AN INVESTIGATION INTO THE POSSIBLE ORIGINS AND NATURE OF ANY PREFERENTIAL TEMPI IN MUSICAL PERFORMANCE

by

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CONTENTS

INTRODUCTION

This investigation arose from a long interest in the physical and physiological factors affecting musical perception and ability. Recent work in a college primarily concerned with movement education and an increasing preoccupation with the movement and movement speeds associated with dancing, musical performance and tempo initiation finally focussed the writer's attention on preferential tempi.

The Problem

There is little doubt regarding the supreme importance and critical nature of tempo choice in performance. Musicians in many centuries have testified to this:-

> 'There being nothing more difficult in Musick then playing of true time . . .'
> (Henry Purcell, 1696)

> 'Many a one would like to know how the true mouvement of a musical . . . can be known. Such knowledge, alas, is beyond words. It is the ultimate perfection of music, accessible only through great experience and talent.'
> (Mattheson, 1739)[1]

> 'Before beginning to play one must consider the piece thoroughly; every effort must be made to discover the character, the tempo and the kind of movement proper to it.'
> (Leopold Mozart, 1756)

> 'The hardest and most important thing to decide about a piece is its tempo.'
> (W.A. Mozart, in Fox-Strangways, 1929)[2]

> 'Tempo is the body of performance.'
> (Beethoven, in Dorian, 1942)[3]

> 'Conducting is Tempo, Tempo and Tempo again.'
> (Toscanini)

> 'Tempo feeling is a quality common to all human beings. Yet, as the heartbeat varies in different persons, so the degree of tempo feeling differs from one individual to another. The sense of time varies with the age, the country, the race, the century . . . Is it surprising, then, that tempo, more so than dynamics or phrasing, is the most difficult feature of musical performance to approach through the intellect and the analytic method of interpretation? The emotional response of audiences to tempo is determined by the musical habits and conventions of the particular period . . .

1, p.173; 2, p.37; 3, p.179.

> If it is true that the tempo problem is one of intended effect, varying with the changing circumstances of performance, rather than one of arithmetical calculation, then it gives rise to this decisive question: What ultimate goal was the composer seeking with his tempo?'
> (Dorian, 1942)[1]

> 'To set a good tempo; to maintain it flexibly, yet so that the piece ends at the same tempo at which it started; to remember this tempo so as to be able to set it again, within a reasonable margin, at the next performance: these are some of the hardest things in music.'
> (Donington, 1974)[2]

> 'This matter of fundamental pace is the conductor's gravest problem, and I do not think one can ever feel that it is finally solved anywhere. It depends on so many circumstances - hall, players, weather, audience, and the eternal question: Do I really know this work?'
> (Boult, 1963)[3]

However, despite its importance, theory and practice suggest that any absolute tempo sense is rarely as sensitive or permanent as the corresponding sense of absolute pitch. Ebhardt (1898) asserted that consciousness has no means of perceiving absolute rate, and from the world of music, Toscanini's claim that his tempi in later years were the same as in his youth was refuted by objective timings. Further, Fox Strangways (1929) gave evidence to suggest that even composers are not necessarily the best judges of a suitable tempo for their music.

Nevertheless, despite the above, we can be very sensitive to "wrong" speeds once initiated. The feeling of discomfort when performing or listening to a tempo known to be only fractionally different from the "ideal", and possibly not even knowing the direction of "error" is a fairly common experience for many musicians. Similarly, the relaxed confidence arising from an absolutely "right" tempo can give both a performer and listener great satisfaction.

> 'We have often the impression that a tempo is so exactly right that the least change could only be for the worse . . . What we mean is that the interpretation pleases us so well that none could please us better; and that for this interpretation the tempo is exactly right.'
> (Donington, 1974)[4]

1, pp.179/80; 2, p.382; 3, p.10/11; 4, pp.382/3.

Although we probably have no mechanism guaranteeing the precise initiation or recall of an exact or satisfying tempo, relying upon objective timers when necessary, a brief internal "mental" or "physiological" rehearsal combined with the subsequent feel and address of any instrument ensures for many musicians a satisfactory and comfortable performance speed on most occasions.

The Time Element in Music

As tempo is closely related to duration it is necessary first to clarify which aspects of duration and the Time Experience are the concern of this study. With regard to musical time scales, Roederer (1973) identified three distinct areas of psychoacoustical relevance. First there is the "microscopic" time scale of the actual sound vibrations covering a range from about 0.00007 to 0.05 seconds. Then there is the "intermediate" range centred at about 0.1 second representing the time variations of the microscopic features, and concerned with transient changes such as tone attack and decay. However, it is with Roederer's final "macroscopic" time scale ranging from about 0.1 seconds upwards that we are primarily concerned. This is the area of musical tone durations, successions and rhythm.

Cooke (1964) described the three ways duration relationships or tensions function in music. They are through phrasing (staccato-legato), movement (even-jerky) and, most fundamentally, tempo (slow-fast). He remarked that it may seem strange to define tempo as a function of duration, but it is obvious that a slow tempo is created out of successive beats of long duration and a quick tempo out of short beats. When the beats "take their time" the tempo is slow. These three duration tensions may well be interrelated and it is further suggested by the writer that musical durations longer than the beat are also significant for tempo. Sustained "filled" notes or unfilled "rests" are rarely free from a feeling of movement and progression, and the durations of rhythmic units, bars, phrases and even longer periods may be important but less conscious factors. A musician could therefore have rhythmic, cadential or other temporal "goals" for which he "aims" with his tempo. Indeed, related to this, evidence will be given later that some musicians have an unconscious duration control over whole movements or works.

Roederer rightly complains that the physics of music for more than a century has been almost solely preoccupied with the "microscopic" end of musical durations. The present writer is also only too aware of the meagre literature directly supporting his study. Nevertheless, it is hoped to show that the previous extensive investigations of the Time Experience are of interest in relation to Musical Tempi. This interest is particularly centred on the numerical data in Time and Rhythm Psychology concerned with limits, sensitivity, estimation and preference. In this respect, the data concerning both very short and longer durations, filled and unfilled intervals are equally relevant.

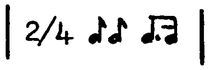
Definitions

A number of terms to be extensively used in the study need to be defined. Although some of the following definitions could be disputed, or are arbitrary, they will be consistently applied by the writer to his own thinking and experimental work.

Pulse

To avoid confusion in both the physiological literature and the writer's experimental data, this term has been reserved solely for use in connection with the heart beat.

