed in the key of C major. These

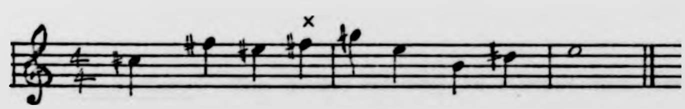
TASK	P-I	CONTOUR
LENGTH	3 5 7 9 11 13 15	3 5 7 9 11 13 15
EXPERIMENTAL TRIALS	12 for each length	12 for each length
CATCH TRIALS	4 for each length	4 for each length

Table 6.1 Experiment 4: Design.

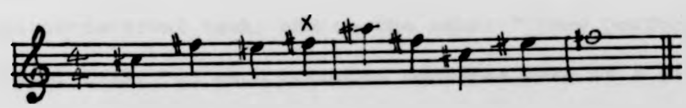
melodies were exactly the same as those used for the pitch-interval tasks in Experiment 3. For each of the melodies a comparison melody was composed in the key of F sharp major. For 12 of the comparison melodies, there was one pitch-interval alteration. These alterations were exactly the same as those used for Experiment 3 for each melody length. However, after the alteration occurred, the interval between the alteration and the succeeding note was the same as it had been in the C major melody. The melody below:



possessed a comparison melody as follows:



(In Experiment 3 this same melody possessed this comparison melody):



For the other 4 comparison melodies for each length, the melody was correctly transposed throughout. These were catch trials. Details on the distribution of the alterations within each set of melodies can be seen in Table 5.3, and were exactly the same as for Experiment 3. The only difference between the comparison melodies used in this experiment and Experiment 3 was in the nature of the melody after the alteration had occurred. All the melodies used in this experiment can be seen in Appendix 3.

(B) Contour

The 7 sets of 16 melody pairs used in this part of the experiment were exactly the same as those used in Experiment 3 (see Chapter 5, Methods section (Melodies)).

Again, the distribution of the contour alterations was exactly the same as in Experiment 3 (Table 5.3).

6.2.6 Procedure: The order of the 14 conditions (see Table 5.1) was counterbalanced according to Table 5.2. Subjects attended the laboratory on 14 occasions and participated in only one condition on each occasion. On 7 occasions subjects performed a pitch-interval task, and on the other 7 they performed a contour task. On each occasion melodies were of a different length.

The procedure for the pitch-interval and contour tasks was identical to Experiment 3 in every way. For details see the Procedure section of Experiment 3. As noted before, the crucial difference between the experiments was in the nature of the pitch-interval comparison melodies after the alteration had occurred.

6.3 RESULTS

Mean reaction times were calculated for each of the subjects in each of the 14 task/length conditions. These means were collapsed across serial position of alteration, which will be considered later.

In addition, a percentage accuracy score was calculated for each of the subjects in each of the conditions by taking the number of reaction times produced in each of the conditions and calculating a percentage of the total number of responses possible in each of the conditions.

Experiments 3 & 4 are very similar -- the contour task was identical and the pitch-interval task was also identical except for the crucial difference in the nature of the melody after the alterations had occurred in the comparison melodies. Thus the results from this experiment will be considered in two ways; first, alone and second, as a matched pairs comparison with the results obtained in Experiment 3.

6.3.1 Experiment 4 only

The mean reaction times for each of the 14 task/length conditions can be seen in Table 6.2.

A 2-way task x length ANOVA was carried out, and can be seen in Table 6.3. There is a significant effect for task,

LENGTH	P-I	CONTOUR
3	726	491
5	718	559
7	870	516
9	868	738
11	1086	772
13	988	828
15	1012	999

<u>Table 6.2</u> Experiment 4: Mean RTs for each Task/Length condition.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	2173788	9	241532		
ERROR (WITHIN SUBJECTS)	5192109	117	44377		
TASK	1380000	1	1380000	31·07	<0·001
ERROR (TASK)	420984	9	46776		
LENGTH	2963760	6	493960	11·13	<0·001
ERROR (LENGTH)	13985978	54	258999·6		
TASK x LENGTH	436448	6	72741·3	1·64	0·2
ERROR (TASK x LENGTH)	1585143	54	29354·5		

<u>Table 6.3</u> Experiment 4: Task x Length ANOVA (RT data).

caused by overall faster responses to contour than pitch-interval alterations (means are 700ms for contour, 895ms for pitch-interval) and a significant effect for length (reaction times become slower with increasing melody length). There is no significant interaction between the two. The relationship between pitch-interval and contour can be seen in Figure 6.1.

Post hoc analysis (Tukey's a) reveals a critical value of 204ms for significance at the 0.01 level and a level of 153ms for significance at the 0.05 level.

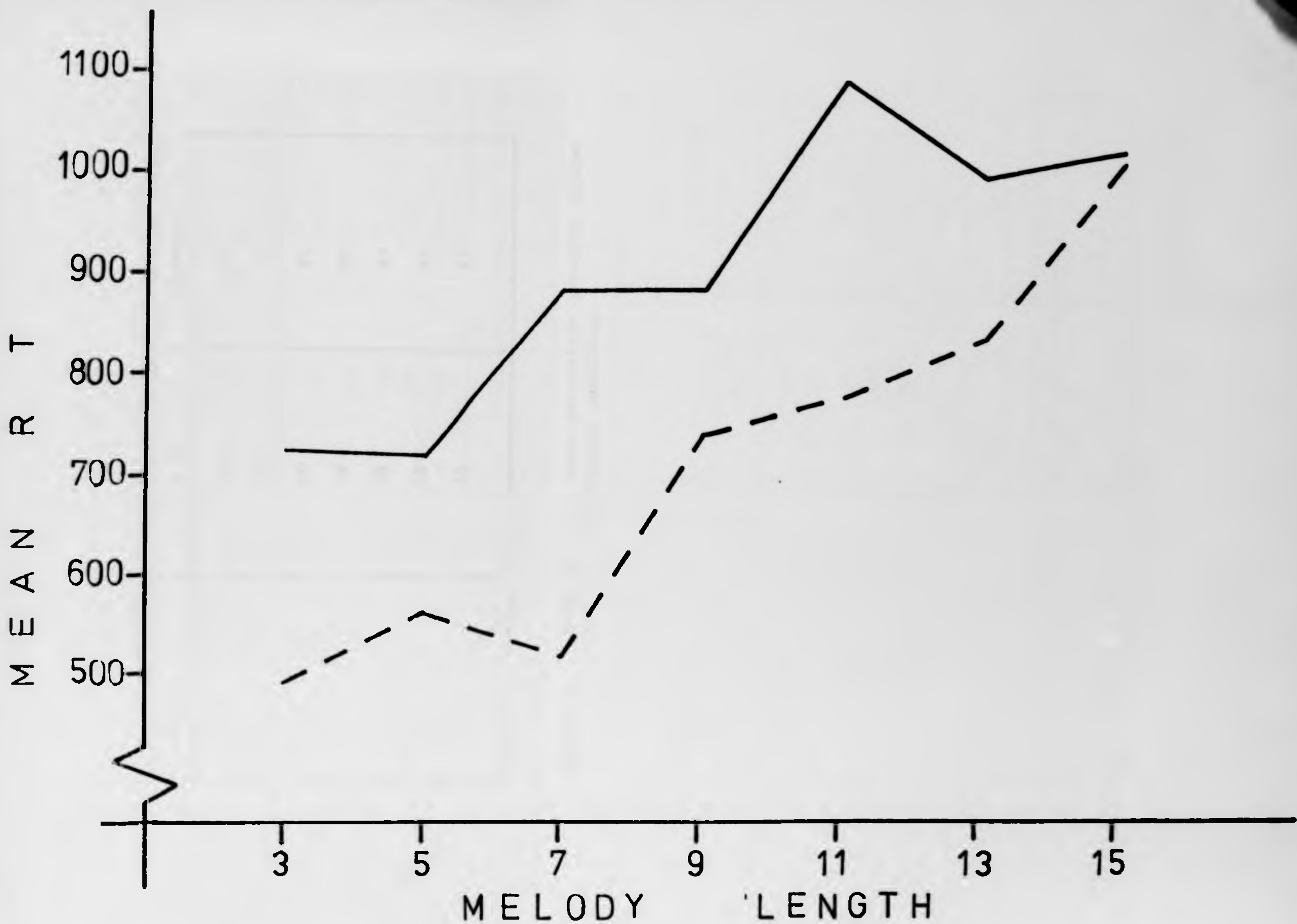
The percentage frequency of response in each of the conditions can be seen in Table 6.4. Comparison of Tables 6.2 and 6.4 show that there is no speed/accuracy trade-off, but that as reaction times slow, accuracy also decreases. This was also found in Experiment 3.

6.3.2 Experiments 3 & 4

A comparison of the mean reaction time scores produced in each of the 14 task/length conditions for each of the experiments can be seen in Table 6.5.

A comparison of the percentage frequency of response can be seen in Table 6.6. The reaction times for pitch-interval in Experiments 3 & 4 can be seen compared in Figure 6.2 and the contour means compared in Figure 6.3

FIGURE 6.1 Relationship between task and length (Experiment 4, RT data).



LENGTH	P-I	CONTOUR
3	68	93
5	72	84
7	60	71
9	59	49
11	38	47
13	58	35
15	45	22

Table 6.4 Experiment 4: Mean percentage accuracy scores for each Task/Length condition.

LENGTH	TASK			
	P-I		CONTOUR	
	EXP.3	EXP.4	EXP.3	EXP.4
3	736	726	489	491
5	813	718	677	559
7	878	870	702	516
9	760	868	681	738
11	920	1086	810	772
13	831	988	855	828
15	680	1012	1080	999

Table 6.5 Experiments 3 & 4: Comparison of mean RTs for each Task/Length condition.

LENGTH	TASK			
	P-I		CONTOUR	
	EXP.3	EXP.4	EXP.3	EXP.4
3	70	68	87	93
5	66	72	82	84
7	58	60	78	71
9	53	59	50	49
11	37	38	43	47
13	40	58	38	35
15	38	45	27	22

Table 6.6 Experiments 3 & 4: Comparison of percentage accuracy scores in each Task/Length condition.

FIGURE 6.2 Comparison of RT data from Experiments 3 & 4 (Pitch-interval task).

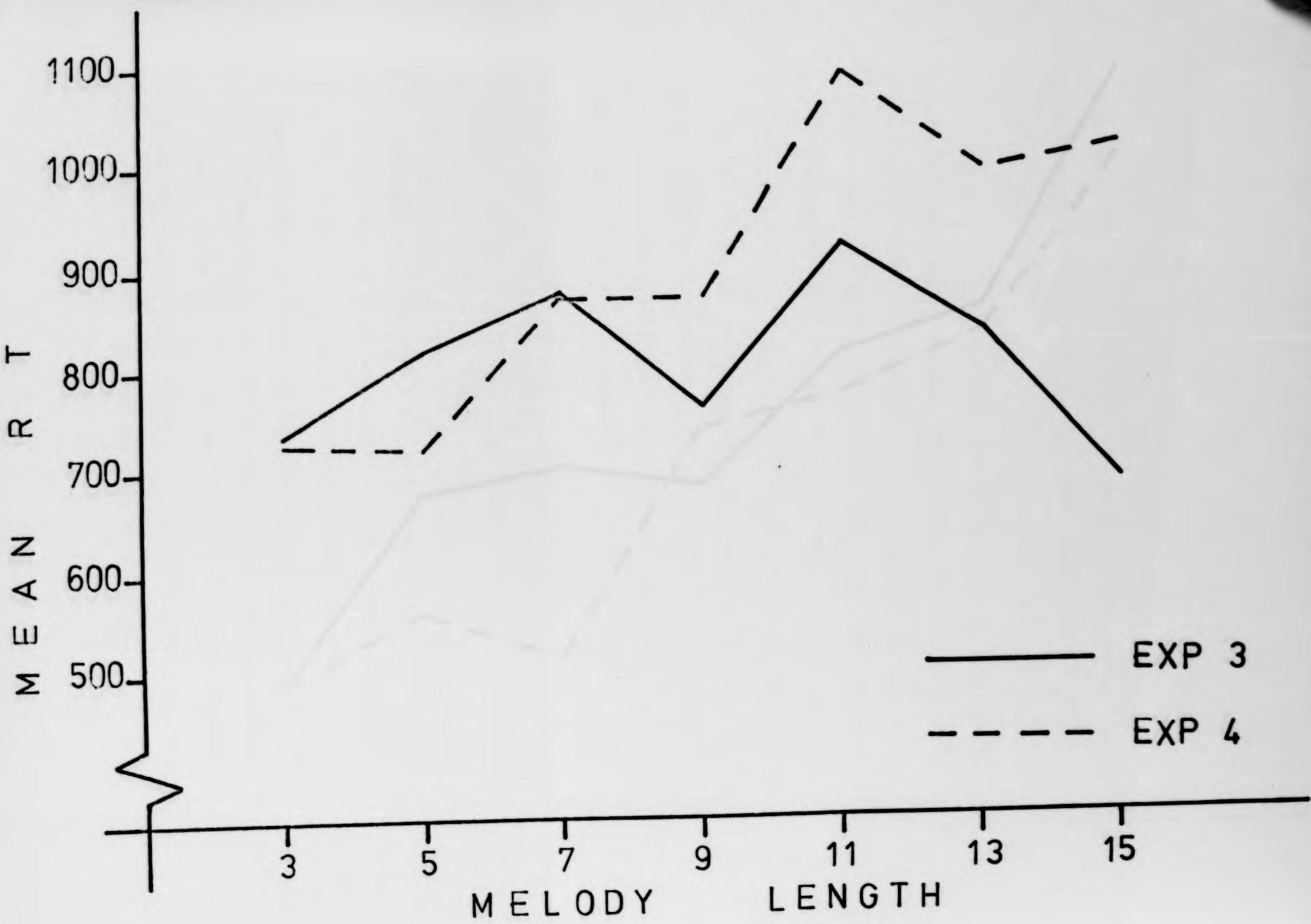
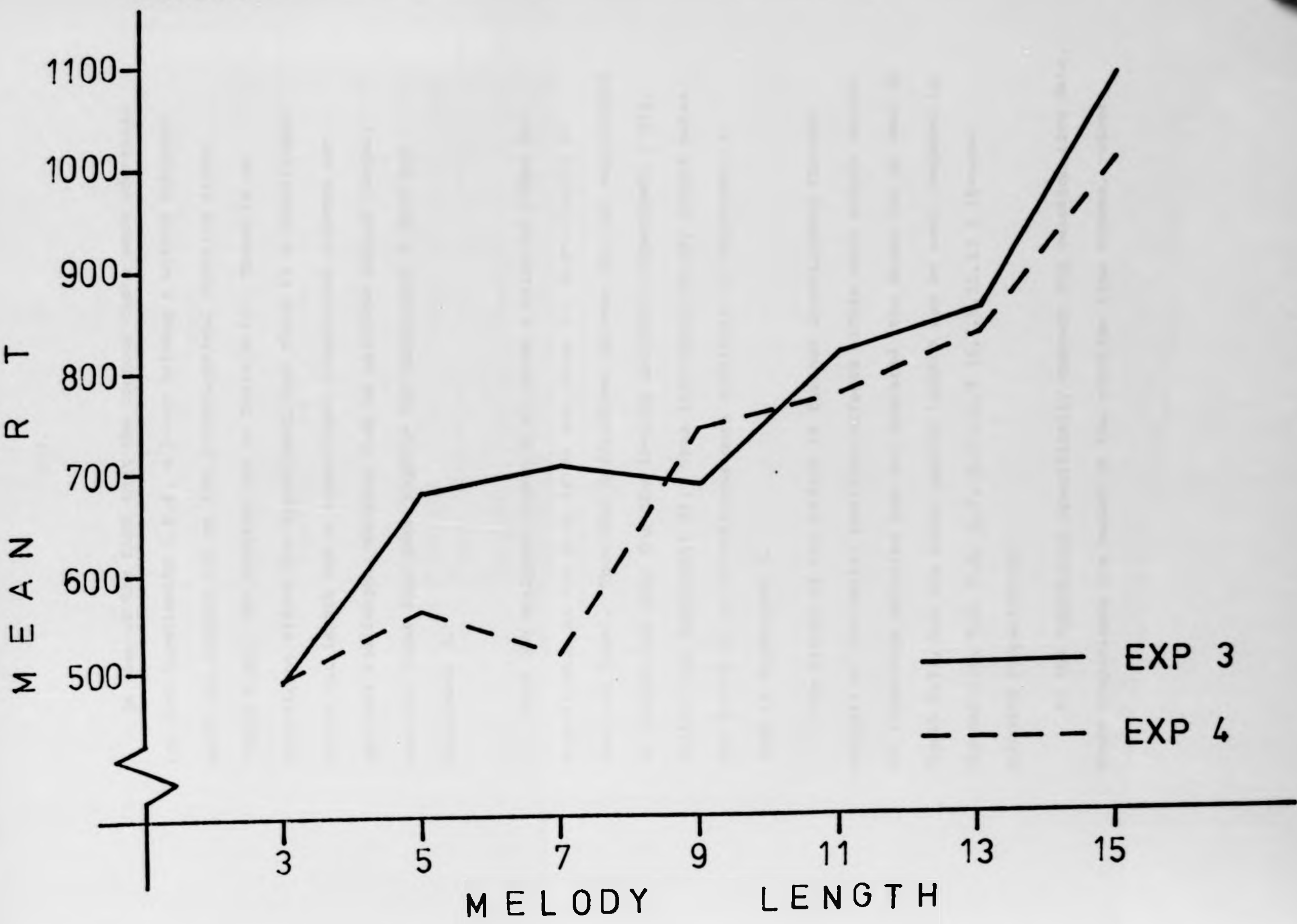


FIGURE 6.3 Comparison of RT data from Experiments 3 & 4 (Contour task).



In view of the fact that the contour tasks were identical for both Experiments 3 & 4, a 2-way between x within subjects ANOVA was carried out on the pitch-interval reaction times (Table 6.5). The results are in Table 6.7. There is no significant effect for experiment, but there is a significant effect for length and a significant interaction between experiment and length, showing that as melodies become longer, reaction times slow more rapidly for Experiment 4 than for Experiment 3.

Post hoc analysis (Tukey's a) gives a value of 238ms for significance at the 0.01 level and 180ms for significance at the 0.05 level. Thus the differences between the two experiments is significant only for the 15-note melodies (Experiment 3 sig. faster than Experiment 4). Thus increasing melody length makes the detection of alterations more difficult in Experiment 4 than in Experiment 3.

The nature of the effect is further investigated through analysis of the serial position effects within each melody length. The three-note melodies are not compared (the means can be seen in Figure 6.2), but the other melody lengths can be seen compared in Figures 6.4, 6.5, 6.6, 6.7, 6.8 & 6.9 (5,7,9,11,13 & 15-note melodies respectively).

As the hypotheses specifically concern the reaction time data, these comparisons are based on the reaction time scores, rather

TASK	SUM OF SQUARES	df	MEAN SQUARE	F	p
BETWEEN SUBJECTS (TASK)	336270	1	336270	2•52	0•2
ERROR	2401164	18	133398		
WITHIN SUBJECTS (LENGTH)	1106292	6	184382	4•44	<0•001
TASK x LENGTH	625180	6	10417	2•51	<0•05
ERROR (TASK x LENGTH)	4481957	108	41499•6		

Table 6.7 Experiments 3 & 4: Experiment x Length ANOVA for P-I tasks (RT data).

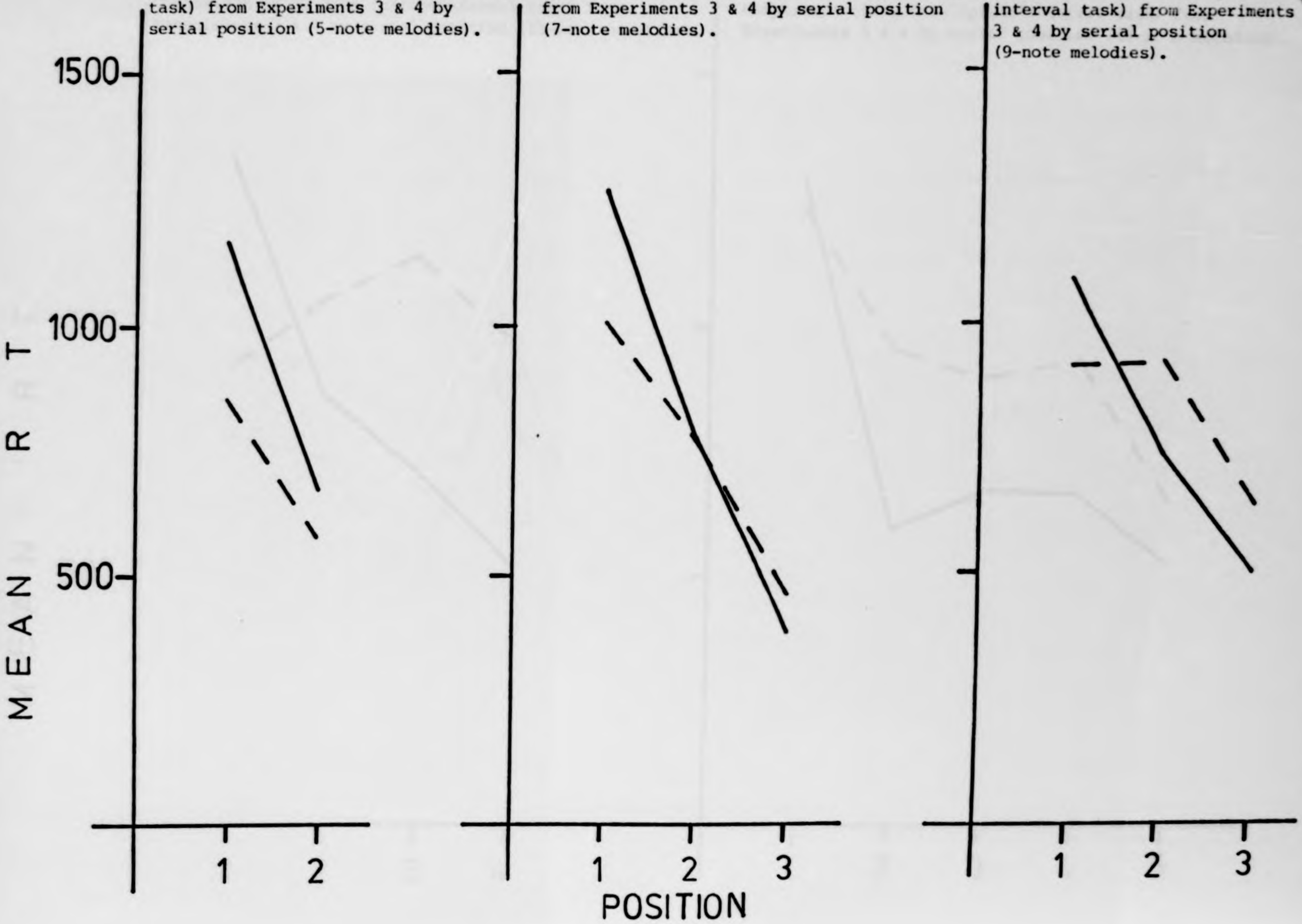


FIGURE 6.4
Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (5-note melodies).

FIGURE 6.5
Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (7-note melodies).

FIGURE 6.6
Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (9-note melodies).

FIGURE 6.7

Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (11-note melodies).

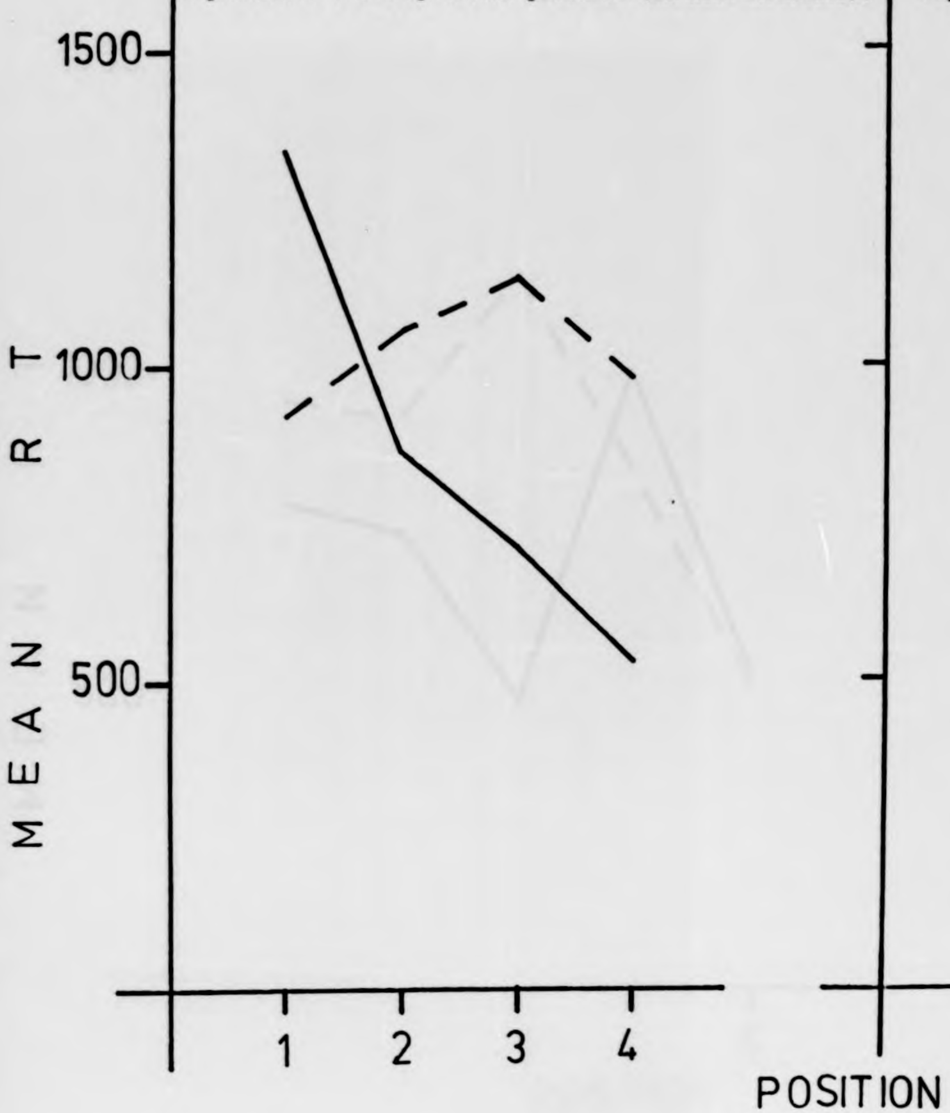


FIGURE 6.8

Comparison of RT data (pitch-interval task) from Experiments 3 & 4 by serial position (13-note melodies).

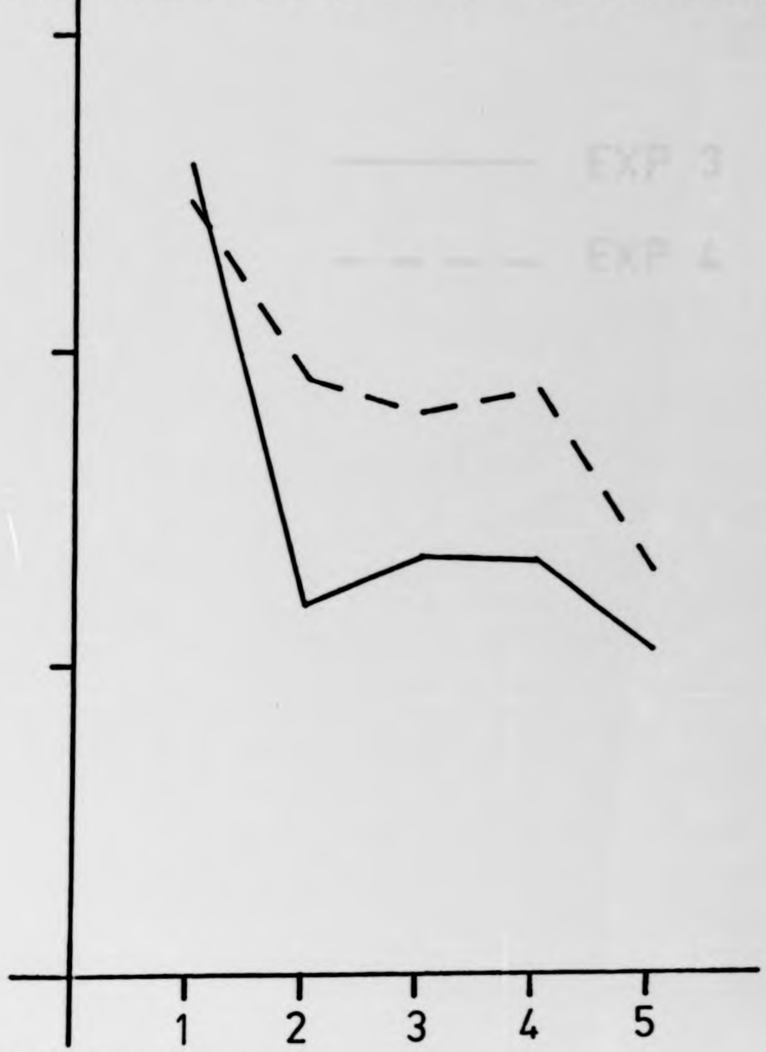
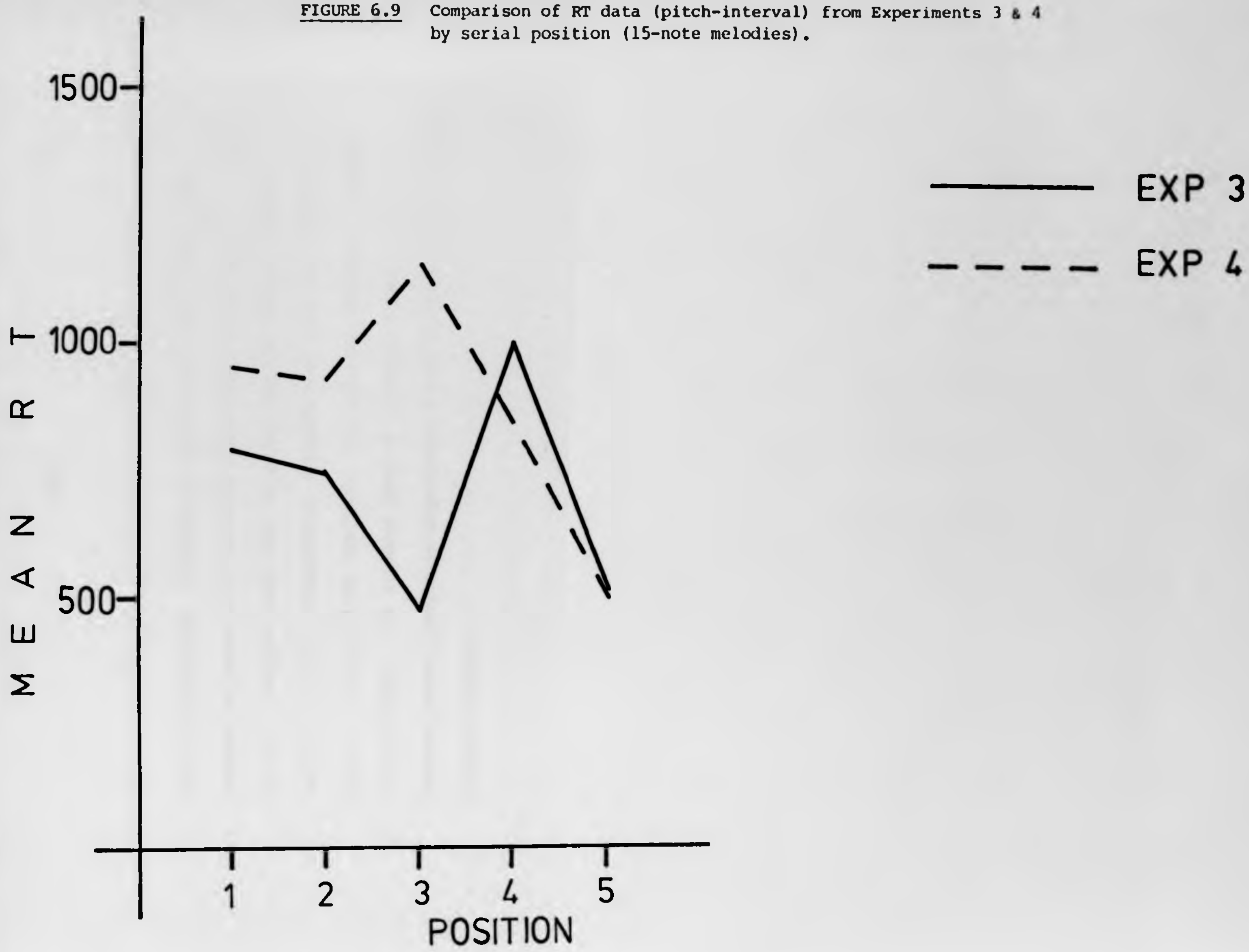


FIGURE 6.9 Comparison of RT data (pitch-interval) from Experiments 3 & 4 by serial position (15-note melodies).



than the percentage accuracy scores which have, anyway, been compared in Table 6.6. As with Experiment 3 the amount of data for each task/position cell is small for the longer melody lengths, so these comparisons (Figures 6.4 to 6.9) will not be subject to statistical analysis, but will be discussed in more general terms. The slowing down of reaction times with increasing melody length in Experiment 4 can be seen in more detail in these figures.

6.4 DISCUSSION

The results obtained from the current experiment alone will be considered briefly; a more detailed discussion of the comparison of Experiments 3 & 4 will then follow.

6.4.1 Experiment 4

The central interest in this experiment is that of the pitch-interval task; consequently there were no particular hypotheses about the outcome of Experiment 4 alone. Table 6.2 shows that there is a significant effect for task, caused by the overall faster reaction times produced to the contour than the pitch-interval task. The pitch-interval task is significantly more difficult than the contour task. The interaction between pitch-interval and contour in this task is not significant, and *post hoc* analysis (Tukey's a) shows that the difference between pitch-interval and contour are significant for all melody lengths except the two longest ones -- 13- and 15-note melodies. Contour reaction times are significantly faster than pitch-interval reaction times for all other melody lengths.

The relationship between pitch-interval and contour does change with increasing melody length, however, as evidenced by Figure 6.1. Contour is relatively more salient in the shorter melodies, a finding which replicates that of both Experiments 2 & 3. This will be discussed in Chapter 7 in more detail.

The lack of significant interaction between pitch-interval and contour is caused by the different pitch-interval task set in this experiment, and it is the result from this task alone that is of central interest.

6.4.2 Comparison of Experiments 3 & 4

Inspection of Table 6.4 shows that the reaction times produced in the contour task in each of the experiments is very similar. As this task was identical for both experiments, this demonstrates that the ability of the two groups of subjects to perform the tasks set was similar (Figure 6.2). The groups of subjects used in the two experiments can therefore be compared. The scores differ most on the pitch-interval task which was of course different between experiments (Figure 6.3). This will be discussed below.

Inspection of Table 6.5 shows that the performance levels of both sets of subjects was comparable for both the pitch-interval and the contour tasks in terms of percentage accuracy. The major difference, then, between the two experiments is that of the reaction times produced in the pitch-interval tasks.

The 2-way experiment x length ANOVA illustrates the difference between the pitch-interval tasks in each of the experiments (Table 6.7). There is no overall effect for experiment, which suggests that overall the two pitch-interval tasks were not of different degrees of difficulty. There is a significant effect for melody length, caused by the slowing down of reaction time with increasing melody length.

Attention was drawn to the problems of increasing melody length in melody perception experiments in the introduction. By increasing context quantity it is very easy to overload the limited capacity of short-term memory. One of the ways to infer processes in melodies of different lengths is to compare melodies of the same length for the different tasks. This is done in the 2-way ANOVA, in particular the finding of an experiment x length interaction (Figure 6.3). For the 3-note melodies there is no difference between the reaction times produced in each of the experiments. In general, the differences between the two becomes larger with increasing melody length until, for the 15-note melodies the difference is large and signficant (Tukey's a = 238ms for significance at the 0·01 level).

The central hypothesis is therefore supported; for shorter melodies there are no differences in the reaction times produced to alterations of both types (Experiment 3 & Experiment 4 alterations); for longer melodies, the difference becomes larger until eventually it becomes significant.

The results suggest that with increasing melody length, deviations from the tonal centre become more important to the listener.. For the shorter melodies there are no differences between the reaction times to each of the pitch-interval tasks for melody length, caused by the slowing down of reaction time with increasing melody length.

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The results suggest that with increasing melody length, deviations from the tonal centre become more important to the listener.. For the shorter melodies there are no differences between the reaction times to each of the pitch-interval tasks because the tonal centre is not clear; deviations from it are therefore of no importance to the listener. Once the first tonal centre has been established, however, a deviation from it, and movement into a new tonal centre, slows down reaction times. Thus, for the longer melodies, alterations are harder to detect in Experiment 4 than Experiment 3.

The direction of this effect is rather surprising and more light can be shed on the rather counter-intuitive result by consideration of the serial position effects within each melody length (Figures 6.4 to 6.9). It must be remembered that due to the nature of the data obtained, the results have not been subject to statistical analysis; the central argument must, therefore, come from the overall results already discussed.

Inspection of the Figures shows that, for Experiment 3 there are quite pronounced serial position effects with, apart from a few anomalies, a speeding up of reaction time with increasing serial position. This can be interpreted as showing that the tonal centre has become more salient with increasing melody length.

The results from Experiment 4 show very much the same trend for melodies up to 7 notes in length; however, at 9 notes and beyond, there is quite a difference between experiments, with reaction times in Experiment 4 being generally slower. This is confounded by the observation that, for the first position, the reaction times seem to be faster for this experiment.

Thus there is a situation where the different task set in Experiment 4 produces faster reaction times in the <u>early</u> positions but slower reaction times in the <u>middle</u> positions, and rather similar reaction times for the <u>late</u> positions. Overall, the difference in reaction times is only significant for the 15-note melodies.

It is suggested that this tendency reflects the salience of the tonal centre at different points in the melody. At the beginning of the melody alterations might be detected faster in Experiment 3 because, in this position, it is either note 2 or note 3 that is altered. Thus the listener might adopt the strategy of comparing both the second and the third note with the first on a simple interval basis. In Experiment 3 the effect of an altered note on note 2 means that the precise interval relationship between the <u>first</u> note and all <u>successive</u> notes is altered. Thus, using the first note as an anchor, subsequent notes might be compared on a strict interval-similarity basis, with no account taken of the tonal centre or the interval between notes 2 and 3 because the tonal centre has not yet been established.

Thus, in the first three notes, the listener might be using the fact that <u>two</u>, rather than <u>one</u>, of the intervals has been altered with respect to the first, which in turn makes the alterations easier to detect.

As the melodies progress, however, the presence of these two (and more) altered intervals slows down, rather than speeds up, alteration detection. This is interpreted as suggesting that as more notes are heard the tonal centre necomes more clearly established. Thus listeners do not have to -- ind eed may not be able to -- compare each note with the first in this uncertain way. They are comparing the melody, as a whole, to the first on the basis of a contextually established tonal centre. Once the alteration occurs, the listener reorientates him/herself into the new key -- quite quickly, the data suggests. Once this has been done the listener notices in <u>retrospect</u> that an alteration has occurred; thus the reaction times are slower in Experiment 4 than Experiment 3.

Thus, in the middle of the longer melodies the listener is able to take account of both the original tonal centre and the second, and bases his/her judgment rather more on this than comparison with the first note -- which is not necessarily the tonal centre.

At the end of the melodies there is again a convergence of reaction times (apart from the 13-note melodies) between experiments. At this point there is no new tonal centre to be established, as the end of the melody has been reached. Therefore, there is no time for the listener, in Experiment 4, to establish a new tonal centre and thus the perceptual effect of alterations at the end of melodies is very similar for both experiments. This explains why the reaction times are also rather more similar than those obtained in the middle of the longer melodies. This interpretation does, at first glance, seem rather at variance with the results obtained in Experiments 2 & 3, as it suggests that comparison might take place on an interval basis right from the start of the melodies. However, inspection of the graphs shows that, overall, especially for Experiment 3, alterations are detected at a faster speed with increasing serial position. It is the <u>relative</u> speeds (between Experiments 3 & 4) that is important. Performance in one task is compared with the other for each serial position, regardless of the overall performance level.

It should also be remembered that for the shorter melodies the contour, again, is more salient than pitch-interval anyway. It is nowhere claimed that early on in melodies pitch-interval <u>cannot</u> be encoded, just that it is not very salient at this point.

One essential difference between the comparison melodies is that in Experiment 3 there are two altered intervals (from preceding note to alteration, and from alteration back to the original key) whereas there is only one altered interval in the comparison melodies of Experiment 4. This has a greater effect with increasing serial position and shows that, in the first position, the listener takes no account of this because each of the notes (2 or 3) is being related to the <u>first</u> and not each other -- thus alterations are easier to detect in Experiment 4. For the later positions, each successive interval is related to adjacent notes in a more flexible way, which in turn reflects the salience of the tonal centre. This <u>one</u> altered interval makes the altered note harder to detect than when there are <u>two</u> altered intervals. The abrupt modulation caused by this helps the listener to realise that an alteration has occurred.

Thus, the effects of the alteration with changes in serial position is thought to reflect qualitative differences between the way listeners process melodies in which no tonal centre has yet been established and where this has been established, and a further, new tonal centre is able to establish itself. It must be noted that the serial position analysis is not based on statistically significant differences, so the interpretation given above must remain tentative. It can be inferred, however, from the overall effect of task difference as shown in Table 6.3 and Figure 6.1.

What the results, and the comparison with Experiment 3 do show is that with increasing melody length, and increasing serial position, listeners' judgments about alterations are based more on the presence of an established tonal centre than in shorter melodies, and positions early on in a melody.

6.5 INTRODUCTION

Throughout the experiments reported so far in the thesis, subjects have been asked to detect pitch-interval or contour alterations in comparison melodies heard in a different key. Apart from these being rather different tasks, which has been made clear throughout, there is another important methodological point which should be investigated. This will be dealt with briefly in a short experiment to be reported here.

In order to achieve a contour alteration the altered note needs to be at least a third different from its comparison in the first melody. In the methodological chapter (Chapter 2) attention was brought to the constraint that the pitch-interval values in contour comparison melodies were rarely more than a third larger or smaller than their equivalent notes in the comparison melodies. However, the alterations were often larger than this, for reasons mentioned above.

In contrast, the pitch-interval alterations were often smaller than this -- from a semitone upwards. Clearly, this may have some effect both within and between tasks. The following experiment requires subjects to detect pitch-interval and contour alterations in 9-note melodies (the length was chosen so as to generate a reasonable performance level). The alterations were of two sizes for each task, large and small. For the pitch-interval task the small alterations were of a semitone or a tone,the large of a third. For the contour task, the small alterations were of a third -- as small as they could possibly be -- and thus the same size as the large pitch-interval alterations. The large alterations were usually of a sixth.

There are no specific hypotheses about the outcome of the experiment; it is carried out in order to test whether alteration size has any pronounced effect.

EXPERIMENT FIVE

6.6 METHOD

6.6.1 Subjects: 18 subjects participated in 2 experimental sessions. Every subject was a musician who had been learning at least one musical instrument for a minimum period of five years during the period immediately prior to the experiment.

6.6.2 Task: Subjects participated in 2 different tasks, one of which was pitch-interval, the other of which was contour.

In the pitch-interval task, there were 16 trials. In each trial subjects heard a 9-note melody in the key of C major. After a five-second pause, a comparison melody was heard in the key of F sharp major. In the comparison melody there was one pitch-interval alteration. The task was to detect this alteration, and to press a button as quickly as possible. In half of the trials, the alteration was by a semitone or a tone relative to the new key, and in half the trials the alteration was by a third (major or minor).

In the contour task subjects heard a melody in C major in each trial. After a five-second pause another melody was heard in the key of F sharp major, sharing the same contour as the first. At one point there was a contour alteration so that a note went down when it should have gone up or *vice versa*. The task was to detect this alteration and to press a button as quickly as possible. In half of the trials the contour alteration was a third different to its counterpart in the first melody; in the other half of the trials, it was by a sixth ± a tone. There were 16 trials in all.

6.6.3 Design: There were 2 nested factors -- task (pitch-interval/contour) and size of alteration (small/large). The design of the experiment can be seen in Table 6.8.

Each type of alteration was distributed evenly throughout the melody lengths, with one alteration of each type in each serial position from notes 2 to 9.

6.6.4 Counterbalancing of subjects: Subjects participated in two experimental sessions -- one pitch-interval and one contour. The order of these sessions was counterbalanced across subjects. Subjects participated in the whole of one task on each occasion, and so performed in both the 'small' and 'large' conditions on each occasion. The order of these was randomised so that subjects never knew whether they were to hear a small or a large alteration in each case.

6.6.5 Melodies: 2 sets of 16 melodies were composed. One set was used in the pitch-interval task, one in the contour task. The sets were designed as follows:

TASK	P-I	CONTOUR
SMALL ALTERATIONS	8 (semitone) (or tone)	8 (third)
LARGE ALTERATIONS	8 (third)	8 (sixth) (± 1 tone)

Table 6.8 Experiment 5: Design. ( )= size of alteration).

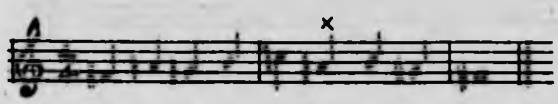
(A) Pitch-Interval

Sixteen melodies were composed in they key of C major. For each melody a comparison was composed in the key of F sharp major. Each comparison melody possessed one pitch-interval alteration in one serial position; in 8 of the melodies the alteration was by a semitone or a tone relative to the new key. Thus the melody below:

possessed a comparison melody as follows:

For the other 8 melodies the alterations were by a third. Thus the melody below:

possessed a comparison melody as follows:

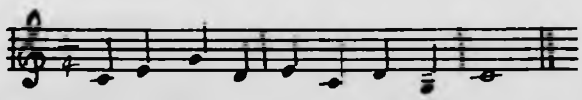


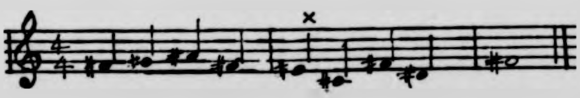
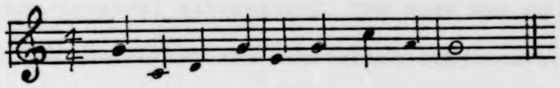
For each set of eight melodies, the alterations were distributed evely throughout the melodies, with one alteration on each of the melodies from serial position 2 to 9.

(B) Contour

Sixteen melodies were composed in they key of C major. For each melody a comparison melody was composed in the key of F sharp major. Each comparison melody shared the same contour as the first, except that at one point there was a contour alteration.

For 8 of the melodies the contour alteration was such that instead of a note going up or down by a tone, it went in the opposite direction, again by one tone. Thus the pitch-interval change was a third (the same as the large pitch-interval alterations). For example, the melody below:



possessed a comparison melody as follows:

For the other 8 melodies, the alterations were by a sixth ± 1 tone. For example the melody below:

possessed a comparison melody as follows:

For each set of 8 melodies the alterations were distributed evenly throughout the melodies, with one alteration on each of the melodies from serial positions 2 to 9.

All the melodies used in this experiment can be seen in Appendix 4.

6.6.6 Procedure

Pitch-Interval Task

1. Subjects participated in 4 specially composed practice trials. The procedure was exactly the same as it was for the experimental trials.
2. In each experimental trial subjects heard a 9-note melody in the key of C major. They were asked to attend to the pitch-interval relationships.

3. After a five-second pause the same melody was heard in the key of F sharp major. This comparison melody possessed one pitch-interval alteration. The task was to detect this alteration.
4. On detecting the alteration subjects were required to press a button as quickly as possible.
5. Each trial proceeded in the same way. In half the trials alteration was by a semitone or tone (small) and in half it was by a third (long). The order of the 16 trials was randomised so that subjects never knew whether an alteration was to be large or small.
6. Melodies described in Melodies A were uased in this part of the experiment.

Contour Task

The procedure for the contour task was exactly the same as for the pitch-interval task, except that subjects were required to attend to the contour of the melodies.

After practice (across 4 specially composed practice trials), subjects participated in 16 experimental trials.

In each trial they heard a melody (9-notes) in the key of C major. They were asked to attend to the contour of that melody. After a five-second pause a comparison melody was heard in the key of F sharp major. This comparison melody shared the same contour as the first, except at one point there was a contour alteration. The task was to detect this alteration and to press a button as quickly as possible. In half the trials, the contour alteration was a third different, in absolute terms, to its counterpart in the first melody, and in half the trials it was a sixth($\pm$ a tone) different. The order of the 16 trials was randomised for each subject separately. Melodies described in Melodies B were used for this task.

6.7 RESULTS

A mean reaction time was calculated for each subject in each of the four task/alteration size conditions. These means can be seen in Table 6.9. It can be seen that there is very little difference between reaction times in any of the conditions.

A 2-way task x alteration size ANOVA was carried out and the results can be seen in Table 6.10. There is no significant effect for task, no significant effect for alteration size, and no significant interaction between the two.

Post hoc analysis (Tukey's a) reveals a critical value of 69ms for significance at the 0.05 level and 95ms for significance at the 0.01 level. Therefore none of the differences are significant.

Error rates were also considered and these were very similar for all conditions and all were at approximately 40%.

TASK	P-I	CONTOUR	MEAN
SMALL	525	521	523
LARGE	537	548	543
MEAN	531	535	

Table 6.9 Experiment 5: Mean reaction times in each task/alteration condition.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	854466	17	50262·7		
ERROR (WITHIN SUBJECTS)	788788	51	15466·4		
TASK	260	1	260	0·017	0·9
ERROR (TASK)	393626	17	23154·5		
ALTERATION SIZE	6664	1	6664	0·431	0·5
ERROR (ALTERATION SIZE)	232352	17	13667·8		
TASK x ALTERATION SIZE	946	1	946	0·061	0·8
ERROR (TASK x ALTERATION SIZE)	162810	17	9577·1		

Table 6.10 **Experiment 5: Task x Alteration size ANOVA. (RT data).**

6.8 DISCUSSION

From both the reaction time and the percentage accuracy measure it can be seen that there are no significant differences either within or between tasks.

This suggests that manipulation of alteration size has little effect on the speed or accuracy with which alterations are detected; thus, the methodological approach taken so far is fairly robust to manipulation of alteration size in this way.

In addition, it can be seen that alteration size has no differential effect on the detection of pitch-interval and contour alterations, which can be seen especially from comparison of the large pitch-interval and small contour alterations, which were physically of the same magnitude.

It is important to note that the alterations used in each of the conditions (see Appendix 4) made the comparison melodies no less tonal than they had been before; it is likely that this has an important effect, as subjects would detect alterations that destroyed the tonality of the melody more quickly than those that maintain the tonality of the melody. When alterations that are outside the tonality of the melody are used, it is possible that subjects make judgments about the tonality of the melody rather than note-for-note comparison,which is the task required of them in this thesis. Thus, when larger alterations are used, but where these do not destroy the tonality of the melodies in any way, alteration size seems to have little effect for both the pitch-interval and the contour tasks.

The main purpose of Experiment 5 was to investigate a methodological problem which has occurred thus far in the thesis. In that alteration size seems to have little effect, this technique will continue to be used in the rest of the thesis.

CHAPTER SEVEN

Several findings have been made in Experiments 2,3 & 4 and this next chapter summarises them, discussing them in more general terms. The results will be discussed in three ways: first, stressing the contribution of the findings to the study of melody processing, and second, dealing with the differences between pitch-interval and contour. The third puts a musicological view of the findings thus far.

7.1 The study of melody processing

Much recent research into the cognitive processing of melodies has stressed the importance of contour relationships thus moving away from the pre-occupation with the importance of the pitch-interval relationships which was reviewed in the first chapter.

Many studies have suggested that as a melody is heard both pitch-interval and contour are encoded in some way (for example Cohen, 1975; Dowling, 1978, 1982; Idson & Massaro, 1978; Teplov, 1966). However, no real reasons are suggested as to how, or why, this might be so or how it might take place. Why should the listener encode contour when pitch-interval appears to be the more important element in melody perception?

The results from Experiments 2, 3 & 4 show that, overall, contour is more salient than pitch-interval when novel melodies are heard in transposition. Dowling & Bartlett (1981) suggest that, under some circumstances, for instance when melodies are novel or transposed, pitch-interval is of little use to the listener. Dowling (1982) has emphasised this more recently:

> "...contour information is very important under some circumstances -- especially when tonal context is weak (as with atonal melodies) or confusing (as with tonal imitations). Contour is less important with familiar melodies, or even novel melodies remembered over periods of minutes..." (p427).

Why is contour so important under these circumstances? It is clear that it is not _just_ the contour-preserving nature of tonal answers that makes them confusing -- they are usually musical paraphrases and it is this that makes them confusing. However, repetition of phrases at different pitch levels, where only the contour is preserved, (although these repetitions cannot really be considered as 'tonal answers') is widespread in music. Although these 'repetitions' are not precise pitch-interval transpositions they are often contour-preserving. If the listener notices similarities between themes, which is often the case, then it is likely that contour does have some importance to the listener.

Contour is likely to be important when tonality is weak because the listener has difficulty establishing a tonal centre, a topic to be discussed later in this chapter. In addition, contour might be more important when the same melody is heard twice in quick succession, being transposed the second time. Under these conditions, an 'acoustical trace' might make one might make one hearing interfere with another in a way which might not occur when the same melody is heard over a longer time-span.

Any condition which serves to make the tonal centre unclear, or confusing, makes the contour relationship more important -- but it is its salience relative to the pitch-interval relationship that confers its importance. Pitch-interval is simply not very salient under these sorts of conditions.

Many studies in which subjects are required to listen to short, novel, melodies and then to hear them transposed (for example, Attneave & Olson, 1971; Cohen, 1975; Cuddy, 1982) have found low performance levels. These conditions are just those that are likely to make the establishment of the tonal centre difficult and thus the pitch-interval relationships are not readily encoded. It is possible that in fact the contour is the more salient feature under these types of circumstances.

Thus contour and pitch-interval are interdependent, with their importance relative to one another depending upon the current context of the melody, and the tonality at any one point. Thus contour is likely to be more important in short melodies, as this will reduce the likelihood that a tonal centre can be established. In both Experiments 2 and 3 it was found that there was an interaction between melody length and task. This interaction suggests that contour is more salient than pitch-interval for short melodies, whereas pitch-interval is more salient than contour for longer melodies. Of course, there is a large effect for length, but it is the relative salience of each type of relationship that is of interest.

Again in both experiments, it was found that, in general, performance on the pitch-interval task improved with increasing serial position. This finding suggests, in general, that pitch-interval becomes more salient as a melody progresses when novel melodies are transposed. Experiment 4 demonstrates this in particular, showing how interval relationships become more important to the listener with increasing melody length.

Serial position thus has an important effect and this effect is in complete contrast to the more general findings for serial position (for example, Murdock, 1962; Sperling, 1960; as well as in music studies such as Taylor, 1972; Williams, 1975; Cuddy, 1982). In these studies, recall of information is worst when items occur in the middle of a sequence; performance is best when items occur in the early or late positions. In Experiments 2 and 3 performance was best in the middle position and worst at the beginning and end of melodies for the pitch-interval task. However, these studies are, in the main, concerned with the recall of <u>discrete</u> items in a sequence; melody perception is concerned with <u>relationships</u> between notes.

Contour is most important for short melodies, and at the beginning of melodies in general when they are novel and transposed; however, it is easily lost with increasing melody length and serial position. This suggests that melodies are not processed either on the basis of pitch-interval or contour, but that both types of relationship are encoded in some way but that, at any point, one or other is more salient and accessible to the listener. This will be discussed in more detail in the following section.

7.2 Pitch-interval and contour as cognitive codes

The relative nature of pitch-interval is often stressed (for example, Sloboda, *in press*; Risset, 1978; Ward, 1970). Many studies have shown how pitch-interval is better encoded and reproduced when in the presence of some sort of context (the importance of this was stressed in Chapter 6). Work by Krumhansl (1979) suggests that the perception of the pitch-interval relationships between notes depends upon the relationship of notes to a contextually established tonal centre, again illustrating the importance of the presence of a tonal centre for pitch-interval.

The context, therefore, is generally the presence of a tonal centre, which is a sense of the key,or possibly scale,on which the melody is based at any one point in time. This tonal centre can ultimately be seen in terms of a set of frequency values which are interpreted with particular significance. Each of the notes of the melody are related to the tonal centre in a fairly precise way. Thus pitch-interval cannot be viewed in quite the same way in quite the same way as many types of relational information, in the way that, for example, Kohler (1938) considered this concept. Amongst a system of relationships, pitch-interval ultimately depends upon absolute values. It is thus less relational than contour.

Contour, on the other hand, is purely relational; it does not require the location of an absolute tonal centre in the same way as pitch-interval; in addition, the magnitude of the change of direction does not matter in the same way that it does for pitch-interval.

It is suggested that the relative nature of pitch-interval is overstressed and that there are important, absolute features of a melody in terms of pitch-interval that should be considered, particularly the absolute nature of the tonal centre. One cannot logically argue that totally relational information depends upon, at least to some extent, an absolute value for its accurate encoding, which is the case for pitch-interval.

In terms of the relationship between pitch-interval and contour, then, a shift from contour-salient to pitch-interval--salient melody processing (as found in Experiments 2, 3 and 4) suggests movement along a continuum from relative to a more absolute form of encoding. Of course, pitch-interval cannot be completely absolute; it is likely that the contrast between relative and absolute information is not a dichotomous one, but exists as a continuum from one form of information to the other, with most forms of information existing somewhere along this continuum.

Jones (1978) suggests that the processing of melodies might take place along different levels at different times, and includes pitch-interval and contour as two of the possible elements in a melody that are represented; the results of the experiments reported here suggest that the relative element, the contour, is the first more salient feature of a melody; once a tonal centre has been established, and this can only be done by the notes of the melody themselves, then pitch-interval is encoded on a relative basis to an established absolute (the tonal centre).

Conditions where the abstraction of a tonal centre is difficult should, therefore, serve to make contour more important and this is most definitely the case when melodies are novel and transposed. Experiments 2 and 3 demonstrate the importance of contour under these conditions. In addition, it is likely that the length of a melody also affects the ability of the listener to establish a tonal centre. Bissell (1921) says:

> "...how does the listener know on hearing the first tone of the melody whether it is the tonic or any other? Nothing can be definitely settled until the next tone, or several tones, are heard and a succession noted". (p47).

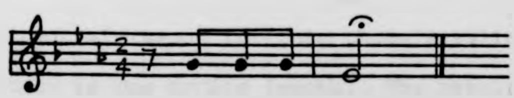
Only the notes themselves can reveal the tonal centre; thus a pertinent question to ask 'How many notes are necessary to establish a tonal centre?'. This is obviously a rather naive question to ask because it is likely that, in published music which has been thoughtfully composed, the composer will exploit the listener's need to establish a tonal centre and to construct the music in a variety of different ways. This is discussed later in the thesis.

The question as to how quickly, and indeed how, tonal centres might be established by a listener has been considered by a number of investigations (for example, Longuet-Higgins & Steedman, 1971; Steedman, 1972; Longuet-Higgins, 1976; Brown & Butler, 1981; Butler, 1983) and these will be discussed in Chapter 11.

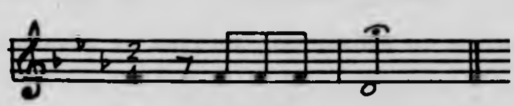
Thus the establishment of the tonal centre takes time, in terms of the number of notes heard. In Chapter 2 it was made clear that the use of a reaction time measure was as an index of the availability of pitch-interval or contour information at any point; thus the significantly faster reaction times obtained for increasing serial position in Experiment 3 for the pitch-interval task for melodies of up to 9 notes in length show that it takes time to establish a tonal centre. This was further investigated in Experiment 4.

7.3 Musicological implications

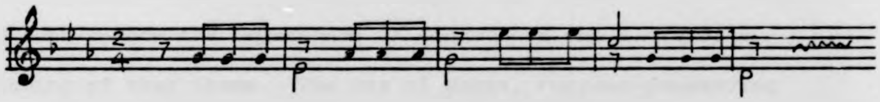
Davies (1979) points out that even for familiar melodies they are heard 'out of the blue' -- the listener does not normally retain information about the precise key (an absolute) of a melody. Whether a melody, objectively, is transposed or not from a previous hearing, as far as the listener is concerned it is a 'transposition'. Thus, even when it is familiar, the listener has to locate a tonal centre for a melody. It is likely that the memory trace will speed up the location of this tonal centre (that is, the listener can 'anticipate' notes to come later in the melody). However, it is still likely that the tonal centre becomes clearer as more notes are heard. Short sequences, then, might be more salient in terms of contour than pitch-interval, especially if, after a short opening theme, the theme is repeated at different pitch levels, so that it becomes difficult for the listener to locate a tonal centre. One such theme is as follows:



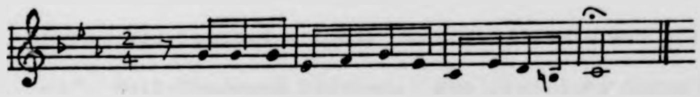
This opening, if it is long enough to suggest <u>any</u> key, might suggest both C minor and E b major (Bissell (1921) says that most themes open with a succession based on the tonic triad). <u>Before</u> tonality can be certain, the theme is repeated at a different pitch level:



Here, the precise pitch relationship is different but the contour conveys a sense of unity between the two themes (the rhythm is also important but the theme is almost devoid of rhythmic sense in this case). Throughout the first movement of Beethoven's Fifth Symphony this same contour-preservation is maintained:



The use of a contour reversal in the bass part is also salient as a contour reversal. Thus, the use of contour in this theme conveys both a sense of unity when it is preserved and a sense of contrast when it is reversed. It is argued that changes in pitch-interval values do not affect this sense of unity in such a strong way because these relationships in themselves are less salient than the contour relationship. It is also proposed that the central reason for this theme's salience in terms of its contour is due to its length. The results of Experiments 2 and 3 suggest that contour is very salient in short melodies.

Davies (1979) also suggests that in natural surroundings when melodies are heard there is no initial sequence; however, in music such as that described above, the opening theme can be considered as an initial sequence. The way this is encoded colours the way all subsequent themes are perceived. It is interesting to reflect the nature of successive phrases if this had been the opening theme:

More notes, therefore, might make the tonal framework clearer and thus reduce the importance of contour in the listener's encoding of that theme. The use of short, contour-preserving themes as a compositional technique is widespread in music, in particular in sonata form, particularly as used in symphonic opening movements. Composers not noted for their symphonic style, or those that wrote symphonies which are much criticised, interestingly, are often composers who tend to write long, tuneful melodies. A prominent example of this sort of style was Tchaikovsky. It may be that the length of the melodies he composed do not lend themselves to contour-preservational techniques, which in turn is one of the best ways to write a cohesive, unified symphonic movement as evidenced by the first movement of Beethoven's Fifth symphony.

The melodies used in Experiments 2,3 and 4 were tonal throughout; however, music is obviously not equally tonal throughout. An experiment by Cohen (1981) demonstrates how the feel for a tonal centre can be affected by exposure to short passages of music. In one experiment subjects were required to sing the scale of a musical fragment that they had just heard. By judging what they sang, it could be determined whether or not the listener had located a tonal centre. Cohen used preludes from Bach's Well-Tempered Klavier. She played subjects the first four notes, the first four bars or the first eight bars before asking subjects to sing a scale, which they felt to be the key of the music. The results indicated that detection of the tonal centre was greatest when only the first four notes had been heard.

These results suggest, on first analysis, to be in complete contrast to the results obtained in the preceding experiments. However, it in fact illustrates a very important point. Composers compose for art's sake, not to understand melody perception. It was common for Bach to change key relatively early on in a piece -- but to make this clear to the listener the composer must first establish a home key. Thus he is likely to do this as soon as possible. By the time four or eight bars are heard the composer is likely to have modulated or be in the process of doing so, and thus a single tonal centre might be less clear.

Composers exploit the need to establish a tonal centre at the beginning of their music and can either make it immediately clear (as in the example above) or consciously delay it; either way, it is suggested that the use of actual music in the investigation of melody processing might not always be suitable. In effect, the composer is always one step ahead of the psychologist.

7.4 Conclusion to Chapter 7.

The results of Experiments 2,3, and 4 suggest that the salience of pitch-interval and contour in novel, transposed melodies varies both as a function of melody length and serial position.

This finding has been explained in terms of the study of the cognitive processing of melodies, in terms of the way pitch-interval and contour might be encoded and in terms of the relationship between the experimental findings and the way music itself is composed.

The following experiments investigate the relationship between pitch-interval and contour when melodies are untransposed and when they are more familiar than in preceding experiments (Chapters 8 and 9 respectively).

Chapter 10 investigates the relative/absolute contrast suggested in this chapter as the fundamental difference between pitch-interval and contour, more directly, using an experimental paradigm which separates pitch-interval and contour by their informational differences.

CHAPTER EIGHT

8.1 INTRODUCTION

The results up to this point suggest that the processing of novel, transposed melodies might progress along a contour--pitch-interval continuum. This in turn was suggested as being due to the need to establish a tonal centre, which is absolute in nature, for the accurate encoding of pitch-interval which is not necessary for contour.

Although, under most natural conditions, listeners do not *know* whether a familiar melody has been transposed or not, as they do not normally retain information about the precise key of a melody, it is likely that the perceptual effect of hearing a transposed melody (which is known to be transposed) in a short-term memory paradigm (used in Experiments 2, 3 & 4) is similar to more natural listening conditions. Davies (1978) points out that normally, even familiar melodies are heard in transposition -- listeners have to locate a tonal centre in the same way as for novel, knowingly transposed melodies. This topic is investigated in the next chapter (Chapter 9).

However, what happens when melodies are untransposed and, furthermore, the listener knows them to be untransposed? Under these circumstances the listener might not need to locate a tonal centre in the same way that they do when a melody is transposed.

It is possible that this may not be an important ecological question, due to the statements made above. It is likely that the occasions when a listener knows that a melody is untransposed are relatively rare. In the first chapter, the contributions made to the study of melody processing by studies in absolute pitch retention and so on were reviewed, and it was pointed out tht the decay of pitch information is so rapid, and the tendency for even possessors of A.P. to infer relationships between notes is so strong that it is likely that the study of absolute pitch, *per se*, will eventually contribute little to the understanding of melody perception.

In addition, then, it is unlikely, logically, that the encoding and processing of untransposed melodies is fundamentally different to the encoding and processing of transposed melodies -- relationships between notes might still be more important than absolute pitch values.

White's study of the perception and recognition of distorted, familiar melodies (1960) shows that it is the relationships between notes, and not precise pitch values, that are important. Dewar's study (1974) found that, when melodies were untransposed, and were known to be untransposed, then subjects judged alterations in these melodies to be greater when the size of the alteration increased -- this again suggests that even in knowingly untransposed melodies, relationships between notes are more important than absolute pitch values.

However, in melodies which are known to be untransposed, listeners do not need to locate a tonal centre in the same way -- at least, it should not take as long when melodies are transposed to an unknown key -- thus the processing of untransposed melodies is likely to be different from the processing of transposed melodies for this reason alone. This is investigated in the following experiment.

When melodies are untransposed in a short term memory paradigm, contour may not be as important to the listener, because the absolute information, the tonal centre, will have been established, at least to some degree, on the first hearing of a melody, which is then reinforced on the second hearing. Contour is not essential in the same way.

However, given that it is very likely that relationships between notes are of greater importance than precise pitch values even when melodies are untransposed, it is likely that contour does play a role in the processing of untransposed melodies, but not the overwhelming one it does in transposed melodies.

The experiment reported in this chapter assesses the importance of the contour and the pitch-interval relationship in untransposed melodies. It was said earlier that the question may not be important ecologically, as the listener does not normally retain information about the absolute key of a melody. However, there are two cases, one of which is particularly important, where the listener does know that a melody has or has not been transposed, because successive playings of a melody or theme are heard over a short period of time. These are (a) in many of the 'melodic memory' sections of tests of musical ability and (b) in music itself.

Each of these two topics will be dealt with separately below.

8.1.1 Tests of melodic memory

In most tests of melodic memory (an important part of many of the published and unpublished tests of musical ability) subjects are asked to listen to a melody or a tonal sequence heard in a key, then after a short pause they are requested to listen to a repetition of that melody which possesses some sort of alteration (as in the experiments reported thus far in this thesis). In many cases, this melody (or sequence) is an untransposed version of the first melody and the alteration is an altered note (for example, Seashore (1960 revision); Drake (1931); Wing (1961); Gaston (1957), and Farnum (undated)). Other tests require detection of some more global change such as change in key (some of the Drake items involve changes of this sort). The tests of Gordon (1965) and Stankov & Horn (1980) also require the detection of more global changes.

However, one test, that of Lundin (1949), requires subjects to detect alterations in transposed melodies in the same way as in Experiments 2, 3 & 4. These tests are, however, unpublished. It is interesting to note that the tests devised by Lundin might result in quite different responses to those obtained from tests where melodies are untransposed, because the listener would not have to locate a tonal centre in the same way for untransposed as for transposed melodies.

The important point to note is that all these tests claim to investigate melodic memory. Which test is the most naturalistic?

In the following experiment, 5-note and 15-note melodies are heard in they key of C major. After a 5-second pause a comparison melody is hear which either shares the same pitch-interval values or the same contour, in the same way as in earlier experiments. However, these comparison melodies are untransposed. The difference between the results obtained in this experiment will be compared with results obtained in Experiment 2, where melodies of 5- and 15-notes were heard, but where the comparison melodies were transposed. This comparison will draw out any important differences between the tests of melodic memory reviewed above.

8.1.2 Non-transposition in music

It was a favourite device of Wagner's to repeat themes (which he called 'leitmotifs') at the same pitch level throughout his large music-dramas. However, the time intervals between subsequent playings of these leitmotifs makes it unlikely that these are recognised as being in the same key -- most people know this fact only because they are told. Repetition of themes at the same pitch level and preserving pitch-interval relationships (that is, an exact repetition), is relatively uncommon in music -- perhaps because the pitch-interval relationships are _so_ salient that sheer repetition would make the music rather boring. However, the use of short, contour- and rhythm-preserving themes is very common. This suggests that contour, although not being _as salient_ as pitch-interval, has some degree of salience even when the pitch-interval relationship itself is overwhelmingly important because the listener is often aware of the unity of themes constructed in this way.

Thus, the contour and the pitch-interval relationship might both be important when melodies are knowingly untransposed, but the relative salience of each may change from when melodies are knowingly transposed. It was made clear in the first chapters that the concern is not with whether melodies are processed on the basis of pitch-interval or contour, but with the relative salience of each type of relationship under different conditions. It is likely that contour _is_ salient when melodies are untransposed, but not _as_ salient with relation to pitch-interval, as when melodies are transposed. If contour is salient in some way when melodies are untransposed, this in turn suggests that relationships can be processed in untransposed melodies, rather than being concerned with absolute pitch-values, as the contour relationship can only be relational.

In the following experiment subjects were required to listen to melodies of 5 or 15 notes in length and to then detect changes in pitch-interval or contour in comparison melodies knowingly heard in the same key. For the pitch-interval task subjects were requested to detect an altered pitch-interval value, and for the contour task they were required to detect an alteration in contour in a comparison melody sharing only the same contour, but possessing a contour alteration at one point.

It was hypothesised that pitch-interval would be more salient overall than contour, in contrast to the findings of Experiment 2 where contour was found to be more salient overall than pitch-interval. The central reason for this is that the listener would not need to locate a tonal centre for the encoding of the pitch-interval relationships in the comparison melodies in the same way as for the transposed melodies in Experiment 2.

In addition, it was hypothesised that contour, although not being as salient as when melodies are transposed, would be salient to some degree because of the important part it plays in untransposed melodies, themes and so on. In addition, if contour is salient in some way, this suggests that relationships are important even in untransposed melodies.

In terms of the results predicted, it is predicted that there would be an overall significant effect for task, showing pitch-interval to be more salient than contour; there would be a significant effect for melody length, since longer melodies are more difficult to process.

Most centrally, it was predicted that there would be little or no interaction between task and length as found for Experiment 2. The main cause of the task x length interaction in Experiment 2 was due to the significant differences between pitch-interval and contour for both melody lengths, with contour being significantly more salient than pitch-interval for the 5-note melodies and pitch-interval being significantly more salient than contour for the 15-note melodies. The superiority for contour for the short melodies was thought to be due to the fact that a number of notes were necessary to reveal the tonal centre. This should not be necessary for untransposed melodies and so the superiority for contour in the shorter melodies should disappear in the present experiment. In summary, there should be no melody length for which contour is more salient than pitch-interval, in contrast to Experiment 2.

The same melodies are used in this experiment as were used in Experiment 2, <u>except that</u> the comparison melody was heard in the same key as each initial melody.

EXPERIMENT SIX

8.2 METHOD

8.2.1 Subjects: 20 subjects participated in 2 experimental sessions. Every subject was a musician who had been learning at least one musical instrument for a minimum of five years during the period immediately prior to the experiment.

8.2.2 Task: Subjects took part in two experimental sessions, one of which will be referred to as pitch-interval, the other as contour.

In the pitch-interval task subjects were required to listen to a series of 48 melody pairs, half of which were 5 notes long and half of which were 15 notes long. In each trial, a melody was heard in the key of C major and subjects were asked to attend to the pitch-interval values of the melody. After a five-second pause the same melody was heard in the same key. This comparison melody possessed one pitch-interval alteration at one point in the melody. The task was to detect this alteration and to press a button as quickly as possible.

For both the twenty-four 5- and 15-note melodies, there were 18 trials where the comparison melody possessed one pitch-interval alteration and 6 trials where the comparison was an exact repetition of the first. These were catch trials.

In the contour session subjects again listened to a series of 48 melody pairs, half of which were 5 notes long and half of which were 15 notes long. In each trial a melody was heard in the key of C major and subjects were required to attend to the contour of this melody. After a five-second pause another melody was hear in the same key, but sharing only the same contour. This comparison usually possessed one contour alteration. The task was to detect this alteration and to press a button as quickly as possible.

Again, for both the 5-note and the 15-note melodies, there were 18 trials in which the comparison melody possessed one contour alteration, and 6 trials in which the comparison melody was exactly the same as the first melody throughout. These were catch trials.

The order of the 48 trials in each of the sessions was separately randomised for each of the subjects.

8.2.3 Design: There were 3 nested factors -- task (pitch-interval/contour), length of melody (5/15 notes) and serial position of alteration. The design of the first two factors can be seen in Table 8.1.

The third factor, serial position of alteration, was a control factor. Alterations were distributed evenly throughout the melodies for each condition, and can be seen described in the Melodies section below.

TASK	P-I		CONTOUR	
LENGTH	5(24)	5(24)	5(24)	5(24)
EXPERIMENTAL TRIALS	18	18	18	18
CATCH TRIALS	6	6	6	6

Table 8.1 Experiment 6: Design.
( ) = number of trials.

SUBJECT	ORDER OF TASK		ORDER OF LENGTH	
1, 5, 9, 13, 17	P-I	C	5	15
2, 6, 10, 14, 18	P-I	C	15	5
3, 7, 11, 15, 19	C	P-I	5	15
4, 8, 12, 16, 20	C	P-I	15	5

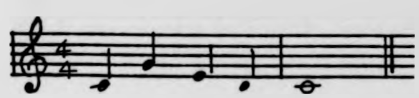
Table 8.2 Experiment 6: Counterbalancing.

8.2.4 Counterbalancing of subjects: The order or presentation of conditions can be seen in Table 8.2. Subjects participated in only one task (for both melody lengths) on each of the two occasions that they attended the laboratory.

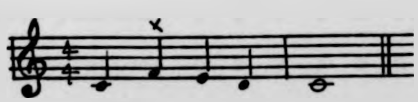
8.2.5 Melodies: Two sets of 48 melody pairs were composed. One set was used in the pitch-interval task, the other in the contour task. The sets were designed as follows.

(A) Pitch-interval

Twnety-four melodies were composed in they key of C major. Each melody was 5 notes in length. For each melody a comparison melody was composed in they key of C major. Eighteen of these comparison melodies possessed one pitch-interval alteration at one point in the melody. For example, the melody below:



possessed a comparison melody as follows:

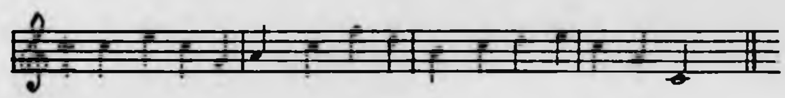


Throughout the 18 melodies, the alterations were distributed as follows:

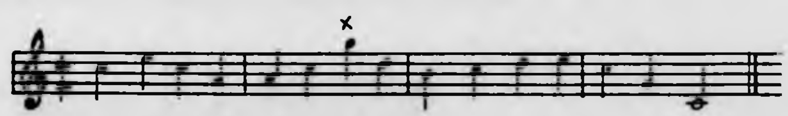
Serial position	1	2	3	4	5
No. alterations	0	6	6	6	0

For the remaining 6 melodies, a comparison melody was composed which was an exact repetition of the first melody. These were catch trials.

Twenty-four melodies were composed in the key of C major which were all 15 notes in length. For each melody a comparison was composed, again in the key of C major. Eighteen of these comparison melodies possessed one pitch-interval alteration relative to the first melody at one point in the melody. For example,the melody below:



possessed a comparison melody as follows:



Throughout the 18 melodies,the alterations were distributed as follows:

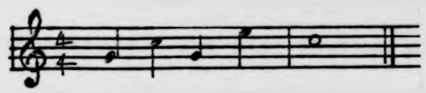
Serial position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. alterations	0	2	2	2	0	0	2	2	2	0	0	2	2	2	0

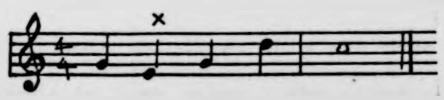
For the remaining 6 melodies a comparison melody was again composed in C major which was exactly the same as the first melody throughout. These were catch trials.

(B) Contour

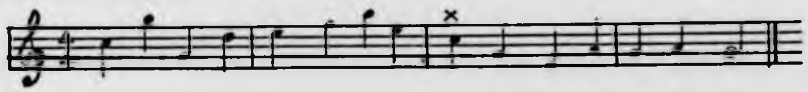
Twenty-four 5-note and 15-note melodies were composed in the same way as for Pitch-interval (A) above. Each of the melodies were in C major. A comparison melody was written, for each melody, also in C major.

For the twenty-four 5-note melodies, 18 comparison melodies possessed only the same contour as the first melody except at one point, where there was a contour alteration. For example, the melody below:



possessed a comparison melody as follows:

For the other 6 comparison melodies the contour was the same as the first melody throughout. These were catch trials. The distribution of the alterations was exactly the same as for the pitch-interval melodies above.

For the twenty-four 15-note melodies, 18 of the comparison melodies possessed one contour alteration with respect to the first melody. For example, the melody below:

possessed a comparison melody as follows:

For the other 6 comparison melodies the contour was exactly the same as the first melody throughout. These were catch trials. The distribution of the alterations was exactly the same as for the pitch-interval melodies (A above).

All notes were 500ms in length except the last, which was 2,000ms long for the 5-note melodies and 1,000ms long for the 15-note melodies. This was done in order to maintain melodic balance in both cases. The melodies were the same as those used in Experiment 2 (Appendix 2) but the comparisons were not transposed.

8.2.6 Procedure

The conditions were blocked into 4 task/length conditions. Subjects participated in 2 conditions on each occasion they attended the laboratory. On each occasion they performed only one task -- pitch-interval or contour -- but listened to melodies of both lengths in separate blocks (see Table 8.2).

The order of trials within each block was randomised for each subject separately.

Pitch-interval task

1. Subjects were given practice at the task across 4 practice trials. The procedure for the practice trials was exactly the same as for the experimental trials. The practice trials were especially composed.

2. In each experimental trial subjects heard a 5- or 15-note melody (depending on the experimental block they were performing) in the key of C major. They were required to attend to the pitch-interval values of the melody.

3. After a five-second pause the same melody was heard in the same key. This melody usually possessed on pitch-interval alteration with respect to the first melody.

4. Subjects were required to detect this alteration and to press a button as quickly as possible when it had been heard. The reaction time was measured to the nearest millisecond.

5. Each trial proceeded in the same way. For each of the melody lengths there were 18 trials in which the comparison melody possessed one pitch-interval alteration, and 6 where that comparison melody was exactly the same as the first melody throughout. These were catch trials.

6. There were 24 trials in all for each of the pitch-interval blocks. When subjects had completed the block for one of the melody lengths they proceeded to the other length block for the same task (pitch-interval). The counterbalancing of blocks can be seen in Table 8.2.
7. The order of the 24 trials within each block was randomised separately for each subject in each of the blocks.
8. Melody sets described in Melodies A were used in this part of the experiment.

The procedure for the contour task was exactly the same as for the pitch-interval task except that after four specifically composed practice trials, subjects were required to detect contour alterations in the comparison melodies. Both first melodies and comparison melodies were always heard in C major. For each of the melody length blocks there were 18 trials where the comparison melodies possessed one contour alteration and the task wasto detect this alteration and to press a button as quickly as possible. For 6 of the trials in each of the melody length blocks, the contour of the comparison melody was exactly the same throughout. These were catch trials.

Again, subjects participated in 2 melody length blocks, and the order of presentation of the blocks can be seen in Table 8.2. The order of the 24 trials in each of the blocks was randomised separately for each of the subjects in each of the blocks. Melodies described in Melodies B were used in this part of the experiment.

The order of the tasks (pitch-interval/contour) was also counter-balanced across subjects (see Table 8.2).

8.3 RESULTS

Mean reaction times were calculated for each of the subjects in each of the task/length conditions. These results were collapsed across serial position of alteration. The means for each of the 4 conditions can be seen in Table 8.3.

The results of a 2-way task x length ANOVA can be seen in Table 8.4.

There is a significant effect for task caused by the faster overall responses to the pitch-interval task than the contour task (see Table 8.3). There is also a significant effect for length with alterations in the 5-note melodies being detected significantly faster than those in the 15-note melodies (see Table 8.3).

The interaction between task and length is not significant; the relationship between task and length can be seen in Figure 8.1. *Post hoc* analysis (Tukey's a) reveals a figure of 101ms for significance at the 0·01 level and a value of 74ms for significance at the 0·05 level. This shows that the difference between tasks is not significant for the 5-note melodies, but is for 15-note melodies, with pitch-interval alterations being detected at a significantly faster speed than contour. In addition there are significant differences between the 5-note and the 15-note melodies for both melody lengths, with reaction times being significantly faster for the 5-note melodies for both pitch-interval and contour.

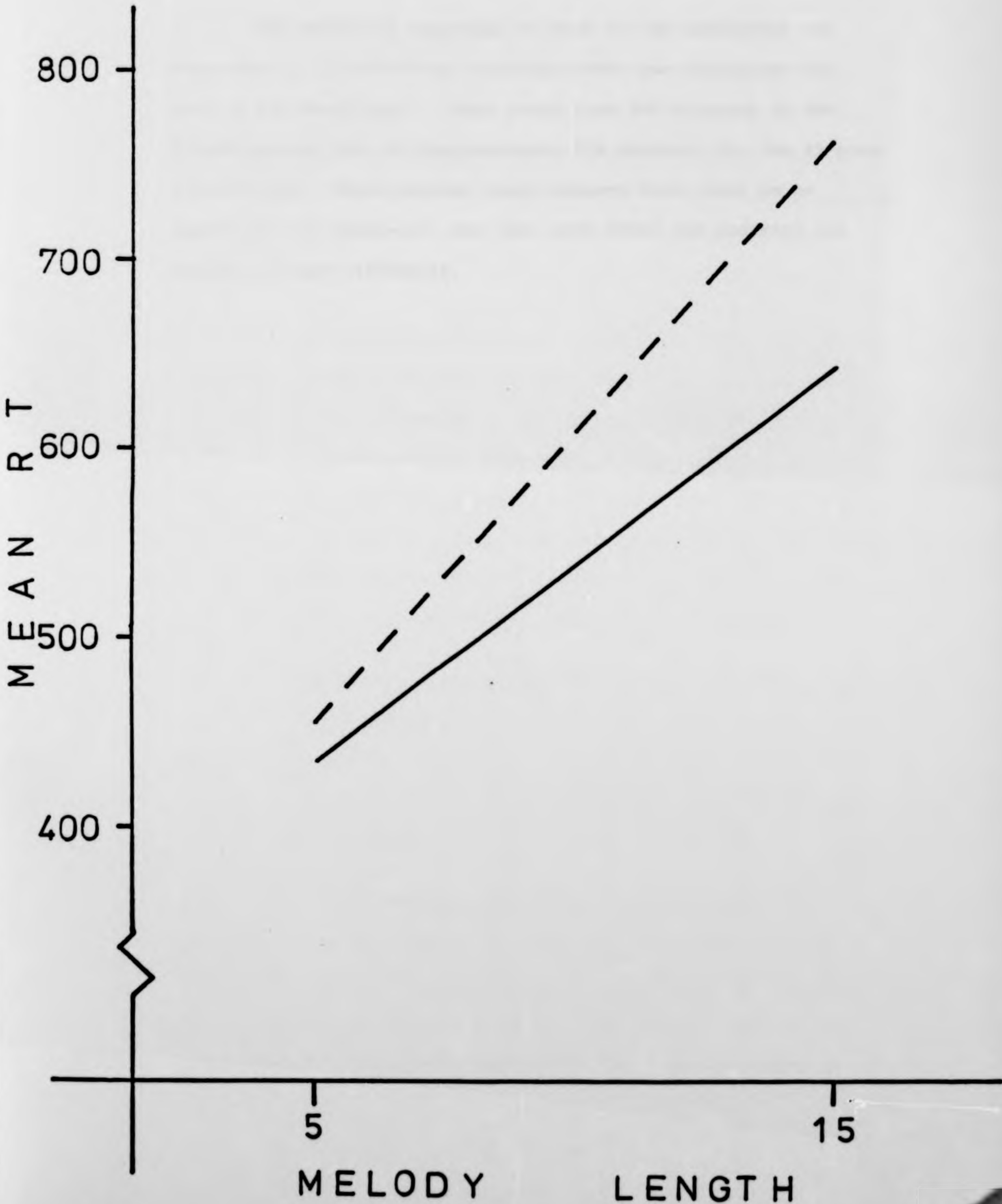
TASK	LENGTH		
	5 NOTES	15 NOTES	MEAN
P-I	433	642	538
CONTOUR	454	761	608
MEAN	444	702	

Table 8.3 Experiment 6: Mean RTs for each Task/Length condition.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	1065535•2	19	56080•8		
ERROR (WITHIN SUBJECTS)	772841•9	57	13558•6		
TASK	93268	1	93268	6•9	<0•05
ERROR (TASK)	358328•6	19	18859•4		
LENGTH	1264830	1	1264830	93•3	<0•001
ERROR (LENGTH)	188818•2	19	9937•8		
TASK x LENGTH	45442	1	45442	3•4	0•07
ERROR (TASK x LENGTH)	225695•3	19	17878•7		

Table 8.4 Experiment 6: Task x Length ANOVA (RT data).

FIGURE 8.1 Relationship between task and length (Experiment 6).



The number of responses in each of the conditions was also taken and a percentage accuracy score was calculated for each of the conditions. These range from 90% accuracy in the 5-note contour task to approximately 50% accuracy for the 15-note contour task. These results again suggest that there is no speed/accuracy trade-off, but that both speed and accuracy are indices of task difficulty.

8.4 DISCUSSION

Table 8.4 shows that there is a significant effect for task, caused by overall faster responses in the pitch-interval task than the contour task (see Table 8.3). This finding supports the central hypothesis that when melodies are untransposed pitch-interval is overall a more salient element than contour.

This finding is in complete contrast to Experiment 2 where contour was found to be more salient than pitch-interval when melodies are transposed. It cannot be argued that the different experimental technique used in Experiment 2 accounts for this difference (for example, the use of a scoresheet method and the manipulation of intra-trial intervals) as the result from this experiment was replicated in Experiment 3 which used exactly the same experimental paradigm as this present experiment.

Pitch-interval values, which are pitch relationships, are more salient than contour when melodies are untransposed, which may be due to the fact that the listener does not need to locate a tonal centre in the same way as it is necessary to do so when melodies are transposed.

This hypothesis is further substantiated by the fact that there is no significant interaction between task and length, as there was found for Experiment 2. This can be seen in Figure 8.1. *Post hoc* analysis (Tukey's a) shows that the difference between pitch-interval and contour for the 5-note melodies is not significant; it is, however, for the 15-note melodies, with the speed with which pitch-interval alterations were detected being significantly faster for pitch-interval alterations than contour alterations.

First, the finding for the 5-note melodies will be discussed. The difference between pitch-interval and contour is not significant for this melody length and this has two implications:

(1)That in contrast to Experiments 2 & 3 contour is not more salient than pitch-interval. This is probably because the listener does not need any time, or very much time, in the form of actual notes, to locate the tonal centre of the melody and, therefore, the pitch-interval relationships are immediately salient.

(2) The finding that contour could be processed approximately at the same level of performance as pitch-interval is somewhat surprising. If contour is not essential in the perception of untransposed melodies in the way that it is in transposed melodies, how is it that, when asked to do so, subjects can attend to the contour relationships? The implication of the finding is that if, when asked to do so, subjects can attend to contour quite well under these circumstances, then it is likely that they <u>do</u> do so under more natural circumstances. This does not mean to say, of course, that subjects were not <u>aware</u> that the pitch-interval values had been altered in the comparison melody;

pitch-interval is more salient than contour when melodies are untransposed, and so this view would be very difficult to uphold. Although subjects are aware that pitch-interval values of a melody have been altered, they can also turn their attention to the contour relationship, another level of relationship. This will be discussed with reference to Dowling's (1978) work later in the discussion.

Music itself suggests that contour is very important in untransposed melodies and this will also be developed later in the chapter.

However, the ease with which contour can be processed, as evidenced by the results obtained in this experiment, addresses the other topic of this chapter which is that of the importance of relationships in untransposed melodies. The only way contour can be processed is in terms of relational encoding rather than on any absolute basis. This suggests that, in general, relationships between notes are as important, if not more so, than absolute values even when melodies are untransposed.