Beat

The unit of musical movement which, if interpreted by a conductor would give the most comfortable beating speed, and therefore closely related to Tactus. However, because of the hierarchical nature of the musical mensural system, ambiguity can arise between the basic elements of note value, beat and bar. Although the beat is usually, but not necessarily, given by the time signature, it is not always represented by the most common note value, and it is even possible for the prevalent note movement to be faster with a slow beat than with a fast one. Internal musical factors and particularly the tempo are therefore inseparable from any consideration of the beat. For example,  at a slow speed and with frequent chord changes will certainly be felt to have a quaver beat.

Nevertheless, although simultaneous different interpretations of the beat unit are sometimes possible, and that, given a choice, a smaller number of beats is generally to be preferred, the writer has avoided any ambiguity in the experimental programme by using music with an unequivocal crotchet beat movement.

Tempo, Speed, Rate or Pace

These terms are variously applied to the frequency of the musical beat, heart pulse or other modes of movement or activity. With regard to music, it seems, as Sachs (1953) suggests, that tempo applies to two different concepts. One, the real, physiological tempo, varies within the limited range of feasible steps and beats. The other is psychological and more a mood than tempo, to which the Italian speed words such as adagio and allegro apply. However, it is with the physiological tempo, the speed of the beat as defined above, that this study is concerned.

Metre

As the term Time is going to be used only in its general sense, Metre is to be regarded as a synonym for Time (Signature). Unless specifically mentioned, the additional implications of rhythmic or poetic metre are not intended.

Rhythm

Musicians rarely agree as to the definition of Rhythm. Sachs (1953)[1] puts it well:-

> 'What is Rhythm? The answer, I am afraid, is, so far, just - a word: a word without a generally accepted meaning. Everybody believes himself entitled to usurp it for an arbitrary definition of his own.'

Sachs goes on to give a masterly and comprehensive survey of all aspects and shades of meaning associated with the term. Essentially, however, the writer believes just two main concepts are involved, an elementary and more subtle related one:-

(a) The proportional relationship and tension between a regular underlying explicit or implied metre and the actual note values used. Where no regular beat is present, as in some contemporary music, the same principle perhaps may be applied to any three successive musical events, two events establishing a momentary standard to which a third can be related.

(b) The feeling of movement and progression towards a "goal", whether that movement is explicit as in the dance or implied in musical momentum. The writer suggests there is an hierarchy of "goals" from the beat, metrical accent and phrase end through to longer-term and more unconscious "goals".

Unless otherwise indicated, the writer will use the term in the former elementary sense, although the latter definition acknowledges the possible importance for tempo of the duration of longer musical units. Unfortunately, in the literature it has often been used loosely with various psycho-physical connotations or as a synonym for regular pulsation.

Preference

It will not be appropriate here to anticipate either the full discussion of this term in Chapter 4, where it is also considered in

[1] 1, p.12.

relation to "Choice", or the specific definition later given in relation to the Main Experimental Programme. In the literature a simplistic view is taken, with an emphasis on broad general preferences based on much averaging of individual data in both Psychophysics and Movement. There has been comparatively little regard to more precise individual preferences and differences, and certainly no previous author has discussed questions such as the relationship of performing and comparison preferences, objective and subjective preference, precision, consistency and variation of preference, and, most fundamental of all, the definition of "Preference" itself.

Other Terms used in the Psychology and Movement Literature

Where possible, the terms used in the literature have been standardised whatever the original author's terminology. Duration will be used consistently for single filled or unfilled intervals, Tempo in relation to multiple intervals in succession, movement or pulsation, and Time always in its general rather than tempo or metrical connotations. Rhythm however, in the literature of Time Psychology and Movement, invariably refers to rhythmic action, reaction or response, and is often a purely psychophysical concept as opposed to the writer's musical definition. A related term, the Rhythmic Group, much used by some writers, describes a group of notes comprising an accented note and one or more unaccented ones.

In both the literature and the writer's original work the same distinction is made between Physical and Physiological. The former will refer only to the overtly mechanical aspects of the body and particularly its dimensions and movements. All other activity, from the fundamental electro-chemical neural processes to the heart pulse and respiration will be termed Physiological. "Universal" will refer to any identical and unvarying parameter common to all mankind, "General" to a less rigorous or precise common similarity between subjects, and "Personal" to the unique characteristics of one individual.

Data

Musical tempi and the psychophysical and movement data for both single durations and tempo will be given either as the duration of one beat (in msecs for all small values), even when originally published as a rate, or, where appropriate, as a metronome rate (MM). This consistency will facilitate comparison between the different types of data and the writer's experimental results. It must be pointed out, however, that in the literature the different methods often used in ostensibly determining identical parameters may have influenced the results and make comparisons less valid. In addition, the method of determining the tempo in the writer's experiments, by dividing a total duration by the number of beats contained in it acknowledges the role duration, as opposed to rate, may play in controlling tempo.

In the graphical presentation of the writer's results the simultaneous use of both a duration and MM scale will make their equivalence clear.

Brief Literature Survey

Even allowing for a very varied and undefined use of the term "Preference", there has been comparatively little previous research and certainly no extensive specialist experimental study based on the performance of music. Previous authors have usually held one of two views with regard to "Preference": C. Seashore (1899), Wallin (1901), Miyaki (1902), Stetson (1905), Patterson (1916) and Braun (1927) are among those who assumed one general tempo preference in their work, while Wallin (in 1911), Farnsworth (1934), Harrell (1937) and Hiriarteborde (1954) held that each individual has a preferred speed for different rhythmic groupings. A detailed survey of previous work will be included later.

Early Speculation

The writer was aware that much of the work cited above, together with most of the psychophysical experiments has been concerned with the simple tapping of a telegraph key and not with real musical listening or performance. In the world of practical music any investigator must face the fact that the same piece can be successfully performed at many different speeds both by the same and by different musicians. As a result, no simple view of preference, similar to either of the above is ever here entertained. Only an hypothesis implying that any preference is individual, complex and variable would seem consonant with common sense and musical practice. Certainly an unqualified individual or general tempo preference does not exist, unless a very broad range of tempi can be defined as a single preference. The writer then has always been principally concerned with any precise preferences, individual differences and the reasons for tempo variations rather than with obvious general broad similarities or differences.

This study is based on the premise that tempi preference is an individual matter, with many factors contributing to the tempo initiated by a musician in any situation. It was not until the Pilot Experiments and continuing speculation however that the potential range of possible tempo affecting factors became apparent. Any variation in the musical or performing circumstances appears likely to affect tempi, and it is further suggested that more fundamental psychological and physiological factors, together with movement speeds, may be the ultimate foundation of musical tempi. The working hypothesis for the study and experimental programme may now be stated:

Working Hypothesis

Within the broad range of speeds appropriate for any total musical situation, a musician has one or more relatively precise discrete preferences. These change consistently when any individual, musical or performing factors are varied.