This question cannot be addressed by the pitch-interval task alone in this experiment, as the task could have been performed on an absolute pitch or an interval recongition basis. However, as was pointed out in the introduction, the number of occasions when the listener knows that a melody is untransposed might be relatively few; therefore fundamental differences between the processing of transposed and untransposed melodies are unlikely. It is probable that the main differences between the perception of transposed and untransposed melodies lies in the establishment of a tonal centre.

It might have been possible to manipulate pitch-interval in some way which directly addressed this question (for example, the technique used by White (1960)) but this would have altered the melodies in such a profound way as to make the task so unlike normal melody perception as to lose its ecological validity.

The difference between pitch-interval and contour is significant, however, for the 15-note melodies, and the most likely cause of this is that the processing of 15 notes in terms of contour is a very difficult task; an alternative interpretation is that pitch-interval information ultimately becomes the more salient with increasing melody length, in the same way that pitch-interval information was eventually more salient than contour in Experiments 2 & 3 with increasing melody length.

There was an overall effect of melody length caused by the simple fact that the 15-note melodies are harder to retain in short-term memory than the 5-note melodies. This result is not of great interest in itself.

The main hypotheses put forward in the introduction have been supported; that pitch-interval would be more salient than contour overall and that there would be no interaction between pitch-interval and contour in the same way that there was for Experiments 2 & 3. Both of these results support the hypothesis that the processing of untransposed melodies might be different in some ways than transposed melodies thought to be largely a result of the establishment of a tonal centre in untransposed melodies. This has particular implications for the tests of melodic memory outlined in the introduction.

The combination of Experiments 2, 3 & 6 suggest that results from tests involving transposition should not be regarded in the same light as those not involving transposition. Tests such as Lundin's (1949), which require the detection of alterations in transposed melodies might be affected by strong serial position effects (described in detail in Experiment 3, particularly at the beginning of the melody). Tests involving non-transposition (such as Seashore, 1960) might not involve such effects. It is important to ask which tests of melodic memory might be the most ecologically valid, as these tests are often used to assess meaningful issues and to make decisions on a child's musical training and so on. In that listeners do not normally retain absolute information about a key, it is likely that Lundin's test represents a more ecologically valid measure of melodic memory than many of the tests where the comparison melodies are heard in the same key as the first melody.

The results from the contour task also suggest that relationships between notes are salient in untransposed melodies, and the discussion will now turn to the importance of contour in untransposed melodies.

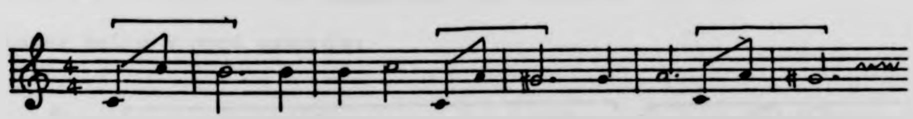
It is clear in the experiment reported here that subjects were aware that the precise pitch-interval values of the comparison melodies had been altered, but at the same time it was found that subjects could, when asked, process the contour relationship whilst taking less notice of the pitch-interval values of the notes. Davies (1978) suggests that contour may only be important when the tonality of a melody is unsure (particularly when transposed). However, it is proposed in this thesis that for transposed melodies contour is more important than pitch-interval, but can be equally, or almost, as important as pitch-interval when tonality is sure. It is not necessary to assume that melodies are processed at only one level at any one time. At the very least, contour is salient to some degree.

Dowling (1978) found that the confusion which subjects found between 'exact same' and 'same contour' when melodies were transposed (see Experiment 2) disappeared when melodies were untransposed. Subjects could easily tell 'exact same' from 'same contour' comparison melodies. Dowling suggests that subjects did not understand the task; however, it would seem that listeners do not need contour in the same way as when melodies are transposed. Contour is not as important, it is not as salient, when melodies are untransposed. This is not to say, however, that it might not be important in some way when melodies are untransposed. For the final part of the chapter the discussion will turn to musicological topics in order to elucidate this point.

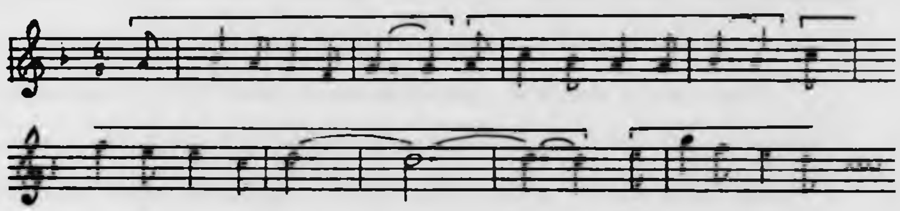
The way that contour is generally used in music is such that a short theme is composed, which is then repeated using only the rhythm and the contour of this theme. The precise pitch-interval relationships are changed, but often the rhythm, and usually the contour, are preserved.

One of the central features of this device is that the themes are very often short; the results of this and previous experiments suggest that the cognitive capacity to process contour itself is very limited; very long themes used in the way described above might not 'work' in the same way. This idea will be developed in Chapter 11.

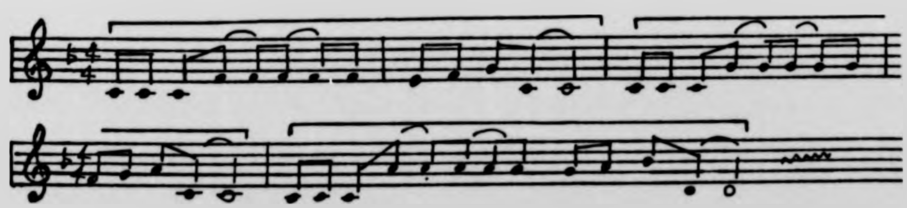
Examples of the technique are so widespread that it would be impossible to do justice to it here. One example of this technique can be seen in the song 'Bali'hai' from the musical South Pacific by Rogers & Hammerstein.



That theme begins on the same pitch level each time and is contour-preserving. It is possible that even though most listeners would be aware that the pitch-interval relationships had changed they would also be aware that the contour has been preserved. Another good example of this technique is in the song "As Time Goes By" :



Although the pitch-interval relationships change each time, the rhythm and the contour remain the same and create a sense of cohesion.

Many popular songs use this technique; analysis of the twenty songs heard in the 1983 Eurovision Song Contest, an important phenomenon to study in the processing of melodies with differing degrees of familiarity as a topic of study, reveals that many of the songs use this device. The 1982 winner being a good example:

Again the contour is relatively short, begins on the same pitch level, but retains only rhythm and contour.

As mentioned before, the use of this device is very widespread in both popular and classical music. The results of this experiment suggest that contour can be processed even when melodies are untransposed, and musicological evidence suggests that contour is important under these circumstances. Contour is not only important when pitch-interval cannot be obtained by the listener -- it also forms an aspect of the processing of melodies when untransposed and is another level at which a melody can be, and is, represented. The pitch-interval relationship under these conditions is <u>so</u> salient that exact repetition would be rather uninteresting -- instead, a less salient feature is preserved (the contour) while the most salient element (the pitch-interval relationships) are altered.

CHAPTER NINE

9.1 INTRODUCTION

In Experiments 2 & 3 the role of pitch-interval and contour in novel, untransposed melodies was investigated. It was found that contour plays an important role under these circumstances. Experiment 4 showed the importance of a tonal centre for the encoding of interval information. Experiment 6 showed that in untransposed melodies contour is less important relative to pitch-interval but is another level at which a melody can be represented.

The following experiment investigates another factor affecting the relative importance of pitch-interval and contour in melody perception. This is the effect of familiarity. It is thought that contour will not be so important under these circumstances, and that precise pitch-interval information will become increasingly salient for reasons discussed below.

Most experiments carried out on the processing of melodic sequences have tended to concern themselves with the processing of newly-composed, novel, stimuli. This is done so as to ensure that all subjects are equally familiar with the stimuli, or to ensure that subjects will never have heard the melodies before. However, the processing of familiar and unfamiliar melodies is thought to be different (see below) and so this may not always be a satisfactory technique (unless, of course, one is concerned with the processing of novel melodies, as has been the concern of this thesis until this point).

Some researchers have used more familiar melodies in their research. White (1960) used familiar melodies in his investigation of the perception of melodies when they were distorted in a variety of ways, and Dowling (1973) used familiar melodies in an investigation into the perception of interleaved melodies, using such melodies as 'Yankee Doodle'. One of the inherent problems in studies of this kind is that there might be differences in the degree of familiarity of the melodies between listeners. Subjects are usually tested to see if they recognise a melody or not before the experiment starts, but this still does not mean that all melodies are <u>equally</u> familiar to all listeners.

Increasing familiarity with melodies may effect the relative salience of different types of relationship. Deutsch (1982a) suggests that interval-class, which is effectively the interval relationship, is probably not the first most salient feature of a melody. Other relationships may be more salient in unfamiliar melodies, with pitch-interval eventually becoming the more salient. White's and Dowling's experiments (above) suggest little about the role of contour in familiar melodies. However, there is a substantial amount of evidence which suggests that contour is particularly important in novel melodies, with pitch-interval information becoming more important as a melody becomes more familiar.

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Attneave & Olson (1971) found that subjects were very bad at transposing isolated novel intervals -- they did not therefore find the pitch-interval relationships very salient under these circumstances. However, subjects were very much better at transposing a familiar melody (the NBC chimes as used on American TV). These chimes are very short (3 notes long) and so it is unlikely that the major influence was a melodic context. It is likely that the major factor causing this difference was the degree of familiarity of the melody. This improved the ability of subjects to transpose accurately in terms of the pitch-interval relationships.

Again, in Attneave & Olson's study, it is likely that subjects' familiarity with the theme was of varying degrees.

Other studies have sought to control the familiarity of melodies by using original melodies, but requiring subjects to listen to them a set number of times. Thus the experimenter has more control over the familiarity of the melody. This does not rule out the possibility that some listeners will have extracted more from a melody over a set number of hearings than others, but this would appear to be a better method than using familiar melodies which would show a much greater range of degrees of familiarity than the method suggested above.

In Dowling's 1978 experiment subjects found the contour relationship very salient when listening to transposed, novel melodies. Deutsch (1979) repeated Dowling's experiment and found that subjects did not become as easily confused between 'exact same' and 'same contour' transpositions, even when melodies were heard in transposition, when the target melody was repeated several times before a comparison melody was heard. This was the case even when the melody was repeated in the same key and subsequent comparisons were played in different keys.

Deutsch's experiment suggests that increased familiarity with a melody improves the retention and encoding of pitch-interval information.

Dowling & Bartlett (1981) found that although both pitch-interval and contour information became more difficult to retrieve from memory with increased time delay between hearing a melody and its subsequent comparison, the discrimination between exact transposition and tonal answers (contour preservations) did not decay. In fact, when testing was delayed, subjects could hardly discriminate between same and different contour comparisons. This suggests that, although contour may be very salient in a short-term memory paradigm, it is very transient and is easily lost.

The experiments reported above suggest that contour information, although easily to obtain and retain for novel melodies over short time spans (and for short melodies, as demonstrated in Experiments 2 & 3) is lost with either time delay between standard and comparison melodies or with increasing familiarity with melodies. It may not be the case that contour information is lost with increasing familiarity, but just that the pitch-interval relationships become more salient.

Dowling & Fujitani (1971) suggest that

> "...subjects appear to have good long term memory for exact interval sizes in the context of familiar tunes..." (p530).

More recently Dowling (1982) states that

> "...contour is less important with familiar melodies or even novel melodies remembered over periods of minutes..." (p427).

The evidence suggests that pitch-interval,although harder to assimilate by the listener initially, is the more enduring feature of a melody than contour, and increases in importance when melodies are retained over longer periods of time (longer than in a typical short-term memory experiment) and with increasing familiarity with melodies, even when they are heard in keys in which they have never been heard before.

In the following experiment the effects of increased familiarity on the processing of both pitch-interval and contour are investigated. Subjects were required to listen to two melodies and to learn the pitch-interval values of one and the contour of another on separate occasions.. During the initial learning phase the melodies were always heard in the same key.

In the experimental trials subjects heard the melody that they had been learning, then, after a short pause, heard another melody in a different key. Subjects were required to detect pitch-interval or contour alterations in this comparison melody depending upon task.

Four melodies were used in the experiment and subjects learned the pitch-interval values of one and the contour of another of the four in each case. Four melodies were used in order to reduce the effect of idiosyncrasies of one particular melody.

The length of all the melodies is 13 notes. Although Experiments 2, 3 & 4 suggest that melody length has an important effect on the relationship between pitch-interval and contour, this was considered to be less important when melodies are learned. The length was chosen in order to make the task of suitable difficulty, as pilot studies suggested that shorter melodies made the task too easy and longer ones made it too difficult.

The central hypothesis tested is that, with increased familiarity, pitch-interval is more salient than contour throughout a melody, even when these melodies are transposed. Thus, overall, pitch-interval would be more salient than contour and there would be no serial positions for which contour is more salient than pitch. Again a reaction time measure is taken.

EXPERIMENT SEVEN

9.2 METHOD

9.2.1 Subjects: 20 subjects participated in 2 experimental sessions. Every subject was a musician who had been learning at least one instrument for a minimum of five years during the period immediately prior to the experiment.

9.2.2 Task: There were two experimental sessions, one of which will be referred to as pitch-interval the other as contour.

In the pitch-interval task subjects were required to listen to a melody 10 times, each time in the key of C major. They were required to attend to the pitch-interval relationships and to learn them.

After this initial learning phase subjects were required to listen to 32 melody pairs. In each trial the learned melody was heard in the original key of C major. After a 5-second pause a comparison melody was heard in the key of F sharp major. This comparison melody usually possessed one pitch-interval alteration in the new key and the task was to detect this alteration and to press a button as quickly as possible.

The comparison melody possessed one pitch-interval alteration at one point in the melody in 24 of the 32 trials.

In the other 8 trials the comparison melody was exactly the same as the original throughout. There were catch trials.

In the contour task subjects were again required to listen 10 times to a melody (different from that which they had heard in the pitch-interval session, or were going to hear) and to attend to the contour of the melody. During the learning phase the melody was always heard in the key of C major.

After the learning phase, subjects were again required to listen to 32 melody pairs. In each trial the learned melody was heard in the original key of C major. After a pause a comparison melody was heard in the key of F sharp major. This comparison melody usually possessed one contour alteration relative to the original melody. The task was to detect this alteration and to press a button as quickly as possible.

Twenty-four of the comparison melodies possessed an alteration of this sort; the other 8 comparison melodies shared the same contour as the original throughout and were catch trials.

9.2.3 Design: There were 2 nested factors -- task (pitch-interval/ contour) and serial position of alteration (collapsed into three positions, Early (notes 2 - 5), Middle (notes 6 - 9), and Late (notes 10 - 13). The design of the experiment can be seen in Table 9.1.

TASK	P-I(32)			CONTOUR (32)		
POSITION OF ALTERATIONS	NOTES 2-5 EARLY	NOTES 6-9 MIDDLE	NOTES 10-13 LATE	NOTES 2-5 EARLY	NOTES 6-9 MIDDLE	NOTES 10-13 LATE
NO. TRIALS	8	8	8	8	8	8
CATCH TRIALS	8 OVERALL			8 OVERALL		

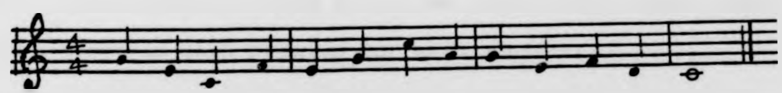
Table 9.1 Experiment 7: Design.
( ) = number of trials.

9.2.4 Counterbalancing of subjects: The order of presentation of the 2 sessions (one pitch-interval and one contour) was counterbalanced across subjects. The second factor, serial position of alteration, was randomised separately for each subject in each of the two conditions.

9.2.5 Melodies: 4 melodies, each 13-notes in length were composed as follows:

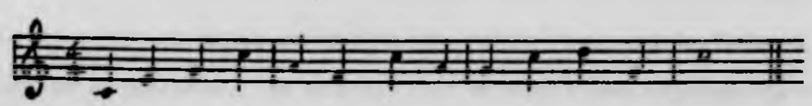
Melody 1

Melody 2



Melody 3

Melody 4



Each melody was in the key of C major. For each melody two sets of comparison melodies were composed as follows:

<u>(A) Pitch-interval</u>

For each melody twenty-four melodies were composed in the key of F sharp major. Each of these comparison melodies possessed one pitch-interval alteration in the new key. An example for Melody 1 can be seen below.

In addition, the melody was correctly transposed into the key of F sharp major. This was to be used as the catch trial (used 8 times in each session for each subject).

The alterations were distributed evenly throughout the serial positions 2 - 13, with 2 alterations on each of the notes across the 24 comparison trials.

<u>(B) Contour</u>

For each melody twenty-four melodies were composed in the key of F sharp major. These comparison melodies shared the same contour as the original except at one point they each possessed a contour alteration. An example for Melody 1 can be seen below.

In addition, 8 melodies were composed for each melody where the contour of the comparison melody was exactly the same as the original throughout. These were used as catch trials in the experiment.

Again, the alterations were distributed evenly throughout the serial positions of the melody, with there being 2 alterations on each of the notes from serial positions 2 - 13.

All the melodies used in this experiment can be seen in Appendix 5.

9.2.6 <u>Procedure</u>: Each subject participated in a pitch-interval task and a contour task, the order of which was counterbalanced across subjects. Subjects attended the laboratory on two occasions, participating in only one task on each occasion.

The procedure for the pitch-interval task was as follows.

<u>Pitch-interval task</u>

1. Each subject was asked to listen to <u>one</u> of the four melodies ten times. They were asked to attend to the pitch-interval relationships, and to learn them. During the learning phase,

the melody was always heard in the key of C major. Five subjects learned the pitch-interval values of Melody 1, five of Melody 2, five of Melody 3, and five of Melody 4.

2. Subjects then participated in 4 specifically designed practice trials. The order of the 4 practice trials was randomised separately for each subject. The procedure for the practice trials was the same as for the experimental trials.

3. In each experimental trial subjects heard the learned melody in the key of C major.

4. After a 5-second pause the same melody was heard in F sharp major. This comparison melody usually possessed one pitch-interval alteration in the new key.

5. Subjects were required to detect this alteration and to press a button as quickly as possible.

6. Each trial proceeded in the same way. There were 32 trials in all. In 24 trials the comparison melody possessed one pitch-interval alteration and in 8 trials the comparison melody was exactly the same as the original melody, but transposed into F sharp major. These were catch trials. The order of the 32 trials was randomised separately for each of the subjects.

7. Melodies described in Melodies Section A were used in this session.

Contour task

The procedure was exactly the same as for the pitch-interval task except that the subjects learned the contour of a melody over 10 learning trials. Five subjects learned the contour of Melody 1, five the contour of Melody 2, five the contour of Melody 3 and five the contour of Melody 4. In no case did a subject learn the contour of the same melody that they had learned, or were going to learn in the pitch-interval task. During the learning phase, the melody was always heard in C major.

After 4 specially composed practice trials, in which the procedure was exactly the same as for the experimental trials, subjects participated in 32 experimental trials.

In each trial subjects heard the same melody in the key of C major. After a 5-second pause a comparison melody was heard in the key of F sharp major which shared only the same contour as the original. In 24 of the comparison melodies there was one deviation in contour at one point in the melody. The task was to detect this alteration and to press a button as quickly as possible.

In 8 of the trials the comparison melody shared the same contour as the original throughout and these were catch trials. The order of the 32 trials was randomised separately for each of the subjects.

The melodies described in Melodies B were used in this part of the experiment.

9.3 RESULTS

Reaction times produced to each of the 24 alterations in each of the conditions were collapsed across the exact serial positions into three position conditions -- Early, Middle, and Late (see Table 9.1).

There were an equal number of reaction times in each of the three position conditions -- eight. A mean reaction time was calculated for each of the subjects in each of the task/position conditions, and the mean of these for 20 subjects can be seen in Table 9.2.

A 2-way task x position ANOVA can be seen in Table 9.3. This shows a significant effect for task, caused by faster responses overall to pitch-interval. There is no significant effect for position, but there is a significant interaction between task and serial position which is illustrated in Figure 9.1. This shows that position has a differential effect on pitch-interval than contour. Reaction times become faster for pitch-interval but slower for contour with increasing serial position.

Post hoc analysis (Tukey's a) reveals a critical value of 61ms for significance at the 0·01 level and a value of 46ms for significance at the 0·05 level. Thus the differences between

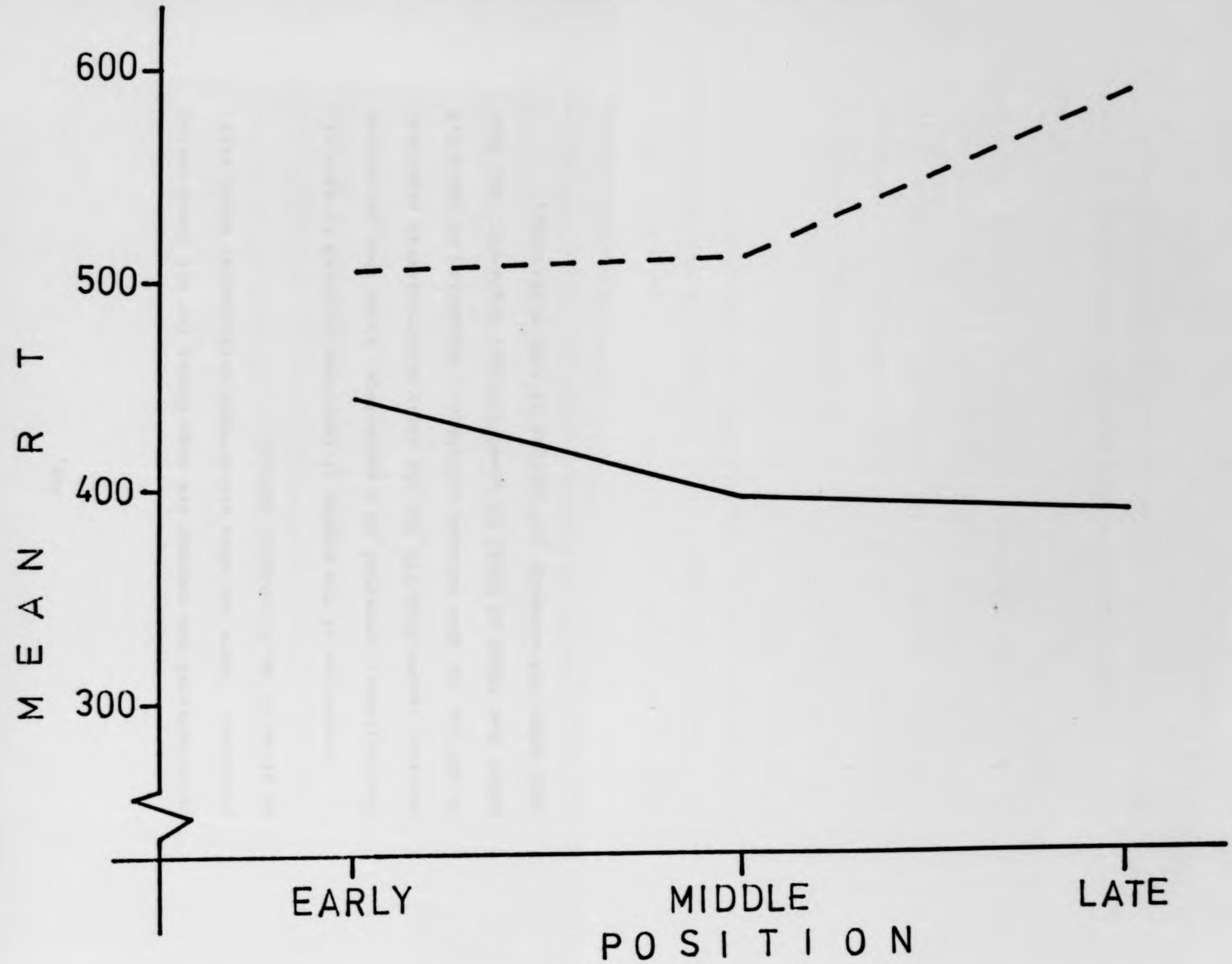
TASK	POSITION			
	EARLY	MIDDLE	LATE	MEAN
P-I	445	396	387	409
CONTOUR	504	509	584	532
MEAN	475	453	486	

Table 9.2 Experiment 7: Mean RTs for each Task/Position condition.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	604•8	19	31•8		
ERROR (WITHIN SUBJECTS)	720822	95	7587•6		
TASK	455754	1	455754	60•07	<0•001
ERROR (TASK)	380674	19	20035•5		
POSITION	23116	2	11558	1•52	0•25
ERROR (POSITION)	144160	38	3793•7		
TASK x POSITION	95910	2	47955	6•32	<0•05
ERROR (TASK x POSITION)	195988	38	5157•6		

Table 9.3 **Task x Position ANOVA (RT data).**

FIGURE 9.1 Task x position interaction (Experiment 7).



pitch-interval and contour are significant for all three serial positions. There are also within-task differences, which will be given in the discussion section.

Inspection of the number of responses produced in each of theconditions, converted to a percentage, shows that percentage accuracy ranges from 97% for the early pitch-interval condition to 46% for the late contour condition. Inspection of Table 9.2 shows that there is again no speed/accuracy trade-off, but that both speed and accuracy are indices of task difficulty.

9.4 DISCUSSION

Table 9.3 shows that there is a significant effect for task, caused by the overall faster responses to the pitch-interval task than the contour task (see Table 6.2). This supports the central hypothesis -- that, for more familiar melodies, pitch-interval would be more salient than contour.

Much of this main result is likely to be due to the effects of the learning process. Deutsch (1979) and Dowling (1978) suggest that pitch-interval becomes more salient as a melody becomes more familiar. Deutsch's experiment in particular suggests that even though a melody might always be heard in the same key in a short-term memory experiment, interval information is more salient than it would be without any learning when these melodies were heard in transposed keys.

Table 9.3 shows that there is no serial position effect -- reaction times were therefore not significantly different in any of the serial positions. This suggests that the effect of serial position itself are of no importance, and so overall superiority of pitch-interval processing is likely to be caused by the learning process itself.

In order to elucidate the importance of pitch-interval further, the interaction between task and serial position is important (see Table 9.1). The interaction shows that the relationship between pitch-interval and contour changes with serial position but *post hoc* analysis (Tukey's a) shows that the difference between pitch-interval and contour is significant for all three serial positions (in the early position at the 0·05 level and at the 0·01 level for the next two positions). Thus pitch-interval was processed at a significantly faster speed for all three serial positions. Pitch-interval was therefore more salient throughout the melodies.

This finding can be directly contrasted with the results obtained in Experiment 3 for 13-note melodies (although it must be remembered that percentage accuracy, not reaction time itself, was used as the results criterion). In Experiment 3 there was no overall significant effect for task and there were no positions where pitch-interval or contour were more salient than each other (see Table 5.12). Increased familiarity with melodies then, confers a greater advantage on pitch-interval processing than it does on contour, even when both have been learned over the same number of learning trials. This finding supports and elucidates the findings of Attneave & Olson (1971); Deutsch (1979) and the hypotheses of Dowling (1982). Contour, even when subjects are explicitly asked to attend to and learn it, seems to be less important in the encoding of more familiar melodies even when that familiarity has been induced in a short-term memory paradigm.

The central hypothesis of the experiment has therefore been supported; however, there are other results in this experiment worthy of discussion.

One point to emerge from this experiment concerns a methodological point first raised in Chapter 3.

The results for the contour task indicate that reaction times slow down with increasing serial position (Figure 9.1). One possible interpretation of this is that the cause is due to the problem of the listener having to 'pick-out' a contour from a new set of notes, which is not the case in the pitch-interval task used throughout the thesis. If this were the only way that contour could be processed then it should be predicted that there would be a progressive slowing down of reaction times with increasing serial position. The results of this experiment suggest that this is not the case. The difference between serial positions Early and Middle is not significant. The difference between Middle and Late positions (and consequently Early and Late positions) is, however. Therefore reaction times do not slow down significantly until serial position 10 (which is the beginning of the Late position). The hypothesis suggested above, therefore, is hard to substantiate from this result, as it was for Experiment 1.

Post hoc analysis of the pitch-interval task shows that there are some within-task effects. The difference between the early and middle positions is significant, with alterations being detected significantly faster in the Middle than the Early positions. There is also a significant difference between Early and Late positions with reaction times in the Late position again being significantly faster than those in the Early position. The difference between Middle and Late positions is not significant.

This suggests that pitch-interval is more salient in the Middle and Late positions than it is in the Early position, a result found in both Experiments 2 & 3. When melodies are learned and when overall position does not have a significant effect, the improvement carries over to the final serial position. This in turn suggests that if a melody was sufficiently well learned, melodies of any length would show a consistent level of performance after the initial few notes had been heard.

The effect for the first few notes, however, shows that even for more familiar melodies, pitch-interval relationships become more salient after a few notes have been heard. Even for familiar melodies it is necessary to establish a tonal centre. As Davies (1978) points out, listeners do not normally retain information about the absolute key of melodies even when melodies are familiar. The location of a tonal centre might be quicker, in terms of notes heard, as subjects can use their memory trace in order to help establish this tonal centre. Thus, establishment of a tonal centre is important in the recognition of melodies as well as the encoding of pitch-interval relationships.

In the experiment described here the subjects could, to some extent, guess the approximate tonal centre of the comparison melody as the relationship between the first hearing and the comparison melody was always the same in each trial. However, there are no such clues in the ordinary environment, and so it is likely that the serial position effect, for familiar melodies, will be stronger when melodies are heard 'out of the blue'.

This is important with respect to some of the arguments put forward in Chapter 7. In particular, it was suggested that the contour of the main theme in the first movement of Beethoven's Fifth Symphony is more salient than the precise pitch-interval values. This might be particularly true when the symphony is heard for the first time; yet it is patently obvious that most people have heard this piece of music more than once.

The results of this experiment suggest that, even when melodies are familiar, the pitch-interval relationships are more salient from notes in serial position 6 onwards (the start of the Middle position). The theme in Beethoven's Fifth Symphony is only four notes long. The pitch-interval relationships in this first theme may not be as salient as they could be, as the similarities between this experiment and natural music perception have been indicated above.

The composer then repeats the theme at a different pitch level -- which, perceptually, may have a very similar effect to a transposition. By repeating only the contour at different levels, added to the fact that it is very short, the contour may remain the more salient element even when a melody is familiar. In effect, the composer can determine which of the relationships between notes is the more salient, and remains the more salient, even though the listener is exposed to repeated hearings of the music.

It is clear that the precise pitch-interval relationships in this piece become more salient with increasing familiarity, but, as indicated in Chapter 8, melodies and themes can be represented at different levels simultaneously.

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CHAPTER TEN

10.1 INTRODUCTION

All the experiments reported in this thesis stress the differences between pitch-interval and contour in melody processing, and explore situations in which each type of relationship might be more or less salient. The following, and final, experiment, considers pitch-interval from a different angle. For this reason, some literature review is necessary and this will be carried out in the following pages.

In Chapter 7 attention was drawn to the fact that contour might be a purely relational form of encoding, whereas pitch-interval depends ultimately on the location of a tonal centre which must be absolute in nature. Once a tonal centre has been established, then pitch-interval encoding can take place relative to this; pitch-interval, although also relative in some ways, relies upon the presence of a sense of key which might be dependent upon a set of absolute frequencies.

Contour seems to be at its most salient when this absolute tonal centre cannot be located -- when melodies are transposed (which makes the location of the tonal centre in tonal space difficult), where the melodies are novel (which makes it impossible for the listener to use the memory trace of a melody to help with the location of the tonal centre) and, when the melodies are short.

Any situation which serves to make the determination of the tonal centre more difficult increases the salience of contour.

When absolutes,in terms of a tonal centre, are available -- when melodies are untransposed, are more familiar and are longer, contour is not such a critical feature of a melody, but yet may still be an important part of melody perception as indicated in Chapter 8. Its relative salience has decreased but it is another level at which a melody might be represented.

The difference between pitch-interval and contour, with the latter being more relational than the former, suggests that both may play different roles in melody perception in general when melodies are heard in a variety of keys. This is the topic of interest in this next chapter.

Throughout the thesis, subjects have heard melodies transposed only to the most distant key possible according to musical theory. However, there is much research to suggest that the key into which a melody is transposed might itself affect the perception of that melody, and this will be considered below.

The observation that a melody could be transposed into a new key and yet still remain recognisable as the same melody was in fact a central motivating force behind the Gestalt school (von Ehrenfels, (1937). The concept of a melody as a 'whole organised in time' was put forward by Koffka (1935).

However, it was also recognised relatively early on that all melodies do not transpose equally well (that is, they are not all equally recognisable when transposed). Juhasz (in Peterman, 1932) found that all 3-note sequences were not equally recognisable when transposed. Wertheimer (1959) proposed that meaningless tone aggregates did not transpose as well as 'good' melodies, which, in the light of this thesis, suggests that the ease with which a tonal centre could be located in the transposed melody affected the encoding of the interval relationships. When melodies were tonal, then this was easier; when the melodies were atonal (which is what was presumably meant by senseless tone aggregates) then location of the tonal centre was more difficult.

Deutsch (1982a) likens melody transposition to transposing a visual shape to a different location in the visual field (after Deese & Grindley, 1947). However, since Juhasz & Wertheimer, a number of studies have isolated some factors which affect the ease with which a melody can be recognised when transposed. Deutsch (1982a) suggests that these results might be due to the difficulties brought about when interval information is projected onto highly overlearned unequal-interval scales (after Deutsch & Feroe, 1981).

However, to make a comparison between visual transposition and the transposition of music is to ignore the fundamental difference between the two. The thesis has drawn attention to the fact that the <u>only</u> way a melody can be known is over time, and although this is important in visual encoding, it is not the prime feature in the way that it is for music. The thesis has demonstrated that the salience of different types of relationship varies with, amongst other things, serial position, and so the passage of time affects the way a melody is encoded. Thus the analogy between visual and auditory transposition is a tenuous one.

Recent studies have isolated a variety of factors which affect the ease with which a melody can be recognised in transposition (Cohen, 1975; Cuddy & Cohen, 1976; Cuddy & Lyons, 1981; Cuddy, 1982). These include the degree of tonality (whether melodies are strongly or weakly tonal), the occurrence of repeated notes in a melody, particularly if the first and last notes are the same (Cuddy refers to this as 'excursion'), the melodic contour of the melody, with more simple contours making recognition easier, and on a more wholistic level, the key into which a melody has been transposed relative to the key in which it has just been heard.

This last factor, referred to as 'key-relatedness' or 'key-distance', has been investigated by a number of researchers, which will be considered below. It is hypothesised that this key-relatedness may have a differential effect on the processing of pitch-interval and contour because of the importance of establishing a tonal centre for the accurate encoding of pitch-interval relationships which is not necessary for contour. First, however, it is necessary to discuss the concept of key-distance in more detail.

The first point to be made is that for key-distance to have an effect on the listener, he or she must be aware of some sort of transposition occurring. This implies that the listener must have knowledge of both the first key and the new key in a transposition. This occurs in music itself; a theme or musical idea, once heard, often reappears in a new key later in a piece. Sometimes the occurrence is soon after it has been heard, sometimes a lot later (like,for example,the reoccurrence of a theme in the dominant in the recapitulation of a sonata-form composition).

Any key, or scale, bears a formalised relationship to each other key. The relationship between the notes within each scale are constant throughout all scales. In all major scales (minor scales are not considered here) the relationship between notes are all of a whole tone except for notes 3 & 4 and 7 & 8, which are of a semitone. This is the same for all major scales; thus in relative terms all scales are identical.

However, they differ in an absolute way in that each scale or key exists in a different part of tonal space, and starts on a different note. Thus keys represent absolutes within a system of relationships -- in relative terms all scales are identical, but in absolute terms they are different.

It is this ultimately absolute nature of a key that emphasises the difference between pitch-interval and contour.

The description of key relationships in music is a topic of interest to both the psychologist and the musicologist, and the relationships between keys are traditionally described in terms of the circle of fifths (Figure 10.1). Keys that are adjacent to one another are closely related whereas those diametrically opposite are the most distantly related.

However, it is clear that the circle of fifths does not take account of all the types of relationships which may exist between keys. Other methods used to describe key relationships are the number of sharps or flats two keys may have in common, or the number of notes they have in common. None of these systems alone is adequate; the circle of fifths does not take account of the importance of the interval of a third, for example.

Longuet-Higgins (1962a & b) unifies all three of these factors and shows how some keys, traditionally considered as being distantly related, are in fact fairly closely related. The circle of fifths in itself does not fully describe key relationships but can serve as a general guide. Equally important, however, is the relationship of the third. Longuet-Higgins (and Longuet-Higgins & Steedman, 1971) shows how key relationships and harmonic relationships in general can be represented in terms of a two-dimensional model, where both the relationships of a fifth and of a third are represented. These models also suggest how keys can be identified.

FIGURE 10.1

CIRCLE OF FIFTHS

Many psychological studies have investigated the effect of key-distance on the perception of transposed melodies and have used the traditional circle of fifths representation in defining the key-distances involved. This is the scheme that will be used in the following experiment, as the experiment is concerned more with the effect of key distance on the relationship between pitch-interval and contour than the more detailed ramifications of the nature of key relationship itself.

The general finding is that recognition of a melody is better when transposed to a closely related key than to a more distantly related key, at least where these relationships are defined by the circle of fifths (for example, Cohen 1975; Cuddy & Cohen, 1976; Cuddy *et al*, 1979; Bartlett & Dowling, 1980; Krumhansl *et al*, 1982; Krumhansl & Kessler, 1982). Melodies and chords appear to be more readily perceived as being the same when transposed to closely related keys than when transposed to distantly related keys, and so would, for example, be more readily recognised when transposed from C to G major than when transposed from C to F sharp major.

Cuddy *et al*, (1979) suggest that the rules of music might reflect the nature of music perception (an idea that will be developed in Chapter 11) and state that the primary function of musical rules is not to generate patterns but to codify the structures of music already composed. They suggest, moreover, that these structures reflect the critical aspects of auditory processes. They suggest, therefore, that the structure of music might shed some light on music processing, an idea that will be developed also in Chapter 11.

Cohen (1975) uses this idea as support for the finding on key-distance reported above. She suggests that the most common type of modulation in music (that is, the way a transposition is effected) is to closely related keys rather than to distantly related keys. This common compositional practice is reflected in listeners' greater ability to recognise melodies (themes) as being the same when this type of transposition takes place over occasions when transposition is to a more distantly related key.

However, there are fundamental differences between the way transposition is achieved in music and the way it is 'achieved' in laboratory experiments. In composed music, there is normally some linking passage which takes the listener from one key to another. There is no such thing as modulation in music processing experiments -- usually there is just a short time interval between one hearing of a melody and another. This is a central difference and relates to the hypotheses to be put forward in this chapter.

Bartlett & Dowling (1980) also carried out a study on key-distance and found the same general effect. However, in the experimental design there were sets of 'lures' which were contour-preserving comparison melodies. The data obtained by Bartlett & Dowling suggests that these lures were more misleading (that is, subjects responded 'exact same' when in fact the comparison melodies were lures, or catch trials) when the comparisons were heard in closely related keys than when they were heard in more distantly related keys. This suggests that contour might be particularly important (more salient) when melodies are transposed to closely related keys than to distantly related keys.

No studies, however, have specifically investigated the effect of key-relatedness on the perception of contour relationships. This is the main concern of this next experiment.

The thesis has stressed the difference between pitch-interval and contour in terms of relative and absolute information, a general issue in cognitive psychology (for example, Kohler, 1938; Bryant, 1974). However, it has been suggested that the distinction between absolute and relative information is not a dichotomous one, rather it is a continuum on which all types of information sit.

Contour can only be relational, and is therefore at the <u>relative</u> extreme of the continuum. It is clear that there are many relational qualities in pitch-interval information (indeed, the title implies relativity). However, pitch-interval ultimately depends upon <u>absolute</u> values within a system of relations. As a demonstration, note that it is equally possible to sing out of tune in any key.

This ultimately absolute quality of pitch-interval is displayed in the idea that, before successful encoding and recognition of pitch-interval can take place, a tonal centre must be located. No such tonal centre is necessary for the accurate encoding of contour information.

Is is hypothesised, therefore, that the processing of pitch-interval might be affected by key-distance, as tonal centres need to be established; different key-distances may make the establishment of a tonal centre more or less easy which in turn might affect the encoding of pitch-interval relationships. Contour, however, should not be affected by key-distance as the processing of this type of relationship does not depend on the location of a tonal centre. If this is the case, then pitch-interval and contour will be demonstrated to be separable and support added to the hypothesis that contour can be, and is, processed and is an important aspect of melody perception and encoding.

In the following experiment melodies are first heard in the key of C major. In each trial a comparison melody is heard in one of three keys -- G major, a closely related key; E major, a more distant key -- this is one example of a key which appears to be quite distant according to the circle of fifth but is, as Longuet-Higgins (1962a) points out, quite closely related to C major if one takes into account the important relationship of the third; and F sharp major, the most distantly related key of the three.

The important point about these three keys is that G major is more closely related than E major which is more closely related than F sharp major. These differential relationships are thought to have an effect on the encoding of pitch-interval but not on contour.

The effect of key-distance on the processing of pitch-interval is also of some interest. Most research shows that melody recognition is better when melodies are transposed to closely related keys than to distantly related keys. However, none of these studies have used a reaction time measure (i.e. investigated melody processing as it occurs) and so it is thought that the results from the present experiment might be somewhat different.

If the encoding of pitch-interval depends on the location of a tonal centre, then it is possible that this is done more easily when melodies are transposed to a distantly related key than when transposed to a closely related key -- for it must logically be the case that differentiation between two absolutes is performed more easily when there are greater differences, which is the case for distantly related keys over closely related keys (for a discussion, see earlier).

The hypothesis concerning the effect of key-distance on pitch-interval is therefore non-directional; it was thought that there would be an effect but it was also thought that a response measure which is taken while a melody is being heard might give different results to the more general findings reviewed above.

In each trial novel melodies are used and the melodies are 9 notes in length. This length was chosen as performance levels are fairly good. It is also a length for which there is no significant effect for task. However, it is hypothesised that there might be a significant effect for task, with contour being processed faster than pitch-interval, because of the introduction of different keys for the comparison melodies which may affect the encoding of pitch-interval but not of contour.

EXPERIMENT EIGHT

10.2 METHOD

10.2.1 Subjects: 18 subjects participated in 2 experimental sessions. Every subject was a musician who had been learning at least one musical instrument for a minimum of 5 years during the period immediately prior to the experiment.

10.2.2 Task: Subjects participated in 2 different tasks, one of which was pitch-interval, the other of which was contour.

In the pitch-interval session there were 24 trials. In each trial subjects heard a 9-note melody in the key of C major. After a 5-second pause a comparison melody was heard in the key of G major, E major, or F sharp major. In the comparison melody there was one pitch-interval alteration at one point in the melody. The task was to detect this alteration and to press a button as quickly as possible.

For 8 trials the comparison melody was in G; for 8 trials in E; and for 8 trials in F sharp major. The order of the trials was randomised so that subjects never knew in which of the keys the comparison melody was to be heard.

The contour task proceeded in the same way. There were 24 trials. In each trial subjects heard a 9-note melody and were required to attend to the contour of this melody. After a 5-second pause a comparison melody was heard in G, E or F sharp major, and this comparison melody possessed one contour alteration at one point.

The task was to detect this alteration and to press a button as quickly as possible.

Again, there were 8 comparison melodies in each of the keys and the order of the 24 trials was randomised.

10.2.3 Design: There were 2 nested factors -- task (pitch-interval/ contour) and key of comparison melody (G major, E major or F sharp major). The design of the experiment can be seen in Table 10.1.

A third factor, serial position of alteration, was not an experimental factor but a control. For each set of comparison melodies there was one alteration in each of the serial positions from 2 - 9.

10.2.4 Counterbalancing of subjects: The order of the tasks was counterbalanced across subjects. The order of presentation of the 24 trials was randomised for each subject in each of the tasks.

10.2.5 Melodies: Two sets of twenty-four melody pairs were composed. One set was used in the pitch-interval task, the other in the contour task. The sets were designed as follows:

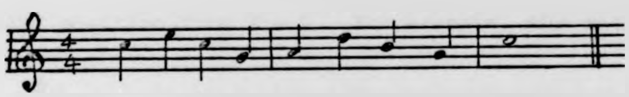
(A) Pitch-interval

Twenty-four 9-note melodies were composed in the key of C major. These 24 melodies were randomly assigned to the three comparison melody conditions, so that there were 8 melodies in each (see Table 10.1). For the set assigned to the G major comparison melody key,

TASK	P-I(24)			CONTOUR (24)		
KEY OF COMPARISON MELODY	G NEAR	E MIDDLE	F# FAR	G NEAR	E MIDDLE	F# FAR
NO. MELODIES	8	8	8	8	8	8

Table 10.1 **Experiment 8: Design.**
( ) = number of trials.

comparison melodies were composed in the key of G major. Each of these melodies possessed one pitch-interval alteration in the new key. For example, the melody below:



possessed a comparison melody as follows:

The alterations were distributed evenly throughout the serial positions of the 8 melodies, such that there was one alteration in each of the serial positions 2 - 9.