Although a precise preference must have finite limits, it must not be too wide or the term becomes meaningless. In any case, precision of preference, like the closely related concept of "same speed" will depend on timing accuracy, scale interval used and other statistical matters. As appropriate definitions of both "same speed" and "preference" are integral with the above hypothesis, their future discussion assumes great importance.

The writer is therefore postulating that a musician, even in free rhapsodic pieces or movements or works requiring many tempo changes, is more likely to perform any section of settled speed at one of his more or less precise "preferential" tempi than at other speeds. He further suggests that in addition to satisfying musical and performing criteria, a musician's movement possibilities are determined by psychological or physiological mechanisms making such tempi either unavoidable or more likely. For many reasons to be discussed later, there is no suggestion that the same speed or "preference" is always performed in given circumstances, or that an apparently spontaneous initial tempo may not be regretted. In addition, as any individual "preferences" have to be reconciled in an ensemble situation, any concept of preference must include the possibility of its being modified.

Outline of Content

Part A - Background Literature and Speculation

As the study breaks new ground, it is necessary in Chapters 1-3 to indicate for the first time the extent and variety of the possible areas concerned with tempo. In addition to Music and associated fields, those areas must come from among the disciplines of Time and Rhythm Psychology, Physiology and Movement, particularly the numerical data, preferences and periodicities. These first three chapters therefore attempt to identify and discuss those topics that are likely to form the background, originate, control, affect or are related to musical and other tempi directly or indirectly.

With the time and space available, the literature of the related fields could not be treated thoroughly in every case. With some topics a comprehensive historical survey has been attempted, but in others only a brief summary of the latest position or a selection of views is given.

Chapter 4 discusses the possible role of these Psychological, Physiological, Movement and Musical Factors in Tempo "Choice" and "Preference", and in Chapter 5 the very limited specific experimental literature of Preferential Tempi is supplemented by general literature and views on both this and many other aspects of musical tempi. Part A therefore puts the writer's experimental work into perspective.

Part B - Experimental Work

The second part, dealing with the experiments, also includes the discussion and final definition of crucial terms such as "same speed" and "preference" itself. It is necessary to point out at this stage that although a very wide range of tempo-affecting factors will be suggested in Part A, the Main Experimental Programme is concerned solely with a selection of the musical or performing variables detailed in Chapter 3. Originally, with a very limited vision of the scope of the task, and before the full variety of tempo-affecting variables was realised, the writer envisaged a comprehensive experimental programme in which preference was to be investigated in the context of all the metres and common rhythmic substructures. When it was seen that metre and rhythm although crucial, were but two of a very large number of factors affecting tempo, it was decided to make that factor a constant by using just one specially composed basic melody for the Main Experimental Programme, and to observe tempo and tempo variation in the context of a limited selection of other variables from the speculative list given in Chapter 3.

Within the limits imposed by the arbitrarily selected music, performing methods and situations, the writer has investigated performing tempi from the points of view of preference generally, discrete preferences and the factors causing significant preference variation. Although the results will be discussed in relation to the Working Hypothesis, it must be admitted that the study completes but a small fraction of the total project implied by the title and theoretically developed in Part A.

Because of the extreme demands on time and patience made by the experiments in the Main Programme, the principal subject in each one was the writer. Indeed, the self-experimentation alone involved over 5,000 performances. The advantages and disadvantages of this necessary self experimentation will be discussed, although the latter were remedied to some extent by much retesting and many confirmatory experiments with a music colleague and a number of students taking music as a second main subject in a college of physical education.

Brief Summary

PART A Background, Literature and Speculation

Chapter 1 Time and Rhythm Psychology

- The Experience of Time
- Unitary Duration
- Duration Indifference Interval, Limen and Weber's Law Application
- Tempo Indifference Interval, Limen and Weber's Law Application
- Tempo Absolute Indifference Interval
- Possible Internal Clocks
- Duration and Tempo Estimation Factors
- Preferred Tapping Rates (By Comparison)
- Subjective Grouping
- The Nature of Rhythm
- Rhythmic Perception Theories
- Rhythmic Imagery

PART A

BACKGROUND, LITERATURE
AND
SPECULATION

CHAPTER ONE

Time and Rhythm Psychology

This chapter will attempt to place the study in the wider context of Time and Rhythm Psychology, including research and views in the relevant psychophysical areas. Because of the close relationship already established between duration and tempo the writer believes he is justified in including the data for both single and multiple duration experiments.

The first experimental work in psychophysics was undertaken in Germany during the latter part of the nineteenth century, and many of the early experiments there and elsewhere may be criticised for their primitive apparatus, unscientific methods and sometimes facile interpretation of results. It has already been remarked in the Introduction that the different methods often used for determining the same parameter also make much data suspect. For example, one may cite the contrasting methods in psychophysics involving comparison or reproduction, filled or unfilled intervals, single or multiple stimuli and absolute or relative overestimation. However, as so many fields have to be covered, practical considerations of space, clarity and time demand that the data be shown uncritically in most cases, without details of methods or numbers of subjects employed.

Another general criticism of much published data is that they are either averages masking wide individual differences, or merely ranges occupied by different individuals. This criticism is particularly relevant in relation to a study primarily concerned with precise individual preferences. Despite this, however, the data are usually presented uncritically in tabular form in order that any general trends of agreement and relationships, both within and between different parameters and subsequently with the writer's results, may be the more easily observed.

There are two more weaknesses that must be mentioned. These weaknesses, inherent in all psychophysical research, and indeed in the writer's own experiments, have been well put by Roederer (1973)[1]:-

> '1) Repeated measurements of the same kind may condition the response of the psychophysical system under observation: the brain has the ability of learning, gradually changing the course of response probability to a given imput stimulus, as the number of similar exposures increases.
>
> 2) The free will of the subject under study and the consequences thereof, mental or physical, may interfere in a highly unpredictable way with the measurements. As a consequence of the first point, a statistical psychophysical study with one single individual exposed to repeated "measurements" will by no means be identical to a statistical study involving one single measurement performed on each one of many different individuals. This difference is due not only to differences among individuals, but also to the conditioning that takes place in the case of repeated exposures. The ultracomplex feedback systems in the nervous system make psychoacoustical measurements particularly tricky to set up and interpret. The consequences of point (2) may be even more far-reaching, particularly for investigations about the role of the conscious self.'

Unfortunately the large number of musical performances required for statistical significance have to be contrived in experimental situations where some degree of self-consciousness and artificiality is unavoidable. Waiting for natural or concert performances to occur in sufficient quantity is quite out of the question.

The Experience of Time

There have been many and varied views on the nature of time and the time experience. Several of the following selection appear to have some relevance to the notion of "reaching out" for a musical temporal "goal".

Bergson (1922), Kleist (1934) and Delay (1942) in their different ways made a distinction between objective time lived and subjective time or protensity. Curtis (1916) found evidence that tones can be taken in either one of two ways, - either as static "length" or moving "progression":-

> '... the sensation has length only in retrospect, has length only after it is over, while it has progression while it is going on.'

Fraisse (1964)[2] took a rather similar view:-

> 'We become conscious of duration through our feelings of time, which are fundamentally the awareness of an obstacle: the interval between what we are doing and what we should like to do

1, p.10; 2, p.12.

> in the near future. We evaluate this duration directly from the number of changes we noticed taking place within it.'

Musicians will generally agree that long notes or rests have a very strong element of progression and movement within them. As the writer is predisposed towards a view that tempo is controlled by the duration of periods longer than the beat, the quotation from Fraisse is particularly interesting; 'What we should like to do in the near future' being the musical "goal" governing our tempo. We may be more conscious of the "going" but it is the "arrival" point that is crucial.

A more literal view of time as movement and progression was taken by Munsterberg (1889), who aimed to found all time phenomena on physiological processes. Many authors have taken a similar view and they will be referred to later in other sections. Others have had a concept of time as a discrete variable, and this will be dealt with under the next heading.

If an individual absolute unit of duration exists, and maximum and optimum as well as minimum perceptual units, then there are decided implications for all activities in which a choice of duration is involved.

Unitary Duration

This and very similar concepts have been given a variety of names by different authors. One family of terms also includes Specious Present, Psychological or Perceived Present, Compass of Consciousness, Temporal Span of Attention, Wave of Attention and Temporal Unity. Much experimental work has been concerned with the upper limit of Unitary Duration, and a very good definition under this last heading is given by Woodrow (1951):-

> '... the maximal time over which may extend a temporal stimulus pattern, the successive parts of which are perceived as a whole, possessing a unitary property of duration.'

The basis of much experimental work in this area has been the duration of the rhythmic group or unit. For example, both Bolton (1894) and Arps (1909) relate rhythmic grouping to a "Wave of Attention" or similar expression. It may be that an individual's maximum acceptable duration for a musical beat, metrical group or measure is related to this concept of an

Upper Limit of Unitary Duration.

The markedly different results shown below are probably due to ambiguity of the meaning of "unity", and to the various methods employed in obtaining the data:-

	Method Used	Upper Limit of Unitary Duration
Dietze (1885)	Max. no. metronome beats equated by cf	12·0 secs
Wundt (1886)	Max. no. impressions distinguished as united cluster	3·6-6·0 secs
Bolton (1894)	Limit of group length condusive to subj. grouping	1·58 secs
Meumann (1894)		4·28 secs
Kastenholz (1922)		2·3 secs
Quasebarth (1924)	Using continuous tones	c. 5·0 secs

Both Pièron (1951) and Fraisse (1964) were of the opinion that the Psychological Present is limited to about 5 seconds, the latter adding that the longest bar of music was about that duration. More often, however, Fraisse considered our "present" consisted of only 2 or 3 seconds.

A possible preferential Unitary Duration has not been the concern of most investigators, although Bolton (1894) found that when Ss listened to equal sounds at various intervals they grouped in such a way that the preferred length of each group remained relatively constant at a little over one second. Patterson (1916) suggested there were unitary pulses of subjective time of about 700 msecs with their origin in walking speed. Pieron (1951) also referred to a "normal" and satisfying unit of psychological time, agreeing with the pulse and certain motor activities, stating that although it differed according to the sensory conditions and between individuals, it was usually a little less than one second. However, the writer has not thus far found any relationship between this value and musical tempo preference. Preferential Unitary Duration will appear indirectly again later in connection with other topics such as Subjective Grouping.

The lower limit has received more attention, and this too has been given different various names for perhaps rather different concepts. Stroud (1956) had a concept of time as a discrete variable and believed that the experimental data suggested that 100 msecs was the duration of the temporal unit or moment. Oatley and Goodwin (1971), referring to the considerable number of investigations concerned both with the Perceptual Moment and the similar but all-embracing Psychological Moment, give the following helpful definition of the latter:-

> 'There is perhaps some minimum time for an event, decision, a percept or a motor output, and everything happens in integral numbers of these quantal events, or psychological moments.'

Ornstein (1969), like Stroud, also comments on the appearance of the 100 msecs figure in much previous work, and although most of the evidence is in favour of this figure, White (1963) and Pièron (1951) referred to a "Psychological Instant" or "Point of Time" with a value of only 10 msecs. Sanford (1971), after quoting much work that seemed to confirm the existence of a discrete processing period of about 100 msecs, nevertheless came to the conclusion that much more research was required before a quantal model of perceptual imput could be accepted. The matter will be raised again in connection with a possible Internal Clock.

Duration Indifference Interval, Limen and Weber's Law Application

The Indifference Interval (II), Point (IP) or Zone (IZ) is where sensory sensitivity to change is greatest, and therefore where judgement is most accurate. By definition therefore, the difference limen, threshold, least perceptible difference or just noticeable difference (jnd) is smallest at this point. Weber's Law states that the difference limen is proportional to stimulus intensity or quantity, with the obvious corollary that if it applies consistently to all durations there can be no Duration Indifference Interval. This law became the basis of Fechner's famous psychophysical relationship in which the strength of a sensation is proportional to the logarithm of the stimulus. Some writers appear to regard the two laws as one and refer to the Weber-Fechner Law.

Because the duration we can most accurately estimate or reproduce may also be related to the duration we "prefer", the many determinations of the Duration Indifference Interval are now given:-

Höring(1864)		between 365 and 454 msecs
Mach(1865)		c.400 msecs
Vierordt(1868)		3·0 — 3·5 secs
		1·4 secs
		1·5 secs
Kollert(1882)		755 msecs
Mehner(1884)	[Note: All intervals odd multiples of lowest one]	710 msecs
		2·15 secs
		3·55 secs
		5·0 secs
Estel(1884)	[Note: All intervals multiples of lowest one]	755 msecs
		1·5 secs
		2·25 secs
		3·0 secs
		3·75 secs
		4·5 secs
Mehner(1885)		5·0 secs
		2·8 secs
		7·5 secs
Thorkelson(1885)		1·5 secs
Wundt(1886)		720 msecs
Glass(1887)	[Found IIs on a 1·25 secs periodicity, although this value not an II itself]	
Nicholls(1891b)	[Ave. value, great indiv. diffs.]	810 msecs
Shaw and Wrinch(1900)		from 175 to 250 msecs
McDougall(1902b)	[Reported II periodicity in multiples of 375 msecs in previous work]	
Stevens(1902)		between 2·4 and 3·7 secs
Wrinch(1903)		1·5 secs
Katz(1906)		600 msecs
Kahnt(1914)		500 msecs
		700 msecs
Kastenholz(1922)	[Found four IIs between 100 msecs and 3·0 secs]	
Quasebarth(1924)		between 2·0 and 4·0 secs
Hulser(1924)		1·8 secs
Dashiell(1928)		between 700 and 800 msecs
Bonaventura(1929)		350 to 400 msecs
		700 to 800 msecs
		2·15 to 2·5 secs
Woodrow(1930)		600 msecs
Woodrow(1933)		600 msecs
Woodrow(1934)		600 msecs
Blakely(1933)		700 msecs
Stott(1935)		920 msecs
Gebhard et al(1955)		200 msecs
Fraisse(1964)		600 to 800 msecs
Michon(1964)	[Commented on number of times II of approx. 700 msecs had appeared in previous work]	

Despite the different methods used in its determination there is a quite extraordinary consistency in most of the above results. Not only does the area around 750 msecs appear with remarkable frequency but many authors have produced data or have commented on the fact that there is a series of Indifference Points involving multiples of either 750 or375 msecs.