Exactly the same procedure was followed for each of the 8 original melodies assigned to the other key conditions. Those assigned to the E major condition had comparison melodies in E major, those assigned to the F sharp major condition possessed comparison melodies in F sharp major. Each comparison melody possessed one pitch-interval alteration in the new key. Again, the distribution of alterations was uniform throughout the serial positions from 2 - 9.

(B) Contour

Twenty-four melodies were composed in the key of C major. These were each 9 notes in length. Eight melodies were assigned to each of the comparison melody key conditions. For those assigned to the G major condition a comparison melody was written in G major, which possessed the same contour as the original, except for an alteration at one point. Throughout the 8 comparison melodies the alterations were distributed evenly with one alteration in each serial position from 2 - 9. For example, the melody below:

possessed a comparison melody as follows:

For the 8 melodies assigned to the other key conditions comparison melodies were composed in the appropriate key and each possessed a contour alteration at one point. The alterations were distributed evenly throughout the serial positions from 2 - 9.

All the notes were 500ms in length except the last, which was 2,000ms in length in order to maintain melodic balance.

All melodies used in this experiment can be seen in Appendix 6.

10.2.6 Procedure: The order of the 2 sessions (pitch-interval and contour) was counterbalanced across subjects. Subjects participated in only one condition on each attendance at the laboratory and therefore attended twice.

The procedure for the pitch-interval task was as follows.

<u>Pitch-interval task</u>

1. Subjects participated in 4 specifically designed practice trials, the order of which was randomised separately for each subject. The procedure for the practice trials was exactly the same as for the experimental trials.

2. In each experimental trial subjects heard a 9-note melody in the key of C major. They were asked to attend to the pitch-interval relationships of this melody.

3. After a 5-second pause the same melody was heard transposed to G major (near), E major (middle) or F sharp major (far). This comparison melody possessed one pitch-interval alteration in the new key. The subject was required to press a button as quickly as possible on detecting this alteration.

4. Each trial proceeded in the same way. For 8 trials the comparison melody was in G major, for 8 it was in E major and for 8 it was in F sharp major. The order of the 24 trials was randomised separately for each subject in each of the conditions, so subjects never knew the key of the comparison melody and so could not predict it in any way.

5. There were no catch trials, although subjects were not informed of this.

6. Melodies described in Melodies A were used in this part of the experiment.

Contour task

The procedure for the contour task was exactly the same as for the pitch-interval task. After participating in 4 specifically composed practice trials subjects participated in 24 experimental trials.

In each trial a melody was heard in C major. Subjects were required to attend to the contour. After a 5-second pause a comparison melody was heard in the key of G, E or F sharp major. This comparison melody possessed one contour alteration at one point in the melody and the task was to detect this alteration. On doing so, subjects were required to press a button as quickly as possible. In 8 trials the comparison melody was in G major, in 8 it was in E major, and in 8 it was in F sharp major. The order of the 24 trials was randomised separately for each subject.

Melodies described in Melodies B were used in this part of the experiment.

10.3 RESULTS

A reaction time was calculated for each of the subjects in each of the task/key conditions, collapsing across serial position of alteration. From hereon they key conditions will be referred to as 'Near' (G major), 'Middle' (E major) and 'Far' (F sharp major).

The mean reaction times can be seen in Table 10.2.

A 2-way task x key condition ANOVA can be seen in Table 10.3. There is a significant effect for task, caused by faster reaction times to the contour than the pitch-interval task. There is no significant key condition effect overall. However, there is a significant task x key condition interaction, illustrated in Figure 10.2. This interaction shows that key has a large effect for pitch-interval, with reaction times decreasing with increasing key-distance; there is little effect of key on contour, however. In addition, reaction times in both tasks become more similar with increasing key-distance.

Post hoc analysis (Tukey's a) gives a critical value of 149ms for significance at the 0·05 level and a value of 200ms for significance at the 0·01 level.

Error rates are approximately 50% for each condition, with little variation. Performance is therefore fairly consistent across all conditions. The greatest variation is in the reaction times (Table 10.2).

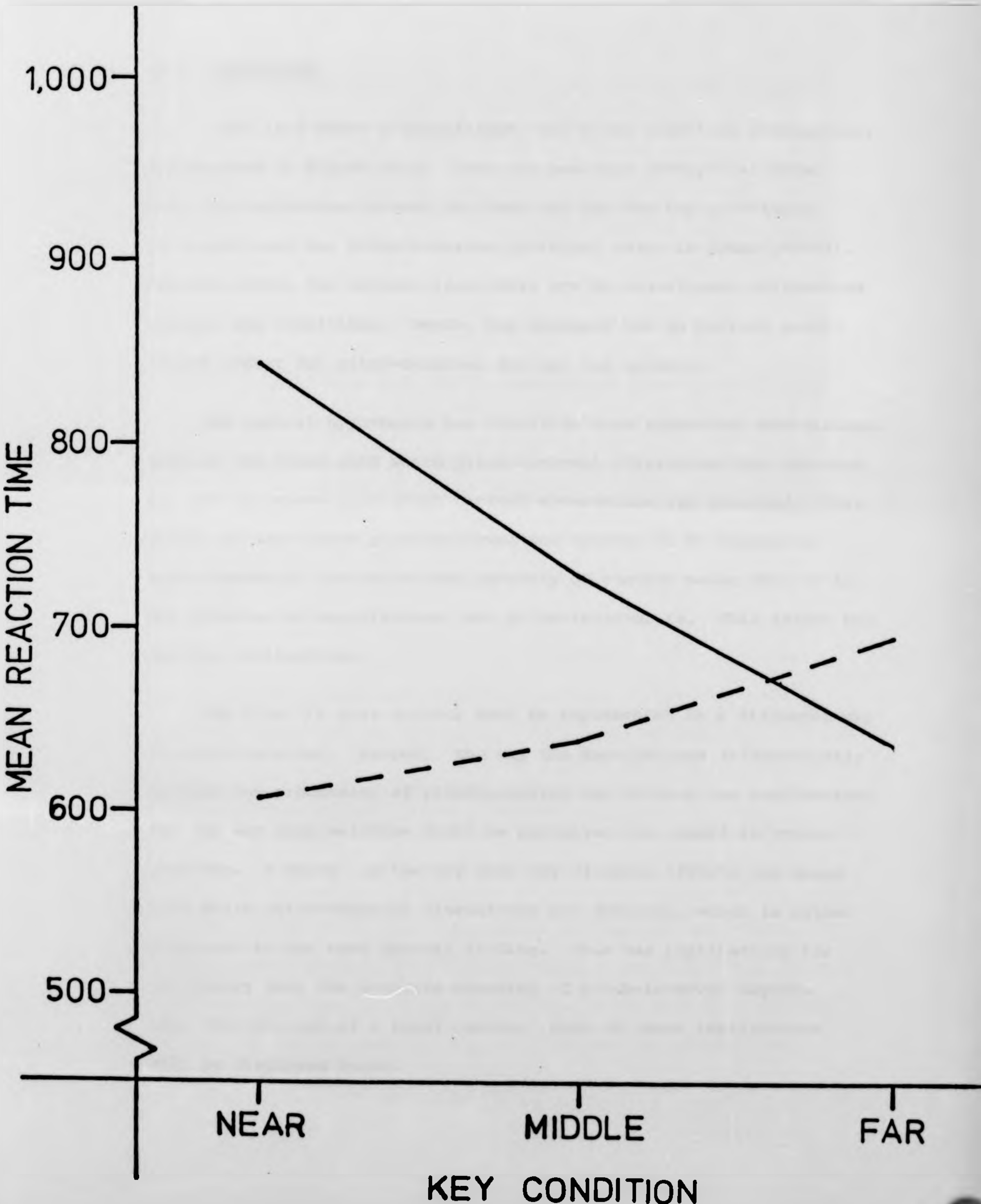
TASK	KEY CONDITION			
	NEAR	MIDDLE	FAR	MEAN
P-I	843	725	632	733
CONTOUR	606	636	692	645
MEAN	725	681	662	

Table 10.2 Experiment 8: Mean RTs in each Task/Key Condition.

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
WITHIN SUBJECTS	3265740	15	217716		
ERROR (WITHIN SUBJECTS)	3385530	75	45140·4		
TASK	190992	1	190992	4·23	<0·05
ERROR (TASK)	985872	15	65724·8		
KEY	66028	2	33014	0·73	0·5
ERROR (KEY)	1132752	30	37758·4		
TASK x KEY	352812	2	176406	3·91	<0·05
ERROR (TASK x KEY)	1266909	30	42230 3		

Table 10.3 Experiment 8: Task x Key ANOVA (RT data).

FIGURE 10.2 Task x key condition interaction (Experiment 8).



10.4 DISCUSSION

Table 10.3 shows a significant task x key condition interaction, illustrated in Figure 10.2. *Post hoc* analysis (Tukey's a) shows that the difference between the near and the far key conditions is significant for pitch-interval (critical value is 200ms $p<0{\cdot}01$). However,within the contour task there are no significant differences between key conditions. Hence, key distance has an overall significant effect for pitch-interval but not for contour.

The central hypothesis has therefore been supported; key-distance affects the speed with which pitch-interval alterations are detected but not the speed with which contour alterations are detected. This result in turn shows pitch-interval and contour to be separable experimentally; the relational property of contour means that it is not affected by key-distance, but pitch-interval is. This result has several implications.

The first is that contour must be represented in a different way to pitch-interval. Second, the way the key-distance differentially affects the processing of pitch-interval and contour has implications for the way that melodies might be perceived when heard in transposition. A third is the way that key-distance affects the speed with which pitch-interval alterations are detected, which is rather different to the more general finding. This has implications for the theory that the accurate encoding of pitch-interval depends upon the location of a tonal centre. Each of these implications will be discussed below.

Table 10.3 shows that there is no significant overall effect for the key-distance factor and Figure 10.2 shows how the relationship between pitch-interval and contour changes with increasing key-distance. There is a significant effect for task, caused by the overall faster responses to the contour task (see Table 10.2). This is due to the effect of unpredictable keys into which melodies were transposed, affecting pitch-interval more than contour.

The results show that pitch-interval alterations are detected significantly faster when they are heard in the far key condition than when heard in the near key condition. This is contrary to the more general finding (for example, Cohen, 1975; Krumhansl & Kessler, 1982). In most studies it has been found that melodies are more easily recognised when heard in closely related than distantly related keys. Cohen (1975) explains this in terms of the observation that this is generally what happens in music -- that themes are transposed to the dominant (the most closely related key) and so common compositional practices may reflect perception.

However, the way transposition is achieved in music itself, and the way it is achieved in music perception experiments is considerably different. This crucial difference will be discussed below.

The interpretation of this result is that, if the location of a tonal centre is necessary for the accurate encoding of pitch-interval relationships, then the location of this centre will be performed better when the listener is able to differentiate between two absolutes -- the tonal centre of the first melody and the tonal centre of the comparison melody. C major and G major are very similar in that they share most of their notes in common. Therefore distinguishing the two might be difficult. However, C major and F sharp major share few notes in common. It may be easier, therefore, to distinguish between the tonal centres of these keys.

This interpretation has implications for the way different types of transposition might be perceived depending upon the key into which a melody is transposed.

The results also show that there is no significant effect for key-distance on the encoding of contour information. This is thought to be due to its totally relational nature. The interaction between task and key-distance further demonstrates the difference between pitch-interval and contour which in turn has implications for the perception of melodies heard in transposition.

Post hoc analysis shows that the difference between pitch-interval and contour is only significant for the near key condition. Contour remains equally salient (although reaction times slow down, but not significantly, with increasing key-distance) throughout. The difference between pitch-interval and contour in the near condition can be interpreted in the following way.

Contour is most important (most salient) to the listener when melodies are transposed to a closely related key. Pitch-interval is less salient in the near key than the far key because it is more difficult for the listener to determine a new tonal centre. When the differentiation between absolutes is at its most difficult, the relational information is at its most important. This interpretation sheds some light on Bartlett & Dowling's (1980) finding that subjects found contour-preserving lures more misleading when heard in closely related keys than distantly related ones. Contour is particularly salient when melodies are transposed to closely related keys. This has implications for the way transpositions might be perceived in music itself.

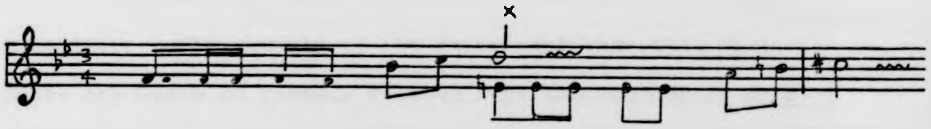
It was pointed out earlier that transposition in music is vastly different to the way it occurs in melody perception experiments. In composed music, a transposition from one key to another is normally affected via a modulatory passage. In melody processing experiments there is no such modulation. There is usually just a gap between the first hearing of a melody and its subsequent comparison, as in the present experiment.

The results of this experiment suggest that when there is no modulatory passage, which prepares the listener for the new key, then the processing of melodies transposed to distantly related keys is better in terms of pitch-interval than when they are transposed to more closely related keys. Observation of music itself suggests that abrupt modulation, without any warning, does sometimes occur. When this does happen melodies, or more usually themes, are sometimes transposed to distantly related keys.

The results of this experiment suggest that encoding of pitch-interval information is better when this occurs than when melodies are transposed to closely related keys. Actual music reflects this. For example, take the popular song "La Mer":

after this theme, which is in F major, is heard, it modulates without warning to A flat major, a moderately distant key:

(see Figure 10.1). Another example can be seen in Walton's piece "Facade" (Yodelling song). Throughout this movement a short fanfare is heard:

Frequently, before this has even finished, it is heard transposed down a semitone, as below:

The key-distance between these two themes is fairly large, and when listening to this music the perceptual separation of the two playings is fairly easy -- the repetition heard a semitone lower is easily recognised as an exact transposition. It is important to note that 'perceptual separation' is totally different to 'physical separation';in terms of physical frequency the starting notes of the two themes is very close, but in terms of key-distance, the keys are very distant.

When modulating to closely related keys, it may not take place on such an abrupt basis as when modulating to distantly related keys. The results of the experiment suggest that pitch-interval relationships are less salient when heard in closely related keys. Commonly, the composer does one of three things when modulating to closely related keys. First, there might be a lengthy modulatory passage which separates the two keys over the passage of time, allowing perceptual separation to take place. A modulatory passage is often in an ambiguous key, linking the two. Second, new material is introduced, which obviously allows perceptual separation.

Third, and most importantly to this chapter, it is often the case that when repeating a theme in a closely related key, the composer will make it contour-preserving rather than an exact transposition. The results of the experiment show that when melodies are heard in closely related keys the contour is more salient than the pitch-interval ralationships, thus preserving contour might induce more of a sense of unity in the listener than preserving the precise pitch-interval relationships.

Given that the circle of fifths does not adequately describe the true nature of key relationships, the use of this device will be restricted to transposition to the most closely related key, the dominant. This often occurs in fugues, where tonal answers are usually played in the dominant. It has already been mentioned that these answers are paraphrases as well as being contour-preserving.

However, in that these answers are generally contour-preserving, it might be that they do confer a sense of unity between the first voice and the answer. Another point to note is that although following voices are written in a different key, they seem not to modulate at all -- which suggests, again, that the confusion between tonal centres is great; it is difficult, therefore, to differentiate them.

This leads to a question which arises from Experiment 6. In this experiment it was found that pitch-interval was more salient when melodies were untransposed. Why, then, is pitch-interval more salient when it is transposed to a distantly related key than to a closely related key? There are two reasons which can be given, which will be discussed below.

The first is that in Experiment 6 listeners knew that melodies were not going to be transposed, whereas in the experiment reported here, listeners knew that a transposition was going to occur, but the key was unpredictable. This may account for the results to some extent.

However, there is another, more important reason. It was suggested above that when transposition takes place to closely related keys it does not seem, sometimes, that a modulation has taken place at all. When modulation to distant keys occurs, the two are clearly separable. Thus the contrast between a close modulation may be the difference between noticing that two things are related or different in terms of the tonal space they occupy.

An analogy can be drawn here between interval perception and melody perception on a more general basis. A melody is more likely to be called a single melody if the interval relationships are small (see Chapter 1) as the frequency of occurrence of an interval is inversely related to its size. However, it is also the case that it is easier to differentiate between two melodies, or a melody that is written in such a way as to promote 'perceptual streaming' (see Chapter 1) if the interval between each of the streams is large.

Therefore, the difference between close and distant modulations may be a contrast between knowing that two themes, or melodies, are related or are different.

In summary, then, the difference between pitch-interval and contour has been extended in this present experiment. They have been shown to be differentially affected by the phenomenon of key-distance, and this difference reflects the way they might be encoded. This has implications for the way melodies and themes in music might be processed and encoded when heard in transposition.

The next chapter presents a summary of the results obtained, and discusses some of the issues arising from the findings. The link between compositional practises and music perception is considered.

CHAPTER ELEVEN

This chapter falls into three main sections. First, a brief summary is given followed by two sections concerning issues arising from the results. The first group of issues arising concern the nature of contour, the tonal centre and other, related, psychological issues.

The second group concerns more general issues such as generalisations from the results to more naturalistic circumstances and to a more general population. Finally, the relationship between music perception and music itself is discussed.

11.1 Summary of results.

Throughout, pitch-interval has been considered as the precise interval differences between notes with contour being simply the ups and downs regardless of interval values.

The thesis has examined the relationship between pitch-interval and contour in melody perception. Melodies were sometimes transposed and sometimes novel. The importance of pitch-interval and contour in the total percept was considered in each experiment; the relative importance of pitch-interval and contour has been the central topic of interest.

Contour has been clearly differentiated from pitch-interval in order to assess its importance in melody perception and it appears that contour does have a role, and quite a different one to pitch-interval, in melody perception. It is not merely pitch-interval's 'poor relation'.

Experiment 1 showed that subjects were able to attend separately to pitch-interval and contour and that the salience of these two aspects varied as a melody progressed.

In Experiment 2 melodies were heard which were novel and transposed after the first hearing, and it was found that contour was more salient than pitch-interval for 5-note melodies, whilst the reverse was true for 15-note melodies. In addition, contour was found to be particularly salient at the beginning of melodies under these conditions and thus a contour--pitch-interval continuum was suggested for the perception of novel melodies which have been heard once and are then transposed.

In Experiment 3 this continuum was further investigated using a wider range of melody lengths. Again contour was found to be more salient than pitch-interval for the shorter melodies, and the reverse for the longest melodies. Contour was again more salient at the beginning of melodies, with pitch-interval becoming more salient after a few notes had been heard -- after contour had been at its most salient.

The processing of pitch-interval and contour was further investigated in Experiment 4, where a slightly different pitch-interval task was performed. In this task, abrupt modulations were introduced. As melodies got longer, and with increasing serial position, these modulations had a greater effect on the detection of alterations. This was interpreted as showing how the tonal centre became clearer with both increasing melody length and serial position.

Experiment 5 showed that the effect of the size of the alterations used in the contour and pitch-interval tasks was not a significant source of variance.

In Experiment 6, melodies heard were again novel but were not transposed on a second hearing; for these melodies, pitch-interval was more important in the total percept and contour was never more salient than pitch-interval, in contrast to Experiment 2.

In Experiment 7 original melodies were heard over ten learning trials before the experiment started. Again it was found that pitch-interval was more salient than contour, this time throughout the extent of the melodies. However, it was also found that the salience of pitch-interval increased after a few notes had been heard, as the experimental comparison melodies were again always transposed.

In Experiment 8, the effect of key-distance on the encoding of pitch-interval and contour was investigated. It was found that contour was unaffected by key-distance, but pitch-interval was affected in that alterations were detected more quickly when the comparison melodies were transposed to a distant key than to a closely related key.

The results of the experiments have been interpreted in terms of the need to establish a tonal centre for the accurate encoding of pitch-interval which is not necessary for the encoding of contour. Any conditions which serve to make the tonal centre obscure, or unobtainable, for example, when melodies are novel, transposed or brief, serve to make the contour more important in the total percept, and the pitch-interval values less important.

When melodies are untransposed, longer, or learned, then the tonal centre is easier to establish; under these circumstances the pitch-interval relationships are more salient in the total percept. It is the relative salience of pitch-interval and contour that has been the topic of interest and it is likely that pitch-interval values are more salient, rather than the contour relationships being less, under this second set of conditions. The performance levels in the experiments suggest that this is the case. For example, in Experiment 7, where melodies were learned, the overall performance level was much higher; thus the performance on the contour task may have been very similar to that of other experiments, but with performance on the pitch-interval task being superior to other experiments.

There are several issues arising out of these results, but before they are discussed in detail some criticisms of the experiments should be considered.

The pitch-interval and the contour tasks are not wholly comparable; there may have been a tendency, then, to infer relationships between processes that appear to be experimentally related but may have quite separate mechanisms (Uttal, 1973). The processing of pitch-interval and contour may take place on a quite different basis.

However, music itself suggests an interdependence of the two and so it is likely that they actually are related. For example, when contour-preservation occurs in music, but where the precise pitch-interval values have been altered, the listener is often aware of this. The experimental technique thus replicates processes which actually occur in music, at least up to a point.

However, the strongest evidence that both pitch-interval and contour are related comes from the statistical analysis. In that the tasks are not wholly comparable, little emphasis has been placed upon main effects, although they have been considered. However, most of the important arguments have been based on the interactions, rather than the main effects. It is likely that these interactions are fairly robust, due to the use of a reaction time measure (Pachella, 1974).

The nature of an interaction is that one variable has a differential effect on another depending upon the specific condition; thus, for example, in the interaction obtained between task and length in Experiment 3, there is a differential effect on task depending on melody length. The *post hoc* analysis shows that at one end of the interaction (the shortest melodies) contour alterations are detected at a significantly faster speed than pitch-interval alterations. At the other end of the interaction (the longest melodies) pitch-interval alterations are detected at a significantly faster speed than contour. Both effects cannot be attributed to the different nature of the tasks, that is, the greater amount of change in the contour task.

The consistency of the results and the robustness of the interactions, then, suggest that the results obtained reflect psychological realities. However, the contour and the pitch-interval tasks <u>are</u> different and it is with this difference that the following sections deal.

11.2 Issues arising I

In this section three central issues arising from the results obtained will be discussed. The first concerns the contour relationship itself, on which a great deal of emphasis has been placed. What sort of psychological reality does it possess and how might it be represented? A lot of emphasis has also been placed on the importance of a tonal centre for the encoding of pitch-interval. The questions "What is the tonal centre?", "Why is it important?", and "How is it established?" will all be considered in the second section.

A third section will consider the relationships between the ideas presented in the thesis, which related to music specifically, to other isses of more general interest in cognitive psychology.

11.2.1 The role of contour in music processing

Dowling's series of experiments where contour figures centrally (for example: Dowling & Fujitani, 1971; Dowling, 1972; Dowling & Hollombe, 1977; Dowling, 1978; Bartlett & Dowling, 1980; Dowling & Bartlett, 1981) present a variety of conditions under which contour seems to be more, or less, important in melody processing. The place of contour in melody perception has recently been summarised by Dowling (1982):

> "...it appears that contour information is very important to melody recognition under certain circumstances -- especially when tonal context is weak (as with atonal melodies) or confusing (as with tonal imitations). Contour is less important with familiar melodies stored in long-term memory or even novel melodies remembered over periods of minutes. Meaningful musical context seems to aid memory for interval and/or scale-step information and not contour information.. Contour is easy to extract from a melody but no easier to remember than intervals. Finally, contour seems to be useful as an indexical device to access melodies in long-term storage, but recognition of such melodies seems to critically depend upon scale-step information" (p.427).

Here, Dowling seems to have encapsulated the nature of contour quite clearly. However, this statement is descriptive and does not, in itself, explain why contour plays this role.

However, in that Dowling states "Meaningful musical context seems to aid memory for interval and/or scale-step information..." it seems that the essential difference between pitch-interval and contour has been hinted at, if not explained. The findings of the experiments reported in the thesis clarify and extend Dowling's suggestions.

Dowling's work, along with various co-workers, has been reviewed at various points in the thesis, and will now be taken as a whole and placed into perspective in the light of the results obtained in the thesis, and the interpretation placed on these results.

It is argued here that much of the importance of contour as elucidated both by Dowling and here, stems from the fact that contour does not depend on the establishment of a tonal centre which is, however, necessary for pitch-interval. All of Dowling's results can be explained if this is taken into account. In addition, pitch-interval and contour represent different levels of relationship and so to treat them as somehow equivalent, as Dowling tends to (for example, Dowling & Fujitani 1971) clouds the real importance of contour in melody processing. The treatment of contour in melody as if it were somehow 'equivalent' to pitch-interval is a criticism which can be levelled at other research and this will be discussed later (for example, Idson & Massaro, 1978; Kallman & Massaro, 1979).

Each of Dowling's claims (see above) will now be considered in detail. First, why is contour important when tonal context is weak? This view partly stems from Dowling & Fujitani (1971). In this experiment subjects were presented with 5-note atonal melodies (it is rather interesting that Dowling terms these 'melodies') and were asked to make three sorts of judgments about comparison melodies that were either transposed or not. They were asked to judge (a) whether these comparisons were the same, or different melodies; (b) whether these were exactly the same, or merely contour-preserving and (c) whether the comparison melodies were contour-preserving or not.

The central result was that task (b) was particularly difficult when the comparison melodies were transposed. Thus, subjects found it very hard to distinguish between melodies that were exact transpositions and those that were merely contour-preserving.

It is rather odd that Dowling, in his statement about contour (above) does not include the observation that contour seems to be particularly important when melodies are transposed, as this would seem to be one of the central findings. The finding that contour seems to be particularly important when melodies are transposed, particularly when they have just been heard for the first time, (that is, they are novel) is also one of the central findings of the experiments reported in the thesis.

In Experiments 2 & 3, it was found that in fact contour was more salient than pitch-interval when melodies are heard in one key and then transposed and this is thought to be the result of the dependence of pitch-interval upon the establishment of a tonal centre, of which contour is independent. Experiment 6 shows that when melodies are untransposed, but are the same length (5-notes) then contour is not as salient, relative to pitch-interval, but is another level at which a melody can be represented; it is not contour that is less salient, but pitch-interval that is more salient, because the tonal centre will have been established, at least to some extent, on the first hearing.

This, in fact, was shown in Dowling & Fujitani (1971) as they found that task (c) was equally difficult whether melodies were transposed or not -- subjects were equally able to distinguish between melodies that possessed the same contour and those that did not regardless of whether or not they were transposed. This shows that contour was salient whether melodies were transposed or not -- but was more important, relative to pitch-interval, when melodies were transposed.

However, Dowling & Fujitani also found that when subjects were asked to recognise just the contour, they were significantly worse at this when melodies were untransposed; this presents, at first sight, something of an anomaly. However, this can also be explained if the view of contour and pitch-interval as different levels of relationship is held.

One of the problems in the experiment as described above is that subjects are asked to make two quite different sorts of judgment -- to recognise a melody as the same or different -- that is, a straight recognition task -- and to recognise that one level, that of the contour, had or had not been preserved.

Thus if asked to <u>recognise</u> a melody as being the same or different is likely to be worse on the basis of contour alone when melodies are untransposed, because the pitch-interval values are themselves more salient. The listener therefore bases his or her judgment on the most revealing information available, which will be pitch-interval in this case. Contour is available under these conditions, as the results also show, but recognition itself is likely to be more on the basis of pitch-interval than contour.

Thus judgments based on recognition and on the turning of the attention towards one particular element, which are quite different tasks, are likely to lead to different results depending on whether melodies are transposed or not, for reasons outlined above. It is the relationship between pitch-interval and contour which changes with transposition. In the experiments reported in the thesis subjects are always asked to turn their attention towards pitch-interval or contour, rather than to recognise melodies as being the same or different.

Much of the confounding of this result stems from Dowling & Fujitani's treatment of pitch-interval and contour, as if they were somehow equivalent; in this paper a two-component (interval and contour) theory of melody processing is first put forward.

However, there are some other criticisms of this paper which should be voiced. The melodies used are themselves atonal and were presented at the rather breakneck speed of 0.16 seconds per note -- thus the whole melody took less than one second to play.

One wonders what sort of melodic information could be derived from this brief, atonal event.

The results of Experiments 2 & 3 further put this finding into perspective. It was found that melody length itself might affect the relative salience of pitch-interval and contour, with contour being more salient than pitch-interval for short melodies, but with pitch-interval being more salient than contour for longer, 15-note melodies. Thus Dowling & Fujitani's results might also, to some extent, be a result of the length of melodies used. However, this is rather doubtful in that the melodies used were atonal.

This interaction of length with the salience of pitch-interval and contour can also address other findings. For example, in Dowling (1972) subjects heard variations on an original 5-note theme which were manipulations of the contour (melodies were heard in retrograde, inversion and so on). It was found that subjects were aware of the changes that took place, which suggests that they were aware of the original contour. Would the same results have been found if melodies had been a little longer? Later in this chapter the relationship between the treatment of contour in this way and music perception will be discussed with relation to actually composed music.

Thus, contour is important when tonal context is weak (and when melodies are transposed, whether melodies are tonal or atonal).

It is because the listener has difficulty in establishing a tonal centre that makes contour that much more important in the total percept.

The results of Dowling (1978) also address his two-component theory, and also address the second part of Dowling's statement -- that contour is important when tonal context is confusing. In this experiment subjects were asked to make the same sorts of judgments as in Dowling & Fujitani (1971) and again it was found that, when the comparison melodies were transposed, subjects found it very hard to distinguish between comparisons that were exactly the same and those that were contour-preserving.

This finding can, again, be interpreted in the light of the results of Experiments 2 & 3, in comparison with the results of Experiment 6; the findings of these experiments are in fact more appropriate here, as tonal, rather than atonal, melodies were used in Dowling's study. Even when melodies are tonal, a number of notes are necessary to establish a tonal centre. When melodies are only 5-notes long and are transposed, the tonal centre may not be very clearly established, and thus the contour relationship is that much more important in the total percept.

There is a further result from this study which seems to present something of an anomaly; that is, that listeners only became confused between 'exact same' and 'same contour' comparisons when the comparison melodies were tonal, rather than atonal (all the standard melodies were tonal). This might suggest that in fact contour is less important when tonal context is weak (in contrast to Dowling's claim) as, in these comparison melodies, the tonal centre must, by definition, be more obscure, which should make the contour more important. The results seem to suggest the reverse of this.

However, this finding can be interpreted in terms of the difference between melody and harmony; in differentiating a tonal from an atonal melody, listeners are much more likely to base their judgments on the important harmonic cues than on perhaps more subtle melodic cues; thus, does this result really reflect the inter-dependence of interval and contour, as Dowling claims?

A further result of this experiment is that listeners became very confused between 'exact same' and 'same contour' comparison melodies when the comparisons were not transposed, but started at a different pitch level to the standard melody. This is one case where the tonal context is confusing (see statement by Dowling above). But why is it confusing? Experiment 6 suggests that contour is at its least important when melodies are untransposed, which seems to contradict Dowling's finding.

In Experiment 6, however, the listeners knew that the melodies were not going to be transposed, and all the comparison melodies started on exactly the same note as the standard melodies. In Dowling's study listeners did not know that the comparison melody was in the same key, and were not helped by the fact that the comparison started on a different note. Indeed, the listener, under these conditions, has to ascertain that the comparison is not in fact transposed and so has to establish a 'new' tonal centre for the comparison melody. Thus, the effect of hearing a melody at a different pitch level in the same key might be very similar to hearing a transposition to a closely related key (closely related rather than distantly related, as the 'new' and the 'original' key share many notes in common). The encoding of pitch-interval when melodies are transposed to closely related keys was considered in Experiment 8 (Chapter 10) where it was suggested that contour is at its most important when this occurs. This was discussed at the end of Chapter 10.

Thus the apparent contradiction between Dowling's 1978 experiment and those reported in the thesis can in fact be explained by the important difference between knowing that a melody is untransposed and having to decide whether it is or not. The listener will not be helped in making the decision if the comparison melody begins at a different pitch level to the original melody. This finding of Dowling, then, can also be explained in terms of the results presented in the thesis.

Dowling (1982) further claims that contour is less important with familiar melodies and that recognition of such melodies is critically dependent upon scale-step (pitch-interval) information. In Dowling & Fujitani (1971) listeners were presented with distortions of melodies and it was found that although contour does have some salience, recognition was primarily based on interval recognition. This was investigated more recently in Bartlett & Dowling (1980) where it was found that people were quite good at discriminating between transpositions of well-known songs and tunes that merely possessed the same contour.

Experiment 7 investigated the role of contour in melodies that were learned, at least to some extent, before the experiment, and it was found that under these conditions contour can still be salient, but pitch-interval itself is much more salient -- although, again, at the very beginnings of melodies it still took time to establish the tonal centre.

It must be remembered that the familiar melodies used by Dowling were longer than those used in his short-term memory experiments, and so this itself might have had some effect. However, it is likely that the effects are, in the main, a result of the greater familiarity of the melodies. Again, this can be explained in terms of the greater salience of the tonal centre.

Once the listener has established some sort of memory trace in terms of pitch-interval (how this might be done will not be discussed here) then the listener can use this trace by predicting what will come next; this cannot be done for novel melodies, and thus the listener has to be much more cautious in assigning a melody to a particular tonal centre. This can be done with much more confidence when the melody is more familiar.

Why is contour not so important when melodies are heard over periods of minutes, even if they are novel? Dowling & Bartlett (1981) found that when a comparison melody was heard 31 seconds after the standard, interval information was particularly important; when only a 5-second delay occurred, contour information predominated.

There are two possible explanations for this. The first is that when melodies are heard in quick succession and they are transposed, there might be some sort of 'acoustic' trace which makes the first hearing interfere with the second; thus confusions between tonal centres is greater when the tonal centre of the standard melody can still be remembered. When it cannot, this interference does not occur. However, this is not an experimental artefact but is a process which often occurs in music itself; this was investigated in detail in Experiment 8.

However, another reason for contour's relative unimportance over longer periods of time might be because, as Dowling & Bartlett (1981) have recently suggested, it is relatively undifferentiating.

This may also explain why it might only be used as an indexical device to access melodies in long-term storage (see Dowling 1982 above). It is not just that contour is undifferentiating; it is also because it is more abstract and related only to itself, and not to a tonal centre in the way that does pitch-interval, because it cannot be linked to reference points in the same way.

This leads to Dowling's next claim -- that musical context seems to aid memory for interval which is not the case for contour. This can be seen as the role of the tonal centre. This same importance also suggests why contour is easy to extract from a melody -- it does not depend on the presence of a tonal centre -- it can always be extracted from a melody. But because it refers to a sequence of ups and downs, the listener cannot relate the contour to anything such as a tonal centre. Thus, remembering a contour is very difficult. This explains why contour is thus more transient than pitch-interval.

Thus, the role of contour in melody perception is different to that of pitch-interval. It is a more abstract level, but this does not mean to say that it is always an abstraction from pitch-interval. Because it only refers to itself (in a way it is more relational than pitch-interval) it is harder to retain than pitch-interval, though initially more accessible.

Dowling (1978) proposes a two-component model of interval and contour and, as has been suggested, implies a sort of equivalence of the two. But pitch-interval and contour are not interchangeable in the way that some experiments might suggest (for example, Idson & Massaro, 1978; Kallman & Massaro, 1979; Dowling & Hollombe, 1977).

In these experiments pitch (and/or interval) are manipulated in such a way that they are treated as equivalent; Dowling & Hollombe (1977) for example, show that melodies are most easily recognisable when octaves are split (after Deutsch, 1972 b)if the contour is preserved. Yet, because the contour is preserved, the melody, by definition, becomes more like the original than it would be if the contour was not preserved. As was made clear in the introduction, experimental techniques where this sort of manipulation takes place present very unrealistic conditions for the listener. As Davies (1979) suggests, experiments which manipulate contour, pitch and interval in this rigid way present logically possible assumptions which are not, however, logically <u>necessary</u>. Studies such as Idson & Massaro (1978) and Kallman & Massaro (1979) also manipulate contour, pitch and interval independently. Again, each manipulation makes a melody <u>less</u> <u>like</u> the original and so <u>recognition</u> of melodies is bound to change; but what is it that really underlies the recognition?

It is not possible to manipulate pitch-interval and contour in this way, precisely because they represent different levels of relationship. It is not a question of recognition, or processing, taking place on one level or another, but on a variety of levels where one of the relationships might be more salient than another, depending upon the current context of a melody (which in turn depends upon the availability of a tonal centre).

The experiments reported in the thesis show that contour is available before pitch-interval both as a melody is heard and during the learning process. This clearly demonstrates that they are different sorts of representations which need not necessarily be independent. It is also available before pitch-interval when melodies are transposed, and this depends to some extent on the nature of the transposition, as Experiment 8 shows. Contour and pitch-interval thus interact in a complementary way. They are not independent and do not 'substitute' for one another in melody processing.

Contour, because of its different nature, plays an 'active' role in melody perception (experiments which present the listener with various distortions of familiar melodies, for example, White (1960) seem to use contour in a more 'passive' way). Because it does not depend on a tonal centre for its accurate encoding, it can always be represented. Its importance, however, depends upon the salience of pitch-interval and on the length of contour to be remembered.

Dowling(1978) sees the scale on which pitch-interval values ultimately depend as a ladder, or framework, on which the ups and downs of a melody are hung. This view implies that the ladder, by necessity, is established first. Yet the results of the experiments reported in the thesis and those of Dowling, suggest that, if anything, it is the contour that is available first. Could this, then, be the ladder on which pitch-interval is hung, instead of *vice versa*? The scale, in the form of the tonal centre of a piece at any one point, will be continually changing (this is to be reviewed later). The encoding of pitch-interval will depend on this.

Contour, however, can exist at any point in tonal space and still remain recognisable. Thus, this is the constancy, not the scale. However, it is this very attribute of contour that makes it difficult to retain over any great length (its independence of a tonal centre). Thus, for contour to assume an active role in music perception, the use of short, contour-preserving themes would seem to be one of the best methods of giving a piece of music some sort of cohesion. The use of contour in music does seem to suggest this, and later in the chapter the practice of structuring larger pieces of music from small, contour-preserving themes will be discussed.

In terms of this active role, it is suggested that the percept is being continually updated in terms of its salience with reference to both pitch-interval and contour. This 'working' concept of music perception will also be discussed later.

Thus, in conclusion to this section, it is argued that all of Dowling's results can be explained by one observation; that contour and pitch-interval are different, but interactive ways of representing a melody. Contour is more readily available than pitch-interval and this,along with contour's more relational nature, suggests that contour is the framework on which the ever-changing scale might be placed, and not *vice versa*. Contour and pitch-interval are much more interdependent than any model which treats them as 'equivalent' in some way might suppose.

The rest of the current chapter discusses other issues arising from the experiments reported in the thesis, starting with the nature of the tonal centre which is thought to account for the fundamental difference between pitch-interval and contour. Chapter 12 concerns some more general issues.

11.2.2 The nature of the tonal centre

There are three basic questions to ask about the tonal centre -- "What is it?", "Why is it important?", and "How is it established?".

Each of these questions will be considered.

The tonal centre has been considered throughout as a sense of a tonic, scale, or perhaps a tonic triad (see for example, Steedman, 1972) which indicates a particular key or absolute frequency serving as the tonic of the music at any particular time. Thus, it is absolute in nature.

The tonal centre is a set of interpretations which allow some notes to appear more important than others at a certain point during the progression of a piece. It is likely that the tonal centre will change over time in most pieces of music, and that at some points the tonal centre will be very clear whilst at others it will be unclear or perhaps ambiguous. The relationship between pitch-interval and contour, and the relative salience of each, might depend upon the ease with which a tonal centre can be located at any point in a piece of music.

The tonal centre can be thought of as an anchor at any point in a piece of music. The position of this anchor, however, usually changes over time. Reasons why the tonal centre might be important are rather harder to discern.

The tonal centre may serve as a context in which to place the notes that are heard; when the notes cannot be placed in this context, the relationship which does not take account of it, the contour is more important.

It is worth considering why this type of context might be so important in melody perception for the encoding of pitch-interval relationships in particular. Burns & Ward (1982) suggest:

> "...the perception of individual musical intervals may be even less relevant to the perception of music than the perception of individual phonemes is to the perception of speech..." (p265).

This opinion is endorsed here. Both speech and music concern auditory events but the problem of <u>reference</u> is somewhat different between the two sets of events.

Phonemes, in appropriate groups, refer to external objects, events, ideas, and so on. To what, though, does music refer? This is something of a problem in itself, as there is a distinct contrast between the referentialist viewpoint, which maintains that music refers to events, feelings, and so on <u>outside</u> of the music (for example, Meyer 1967; Teplov 1966), and the absolutist who maintains that meaning in music comes from within itself -- self-reference is most important here (for example, Stravinsky 1947).

From the absolutist's viewpoint, meaning in music comes from within itself; all meaning is therefore embodied. By implication it is the absolutist viewpoint that is more important in the thesis.

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Music might only refer to itself in contrast to speech which refers to external objects. In listening to music, the listener is provided with a series of anchors in terms of tonal centres; if one is currently available, then self-reference might take place more on the basis of precise pitch-interval preservation than contour preservation. That is, the listener will notice self-reference where a theme reappears because it is exactly the same. However, if an anchor is not available, or is ambiguous, the listener might notice self-reference on the basis of contour-preservation. The listener might say that a theme is the same as one previously heard because it is contour-preserving rather than being a precise repetition. Thus the availability of the tonal centre addresses the question "What makes a melody a melody?"; one of the questions put forward at the beginning of the thesis.

At this point, it is worth noting a particular problem of terminology. The differences between pitch-interval and contour have been stressed with reference to absolute and relative information. It is quite possible to see the relationship between the two types of information the other way round (that is, contour as absolute, pitch-interval as more relative). For the present, the view voiced throughout the thesis is the one presented in the concluding pages of the thesis. However, the central point is that contour and pitch-interval are clearly different and that this difference can be seen in terms of a relative/absolute information contrast.

The nature of the tonal centre has been considered along with reasons why it might be important. A further question to be considered is how a tonal centre might be established. This is a large problem and has not been directly considered in the thesis; however, there is a small body of research which has considered this problem, and this will be discussed below.

The basic problem confronting the listener is that of determining which, of all the notes heard, is the tonic; this implies that the listener is able to determine the most important triad -- the tonic triad -- and has to become aware of which of the notes heard are 'important' and which are 'unimportant' as far as determining the tonic is concerned. Bissell (1921) first considered this problem and asked how the listener knows, when the first note of a melody is heard, whether it is the tonic or not. Bisell suggests that he or she cannot do this until several notes have been heard. This is very much the view taken in the thesis; a few notes are necessary in order to establish the tonal centre and until this occurs, contour is more salient. How the tonal centre is established, however, has not been suggested.

In order to elucidate this problem, the work of Longuet-Higgins (for example, 1962a and b; 1965; Longuet-Higgins & Steedman, 1971; Longuet-Higgins, 1976) should be considered, along with the

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In order to elucidate this problem, the work of Longuet-Higgins (for example, 1962a and b; 1965; Longuet-Higgins & Steedman, 1971; Longuet-Higgins, 1976) should be considered, along with the work of Steedman (1972) and, more recently, that of Butler (1983; Brown & Butler, 1981).

The observation that, within a scale, all notes are not equally important, is quite a widely held view. There is an area of research concerned with assessing the relative 'stability' of notes within a scale (for example, Balzano 1978; Krumhansl 1979). The tonic, fifth and third are considered to be more stable and important than other notes within a scale.

Longuet-Higgins also shows that some notes are more important in a scale than others, but extends this in such a way as to formulate new theories of harmonic relationships. Instead of representing a scale as a unidimensional phenomenon thus:

F C G D A E B (5ths)

Longuet-Higgins (for example 1962a) represents a scale bidimensionally thus:

A	E	B		(3rds & 5ths)
F	C	G	D	

In this representation, all of the notes of a scale are present, but in such a way as to emphasise that relationships of a fifth and a third; this two-dimensional representation is then projected on to a third dimension, which is the important relationship of the octave. The notes presented to the listener in Western music are all interpreted as small whole number ratios where the prime factors are two, three or five and no others. For a detailed report, see Longuet-Higgins (1976).

The implication of this representation is that although scales may have many notes in common, the actual function of these notes may be quite different. This has implications for key-relatedness which, in turn, has implications for the detection of tonal centres, which will be discussed in a later section.

Chapter 10 considered key-relatedness and it was pointed out that the circle of fifths, alone, does not account for the subtle relationships which exist between keys. Longuet-Higgins' three-dimensional model demonstrates that although two keys may share many notes in common, the function of these notes within those keys may be quite different. This is the result of giving the relationship of the third its proper status; as Longuet-Higgins points out, to think of the interval of a third as the difference between four perfect fifths and two octaves, instead of an interval in its own right, is to commit a mathematical mistake as well as a musical solecism (Longuet-Higgins, 1962a).

As an example, Longuet-Higgins gives an example of the relationship between the keys of C major and F major -- adjacent on the circle of fifths (see Figure 10.1). C major, according to the two-dimensional representation, is thus:

A	E	B	
F	C	G	D

F major, is thus:

D	A	E	
B^b	F	C	G

A, E, F, C and G are common to both, but the D of each is different. In F major it is a perfect fifth below A, and in C major it is a perfect fifth above G. The two, therefore, should not be confused as they perform quite different functions in their respective keys. Longuet-Higgins develops this three-dimensional model to incorporate intervals (Longuet-Higgins, 1962b) and shows how, within each key, each interval can be expressed in only one way as a combination of perfect fifths, major thirds and octaves.