The difference limen at this point of maximum sensitivity has been found to vary considerably between individuals and has been given a wide variety of general values. However, most determinations have been in the 5 to 12 per cent range. Woodrow (1930), for example, gave a minimum of 7.8 per cent at his 600 msecs [illegible] Indifference Interval, rising in both directions to 10.3 per cent at 200 msecs and 8.6 per cent at 1.0 seconds.

Piéron (1951), relating the IP to the parameters of Unitary Duration, stated that durations between the Psychological Instant of 10 msecs seconds and the IP were usually overestimated, and those between it and the Upper Limit of Unitary Duration similarly underestimated. The great weight of experimental evidence certainly supports this, although Doehring (1961) suggested that this view and judgements generally were often suspect and greatly influenced by the various experimental procedures.

With regard to the Weber Law, most writers have taken the view that it does not hold for perceived duration (Mach, 1865; Vierordt, 1868; Estel, 1884; Mehner, 1884; Stevens, 1902; Bonaventura, 1929; Blakely, 1933; Stott, 1933; Woodrow, 1934; Henry, 1948; Maack, 1948), although Fechner (1860) and Treisman (1963a) were of the opposite opinion. The Literature therefore appears to give little evidence of any proportional relationship between size of limen and duration length, even discounting the minimal values around the II. It is interesting to note that Stevens et al (1941) proposed a quantum theory of discrimination in loudness and pitch, but not in duration. Miller and Garner (1944) also found evidence that loudness discrimination is quantal in character.

Tempo Indifference Interval, Limen and Weber's Law Application

The Tempo Indifference Interval has been variously determined as follows:-

Stevens (1886)	[Between 530 and 870 msecs]	ave. 710 msecs
Wundt (1886)		c. 750 msecs
Meumann (1894)		550 msecs
Benussi (1913)		360 msecs 720 msecs
Harrell (1937)		between 330 and 500 msecs
Pollack (1952)		c. 110 msecs
Mowbray et al (1956)		c. 110 msecs
Michon (1964)	[Commented on number of occasions both his values had appeared in previous work]	c. 110 msecs c. 600 msecs
Fraisse (1964)	[Believed 700 msecs area significant]	
McLaughlin (1970)	[Commented that II often in region of 600 to 800 msecs]	

As in the case of Duration, figures of the order of 700 and 110 msecs frequently occur, and the respective correspondence between Patterson's "Unitary Pulses of Subjective Time" and the Perceptual Moment must be noted. Fraisse (1964)[1] offers an explanation for the prevalence of the former figure:-

> 'It is far more likely that all these phenomena correspond to an optimum rhythm for successive associations in the nervous system. Walking, heartbeats, movements effected at a spontaneous tempo, and perceptions all follow on at intervals of about 700 msecs seconds, which we consider to be the optimum interval for the functioning of the nervous centres because it is the most economical.'

Evidence certainly seems to be mounting in respect of the psychological significance of the 600 to 800 msecs area, and possibly also the simple fractions and multiples thereof. It will later be shown that its MM equivalent has also been of significance for musicians, although the experiments and current musical practice suggest it may not be so today.

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[1] p.128.

The difference limen has again been given generally less consistent values than the Indifference Interval, although Dunlap (1912), in giving 2 and 3 per cent thresholds for two arbitrary rates agrees with the more recent and reliable figures of Michon (1964) who gave values of approximately 1 and 2 per cent respectively for his Indifference Intervals of 110 and 600 msecs. This order of sensitivity also accords well with the writer's own data. In a more practical and directly relevant experiment Binet and Courtier (1896) found that a pianist repeatedly playing a scale of five notes could make a progressive increase of the duration between the notes with a precision of the order of 10 msecs. Piéron (1951) stated that sensitivity to tempo change was much more acute than the discrimination of isolated durations. He added that motor adaptation makes it possible to reproduce tempi with high accuracy, especially when the frequency is near a certain optimum which differs between individuals, quoting Feigel's (1934) experiments where the mean variation was less than 2 per cent for a tempo of MM60.

Although he was concerned with rhythm and not tempo, it is worth noting here that Wallin (1911) was of the opinion that rhythmic limen were not sharp lines like duration thresholds, but extents within which we perceive no rhythmic change. He stated that the breadth of the limen varied with individuals and was wider for slower tempi. Hickman (1968) also found that insensitivity to rhythm was greatest when the pitch was lowest, and this, too, agrees with the general musical experience that rhythmic detail tends to sound blurred at lower pitches.

There is further evidence that Weber's Law may be more applicable to tempo than to single durations. Harrell (1937) asserted it held for at least part of the range of intervals above 1.0 seconds, and Treisman (1963a) again considered that it held, for constant, as well as single stimuli. In addition, the writer's results suggest it may apply also to tempo sensitivity in performing as well as passive situations.

Finally, most workers have found that intervals below the Indifference Point have been overestimated and intervals above underestimated. The possible effect on musical tempi of the various conflicting and compensatory factors arising from this and other psychophysical phenomena will be discussed in later chapters.

Tempo Absolute Indifference Interval

This is defined as the "normal", "neutral", "satisfactory" or "comfortable" tempo compared with which all other tempi are either subjectively fast or slow. It may well be equated with the optimum or preferential Unitary Duration, and indeed, the following authors do not all make it clear if tempo and not duration is employed in determining the data:-

	'SLOW'	'NEUTRAL'	'FAST'
Vierordt(1868) averages:	1·07 secs	640 msecs	420 msecs
Katz(1906)	250 to 550 msecs	600 to 650 msecs	over 650 msecs
Benussi(1907)		580 – 630 msecs to 1·08 secs – 1·17 secs	
Frischeisen-Köhler(1933) [according to S]		550 to 830 msecs	
Abe(1935)		750 to 3·4 secs	
Woodrow(1951) [Observed it tended to be close to 600 msecs]			
McLaughlin(1970) [Stated it had been previously found to be between 630 msecs and 1·2 secs]			

Although the two types of Indifference Interval are not necessarily related, the quotation by Fraisse (1964) in the previous section could also be considered an explanation both for the Absolute Indifference Interval and the continuing appearance of the 600 to 800 msecs region in the "Neutral" column. Piéron (1951) certainly identifies his "normal and satisfying" psychological unit with the area of maximum fineness of discrimination.

McLaughlin (1970) relates the above data to our acceptance of a normal tempo of approximately MM80 - the metronomic equivalent of beat durations of 750 msecs. This concept of a musical "normal" tempo will be examined at length in Chapter 3.

Possible Internal Clocks

The possibility of there being an internal duration measuring mechanism has already been hinted at in connection with Unitary Duration. Various internal "clocks" have been postulated including breathing, heart rate and other physiological processes (Meumann, 1894; Munsterberg, 1889; Stevens, 1902, McDougall, 1902a; Scripture, 1902; Piéron, 1923 and Ochberg et al, 1964), "neural processes" (Bock, 1919; Dimond, 1964), alpha rhythm (Mundy-Castle and Sugarman, 1960), chemical (Hoagland, 1933) and cellular metabolism (Bünning, 1967). In addition, Treisman (1963b) has proposed a model for the internal "clock" based on a pacemaker, counter, store and comparator which would explain the Indifference Interval, Weber Function and the overestimation and underestimation of short and long intervals respectively. Further, the 100 msecs "Perceptual Moment", the 700 msecs "Unitary Pulse" and other parameters in Time Psychology are also likely to be related to any internal "clock", which in turn may have its origin in the fundamental periodicities to be considered in Chapter 3.

Subsequent workers have given little support for a clock based on breathing or other functional periodicities. Gardner (1935), Schaefer and Gilliland (1938) and Bell and Provins (1963) between them found no significant relationship between pulse, respiration, blood pressure or metabolic rate and estimation. Weld (1912) drew attention to the importance of making motor responses, but Harrell (1937) reported that accuracy was not affected by inhibiting sympathetic rhythmic movements, and Renshaw (1932) in fact found that making movements or counting resulted in poorer judgements than immobility.

There has however been considerable support for Hoagland, who postulated that our judgements in varying from day to day may depend on the velocity of an internal chemical "clock"; time appearing to pass faster with a higher body temperature. Baddeley (1966), Lockhart (1967) and Fox et al (1967), all raising the body temperature artificially like Hoagland, Francois (1927) and Pfaff (1968), employing the natural circadian temperature variations, and Bell (1965) all found that higher temperatures were associated with faster reproduced speeds or overestimation of duration. Further indirect support comes from Frankenhauser (1959), who observed that caffeine also caused overestimation.

Colquhoun (1971), while agreeing that most of the evidence supported this relationship, did however mention the work of Thor (1962), whose findings seemed to point to the opposite conclusion, and Blake (1971), who found no consistent trend at all.

The possibility of individual alpha frequency being the measuring rod for duration estimation has received comparatively little support. Sanford (1971), summing up the experimental evidence, stressed that general metabolic factors may be operating to cause both alpha activity and time estimation changes. He does however quote research that suggests that the alpha frequency may sometimes be related to performance, a matter to be dealt with further in Chapter 2.

Whatever the nature of any internal "clock", there is nevertheless considerable evidence that an increase in body temperature is associated with an acceleration of both perceptual and movement parameters, and as Fraisse (1964) points out, because all physiological periodicities, both innate and induced, are governed by the same temperature relationship, their regulation mechanisms must be similar. Many musicians, including the writer, have noticed an apparent relationship between higher body temperature and faster tempi. Whether this relationship is simple cause and effect, dependent upon a common additional factor such as nervousness or increased pulse rate, or due to an acceleration of a more fundamental "internal clock" has not been investigated, although Hoagland and Perkins (1935) did establish that any chemical clock was independent of pulse rate. An important additional point is that body temperature and other parameters not only change because of medical, psychological or environmental causes, but are also subject to endogenous fluctuations both Circadian and otherwise. This is particularly relevant, both for any "clock" and for the writer's experimental programme where the performances take place over several years, and will be dealt with more fully in Chapter 2.

Duration and Tempo Estimation Factors

The interrelation between duration and tempo has already been much commented on. This inability to separate the two may also be seen in many of the experiments supposedly concerned with one or the other. For example, the experiments in which stimuli or reproductions involve single durations, the two clicks bounding the empty durations or the beginning and ending of the filled durations are successive events that may be regarded by the subject as a momentary "tempo". Thus, the factors that cause a single duration to appear longer or shorter may well have the same effect on durations in succession.

It is generally agreed that the attitude of the subject is important in estimating duration (eg Woodrow, 1930 and 1934; Fraisse, 1964) and in particular that the greater the attention paid to an interval the longer it seems (Katz, 1906; Quasebath, 1924; Fraisse, 1964). Falk and Bindra (1954) found that a stress situation, caused by the possibility of an electric shock, produced overestimation, and that overestimation decreased gradually in estimating the same task several times in succession. It is worth recalling here the reservations expressed at the beginning of this chapter by Roederer (1973), concerning the possible weaknesses inherent in any psychophysical experiment involving repeated judgements or performances.

Opinion is divided as to whether there are sex differences in time estimation. McDougall (1904), Yerkes and Urban (1906) and Axel (1924) believed that women overestimate duration more than men, but more recent work suggests either the reverse (Harton, 1939), or that there is no difference between men and women in this respect (Gilliland, 1943; Smythe and Goldstone, 1957).

With regard to the effect on tempo estimation of changes in experimental stimulus or response, there is agreement that listening to or reading a text seems longer than writing it (Yerkes and Urban, 1906; Spencer, 1921; Swift and McGeoch, 1925), that more intense sounds seem longer (Needham, 1935; Olèron, 1952; Hirsch et al, 1956), that higher sounds also seem longer (Cohen et al, 1954) and that changed ambient conditions such as different noise levels appear to affect apparent duration (Hirsch et al, 1956; Hawkes et al, 1960).

Meumann (1894) noted that empty intervals delimited by more intense sounds seem shorter, while Triplett (1931) found that delimiting an empty interval with sounds of higher pitch made it seem longer. McDougall (1903), when introducing a loud sound into a uniform series, caused an underestimation of the interval following and also often a lengthening of the preceding interval. In his work with children, Thackray (1969) observed that his subjects tapped louder and softer respectively when asked to tap fast and slow beats, another case where faster is equated with louder and vice versa.