Thus, for different keys, the 'same' interval (that is, one that might be seen on a piano) might fulfil quite different functions and be described quite differently within different keys. This 'unique' role of intervals within specific keys can thus address the problem of how a listener might determine tonal centres whilst listening to music.

In the identification of tonal centres, the listener is presented with a large number of notes which might occur in many different keys; the listener has to decide which key is actually being implied by the notes. This can be aided by the fact that, within different keys, the same intervals and notes may have quite different functions.

This has been studied in detail by Steedman (Steedman, 1972; Longuet-Higgins & Steedman, 1971). Steedman confronts the problem of determining the tonal centres of all Bach's 48 fugues from the Well-tempered Klavier from the first voice only, using computer algorithms. He sets up a number of constraints which are placed on computer programs based on Longuet-Higgins' theories and introduces a number of new constraints. Several algorithms are tried and the final one he presents is successful in determining the tonal centre in most of the fugues. The actual results will be discussed later.

The nature of the constraints placed on the various algorithms are not given here, and can be seen in detail in Steedman (1972). The final algorithms arrived at successfully found the tonal centre of the opening within the duration of the first voice; in two cases the answer given was ambiguous, in two cases actually wrong. Of most interest to the thesis presented here is the number of notes actually required to determine the tonal centre. This took from anywhere between 3 and 18 notes, but in the majority of cases took from between 4 and 8 notes. These results are entirely consistent with the results presented here, where it has been suggested that until several notes have been heard, the tonal centre is not clear. It has further been suggested here that until detection of the tonal centre takes place, the contour relationship might be the more important.

It has already been noted that the opening of Beethoven's Fifth Symphony is tonally ambiguous, the first four notes belonging equally to C minor and E b major; there is this a good case for suggesting that the contour of this theme might be more salient than the pitch-interval values. Composers are perfectly at liberty to exploit the need for the listener to establish a tonal centre and indeed, do so; this will be discussed later in this chapter.

In addition to Steedman's comprehensive report on the sorts of decisions that might be made in arriving at a correct tonal centre, there is some more recent work by Butler which shows, experimentally, how a listener might determine a tonal centre. It can be seen as complementary to Steedman's work.

Browne(1981) suggested that intervals that are rare and exist in only one key are more likely to be stronger indicators of tonal centres than those that are found in many keys. Thus tonic triads are not very good at indicating tonal centres because they are so ambiguous; on the other hand, the tritone occurs in only two keys which are distantly related. Thus if a tritone is heard one further note will tell the listener, without doubt, which key a piece of music is in.

An experiment by Brown & Butler (1981) shows that listeners are able to locate a tonal centre in only three notes, provided a tritone appears within these three notes, with the third providing the 'context'. Butler (1983) has more recently shown that when the tritone occurs simultaneously, rather than in sequence -- that is, as a chord rather than a melodic sequence -- then location of the tonal centre is even better. Thus Butler's work shows that when sequences or chords that are unique to a key occur, then tonal centres are established much more easily than when tonic triads are heard which can belong in a number of keys.

There is something of a conflict between Butler's work and that of Longuet-Higgins & Steedman (1971) which can, however, be resolved. Longuet-Higgins' theories show how, although keys may have many notes in common, the notes may fulfil quite different functions. Thus, although the notes in the tonic triad of C major occur in many keys, its function in C major is different to any other key. Steedman's algorithms take account of this, and in fact those fugues that start off with the three notes of the tonic triad have their tonal centres detected very quickly. The algorithm was designed such that a note must be proved not to be in a particular key to be eliminated --if it might fit, it is included; the algorithm assumes that the piece begins in the 'correct' key, unless proved otherwise.

Many pieces seem to begin with notes based around the tonic triad (see Bissell, 1921) and so it is natural for the listener to assume that the first few notes of a piece are likely to indicate the key, rather than mislead the listener. Composers, however, do sometimes mislead the listener and Butler's work suggests that the best way to do this might be to use the tritone; this is done in a very well-known piece, to be given later.

Most music does not begin with a tritone, far from it. To assume that an opening triad is actually in the key of the piece is often the correct assumption to make. Occasionally this will be an incorrect assumption, as some of Steedman's examples show. Butler's work is, therefore, limited in its contribution to the understanding of the location of tonal centres at the start of pieces, which Steedman's algorithms address much more comprehensively.

The most appropriate place for Butler's work might be as a decision that could be incorporated into an algorithm -- if a tritone, followed by a note which puts the tritone into context is heard, then they key of the piece is determined unambiguously. If, however, it does not, then other, less confident decisions must be made.

Butler's experimental material is very restricted consisting of sequences of only three notes, and these are artificially controlled. Therefore, they do not represent very naturalistic conditions; it cannot be argued that Steedman's materials are not naturalistic! However, there are still problems with using actually composed music, due to constraints produced by particular musical styles. This is particularly true of one of the rules that Steedman incorporates into his algorithms, which is the 'tonic-dominant preference' rule (from Longuet-Higgins & Steedman, 1971). This rule assumes that if the key of the piece has not been determined by the end of the first voice, then the first note was the tonic; if not, the dominant. This is discussed by Steedman (1972) who suggests that this rule might be particularly effective in determining the tonal centre in a Bach fugue, where the tonic and dominant figure so centrally. This rule may not, therefore, have such powerful effects in some other types of music.

Thus there are problems with using both experimental and 'naturalistic' material in studies concerning the nature of the tonal centre; both types of material can, however, contribute to the understanding of this understudied topic.

Once the tonal centre has been established(and the work reviewed above shows how this might take place),there is an active process whereby the listener may retain this tonal centre, whilst continually assessing each following note which will either re-confirm the hypotheses about the tonal centre, or gradually change as the tonal centre changes. Here Deutsch's work on absolute pitch retention might be relevant, as it shows how absolute pitch can be retained (the tonal centre is absolute in nature) even when inter-vening notes are heard. The nature of this absolute value may change over time.

The tonal centre has been considered in some detail in this section; the next section deals with another set of more general issues arising from the experimental results.

11.2.3 Relationship with other areas in cognitive psychology

Pitch-interval and contour are different levels of relationship; when a tonal centre is clear, the pitch interval values contribute more to the total percept than the contour values. When the tonal centre is unclear then the contour values contribute more to the total percept. Thus, listening to a simple melody might involve a process whereby both (and other) relationships are represented at any one time, but where the importance of each varies according to the current context of the music.

Thus, music processing is not considered as a fixed process but a continually changing, dynamic system in which the percept of the melody is being continually updated. This view of melody processing has parallels with other areas of cognitive psychology, which will be considered below. In addition, the processing of larger musical structures will be considered and paralleled with issues concerning the perception of larger events from smaller, embedded events. Each of these general issues will be considered below.

Claxton (1980) states:

> "...the more realistic, and ultimately more fruitful, question is not 'whether' things are like this or that, but 'when' are they one or the other. In what circumstances does memory, or attention, or language processing, appear thus? In what circumstances does it not? And why the difference?" (p9).

Here, Claxton is talking about cognitive psychology in general, but it applies very centrally to the study of music processing. The questions raised by Claxton are precisely those that have been considered in the thesis. It is not a question of pitch-interval or contour, but of when one type of representation is more important than the other. The circumstances in which one is more important than the other have also been considered, and the reasons why these differences might occur considered in detail.

Deutsch's model of music perception (for example, 1969) treats interval encoding as a fixed process; it does not fully take into account the two-way exchange between the listener and the environment. This is extremely important in music perception.

Neisser (1976) draws the reader's attention to how the current context is particularly important in listening of all types:

> "...the listener continuously develops more or less specific readinesses (anticipations) for what will come next, based on information he has already picked up" (P27).

The listener is continuously acted upon by the environment, and in turn acts upon the environment by way of the variety of cognitive structures, many based on previous experience of the same, or similar, environment. There exists a dynamic system and this is particularly true in music processing.

Particularly, at any point in the melody, or piece, pitch-interval or contour will bear some relationship with one another, with one currently more salient than the other (or perhaps they might be equally salient at that particular point). Depending on the next notes heard, this representation of the melody will change with pitch-interval becoming more important if a tonal centre is clear, or contour becoming more important if the tonal centre suddenly becomes unsure or ambiguous. (Of course, there are other relationships as well, particularly rhythm). The type of representation envisaged is therefore dynamic and 'working'.

The sort of process envisaged for melody and music processing can be encapsulated in the following analogy. A recent study by Cohen & Foley (1983) asked subjects to estimate distances between significant points in a very large building; there is an interesting, if speculative, analogy to the ideas on music processing presented here.

Cohen & Foley asked people to estimate distances between focal points in a building. The experimenters considered the results from subjects who had just been around the building for the first time as well as experienced subjects. A parallel, if tenuous, can be seen between finding one's way around a large building for the first time and locating various focal points, and listening to a large piece of music for the first time which will present the listener with a number of 'focal points' in the form of tonal centres, musical themes, and so on. Two aspects of their results are of particular interest.

The first is that Cohen & Foley could isolate two types of representation -- 'literal scenographic' and 'more abstract -- -- map-like'. They found that increased experience of the building led subjects to favour the more abstract, map-like representation. This can be paralled with the finding in the thesis that increased familiarity leads to a different mode of representation, in terms of pitch-interval over contour. Thus, in both cases, increased familiarity leads to a different mode of representation, or at least one in which one type of representation becomes more salient than the other with experience.

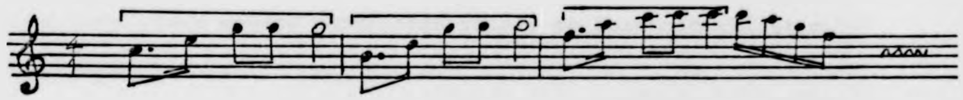
The other finding was that of a 'working map' whereby the subject seemed to generate a working mental map which is continually updated with the current location serving as a reference point. Using this, the subjects maintained orientation. There is an analogy between this idea of a working map and the ideas on the continually changing relationship between pitch-interval and contour suggested earlier.

The 'map-like' imagery proposed by Cohen & Foley is much more comprehensive than 'literal scenographic' in which the subject recalls the immediate environment at any point; thus the scenographic-type imagery can be seen to be perhaps a small, embedded event which combines with other events to make up the larger unit, the 'map'. Cohen & Foley found that when subjects were familiar with the environment, they tended to favour this more global type of representation.

It has often been suggested that the perception of complex events starts off with the perception of smaller, less complex events (Gibson, 1977). This is likely to be true of music -- probably more so in that the larger events occur only after the smaller events have been heard. It may be in Cohen & Foley's study that the 'literal scenographic' is the smaller event and 'abstract - map-like' is the larger, more complex event. Perhaps, in the same way, contour is the smaller, less complex event and pitch-interval in terms of key relationships and so on, is the more global, complex feature of a melody?

The perception of smaller events which combine to create a more complex whole in both a developmental issue (for example, Gibson 1977) and an issue in cognitive psychology (for example, Chase & Chi, 1981). It is also an issue in music perception.

Pick (1979) suggests that for melody perception, the notes of a melody might be the shorter, less complex events which combine to assimilate the higher-order structures. However, it is clear from this thesis that 'the notes' themselves might be represented in different ways; it is the contour relationship that is of most interest here.

Much of music is made up of small, contour-preserving themes, or parts of themes. Very often something that is termed a theme might be made up of a number of contour-preserving (and usually rhythm preserving) themes. The opening of Schubert's Fifth Symphony is a case in point:

Contour, used in this way, might constitute the smaller units from which the larger structures are made. These larger units might constitute themes, sections of movements and so on, or the melodic line in a simple popular song. In order to be used in this way the basic unit must be short. The results reported in the thesis suggest that contour is indeed more salient when melodies are short.

Two more general issues arise from the thesis presented. The first is how far the experimental results generalise to more naturalistic conditions. The second concerns the relationship between music and music perception. It has been suggested throughout that there must be a strong relationship between the two; why this might be so, and the reasons why musical examples have been given in all the experimental chapters,will be discussed in the final section of this chapter.

11.3 Issues Arising II

11.3.1 Generalisations from the experimental results

Each of the experiments described involved a short-term memory paradigm and in most cases the tasks to be performed differed in some way -- sometimes melodies were novel, sometimes they were transposed and sometimes they had been learned. How do each of these short-term memory conditions relate to more naturalistic listening?

In addition, musicians were used in the experiments throughout. How far can results from experiments using musicians be generalised to the population as a whole? This is the second topic considered here.

In Experiments 2, 3 & 4 subjects heard novel melodies which were then transposed to a distantly related key. Under more naturalistic situations a listener might hear a melody and then not hear it again for a matter of days, weeks, or even years (unless it is in the 'Top Twenty' in which case it will be a matter of minutes!). Thus, the listener would not normally retain any information concerning the starting note of the melody and so on -- it would have to be located in tonal space. Thus, in the everyday environment, <u>all</u> melodies are effectively heard in transposition, even if they are objectively untransposed (as they would be if recordings are heard).

Thus, the experimental paradigm does present a naturalistic phenomenon, but there is one major limitation; transposition implies that a listener <u>knows</u> that something, once heard, is now in a different key. Under natural circumstances this is not usually the case. There might, therefore,be some interference between the first and the second hearing of the melodies in Experiments 2, 3 and 4 in the form of some type of 'acoustical trace' which would not be present under normal circumstances.

However, interference or not, the listener must still locate a tonal centre both in the laboratory and under more naturalistic circumstances. One important occasion where transposition knowingly takes place is in music itself; the listener is sometimes, if not always, aware that a change has taken place. It is true that modulations do not often occur to such distantly related keys as those which appear in the experiments, but this was investigated in some detail in Experiment 8 (Chapter 10), where the relationship between pitch-interval and contour when transposition occurs was considered.

In Experiment 6 melodies were untransposed and the listener knew them to be untransposed. This is not typical of everyday experience, but again is representative of a process which actually occurs whilst music is being heard. In addition, this type of situation is present in many tests of musical ability (the 'melodic memory' aspect of these tests). It is a pertinent question as to how representative these tests might be and whether they actually reflect meaningful skills in music.

In Experiment 7 melodies were learned over ten learning trials; this in itself reflects a naturalistic issue, as most pieces of music are heard more than once. However, the period of time over which a and the second hearing of the melodies in Experiments 2, 3 and 4 in the form of some type of 'acoustical trace' which would not be present under normal circumstances.

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In Experiment 7 melodies were learned over ten learning trials; this in itself reflects a naturalistic issue, as most pieces of music are heard more than once. However, the period of time over which a melody would normally be learnt would be much longer, and this has one centrally important implication. Under naturalistic circumstances the listener would have to locate a tonal centre every time the melody was heard; in the short-term memory paradigm this would not be necessary in each trial, only the first. Thus it is likely that under naturalistic circumstances it would take longer for the pitch-interval values to become as salient as they did in Experiment 7. The serial position effect found for pitch-interval in this experiment is likely to occur under natural circumstances, but to be more pronounced.

Experiment 8 is thought to represent the most naturalistic situation because the listener never knew the key in which a comparison melody was to be heard; in everyday listening all music is heard 'out of the blue' (Davies, 1979). Thus the experimental paradigm reflects a situation which occurs at the beginning of a piece of music or melody and,in addition, reflects processes which occur whilst music is being heard (modulation). This was discussed in Chapter 10.

It is considered, therefore, with some reservations, that the experiments carried out do reflect the environment in which melodies would normally be heard; perhaps the strongest link is between the experiments and processes which occur in music as it is being heard. In each of the experiments the process thought to occur in music itself has been suggested.

A second point to be considered is whether the use of musicians as subjects allows the results to be generalised to a more representative population.

Chapter 2 suggested that the differences between musicians and non-musicians may be rather less marked than first appearances may suggest; the differences may be quantitative rather than qualitative, with musicians performing at a higher level than non-musicians, but in much the same way.

A central concern has been the problem of locating a tonal centre when a melody is first heard. Here, musicians can have no advantage over non-musicians, as they do not have any special skills which allow them to predict where, in tonal space, a melody might begin.

Once a melody begins, the musician, possibly due to his or her greater exposure to music, might be able to locate a tonal centre more readily. Burns & Ward, (1982) suggest that musically educated listeners with good relative pitch behave as though they have a moveable conceptual grid calibrated in terms of the pitch relationships between notes. The musicians' greater expertise at predicting the nature of music and how it will progress, will make the location of the tonal centre that much quicker. Thus the contour--pitch-interval continuum is likely to be more pronounced for non-musicians than musicians. Contour may remain salient longer for non-musicians.

In addition, it is likely that musicians find the learning of new melodies easier than non-musicians; thus, in the learning process, musicians are likely to find the pitch-interval relationships salient at an earlier point than non-musicians.

Thus, in general, it is considered that non-musicians would respond in qualitatively the same way, but would find the contour relationships more important both in the processing of novel melodies and the learning of melodies. Thus contour might be more important in the population as a whole than for musicians in particular.

However, it might also be true that musicians are more flexible in their processing of melodies than are non-musicians. The relationship between pitch-interval and contour may be more readily exploited by musicians, who can turn their attention to either of the relationships depending on the current context of the melody. An analogy between the ideas presented here and Cohen & Foley is again appropriate.

Cohen & Foley found that subjects familiar with their environment were more able to integrate the 'abstract - map-like' and the 'literal scenographic', depending on their current circumstances. Practise, therefore, led to flexibility (see Nickerson, 1978).

This may also be true of music processing; musicians are more likely to be able to integrate pitch-interval and contour information in order to make sense of music at any particular point, whereas non-musicians may find it more difficult to do this. There is a link here between laterality and music processing. Gates & Bradshaw (1977a & b, see Chapter 3) suggest that both left and right cerebral hemispheres might be important in the processing of music, and there is some evidence which suggests that the experienced listener is more able to maximise the types of skills attributed to each of the cerebral hemispheres (Selby *et al*, 1982).

Musicians may, therefore, be able to change their mode of representation more readily and to be more flexible, depending upon the current context of the music. However, it must be noted that the difference between an 'expert' and a 'novice' is slightly unusual in music; for most skills, the novice is someone who has never performed a particular task, an expert being someone skilled at the task. What is a novice, though, in music? Everyone listens to music of some sort and it is quite likely that there are many 'musicians' (instrumental technicians) who, in fact, listen to less music than many non-musicians. Therefore, fundamental differences between musicians and non-musicians, particularly when listening to music, are unlikely.

Finally, in this chapter, the link between music processing and music itself will be considered.

11.3.2 Relationship between music and music perception

Neisser (1976), in calling for ecological validity in experimental psychology, states:

> "...perception, like evolution, is surely a matter of discovering what the environment is like and adapting to it..." (p9).

Ecological validity has been a motivating force behind the thesis; however, it takes on a rather different meaning in music. This is because music is not important for survival in the same way that finding about the world might be; though the reason why music ever evolved is a topic of interest.

There should be a strong relationship between music and music perception, however. Music is ultimately dependent on two things -- the composer and the listener. There is no 'environment' and there is no survival value attached to music. This was recognised by Seashore (1938):

> "...it is also admitted that music is in the first and last instances in the mind of the composer and the mind of the listener..." (p14).

It is likely that, at least up to a point, the listener 'finds out' what music is like (as Neisser suggests) and adapts to deal with it. This must be true to some extent because music changes a great deal over time as tastes change and trends die out. However, music, unlike the outside world, is a product of a culture and can thus be absorbed into a culture or rejected by it. It may be that there are some general principles concerning music processing which allow this to take place. The music, by a process of cultural 'natural selection', 'finds out' what perception is like and adapts to it.

Thus styles of composition might determine how perception adapts, but 'perception' might also determine how music adapts; there is a two-way process.

The whole of music history has seen a continually evolving set of styles which depend heavily on previous styles; each time, the listener is presented with something slightly different to which he or she has to adapt. But sometimes too much is asked of our perceptual processes and thus a new style does not become absorbed into a culture, or at least is not as popular as something with which our processes can deal.

Meyer (1967) suggests that, as a rule, music tends to get more complex. This view is based on the expectancy-type approach to music perception and can explain the way styles continually evolve. Each slightly different style presents the listener with something new, and as the listener's experience of that type of music increases, expectations become more precise and so the music seems to simplify, subjectively. However, it is certainly not true that music usually becomes more complex; it is suggested here that not even as a rule is this the case.

What seems more apparent is that music gets more complex over time until it becomes so complex that it is rejected. A new, more simple style sometimes comes out of this, which itself becomes more and more complex until a new 'purge' is necessary. Thus, complexity seems to oscillate. These simplifications of style are often labelled 'new' music -- the title "first modern composer" has been ascribed to many composers -- Palestrina, Monteverdi, Bach, Beethoven, Schoenberg, and so on. These, and other, composers seem to have presented a new way of looking at music and sometimes present a simplification rather than a new complexity in music (with one or two notable exceptions). There seem to have been a number of watersheds of this type during musical history.

A style may not become absorbed into a culture -- indeed might even be rejected by it -- if the listener is presented with so many problems in processing this music that it becomes meaningless. Perhaps the best example of this is from the music of the early renaissance. Again, the absolutist viewpoint is essentially the one taken here.

This type of music,on first hearing, sounds very avant garde. It is likely that it is in fact before anyone's time; the compositions are full of so many devices that it is unlikely that many listeners are aware of the majority of them. For example, the presence of polyrhythms in this type of music is very pronounced. This is where several melodic lines are written over one major theme --

usually a *cantus firmus* -- each of which bears a relation to this main line but little relation to each other. The effect is very like listening to several pieces of music at the same time, and the problems involved in this, as a perceptual skill, are great. This suggests that this sort of style would not readily become absorbed into a culture.

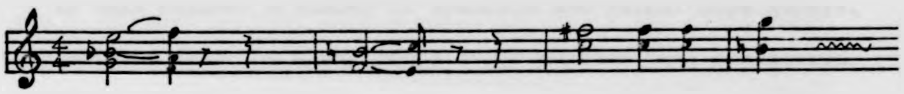
Another favourite device was the writing of canons at every interval and of repeating melodic lines in inversion, or augmenting a line by doubling or trebling the note values or halving them. It is unlikely that the listener was aware of most of these devices and it sometimes appears that they are present for the composer's, rather than the listener's,convenience. A review of these devices can be seen in Blume (1975) or Brown (1976). Legend has it that Palestrina's Missae Papae Marcelli saved music for all time, as the Council of Trent, meeting from 1545 to 1563,had decreed that music which supported religious occasions should be made more simple so that the devotional words could be understood. Palestrina's style is a distinct simplification from earlier styles and it is interesting to note that this simplification spread into secular music, where the understanding of devotional words was not an issue. Thus the music was just <u>too complex</u> for the listener to comprehend and so was eventually rejected. Palestrina's music, however, is still relatively popular today.

One of the most interesting aspects of the simplification of style throughout the renaissance was that of the use of contour. Contour-preservation did occur in the earlier style but on a very general basis where a melody or theme might be turned upside down, reversed, and so on. However, the contour may not have been salient when used in this way. It is interesting to note how imitation developed during the renaissance. Starting from very wholesale imitation, later styles developed imitation where one voice would quickly follow another and imitate on the basis of contour-preservation rather than being exact imitation. Palestrina's style (along with other late renaissance masters such as Byrd, Lassus and Victoria) shows the beginnings of this technique which, in essence, is still present today. The use of short, contour-preserving imitations has thus been absorbed into the culture, suggesting that it reflects a basic cognitive mechanism.

Palestrina was also aware of the interdependence of contour and pitch-interval and used a general rule that if a note went up by more than a fourth, then the direction of the next note was reversed (for a full explanation see Andrews 1958). The use of contour-preservation and this rule are contributors to the particularly 'seamless' polyphonic style of the late renaissance masters.

Thus the role of contour in music can be seen emerging from the renaissance and this suggests that sometimes it is not perception which adapts to deal with the 'environment' (music) but music which adapts to deal with perception. Apart from the importance of contour, the importance of a tonal centre in music perception has also been stressed in the thesis, and discussion will now turn to this.

It is interesting to note how a composer might exploit the listener's need to establish a tonal centre. The composer can deliberately mislead the listener, as in Beethoven's First Symphony:



The music goes quickly through the keys of F major, C major and G major, remaining in G major until the key of the movement, C major, is eventually stated. Thus here the composer can be seen to deliberately draw the listener's attention away from the eventual key of the movement by stating others very clearly. Note that the composer uses the augmented fourth, which is, as Butler's work suggests, the strongest indicator of a tonal centre. Beethoven misleads the listener well.

Later in musical history the composer does not find it necessary to state the key of a piece at all -- the opening of Wagner's 'Tristan und Isolde', for example, never gets closer to resolving than a dominant seventh. It is interesting to note how the need to establish a tonal centre clearly and unambiguously changes over musical history. Haydn, for example, represents chaos in 'The Creation' by the use of music that was very avant garde; yet the whole thing is preceded by a huge chord which states in no uncertain terms the tonal centre. Things have obviously got a lot more chaotic since! However, there are limits beyond which lack of tonal centres in music might make music acceptable and the fact that most currently popular music is tonal in the extreme suggests this.

In this chapter a number of specific and rather more general issues arising from the experiments reported have been considered. The final chapter considers some rather more speculative ideas which the experimental results do not specifically address.

CHAPTER TWELVE

This last, brief chapter presents some further ideas about contour and its relationship to pitch-interval. Although not directly arising from the experimental results obtained, these ideas nevertheless raise issues about the more general role of contour in music perception.

The 'active' role of contour has been stressed throughout the thesis; that is, the answer to the question "What makes a melody a melody?" is that when a tonal centre is not clear then a theme, or melody, might be recognised more on the basis of contour than pitch-interval. If the tonal centre is clear, however, then recognition depends more on pitch-interval recognition. This, in turn, depends largely on the relationship between the keys in which a melody or theme is heard. It has also been made clear that it is a matter of relative salience, rather than contour or pitch-interval being unavailable at any point.

One of the findings has been that contour is available to the listener whether a tonal centre is clear or not. Thus it can remain invariant whilst other relationships (particularly pitch-interval) might change and yet,still a theme may retain some degree of similarity. So contour is always available to the listener, but takes a greater or lesser part in melody recognition depending on circumstances.

One of these circumstances is probably the number of direction changes in the sequence of ups and downs of a melody. In the experiments little attempt has been made to quantify the amount of direction change in the melodies used, and in Chapter 1 it was suggested that experimental attempts to do so might be somewhat fruitless.

It is thought that the amount of direction change (the contour complexity) might, in itself, affect the encoding of pitch-interval relationships themeselves. In order to elucidate this question, it is worth considering the possible origins of pitch-interval and contour awareness and possible reasons for their divergence as two separate, but related, concepts.

Being able to respond to, and interpret, a series of events which take place over time is clearly important in adapting to our environment. Many events, such as speech, are critically structured over time, and making sense of these events is sometimes of direct survival value. Music is clearly not in this class of events, but presents a prime example of an event which can only become clear over time.

The origins of music itself are hard to discern, but one of the most likely origins of music was the need to communicate; pitch-interval and contour can both be seen to be important in the understanding of language which may have transferred to the role of the earliest musical instruments.

In understanding speech, or more primitive vocalisations, there are many paralinguistic elements which can convey meaning. For example, often the only way a listener knows that a question is being asked is that the voice goes <u>up</u> instead of <u>down</u> at the end of a sentence. <u>How much</u> up or down is less important; the direction (contour) is most important. The speaker can convey the emotional meaning in his or her words by the actual <u>range</u> of frequencies covered by a particular speech. If the speaker is very annoyed, or anxious, he or she is likely to cover a wide range of frequencies. If talking normally, without too much emotional content, the range of frequencies covered will be smaller. Thus here precise pitch-interval information is more important than the contour information.

It can be seen, therefore, that both contour and pitch-interval awareness might have originated from the interpretation of language and their initial diversification might stem from this different role in language.

This difference can be seen in various musical spheres, and it is generally the case that contour awareness seems to precede pitch-interval awareness. For example, it is likely that many of the earliest musical instruments were not tuned to precise pitches, and so contour awareness might have preceded pitch-interval awareness anthropologically. There is also some evidence (reported in Shuter-Dyson & Garbriel, 1981) to show that contour awareness seems to precede pitch-interval awareness developmentally. The results of the experiments reported in the thesis show contour to precede pitch-interval awareness both as a melody is heard and in the learning process.

This observation implies that awareness of contour is a very fundamental issue in the study of music perception and that contour and pitch-interval are different, but related. It is the relationship between the possible origins of these two aspects of para-language, and their obvious roles in music, which are the concern here. A particular compositional technique which shows a direct link between music and language will illustrate this point.

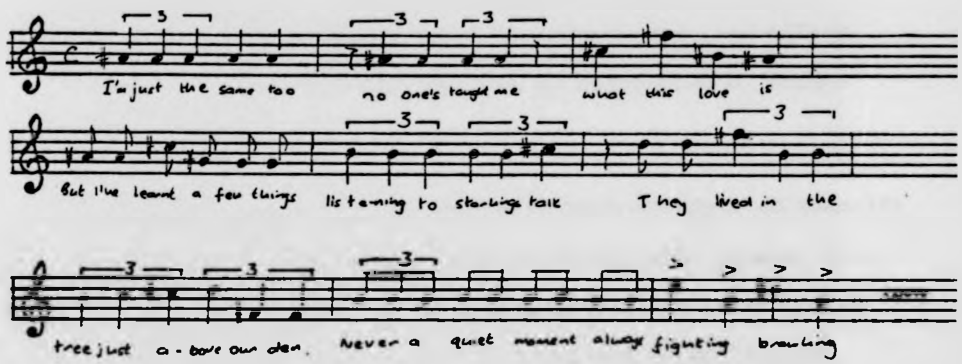
It was a particular desire of Janacek (1854-1928) to reflect real life in his operas (which form a major part of this composer's output) and he believed that this could be best achieved through his native language, Czech.

Janacek spent a lot of his time listening to the rhythms and contours of natural speech, the sounds of animals, inanimate objects and so on, trying to annotate them musically. Janacek incorporated these speech rhythms into his operas showing the natural rising and falling of speech. This technique also appeared in his orchestral writing, though this technique can be seen most clearly in his operas. Often a theme will reappear at various points in an opera in a contour-preserving form, reminding the listener of the event in which this was first heard. This technique confers a particularly organic character on many of Janacek's operas.

In natural speech, a person has a characteristic pitch level around which the voice varies, within limits. Janacek incorporated this aspect of speech into his operas, giving each of this characters a 'reciting note' which represents the natural pitch level of their voice, and the music written for each character rises and falls above and below this note in much the same way as in natural speech. Of course, this is sometimes formalised and the range of frequencies sung is possibly greater than the range of natural speech; however, Janacek succeeded in general in reproducing 'speech rhythms' in his operas.

As an example, an episode from Janacek's opera "The Adventures of the Vixen Bystrouska" (often misleadingly called "The Cunning Little Vixen") in which the heroine, a vixen, is talking to a dog about the activities of some birds, is given. (The fact that many of the characters in this opera are talking animals shows Janacek's use of poetic license; given the unreality of this situation, the speech patterns of these animals are very similar to those of human characters in the opera).

The vixen has a reciting note throughout the opera, around B/Bb above middle C as an adult, higher when she is a cub, around which her speech centres. The speech that the vixen makes is written so that the emphasis, and the contour, is somewhat similar to what it would be in spoken language (of course, the example is much better in the original language, Czech):

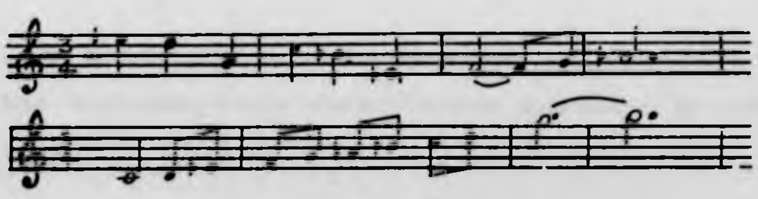


Janacek's music demonstrates quite clearly the possible link between music and language, and the role of contour in particular. One of the most important points about his music, and speech in general, is that the speaker does not start off on a high note gradually reaching a low or *vice versa*. The voice is centred around a particular pitch, or group of notes, about which the voice continually rises and falls. Speech may be easier to interpret when this is the case, rather than the voice changing pitch too rapidly or talking on a monotone. The changes in direction provide a 'framework' for the interpretation of speech.

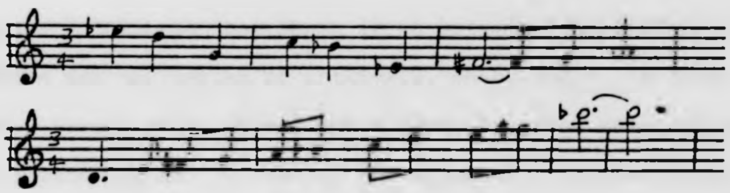
This tendency might have developed in music as well. For example, the technique used by Palestrina -- to change direction if an interval greater than a fourth occurred -- might reflect a desire to keep music around a 'reciting note' and not to incorporate any extreme changes in pitch level; this may explain in part the particularly 'seamless' quality of much of Palestrina's music. Clearly not all composers wish to achieve the same effect, but this serves as an example of the role of contour as a 'framework' in composition.

In the first chapter, it was suggested that attempts to quantify contour are not appropriate (for example: Ortmann 1933; Rosser 1967; Simon 1972; Divenyi & Hirsh 1974 & 1975; Taylor 1976; Dowling and Bartlett 1981). The role of contour as described above suggests that the number of changes in direction, the amount of interval change and other factors (in particular, tonality) might all interact in music perception. Again, contour can be seen as a framework for the encoding of pitch-interval.

In order to demonstrate this point, two examples will be given. These examples demonstrate how the number of direction changes can, in themselves, affect the ease with which the precise pitch-interval values can be encoded, representing two extreme cases. The first example is 'The Swan', a movement from Saint-Saens' "Carnival of the Animals". The first theme is as follows:

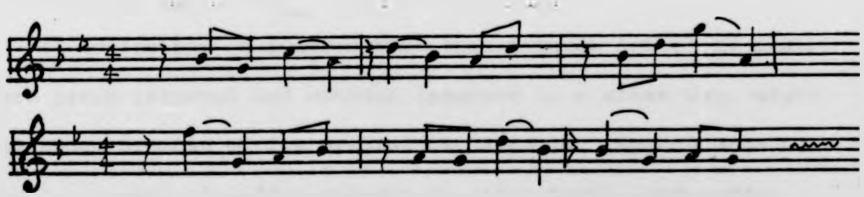


The second is as follows:



This is very difficult to transcribe; the first nine notes are relatively easy, but the rising passage is extremely difficult. It is thought that one of the major factors contributing to this difficulty is the number of notes which occur without a change in direction in the last section. There is no 'framework' in terms of direction changes, on which the listener can place the pitch-interval values.

At the other extreme, the theme from Elgar's "Enigma" variations possesses many changes in direction:



This is again quite difficult to transcribe, but this time the complexity of the contour makes it difficult, which in turn is related to the high number of large interval leaps.

The central point to emerge from these two examples is that to look for a simple rule whereby contour complexity, or contour simplicity, aids pitch-interval encoding is unrealistic; there is more likelihood that there is an optimum number of direction changes for any series of intervals, which might, in turn, depend upon interval size. The first example is below this optimum level, the second higher (of course, the composers had good reasons for making their music like this).

Thus there might be a sort of 'contour pace', that is, an optimum number of direction changes for notes within a given pitch proximity -- which makes pitch-interval easier to encode; too complex a contour overloads the capacity to encode the melody, whilst at the other extreme the listener has nothing on which to 'place' the pitch-interval values. A series of transcription studies, along with perceptual studies, might elucidate the nature of the 'contour pace'.

It is further considered that this natural 'pace' of music, where pitch-interval and contour interact in a close way, might come about because of its origins in language. Speech does not usually consist of sudden changes in pitch level, and sudden changes in direction with every new word, but a continually rising and falling pattern of direction changes, with these changes being neither too rapid not too slow.

Thus, contour complexity has not been considered in the thesis as much because it is a different, and substantial problem and forms a further issue which can be investigated in the future. It is a related issue and will shed further light on the role of contour in music processing.

In order to gain insight into the problem the practices of composers might again represent a starting point. In particular Palestrina's technique could be investigated, as this seems to show quite clearly the possible relationship between interval size and direction of the contour. As before, the composer can be seen to be several steps, at least, in front of the psychologist.

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APPENDICES

		Page
Appendix 1:	Melodies used in Experiment 1	364
Appendix 2:	Melodies used in Experiment 2	366
Appendix 3:	Melodies used in Experiments 3 & 4	372
Appendix 4:	Melodies used in Experiment 5	387
Appendix 5:	Melodies used in Experiment 7	389
Appendix 6:	Melodies used in Experiment 8	394

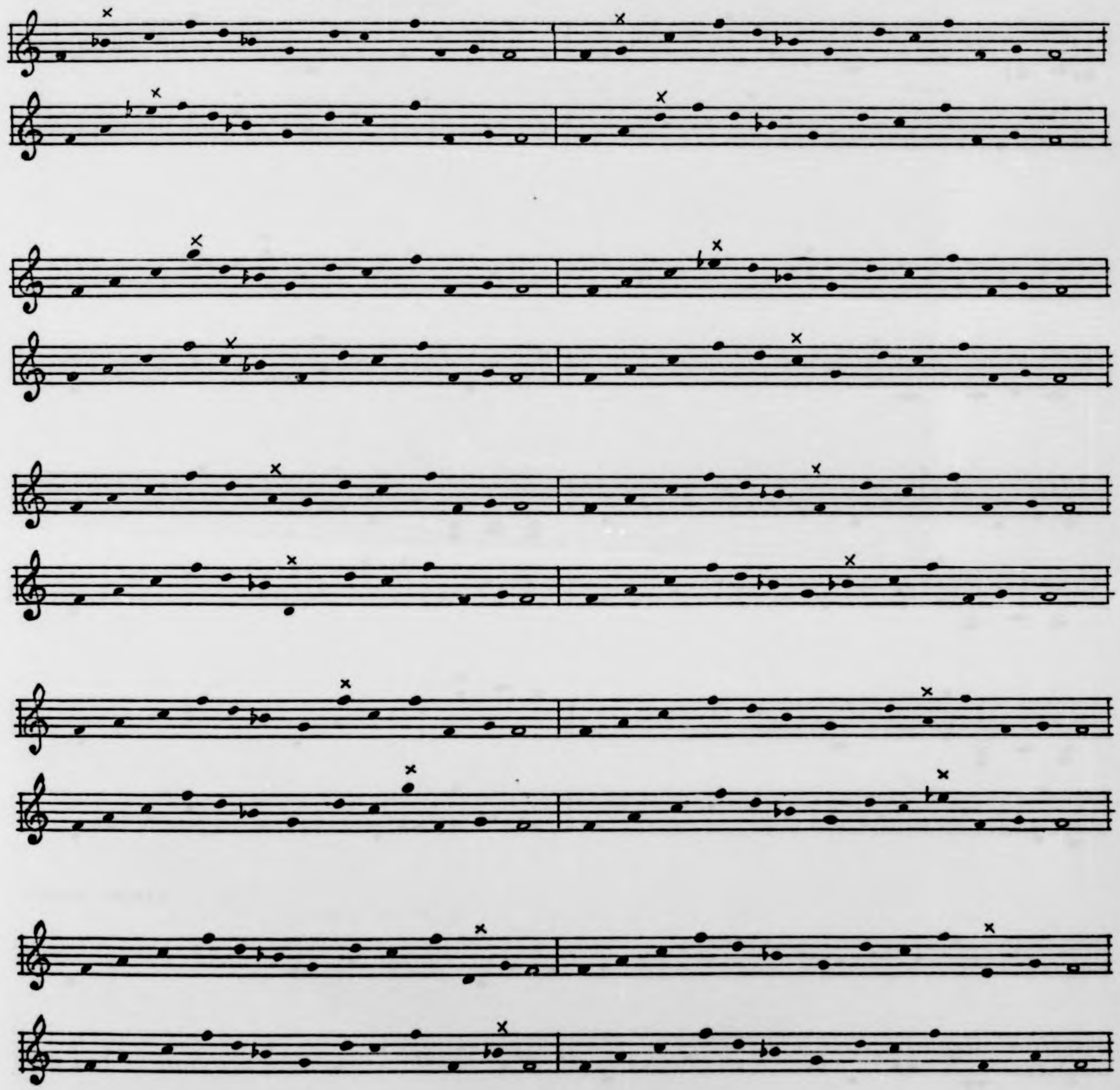
NOTES

(1) Melodies used in Experiment 6 were exactly the same as Experiment 2, except that the Comparison melodies were not transposed.

(2) In Appendix 3, where a blank portion of staff occurs, the Comparison melody is exactly the same as the one immediately to its left.

EXPERIMENT 1

PITCH-INTERVAL



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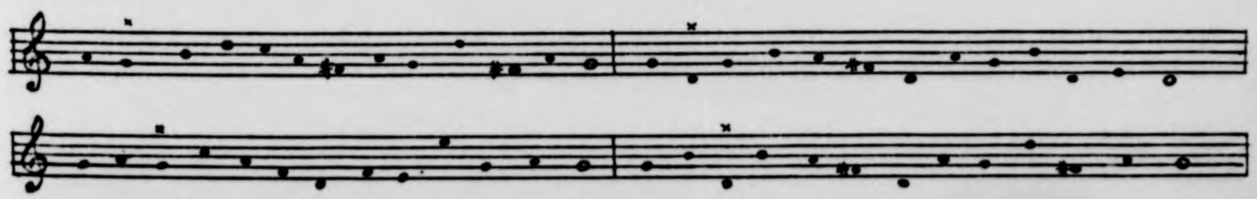
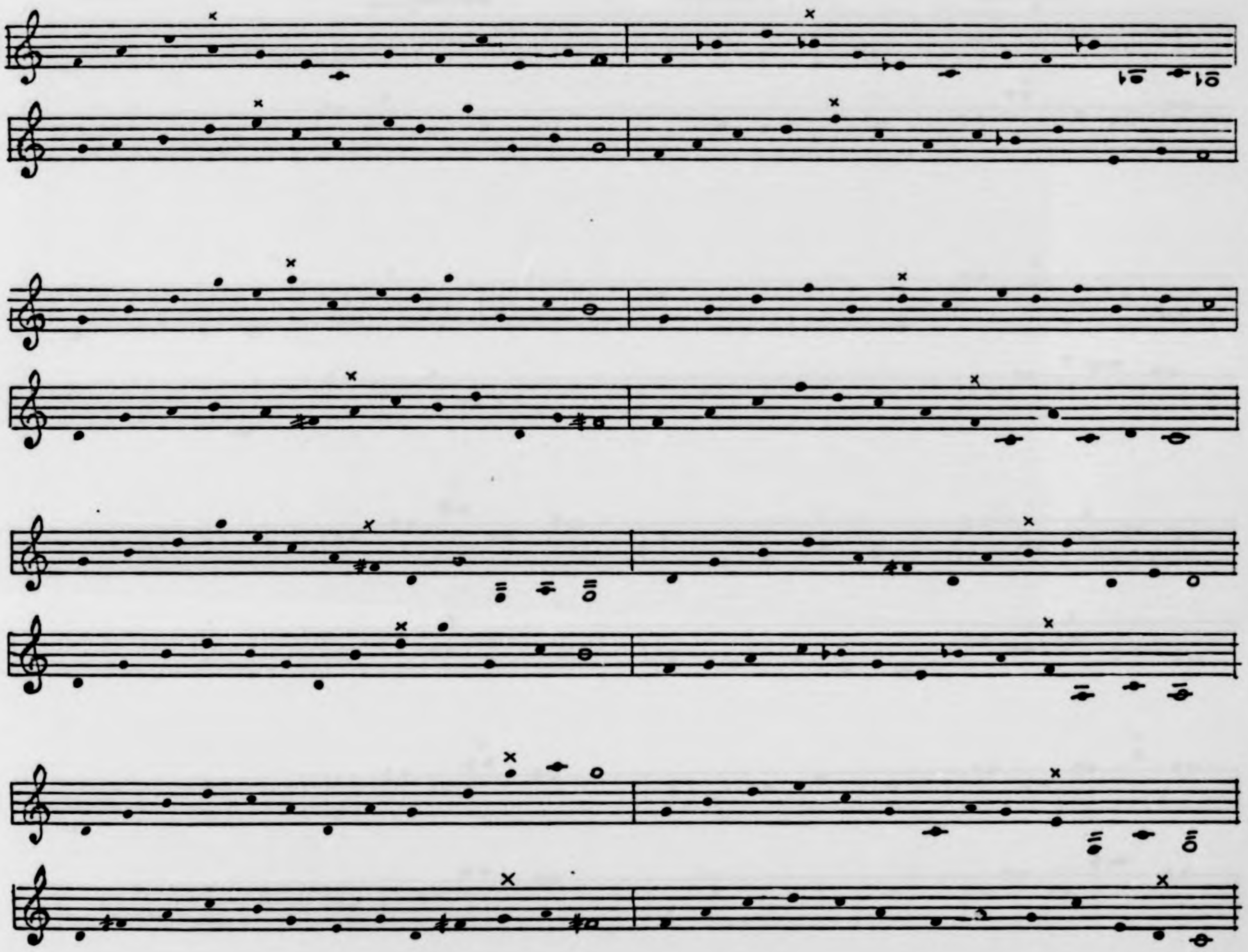
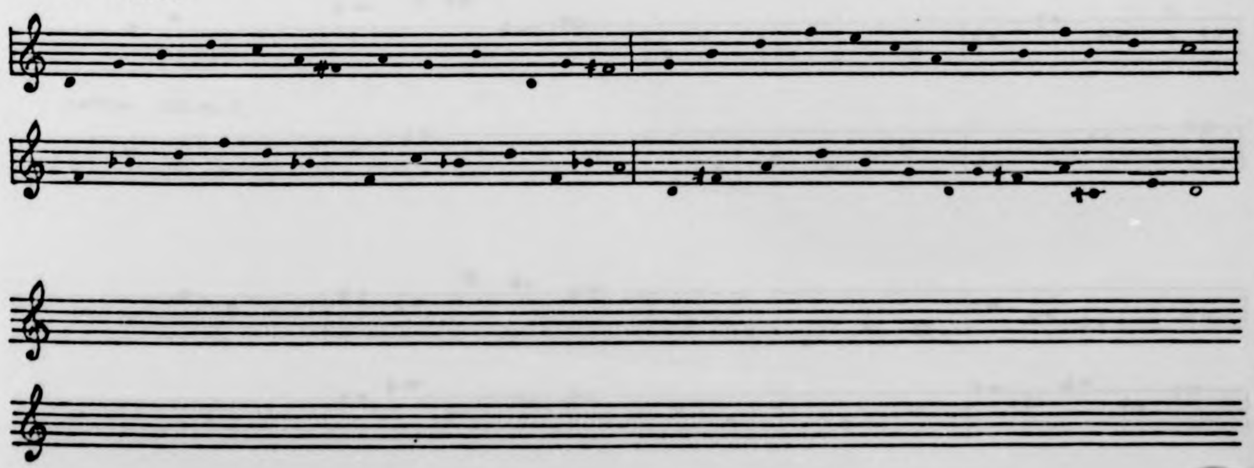
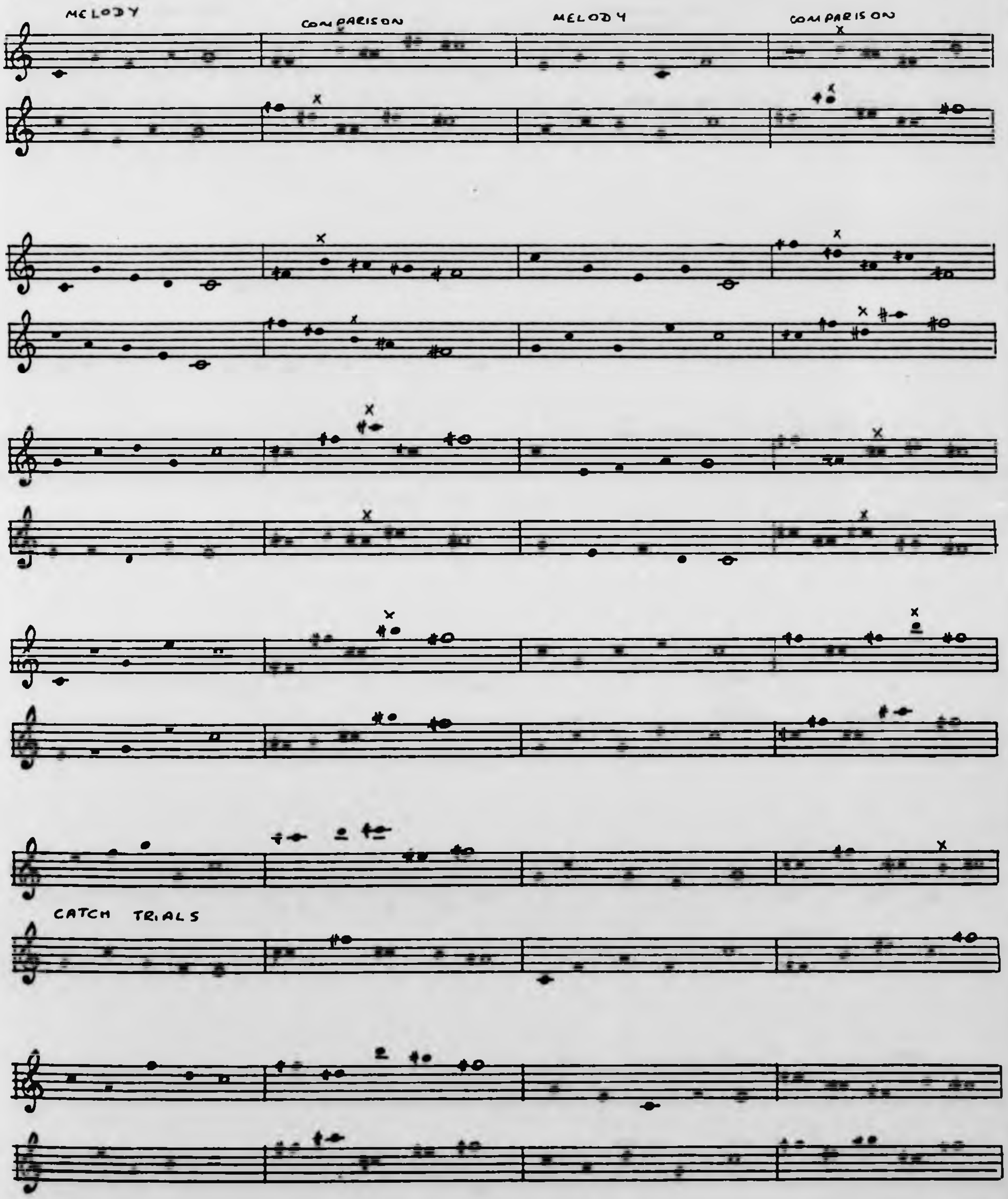
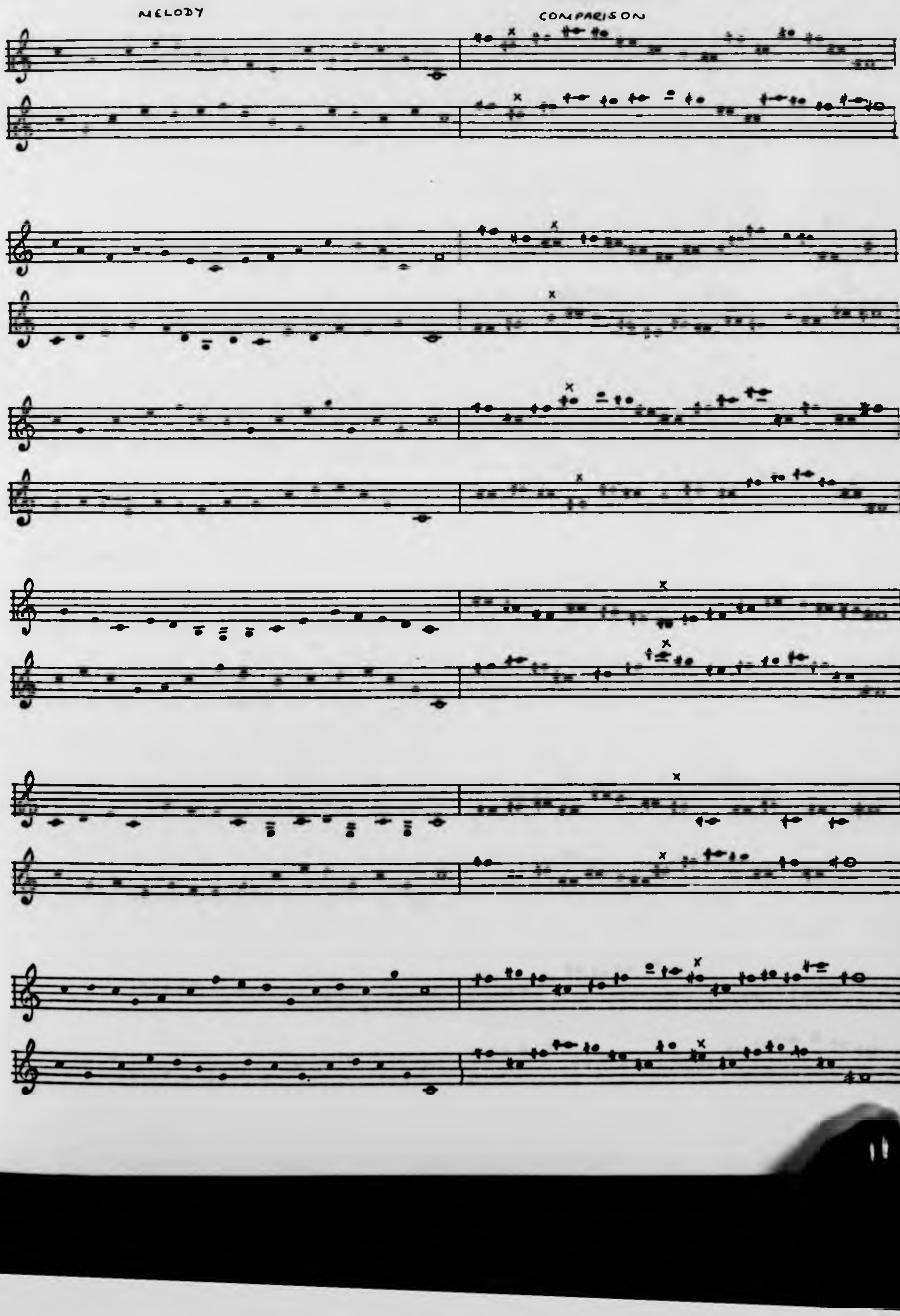
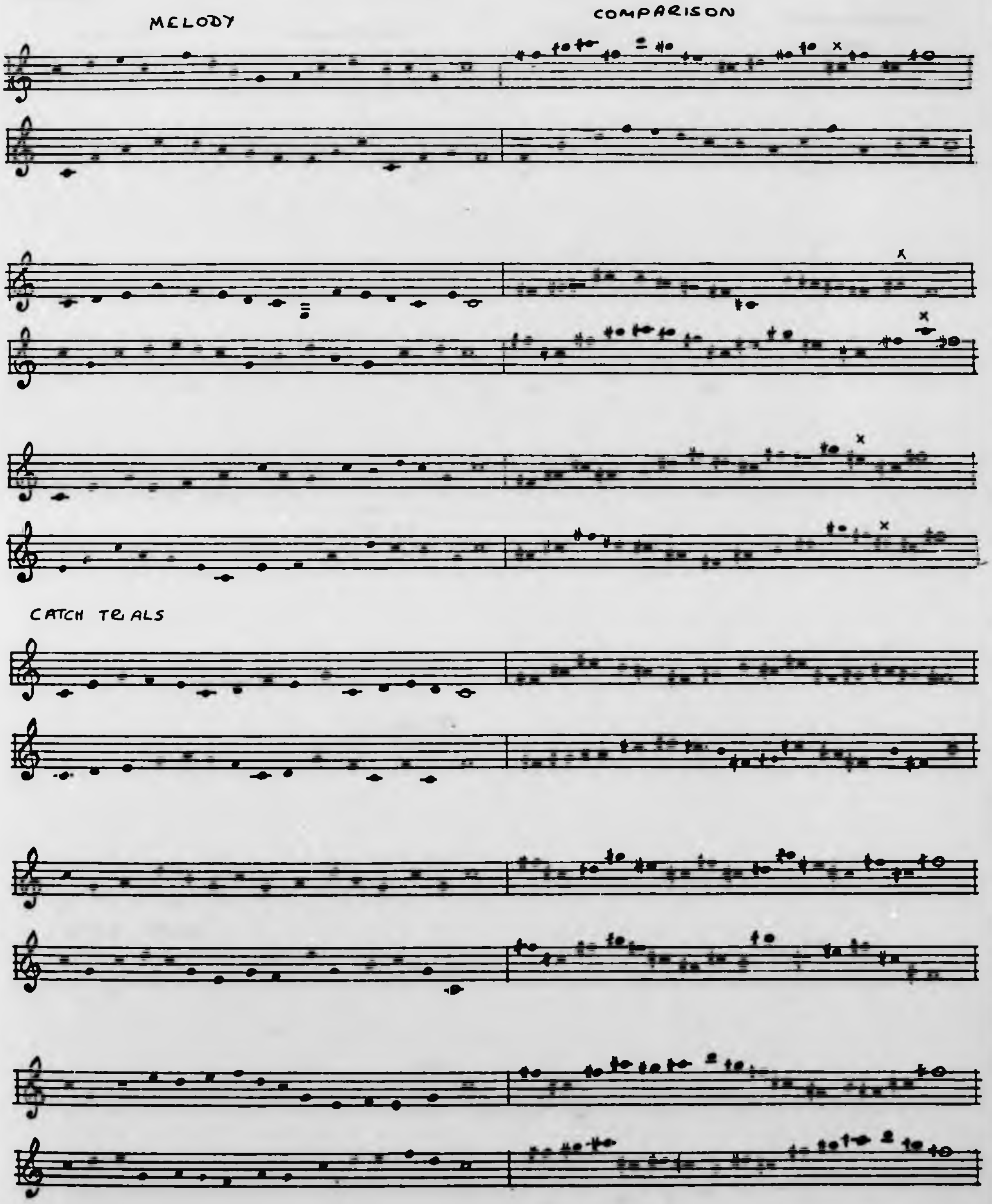



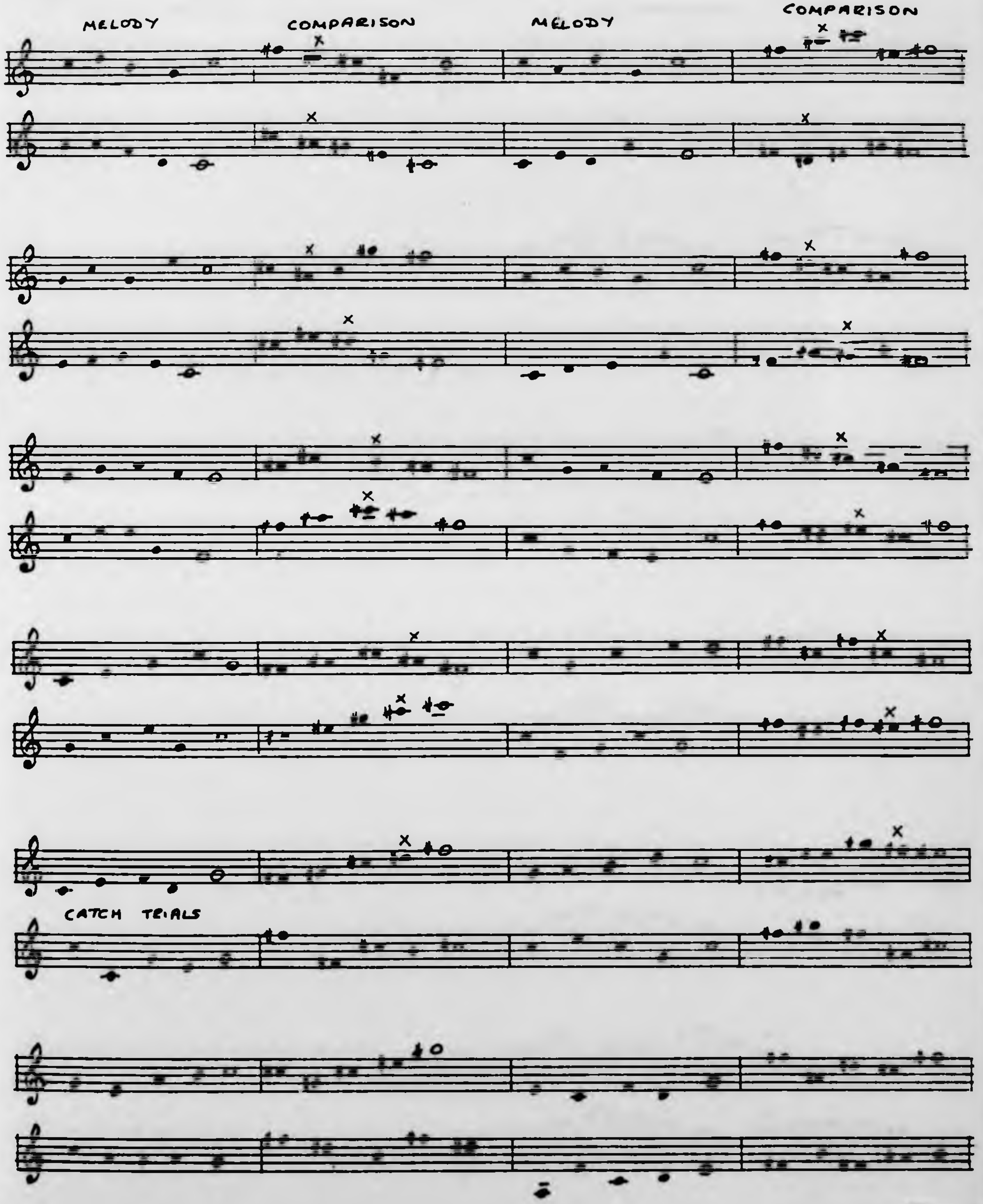
CATCH TRIALS

EXPERIMENT 2 5 NOTES PITCH-INTERVAL



PITCH - INTERVAL 15-NOTE MELODIES



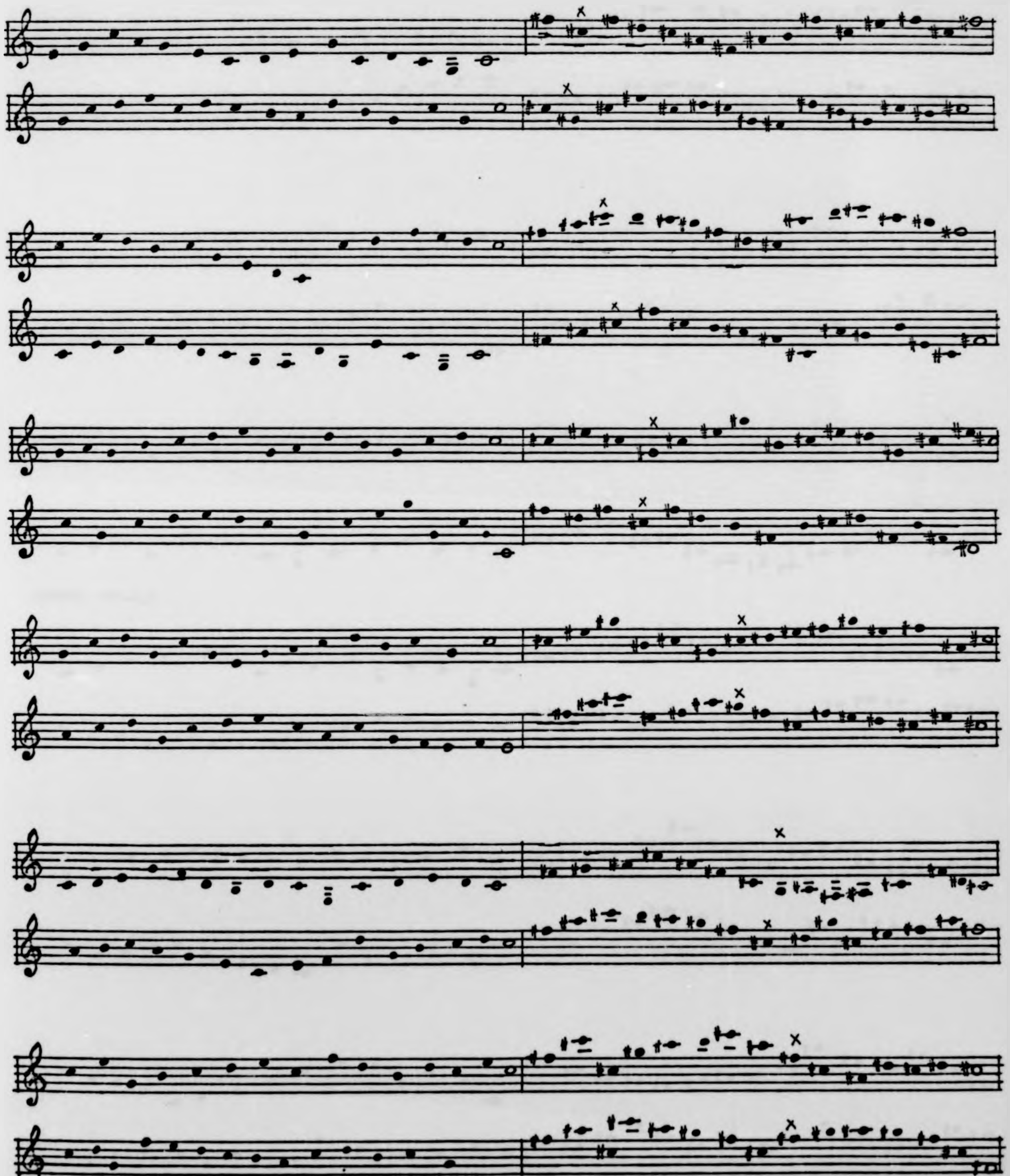

MELODY
COMPARISON
CATCH TRIALS

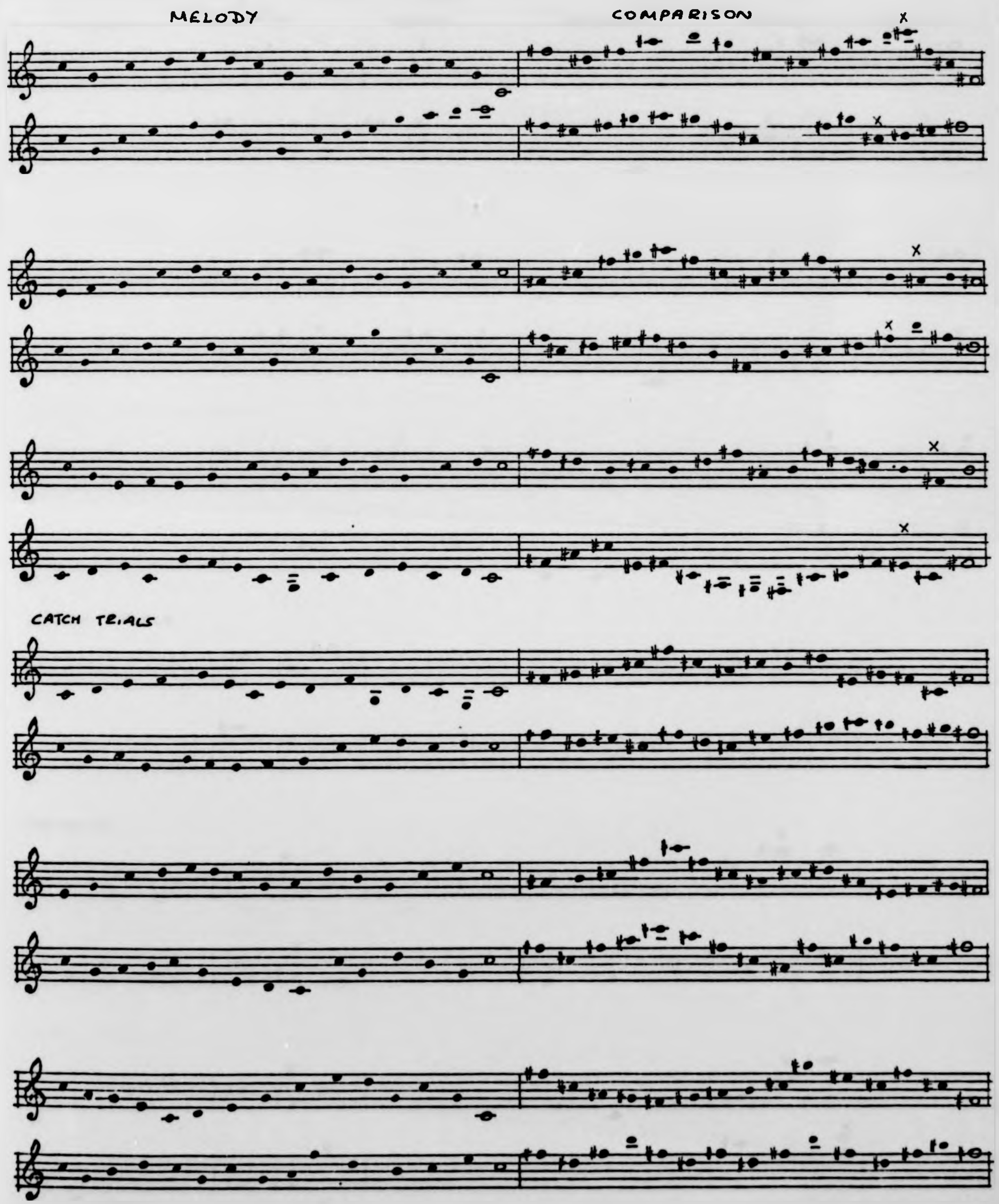
CONTOUR 5-NOTE MELODIES

15-NOTE MELODIES

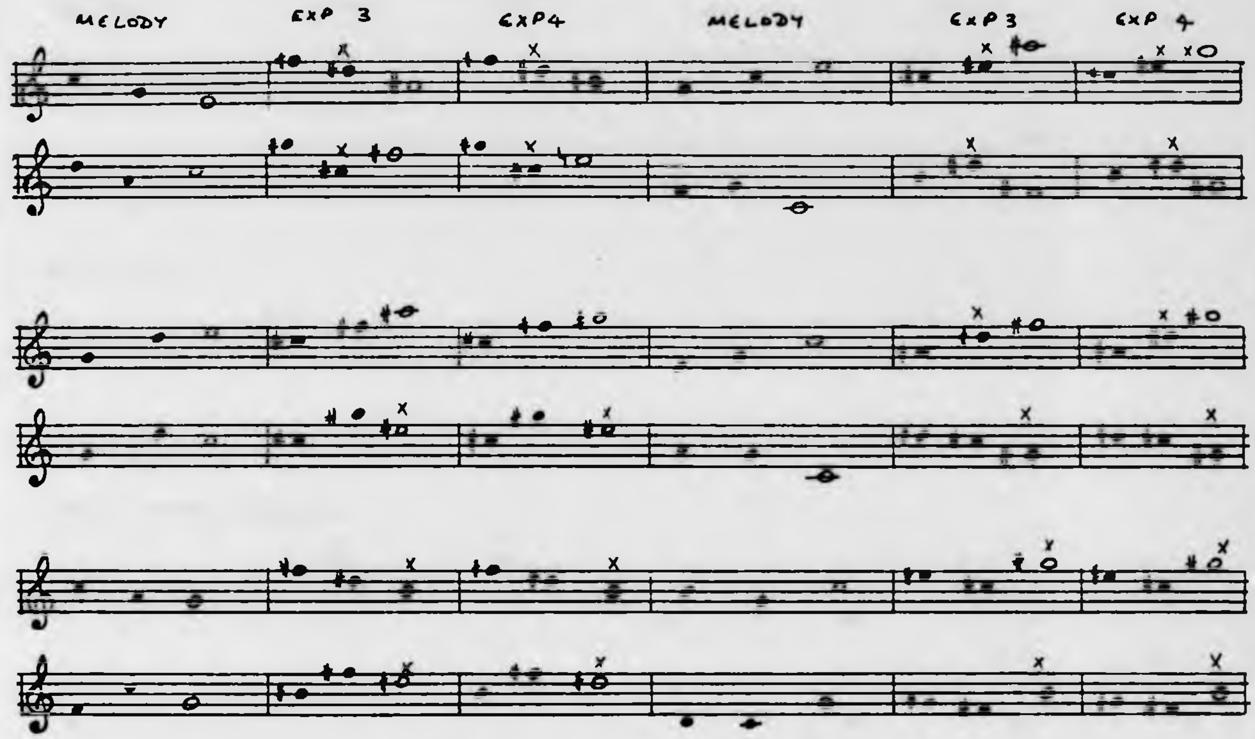
CONTOUR

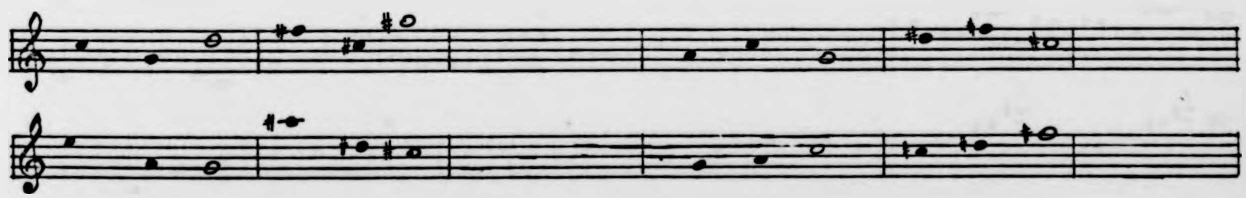
MELODY

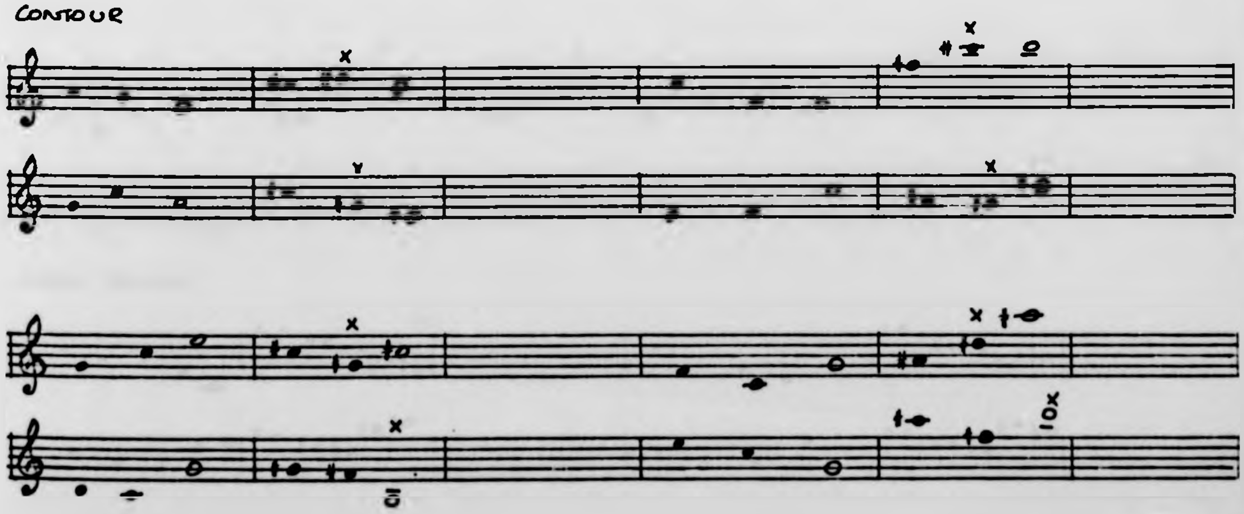
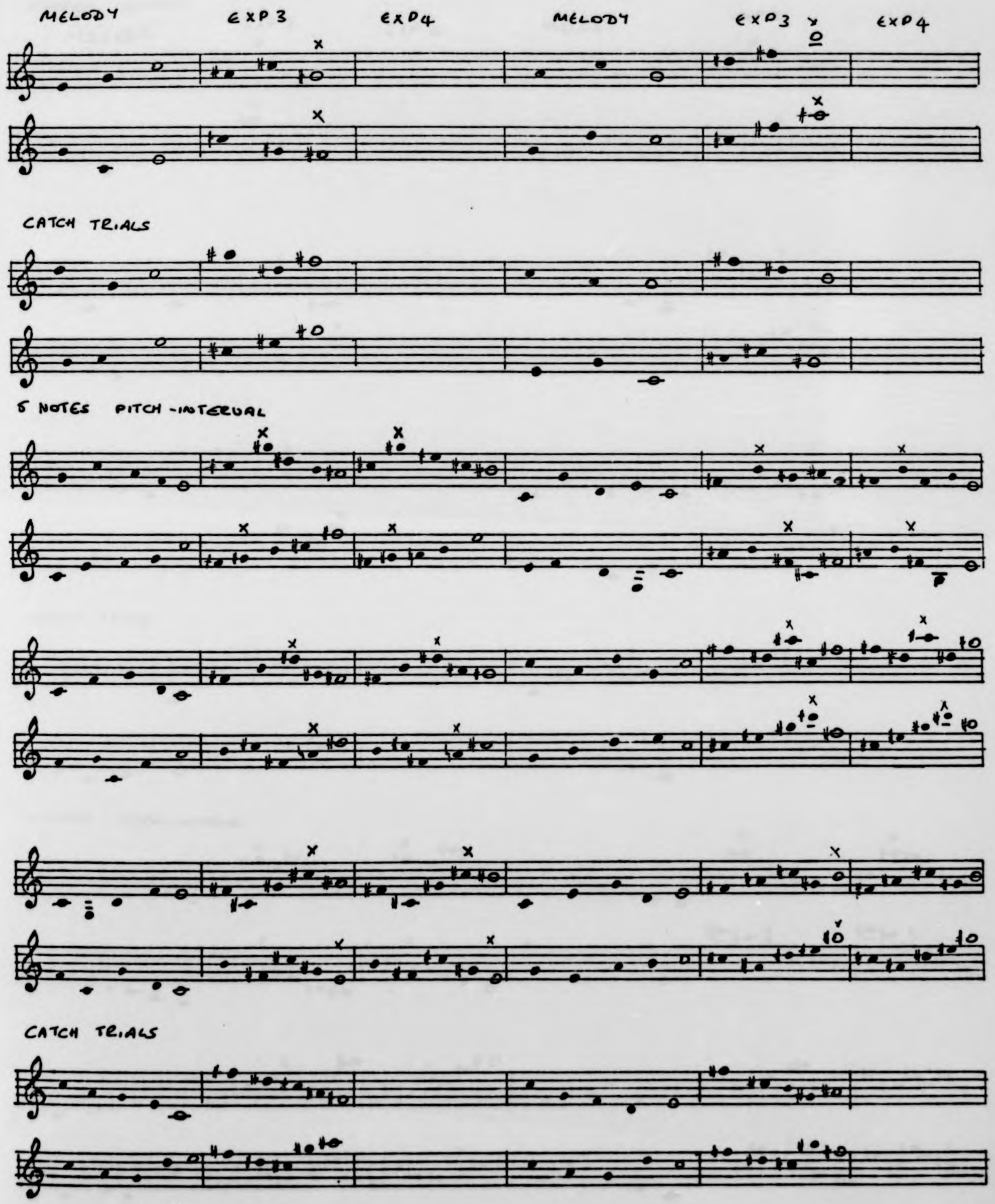
COMPARISON

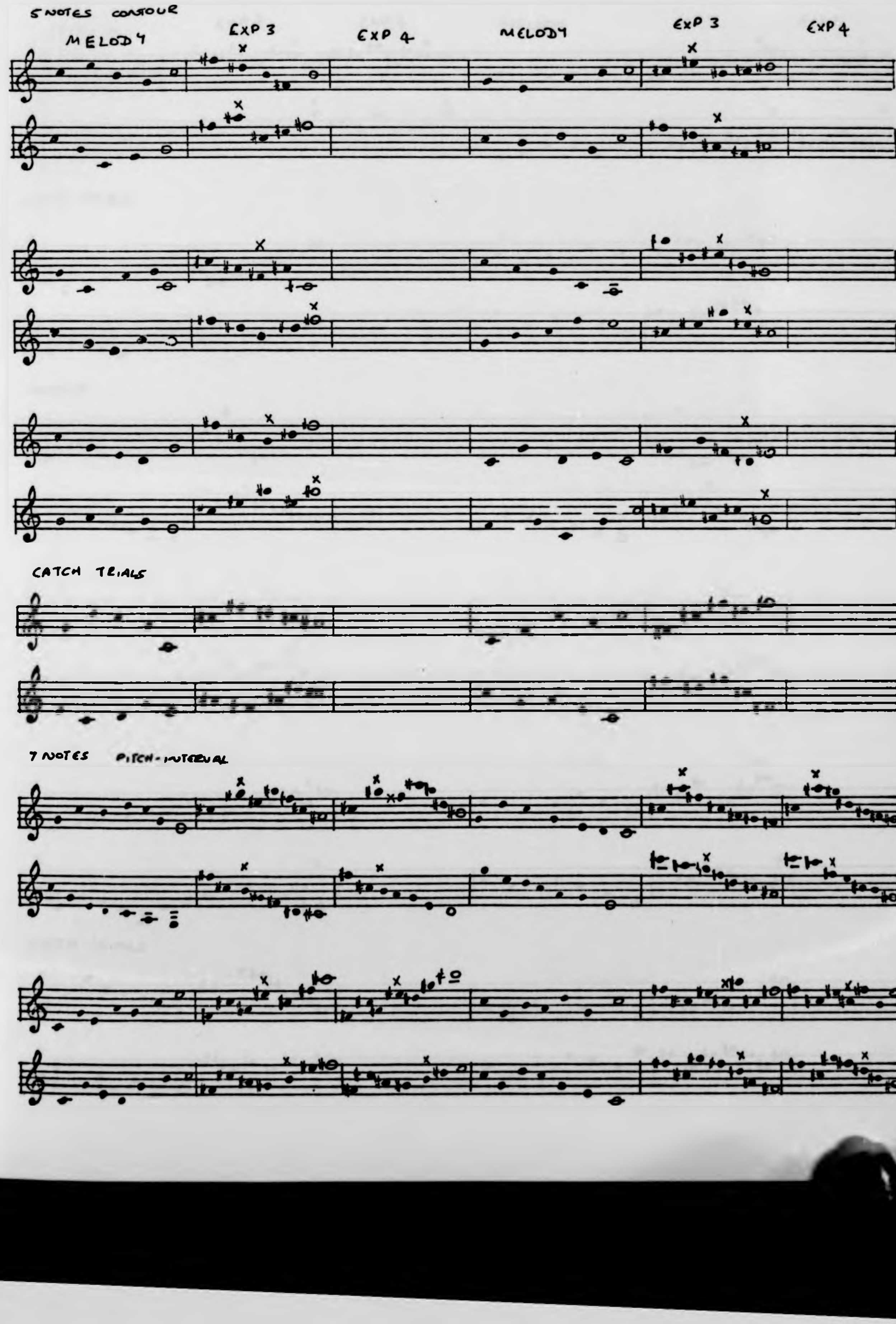



MELODY
COMPARISON
CATCH TRIALS

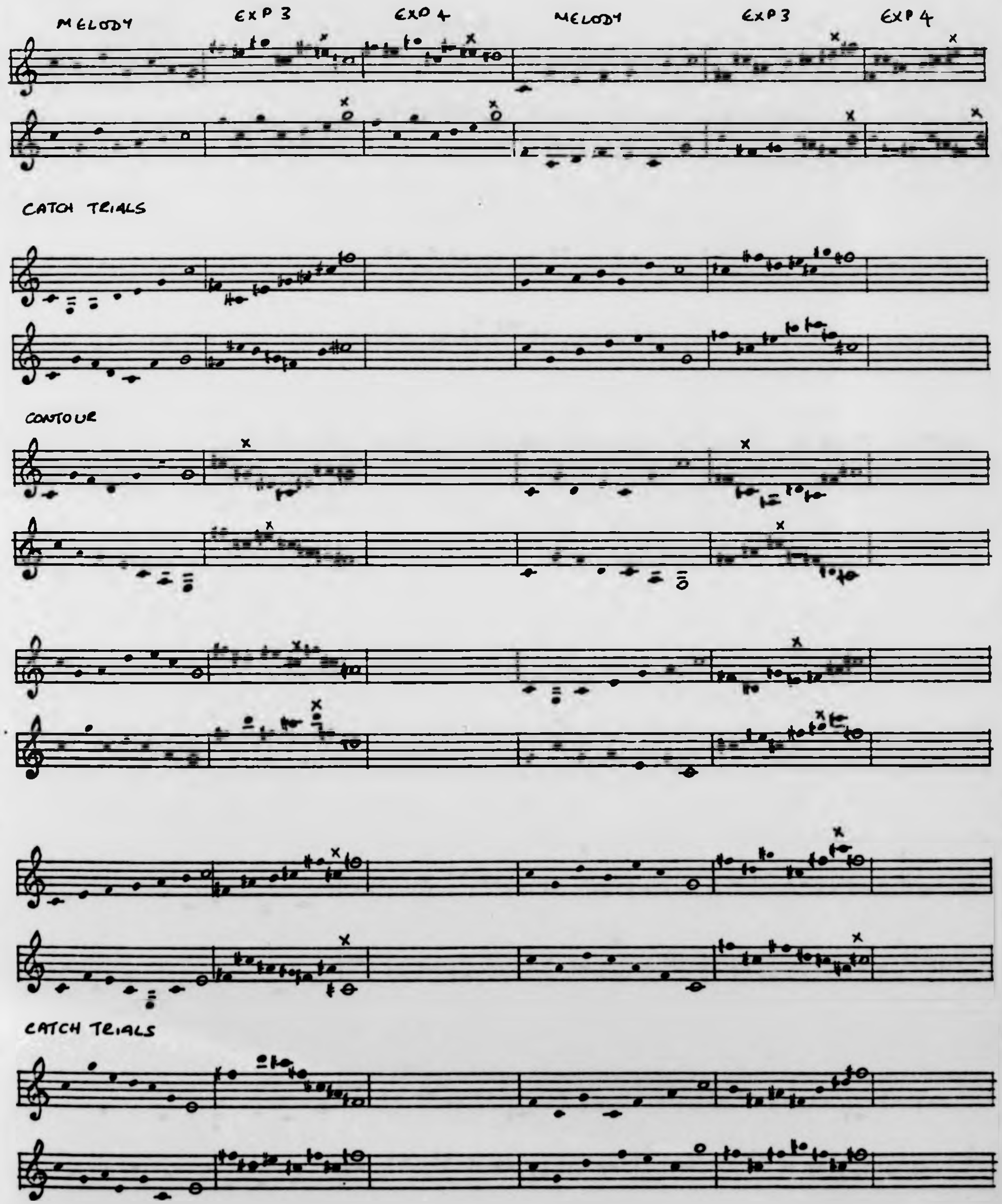
EXPERIMENTS 3 & 4 PITCH-INTERVAL

CATCH TRIALS

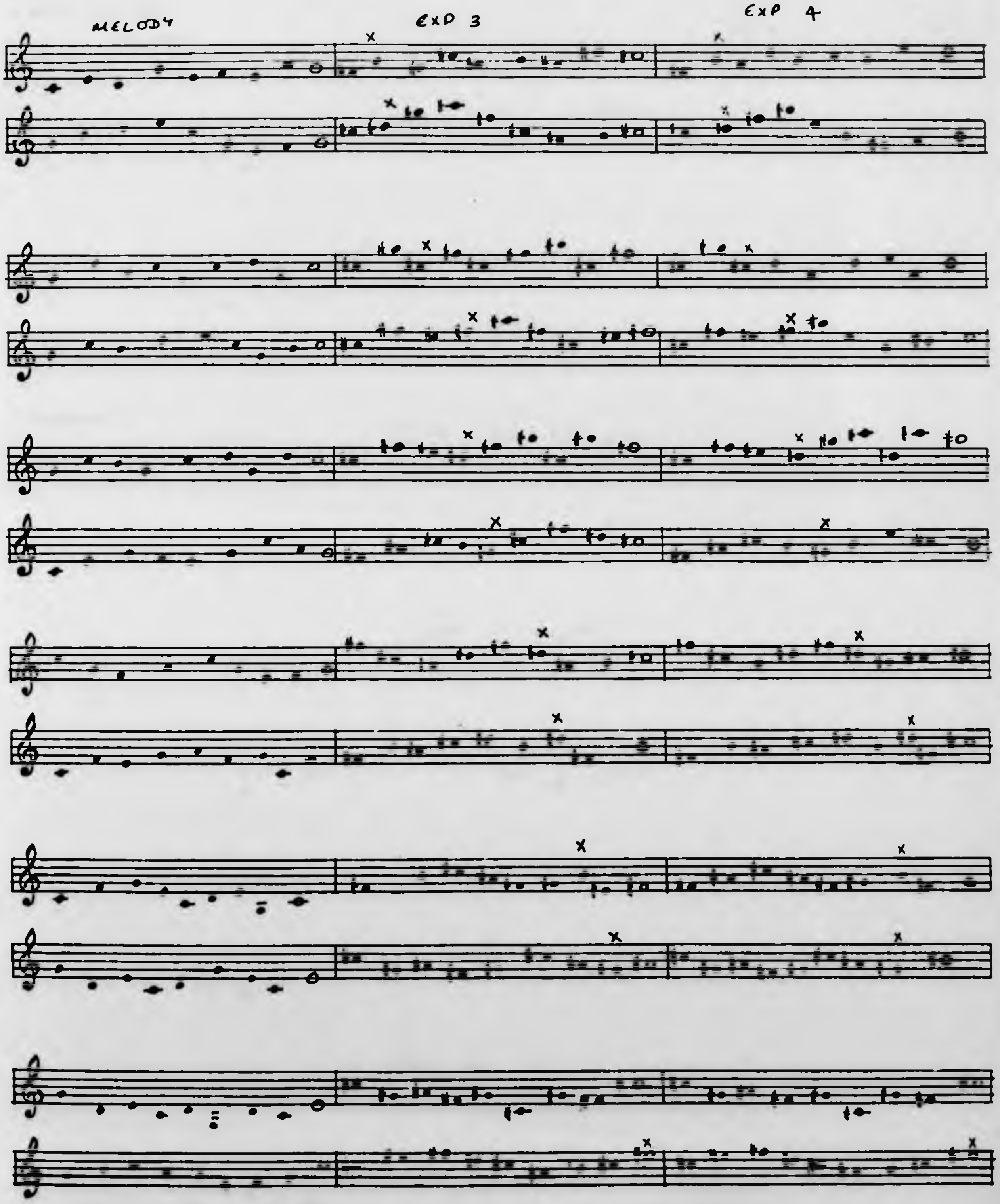


CONTOUR


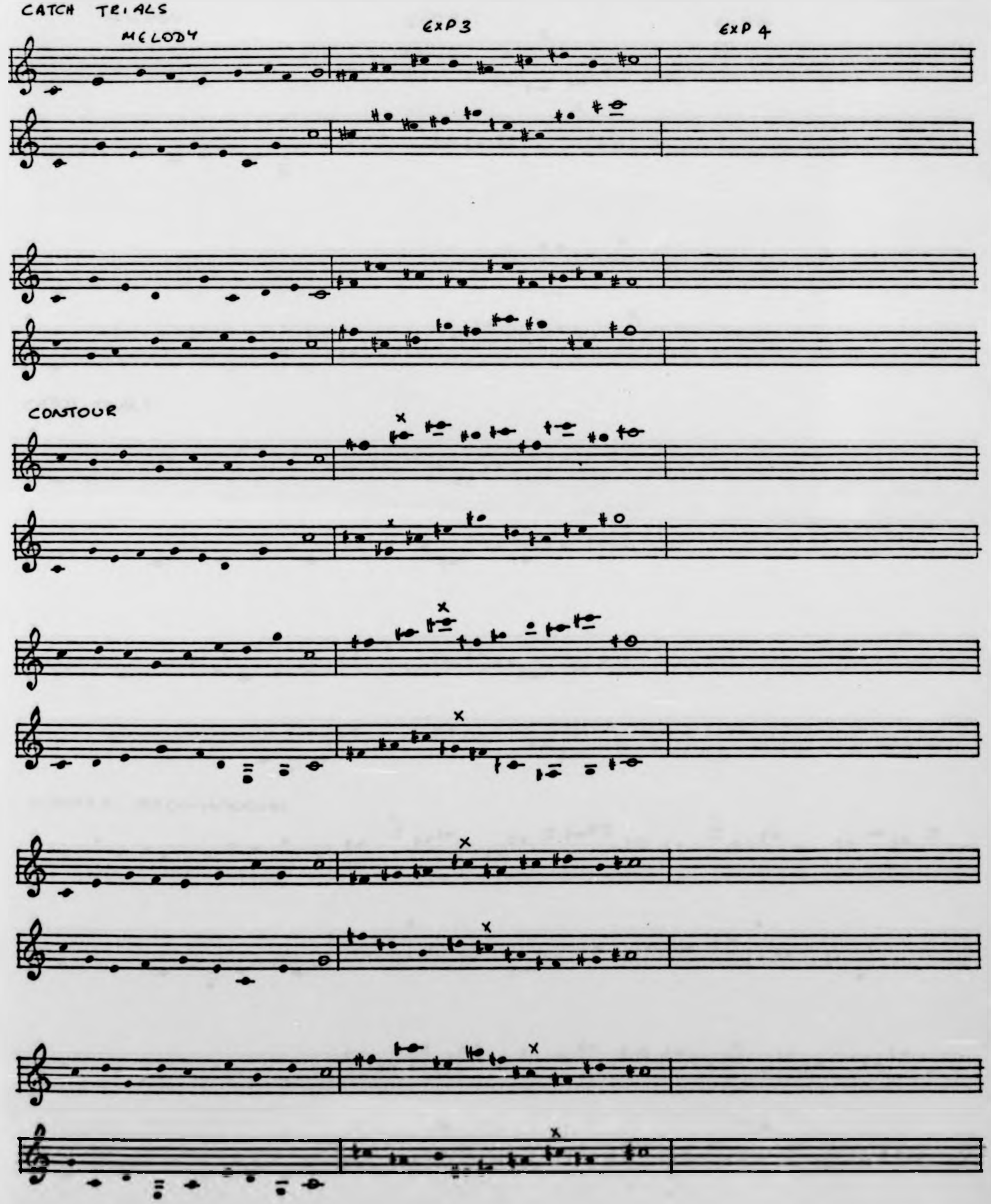
MELODY
EXP 3
EXP4
MELODY
EXP3
EXP4
CATCH TRIALS
5 NOTES PITCH-INTERVAL
CATCH TRIALS