The effect on apparent duration of dividing the interval to be estimated or adding some kind of interpolation has also been considered. In the first case the procedure is akin to the rhythmic subdivision of musical beats and any consistent data must be of interest. However, although Benussi (1913) found that divided filled intervals appeared shorter than empty ones, Wirth (1937) came to the opposite conclusion. Grimm (1934) observed that evenly divided intervals seemed longer than irregularly divided ones, while Anderson and Whitely (1930), working with intervals filled with either rhythmic or non-rhythmic interpolation discovered that the latter were judged longer. Dewolfe and Duncan (1959) came to the conclusion that the more unified the activity the more the duration was underestimated.

Finally, the question of anchor effects must be considered. Both Postman and Miller (1945) and Goldstone et al (1957) found that a reference duration affected estimation of the duration of other stimuli. Miles (1937) noted that in some cases the immediately preceding performance had a predictable effect on the "most satisfactory" rate. Thus this section ends with further evidence that the experimental situation itself must always be taken into account when interpreting any results.

Much of the above will prove to be of interest in Chapter 3 when considering the Structural and other Musical Factors likely to affect tempo. It will also later be shown that the tempi in parallel experimental musical situations behaved as predicted by two of the above findings.

Preferred Tapping Rates (By Comparison)

The data below has in most cases been obtained by subjects preferring metronome rates or clicks in paired comparisons:-

Vierordt(1868)	'Neutral Tempo'	ave.	640 msecs
Wundt(1886)	Optimum interval of succession		300 to 500 msecs
Meumann(1894)	'Preferred Tempo'		400 msecs
Wallin(1911)	[range of 'prefs.' 305msecs-1·37secs]	ave.	519 msecs
Harrell(1937)	[No common 'prefs.' found, but most S's consistent]		

Wallin (1911) observed that subjects nearly always had a preference when comparing two tempi and from his subjects' introspection noted that the most frequent objections to slow tempi included "dragging" and "feeling of suspense", while too rapid a tempo caused "irritation", "too much effort to follow" and "ear throb". The reasons for preference may be of some relevance and they include "least irritation", "easiest to follow", "coincided with ideal beat in head", "imagined clock ticking", "machinery" and "hammer images". Harrell (1937) found that the preferred tempo could not be remembered better than any other, and, in a rather unusual investigation, Foley (1940) discovered that typists and machine operators preferred faster tempi than domestic science students, suggesting that judgements of tempi may be altered by conditioning.

The general broad agreement in the above figures with the 500 msecs region is interesting, as this value became of some significance in the writer's results. Apart from suggesting that the "neutral" column of the Absolute Indifference Interval data also represents an aspect of preference by comparison, no further observations need be made here.

Subjective Grouping

When a series of unaccented regular stimuli is presented, most subjects tend to group them subjectively and "hear" accents in groups of two, three or four, with different tempi tending to encourage a certain type of grouping. With effort however it is usually possible to force the spontaneous grouping to change. The tendency to group is sometimes so strong that it is possible to ignore objective irregular accents and make subjective regular groups instead (Valentine, 1962). Most theories proposed to account for this phenomenon consider the grouping is determined by the "Waves of Attention" previously discussed. Indeed, much of the data in connection with Unitary Duration has been obtained by using this very tendency to group subjectively. This topic, therefore, like the Absolute Indifference Interval, is closely related to the optimum or preferable Unitary Duration, and effectively links the Psychology of Time with that of Rhythm, shortly to be dealt with.

Bolton (1894) noted that the preferred group length for various rates of stimulation generally remained fairly constant at a little over 1 second, with 1.58 seconds given as the maximum possible length of the rhythmic unit. This study and several others previously given suggest that the usual Upper Limit of Unitary Duration is of the order of 2 or 3 seconds, with any optimum value probably not far from Bolton's suggested value. Because of the methods used in many cases, these figures may also represent the maximum and most favourable subjective group lengths respectively. In this connection it is interesting that Fraisse (1956) found that "rhythm" disappeared when the interval between two sounds was greater than 2 seconds.

With regard to the rate and the number of elements in a group, Miner (1903) found no relationship and considerable inter and intra-individual variations. Harrell (1937), although finding no general preferred rates for a particular grouping, noted that most individuals were fairly consistent in their choice and that on average the preferred rate and temporal length of the group increased with the number of elements in it. Again the data is not too inconsistent with Bolton's preferred group length, although the given average group lengths mask wide individual differences:-

Grouping in Twos: 630 msecs
Threes: 790 msecs
Fours: 970 msecs
Fives: 1,140 msecs
Sixes: 1,290 msecs

Harrell also noted that it was more common to group in fours than in threes and twos, and of the nine subjects in his experiment who also took part in a previous experiment by Dunlap (1934) involving preferred tapping rates in threes, only one had a tapping preference similar to the rate most conducive to a triple metre subjective rhythm.

Certain miscellaneous related observations are also of interest.

Woodrow (1911) found that pitch has little effect on subjective rhythm, and Thackray (1969) noted the tendency of long tones to subdivide in the mind in addition to that of shorter ones to group. Most musicians are also familiar with the agogic accent - the subjective stress caused by the relative lengthening of any note. The subjective metrical interpretation of an objective duple stimulus has also been studied. Wallin (1911) found the dominant subjective pattern to be the trochee and this was confirmed by Woodrow (1951) if the rate was moderately slow. In general, Woodrow noted, a regularly recurring accent exerts a group-beginning effect, whereas a regularly recurring longer duration has a group-ending effect.

The probable relationship between Subjective Grouping and Temporal Unity has already been commented on. In addition, despite the evidence of Harrell (1937), it is not unreasonable to suggest a possible relationship between any individual preferred rate for subjective grouping in twos, threes or fours and other forms of preference in those metres. This must remain an area for speculation however as Subjective Grouping played neither a direct nor indirect part in the experiments.

The Nature of Rhythm

In Chapters 1 and 2 it is to be understood that the writer, in common with most authors quoted, will use the term "Rhythm" principally in connection with response, action, regular pulsation or metrical division. If a more musical definition is intended, the text will make it clear.

As the objective aspects of rhythm and rhythmic action in response and initiation cannot really be divorced from the perception of rhythm, the division of material between this and the following section has sometimes been made arbitrarily.