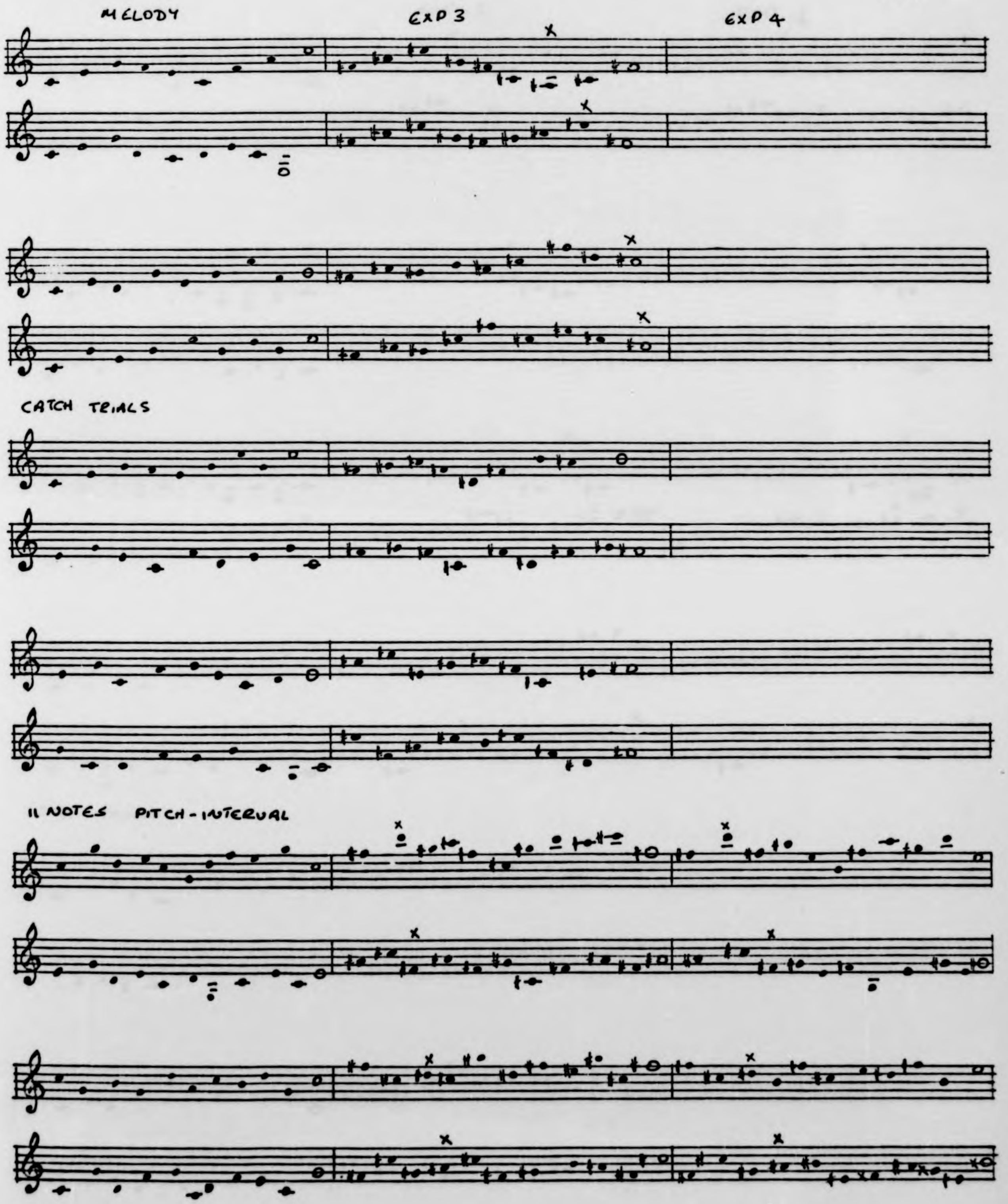
5 NOTES CONTOUR
MELODY
EXP 3
EXP 4
MELODY
EXP 3
EXP 4
CATCH TRIALS
7 NOTES PITCH-INTERVAL

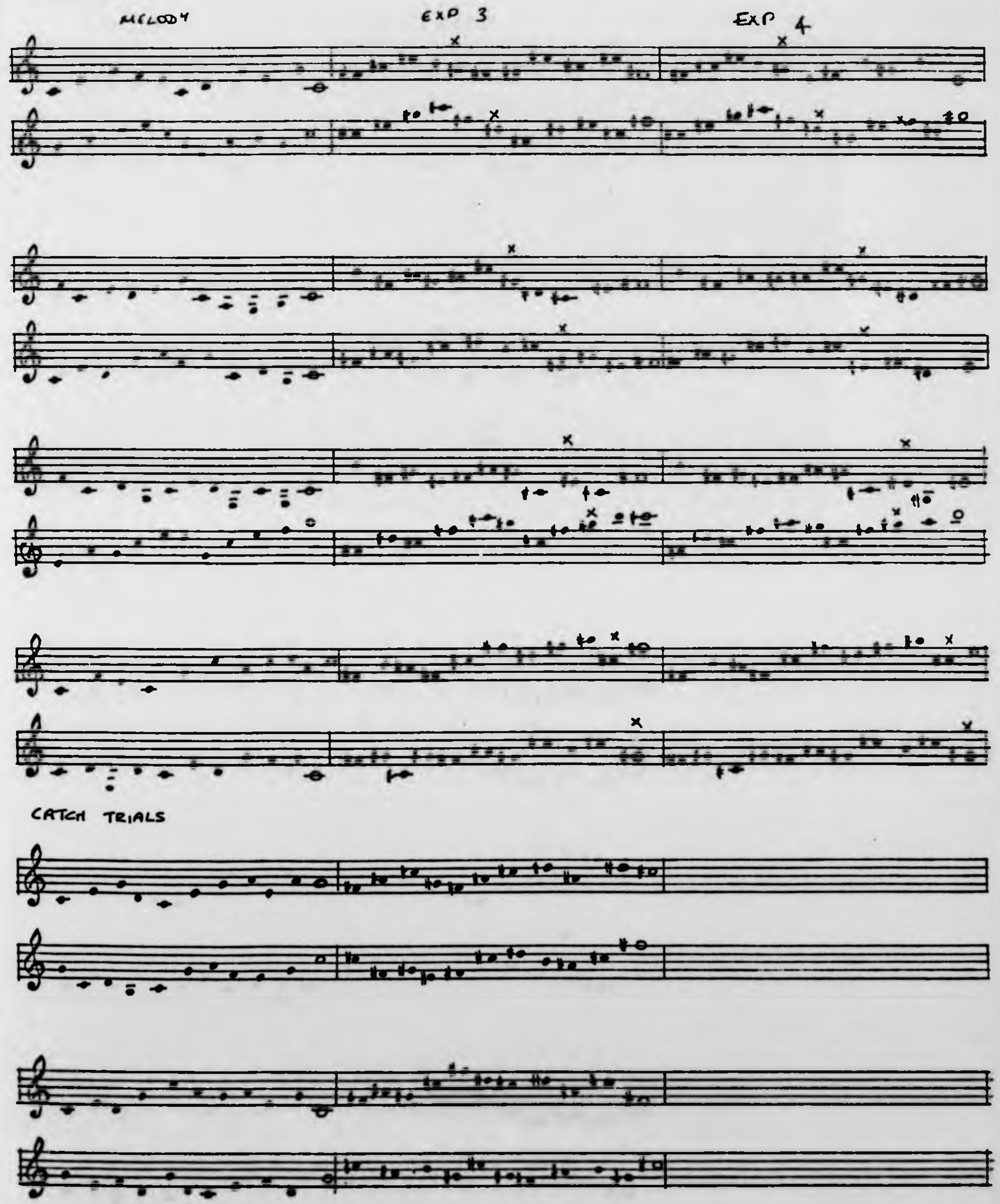

MELODY
EXP 3
EXP 4
MELODY
EXP 3
EXP 4
CATCH TRIALS
CONTOUR
CATCH TRIALS


MELODY
EXP 3
EXP 4

CATCH TRIALS

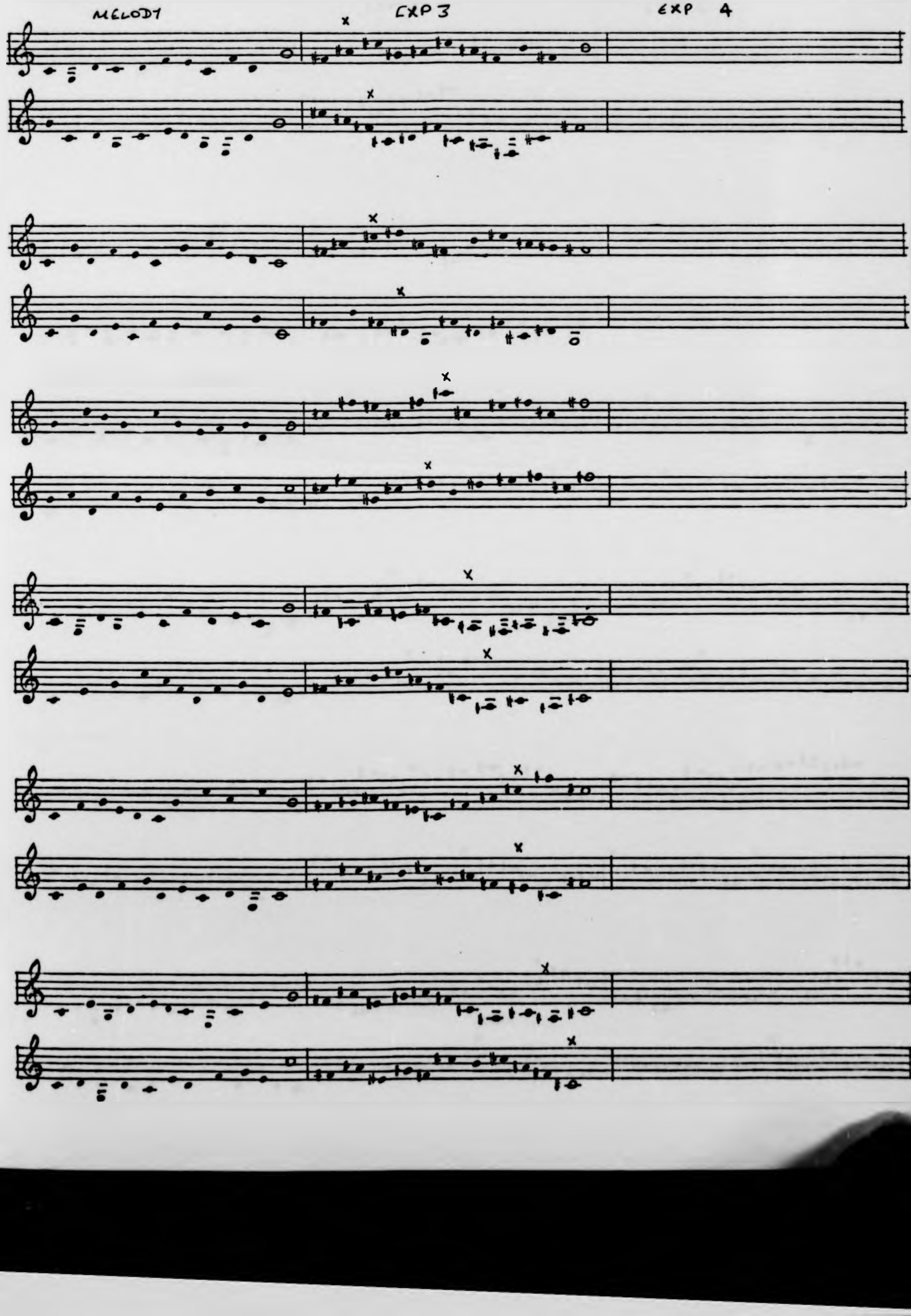


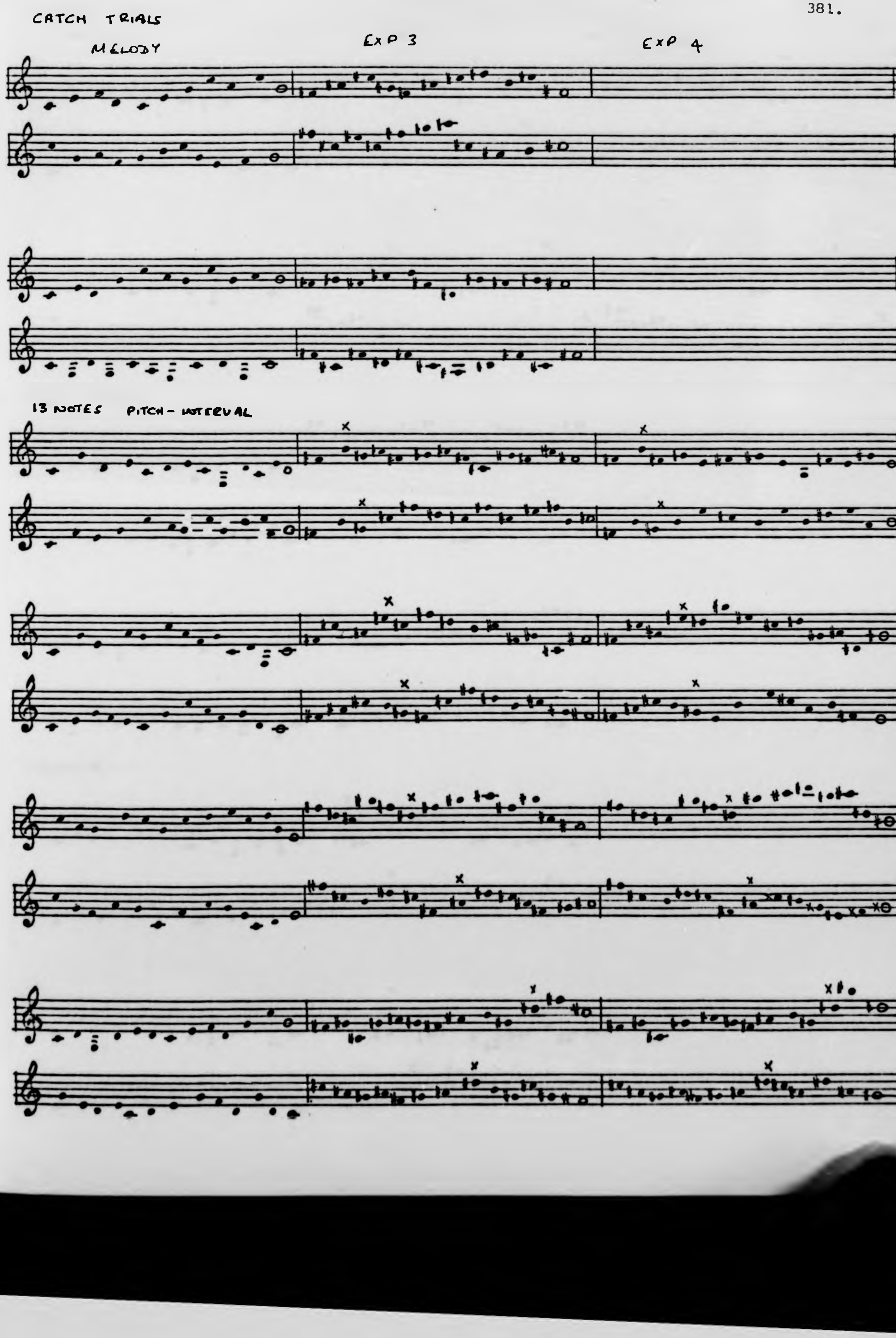

MELODY
EXP 3
EXP 4
CATCH TRIALS
11 NOTES PITCH-INTERVAL


MELODY
EXP 3
EXP 4
CATCH TRIALS

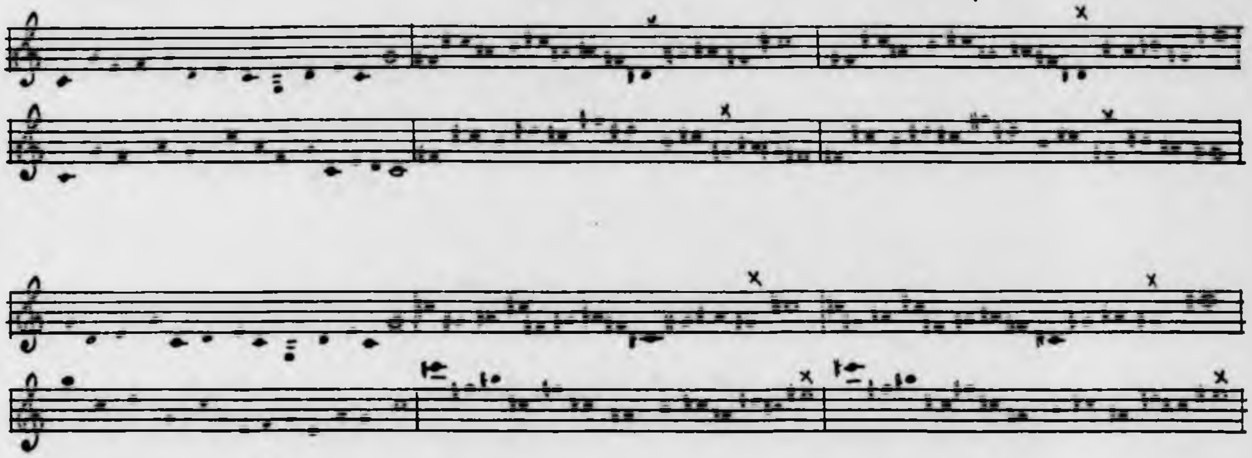
CONTOUR

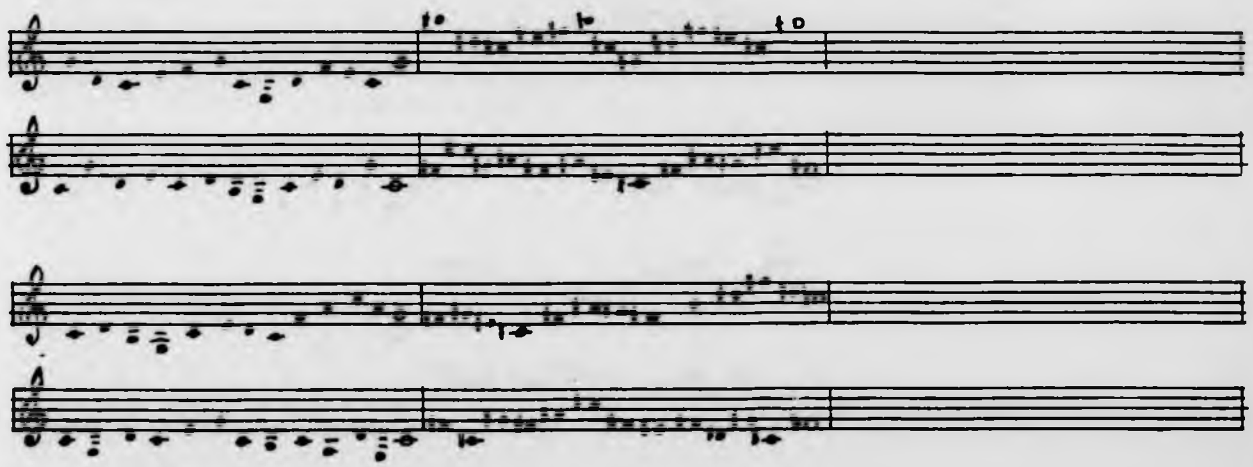
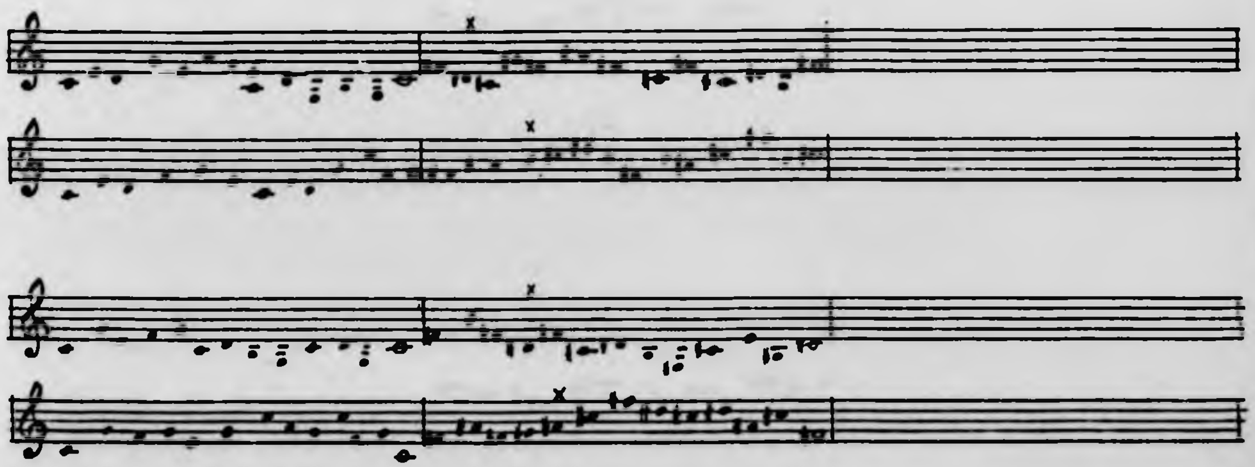
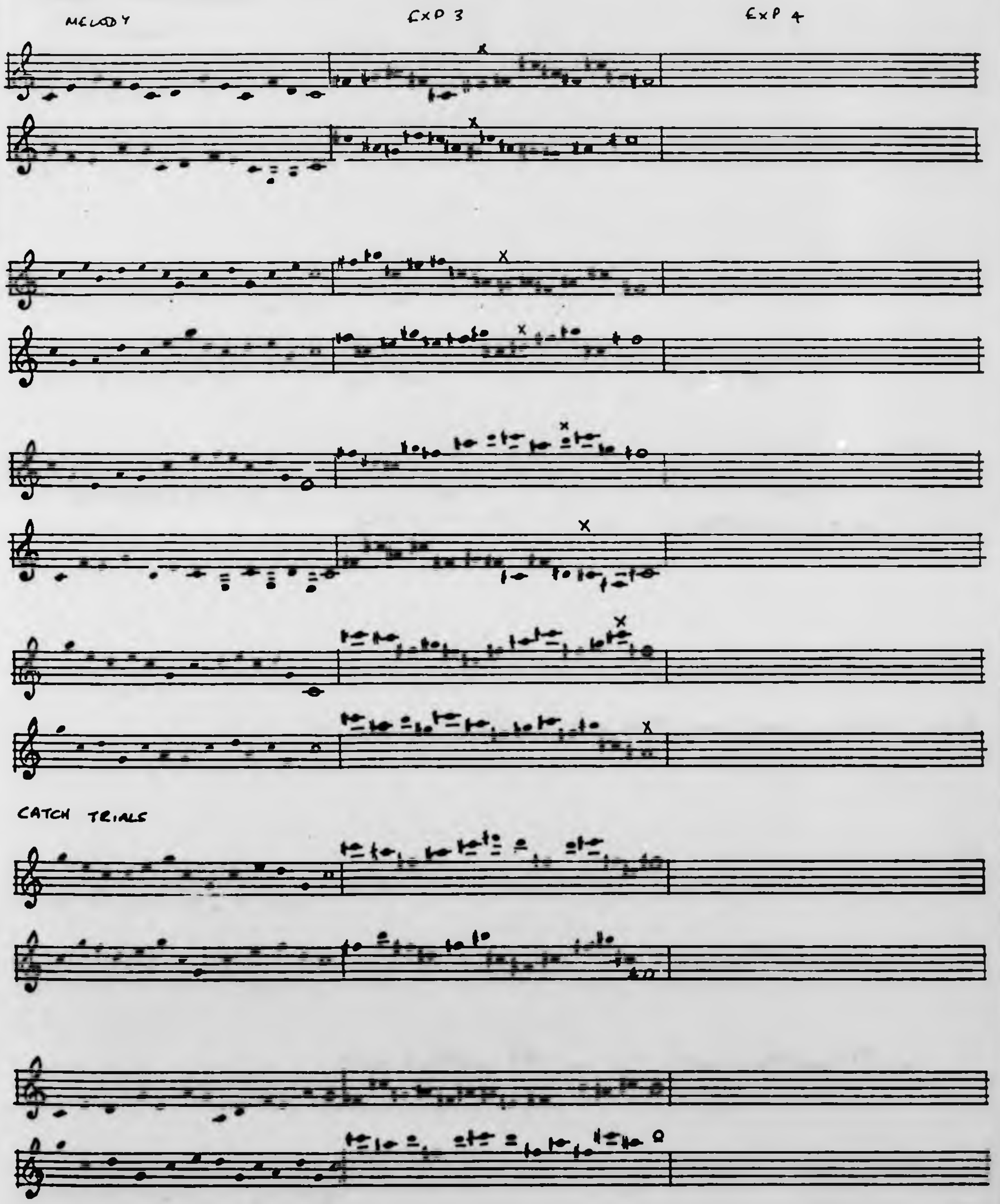
MELODY EXP 3 EXP 4



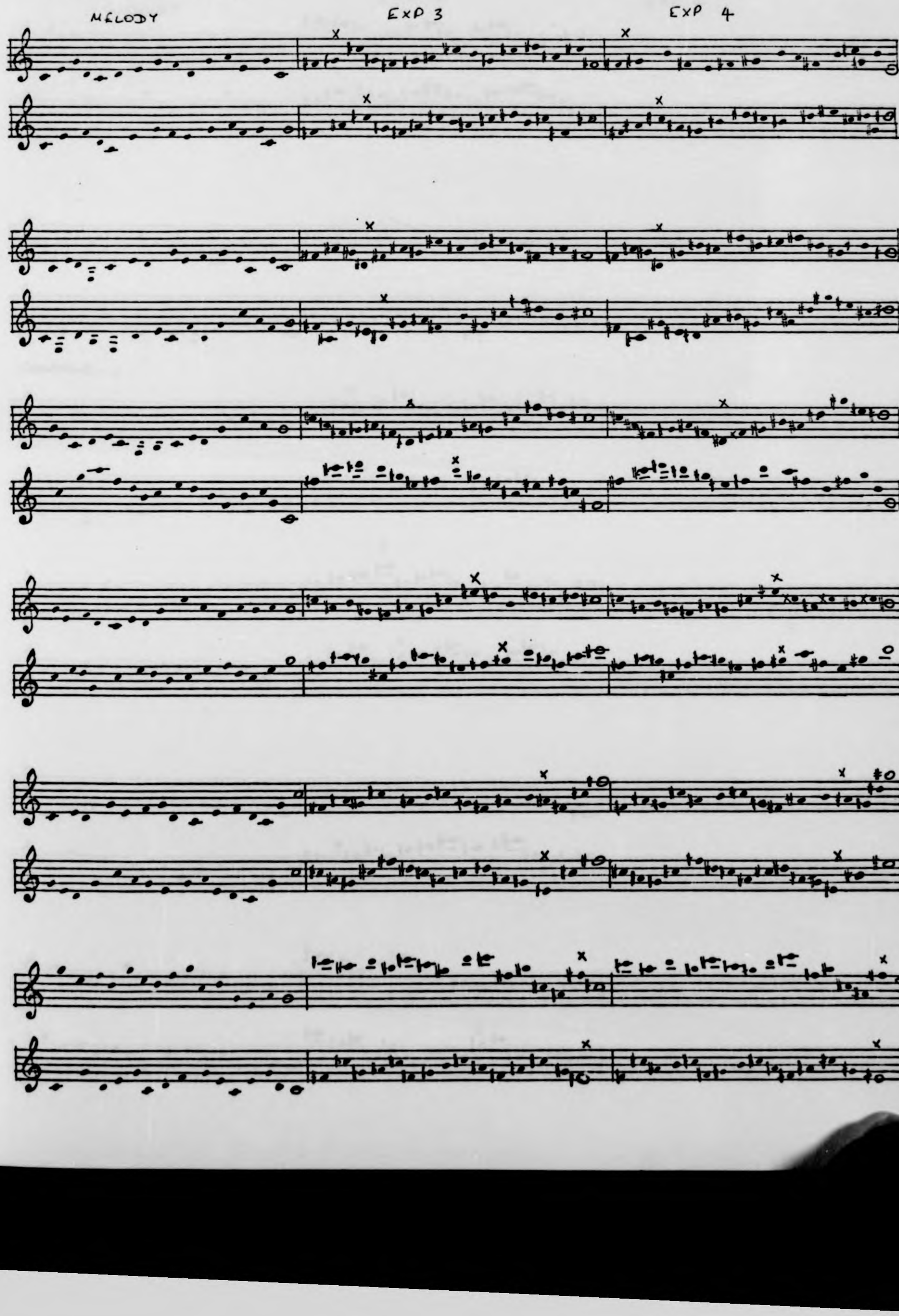

CATCH TRIALS
MELODY
EXP 3
EXP 4
13 NOTES PITCH-INTERVAL

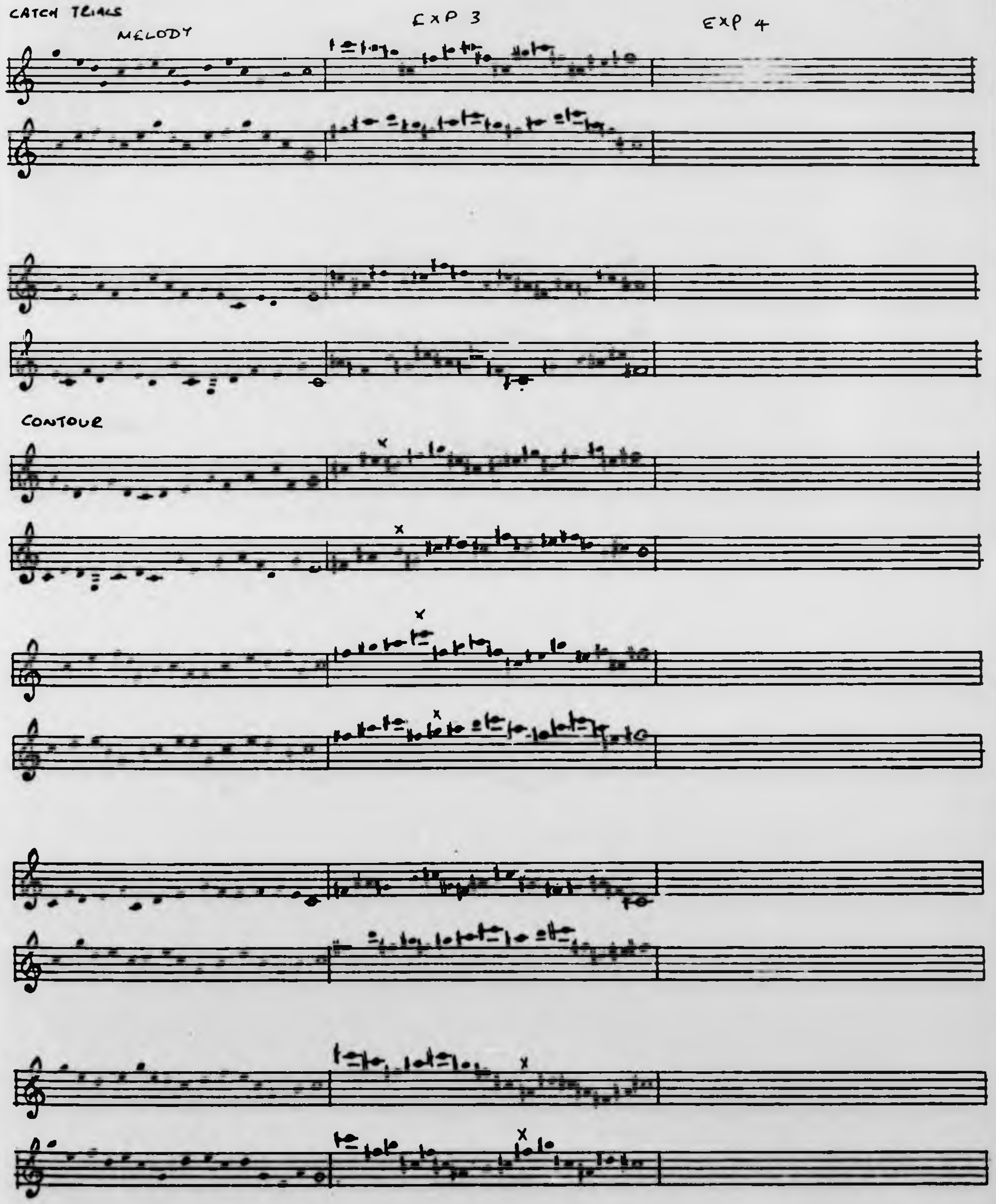
MELODY EXP 3 EXP 4

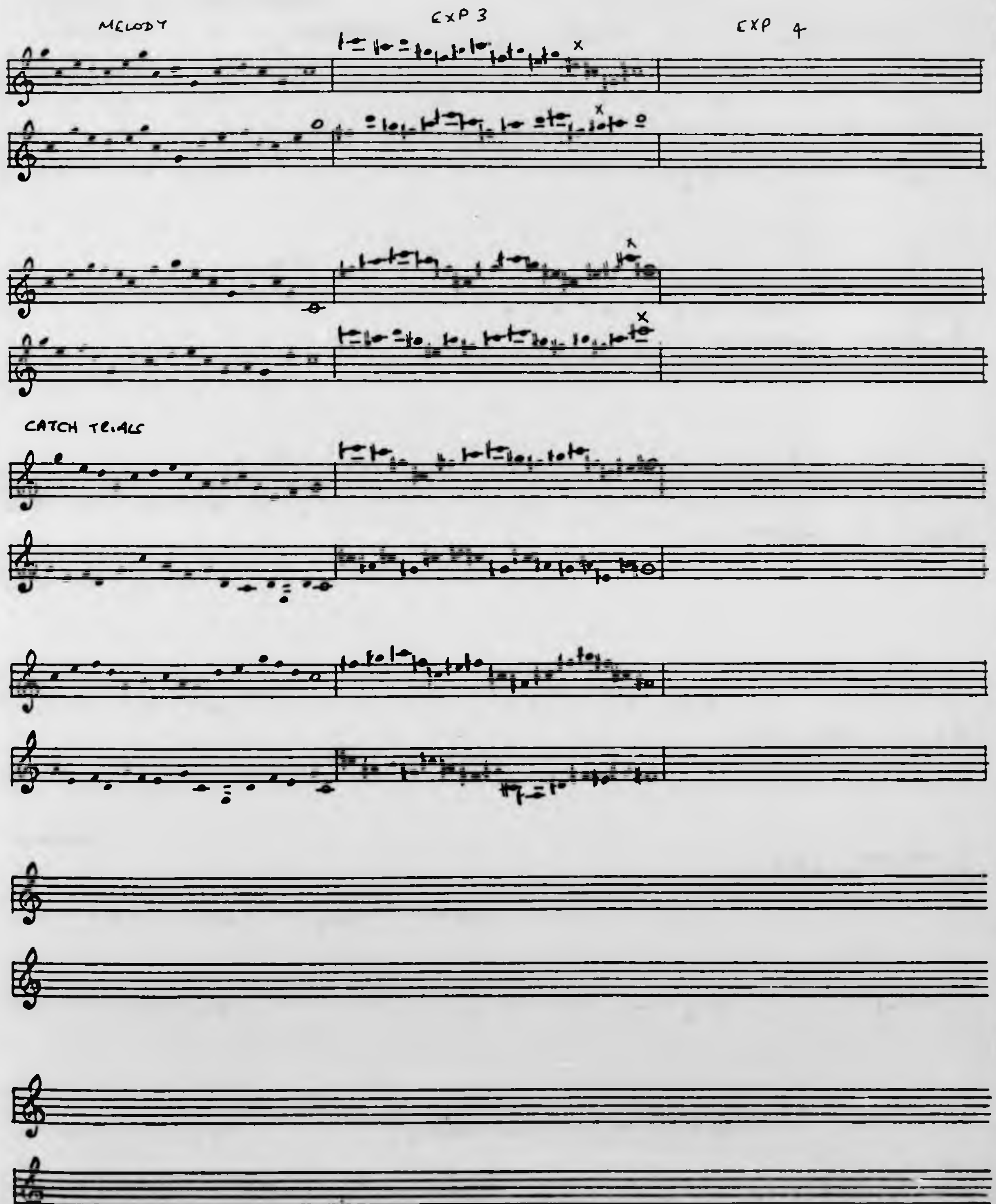


CATCH TRIALS

CONTOUR


MELODY
EXP 3
EXP 4
CATCH TRIALS

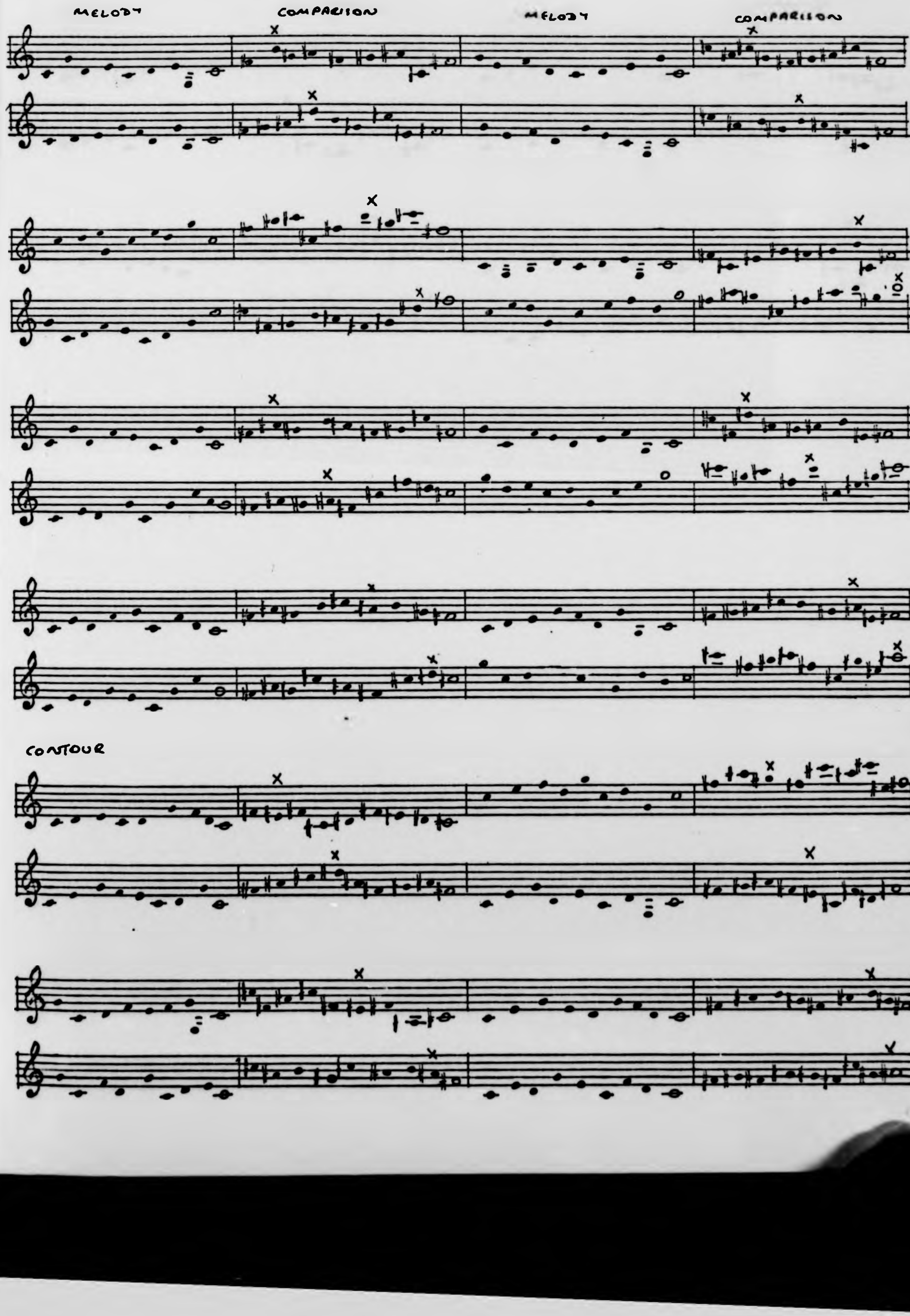
16 NOTES PITCH-INTERVAL

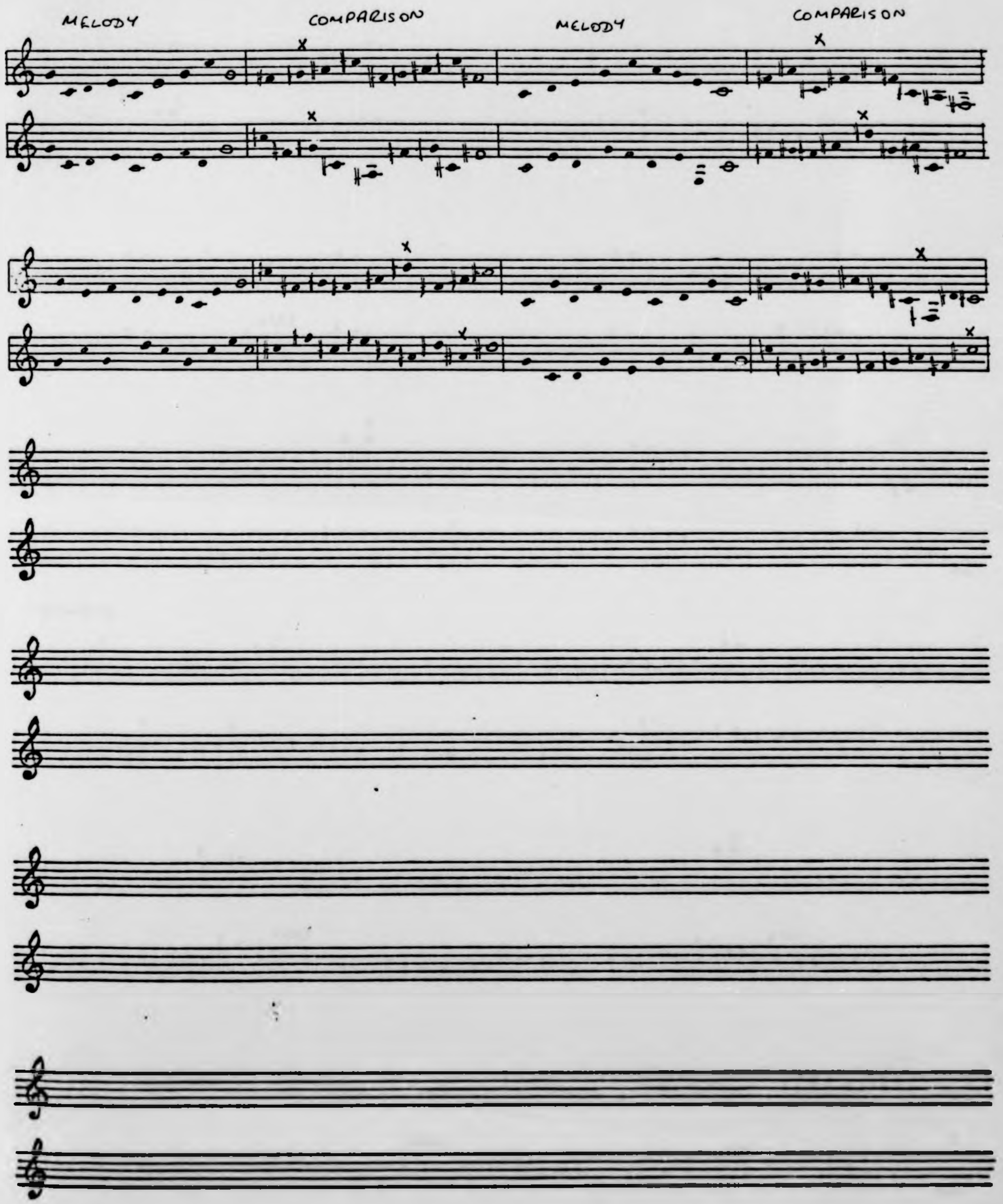



CATCH TRIALS
MELODY
EXP 3
EXP 4
CONTOUR

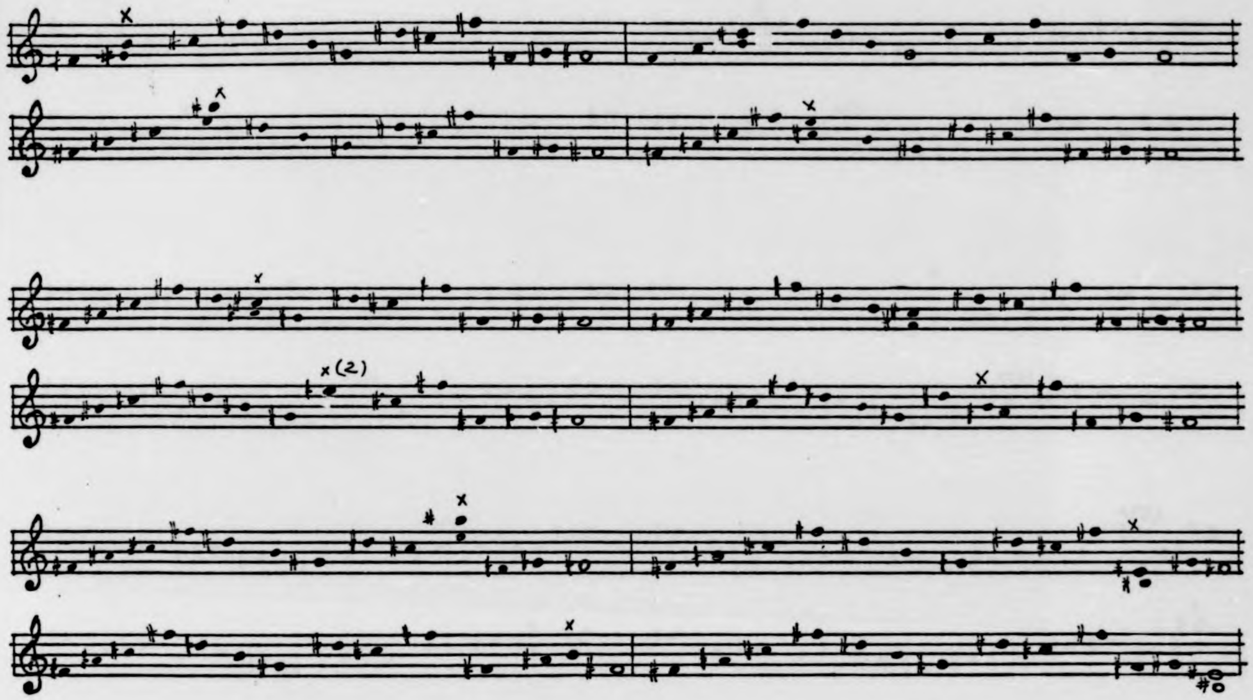

MELODY
EXP 3
EXP 4
CATCH TRIALS

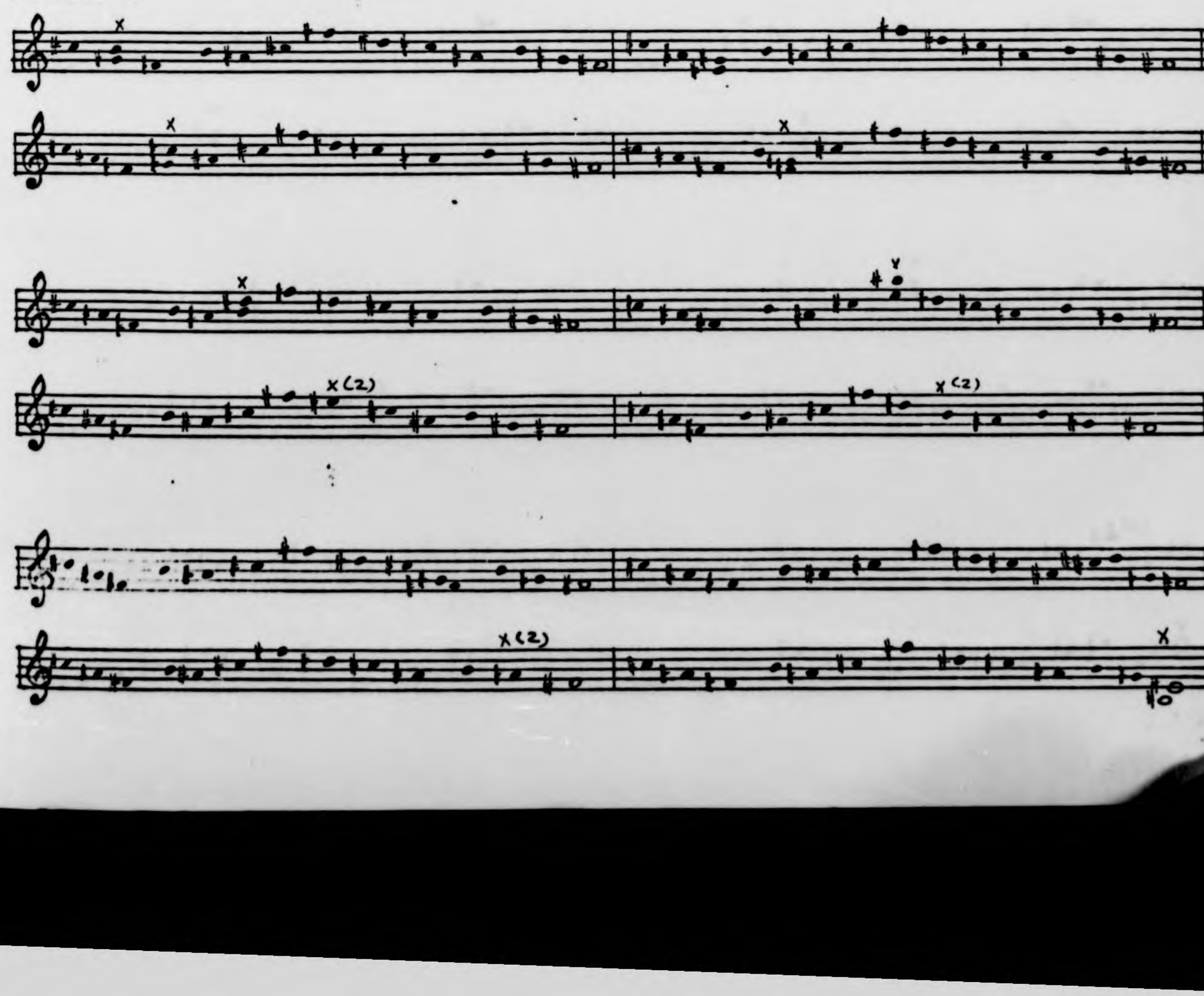
EXPERIMENT 5 PITCH-INTERVAL




MELODY
COMPARISON
MELODY
COMPARISON

EXPERIMENT 7 PITCH-INTERVAL

TUNE 1

TUNE 2



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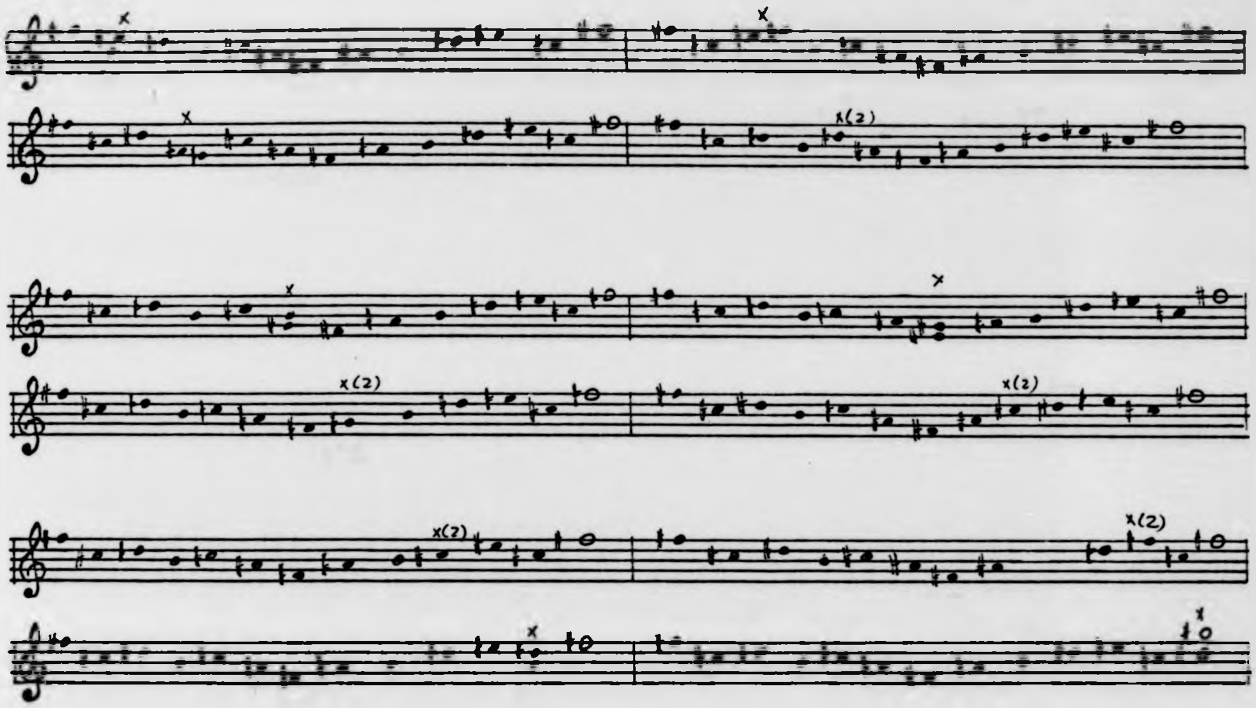
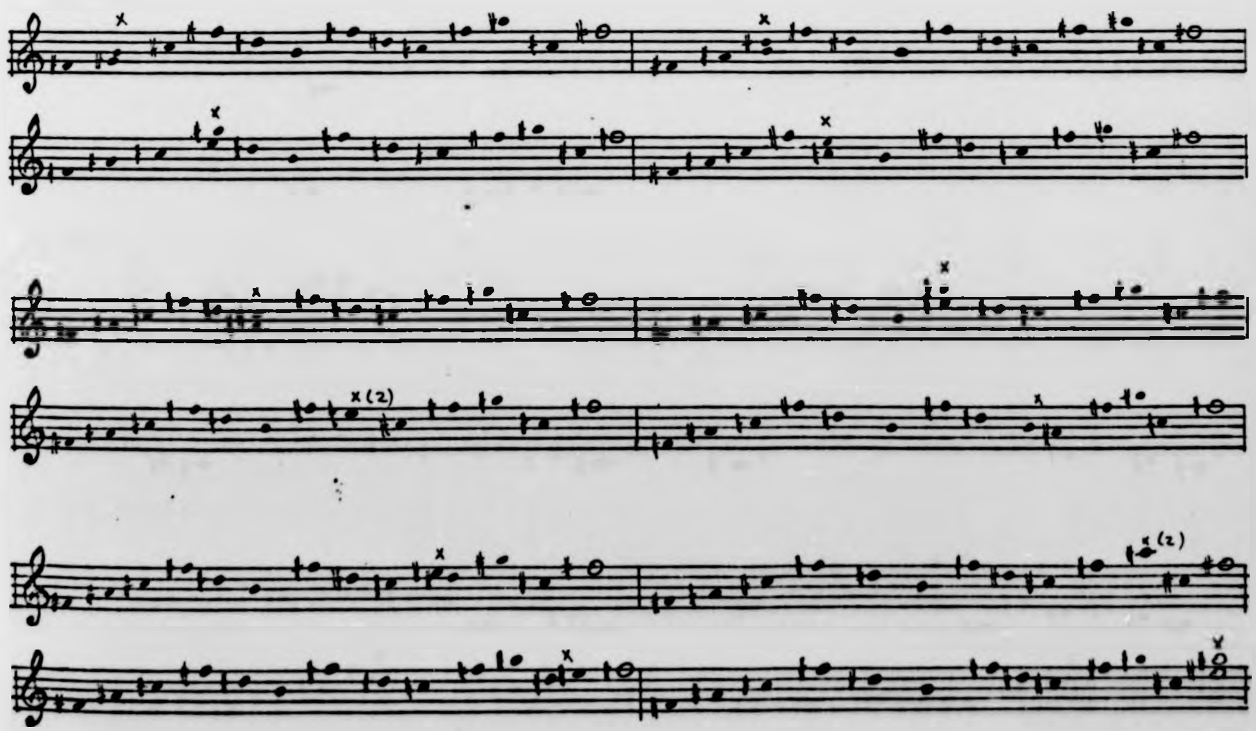
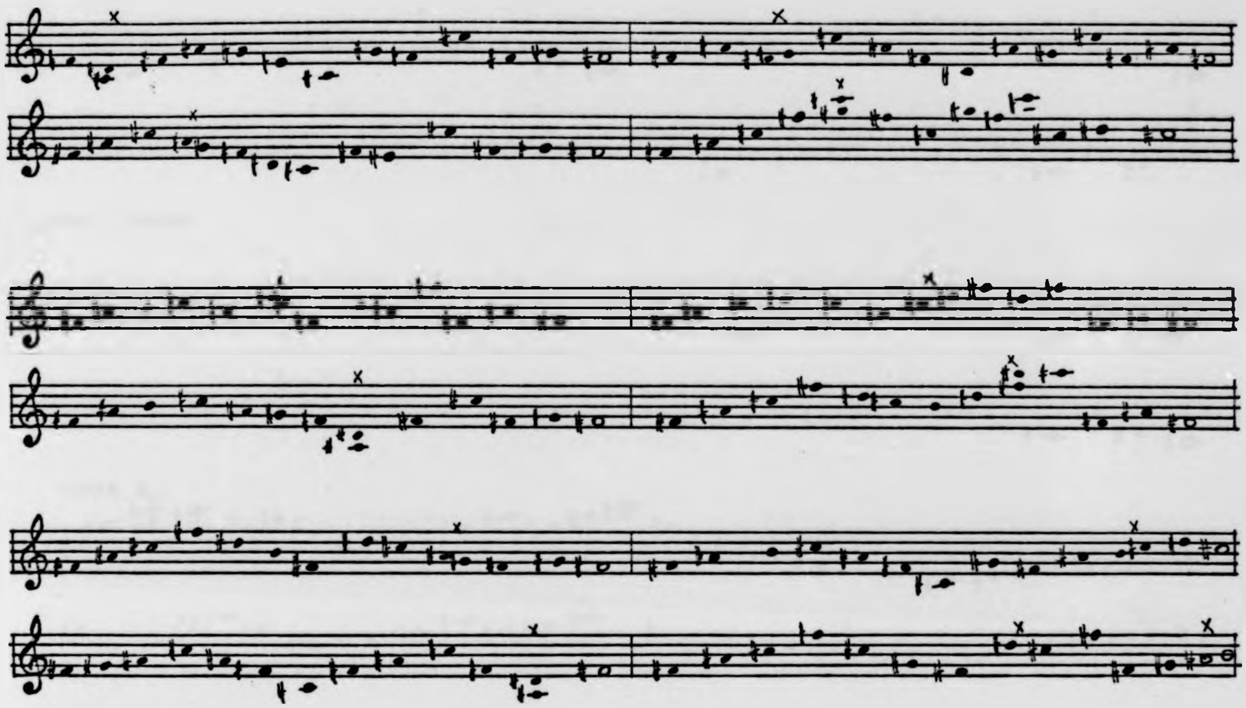
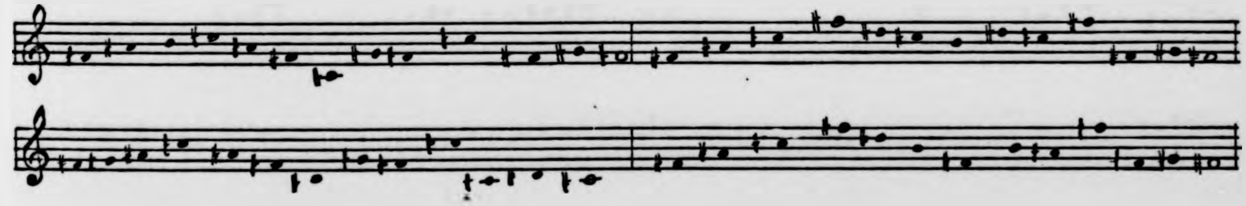
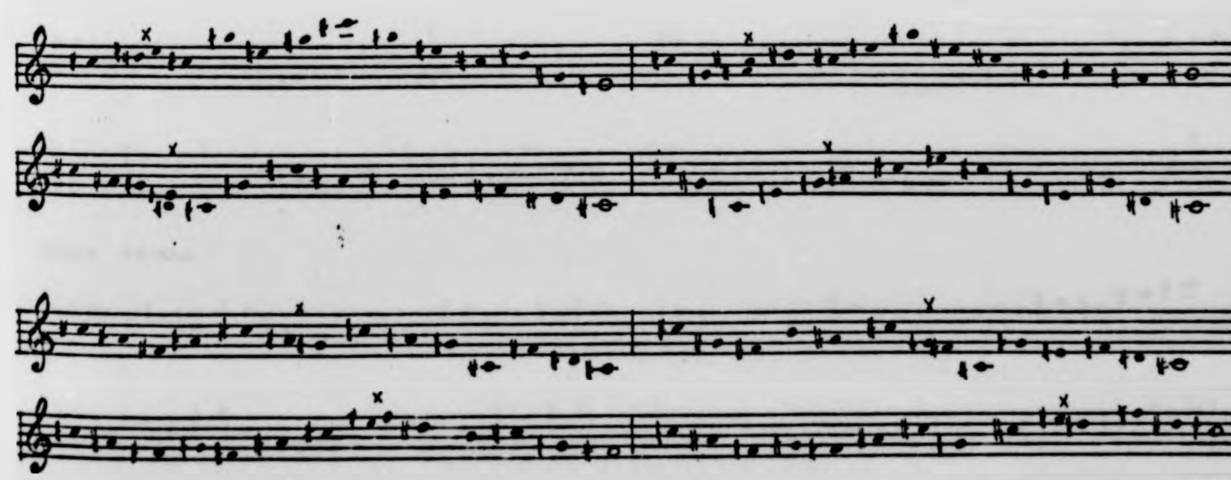
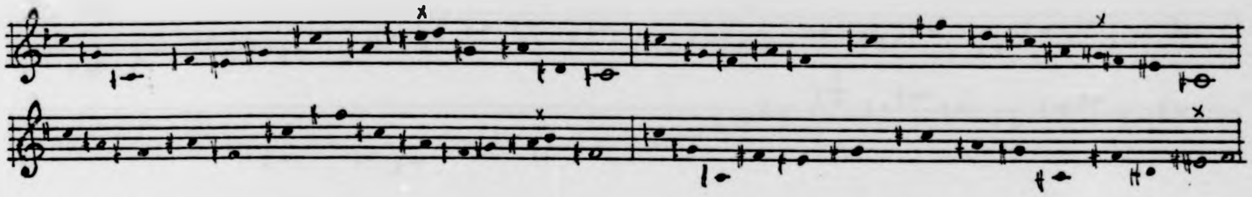

TUNE 4

CONTOUR
TUNE 1

CATCH TRIALS

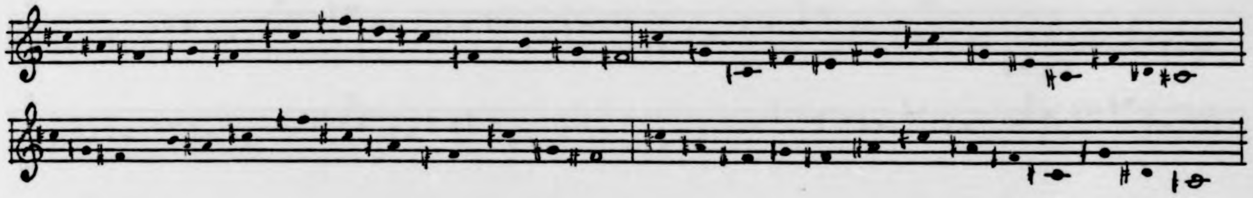


TUNE 2

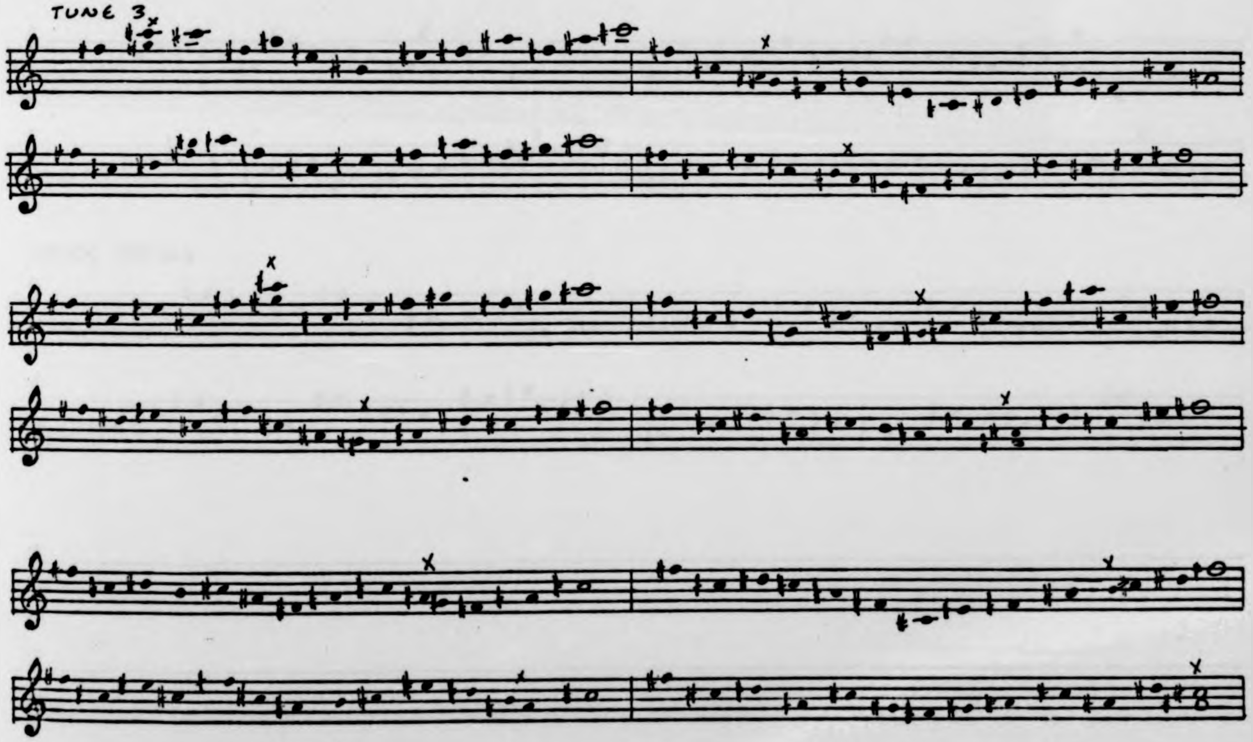




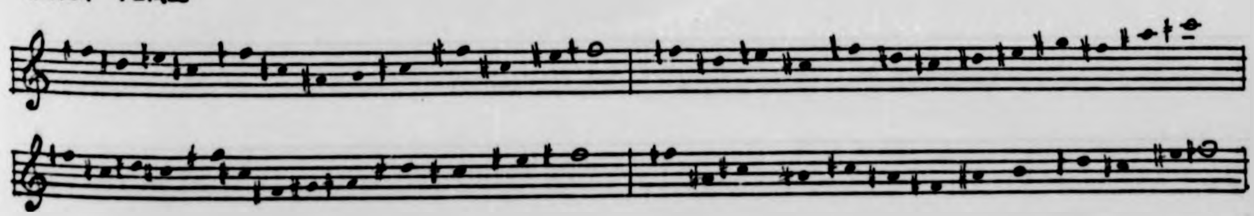
CATCH TRIALS

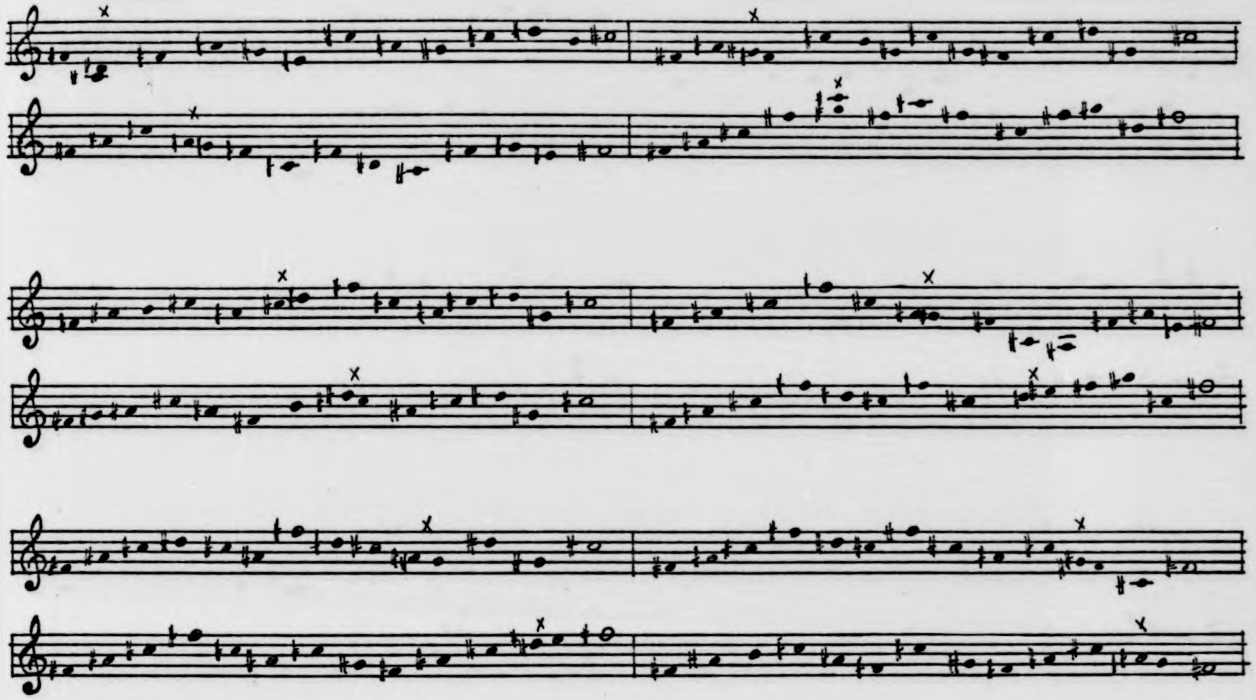


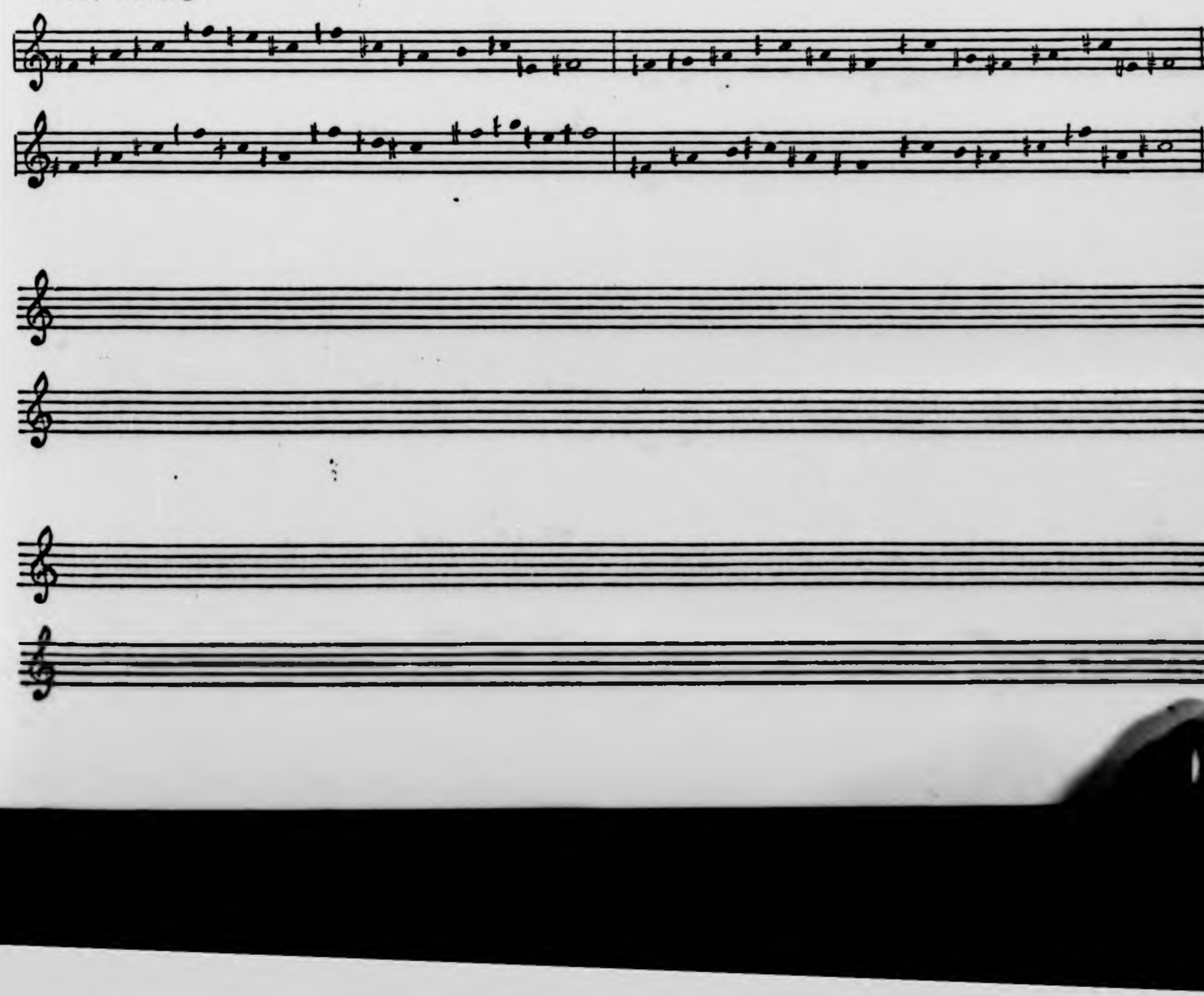
TUNE 3



CATCH TRIALS

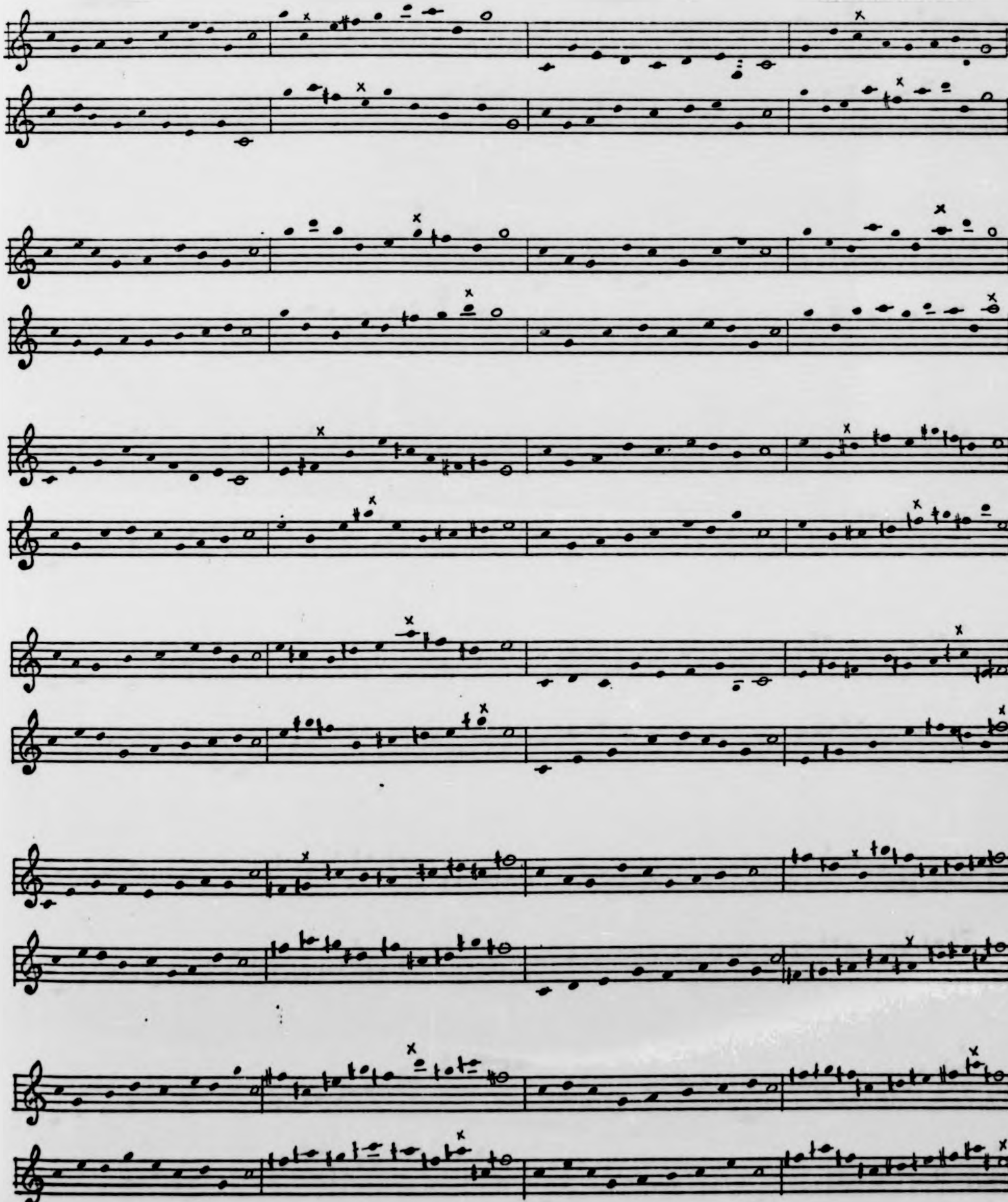


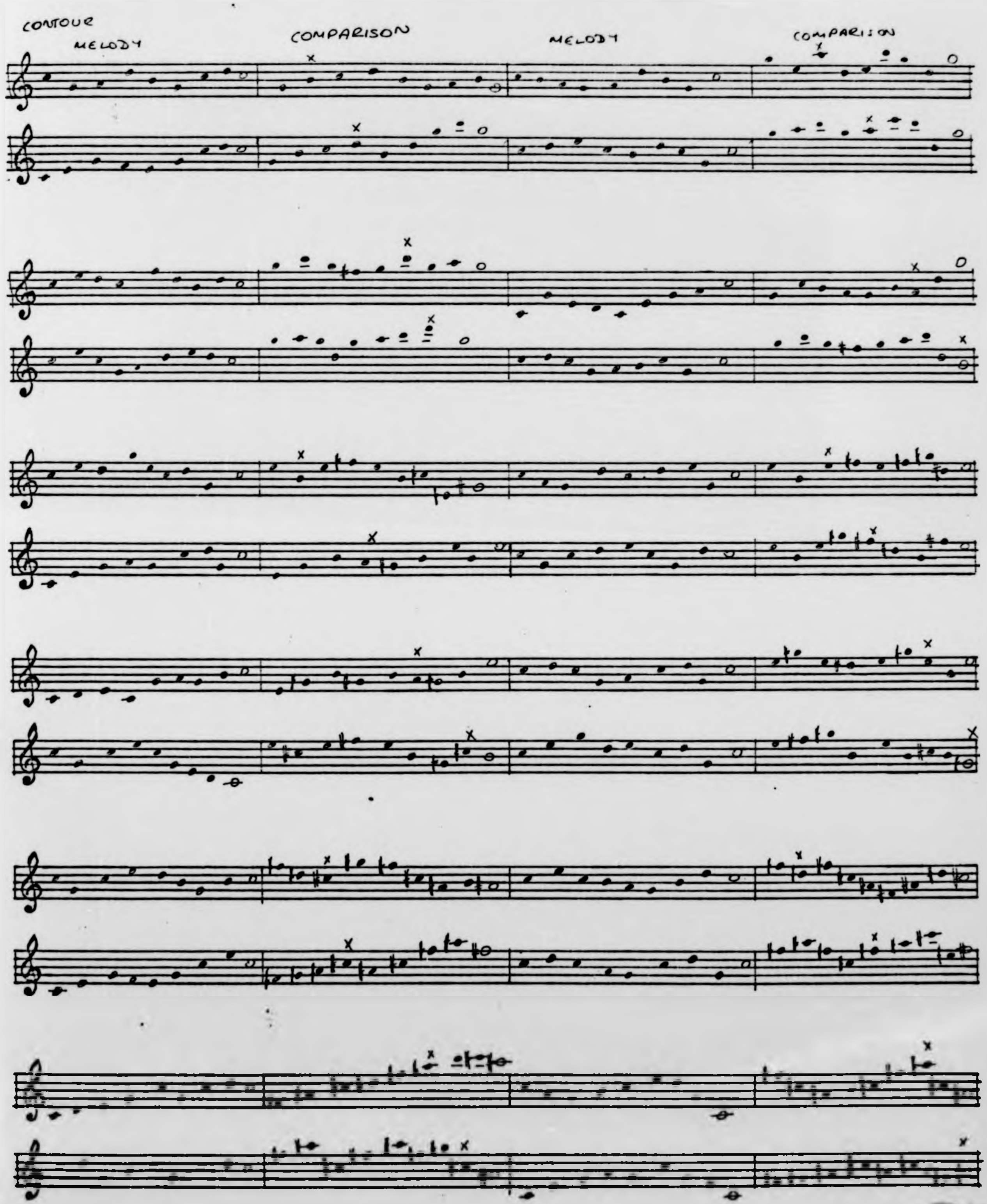
TUNE 4

CATCH TRIALS

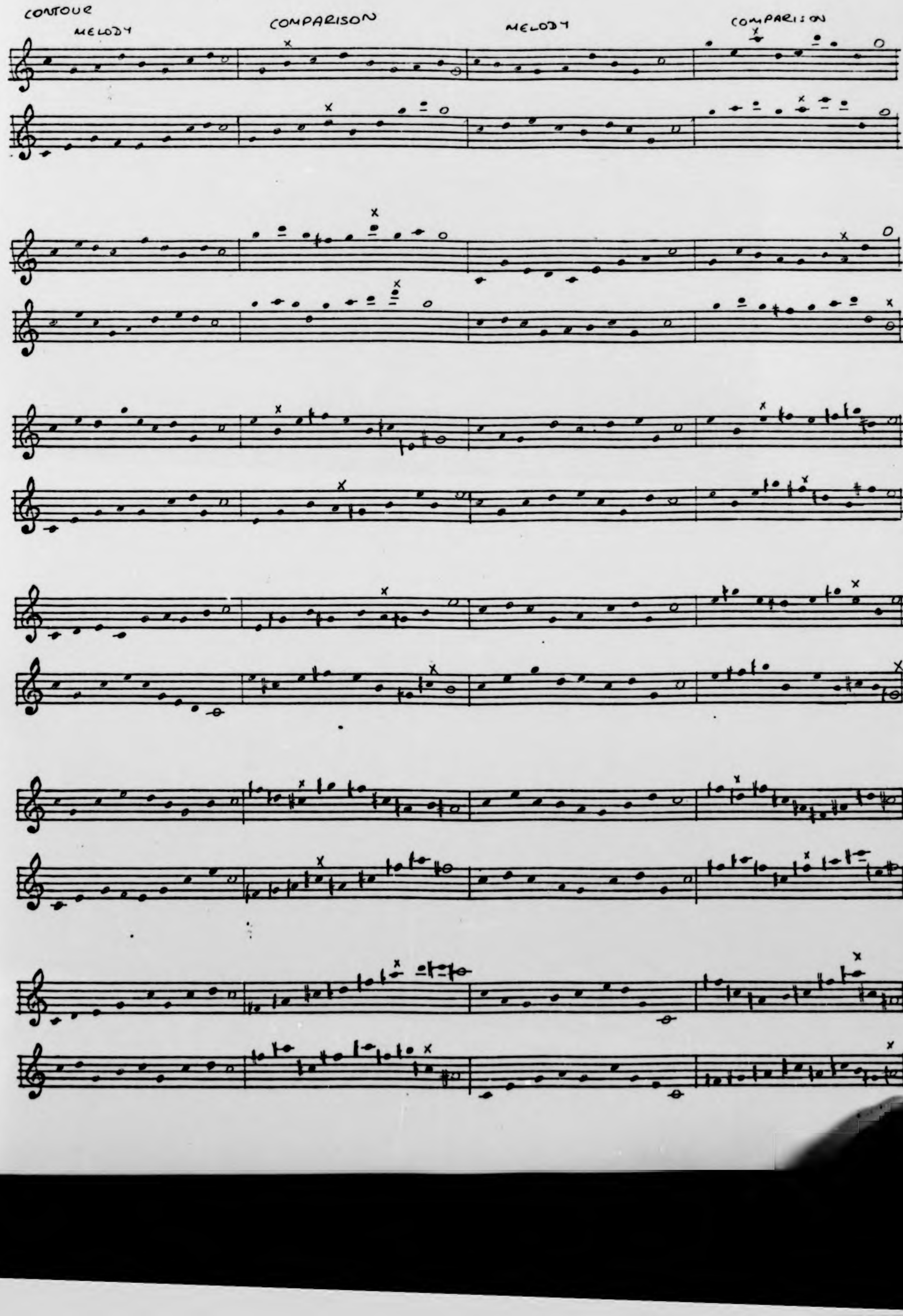


EXPERIMENT 8

MELODY COMPARISON MELODY COMPARISON




CONTOUR
MELODY
COMPARISON
MELODY
COMPARISON


CONTOUR
MELODY
COMPARISON
MELODY
COMPARISON