Many and varied have been the statements, definitions and theories concerning rhythm:-

> 'Rhythm is an emotion discharging itself in ordered moves.'
> (Smith, 1900)

> 'Rhythm is never a fact of perception alone, but essentially involves an active attitude on the part of the apperceiving subject.'
>
> (McDougall, 1902a)

McDougall's belief that rhythmic responses were based on the primitive rate of nervous discharge has already been noted in connection with the Internal Clock, and a much more recent author extends the idea:-

> 'The rhythms tend to spread to almost every other concurrent activity. One falls in step with a band, tends to breathe and even to speak in time with the rhythm. The all pervasiveness of the rhythmic discharge is shown by the great difficulty of learning to maintain two rhythms at once, as in three against four with the two hands. The points to be emphasized here are the widespread effects of the rhythmic discharge indicating the involvement of almost the entire effector system, the concurrent action of the different rhythmic systems, and the imposition of the rate upon both the initiation and speed of movement.'
>
> (Lashley, 1951)[1]

Far more writers have taken a motor view of rhythm. Stumpf (1883) believed that our sense of rhythm was essentially developed in connection with the movements of locomotion. Wundt (1886) and Patterson (1916) also related rhythm to walking, although the latter found that in no cases was the chosen tapping rate the same as, or a simple fraction or multiple of walking or other movements. There is no doubt that periodicity is a fundamental aspect of rhythm and that regular movements in both stimulus and response contribute greatly to pleasure in music, dancing, marching and other activities (McDougall, 1902a). In this respect Oatley and Goodwin (1971) made the interesting suggestion that the rhythmic properties of music are pleasant because of their potential for entraining brain rhythms. Also, when sympathetic responsive movements are inhibited they appear elsewhere in the body or as motor or visual images (Miner, 1903). Squire (1901), however, qualifies this in a direction relevant to this study by asserting that the "natural rate of the individual" is the basis of pleasantness in rhythm. Perhaps the pleasure, efficiency and economy of effort people once found in work-songs and sea-shanties as they moved in regular unison contradicts the individual "natural rate" concept but it certainly adds credence to the following statement:-

[1] 1, p.39.

> 'The origin of rhythm as Bücher has suggested was in forms of concerted work which required blow on blow. That is possibly the genetic reason why the beat, the blow, is the primary thing in the rhythm consciousness. In all forms of activity where a rhythm is required, the stroke, the blow, the impact is the thing; all the rest is but connection and preparation.'
>
> (Stetson, 1905)

The Movement Cycle of any rhythm that Stetson goes on to describe will be discussed in Chapter 2, but the relationship of this cycle to rhythm and the Rhythmic Unit Group is however relevant here:-

> 'If the basis of rhythm is to be found in muscular sensations rather than in the supposed activity of some special "mental" function, the nature of the movement cycle involved is of the greatest interest.'
>
> (Stetson, 1903)

> 'One may say that the unit group is the form in which the various muscle-sets and segments of a limb or organ can all work together freely and easily in a single movement cycle.'
>
> (Stetson, 1905)

Swindle (1913) drew attention to the fact that biological conditions such as two hands, feet and two sides of the body generally favour the development of those rhythms usually considered instinctive, but found that groups of 5, 7, 11 and 13 could, with training, eventually be performed with as much ease and accuracy as groups of 2 or 3. His work led him to assert that rhythm is acquired, not inherited, and in the development of a rhythm the motor activity of the skeletal muscles plays the most important role. This idea is behind the following definition:-

> 'The fact that the basis of rhythm is motor response, and that this motor response is periodic in its nature, and similar to the pendulum in its movement, leads to the thesis that rhythm may be defined as the experience arising from the periodic, pendular, reflex response of characteristic organs to objective stimulation.'
>
> (Isaacs, 1920)

Both Isaacs and McDougall (1902a) noted that the stimulus rate and response rate could be independent, and Philippe (1919) found that a voluntary rhythm may be affected by the involuntary rhythms of breathing, pulse or skeletal muscles. In connection with this, Sherrington (1906), in his experiments with the dog scratch reflex, discovered that the rate of movement was also frequently independent of the stimulus.

Sachs (1953)[1] however reminds us that although rhythm and bodily motion act and react on one another, a purely motor view, in which rhythm depends directly on muscles and sinews, cannot be held:-

> 'Plato, two and a half thousand years ago, was already aware of the absence of rhythm in a narrower sense from the lives of animals, although their bodies are functionally similar to ours. Man is the first animal to dominate rhythm . . . Man does not follow a body-made rhythm in blind passivity. He himself, on the contrary, creates the law of rhythm and forces it upon the motion of his body in walk and dance, in work and play. Music and poetry accept this law to a greater or lesser degree, according to their greater or lesser nearness to bodily motion.'

Although the present writer accepts the above, agreeing that rhythm (or tempo) is not solely determined by motor processes, the experimental evidence gives some support to the hypothesis that each total motor/mechanical performing situation gives rise to a series of available tempi for every individual.

Despite the undoubted and obvious importance of periodicity in rhythm, Glyn (1934) makes the subtle point that the regularity is partly necessary in order to appreciate relationships to or departures from it:-

> 'The law of the union of strict and free form is that relations established by strict form shall be sufficiently perceptible through the inexact relations of free form.'

She also makes the interesting suggestion that there are simultaneous independent rhythms of tempo, pitch, key direction, force and colour, and also an undulatory wave-like rhythm (accelerating and retarding) that can affect them all. Further support for less emphasis on strict regularity in any definition of rhythm comes from McDougall (1902b) who affirmed that it is proportion, not periodicity, that is essential to rhythm, Wallin (1911), who considered intensity differences to be more important than absolute regularity, Fox-Strangways (1929), who asserted that rhythm is simply "flow" and a putting of two things together, Scholes (1938) with his comment that our desire to hurry and linger within a basic speed suggested life instead of mechanism, and McLaughlin (1970) who drew attention to the necessary time

[1] pp.37/8.

tensions created by disturbances of our inborn sense of tempo and regular beat division. The writer agrees with Seashore (1938) who wrote that periodicity alone in music has no rhythmic significance; it is the internal structure of the measures that creates rhythm, and the feeling of progression towards an accentual goal or the end of a phrase with its associated build up of tension on approach and relaxation on arrival. However, periodicity of some kind must be important, for where no metrical structure is objectively present we provide our own by subjectively "hearing" accents and groups. The relationship between Subjective Groups and a possible Wave of Attention has already been discussed, and the further application of any such wave to rhythm generally has been made by Wallin (1901), who suggested "mental beats" as a possible vehicle for rhythm, and Puffer (1905), who stated that musical rhythm depends on the length of the "attention wave". Dunlap (1911) made the point even more clearly by asserting that the rhythmic unit group is a short succession of stimuli which produce on us the effect of all existing together in a single prolonged moment or single "now". The rhythmic unit group of Stetson, based on the Movement Cycle, and that of Dunlap, based on Unitary Duration, may well be the physiological and psychological aspects of the same basic phenomenon.

The following writers also take a more psychological view of rhythm:-

> '. . . the impression of proportion between the durations of the several events or groups of events of which the sequence is composed.'
>
> (Sonnenschein, in Nurullah, 1927)

> 'To convey the feeling of rhythm it is necessary that the elements in a periodic succession should follow one another at such a rate that the first shall not have fallen out of consciousness before the second appears: and that the intervals of time between the two successive elements shall not be so short that the mind is unable to individualise each of the elements.'
>
> (McEwen, 1912)

Seashore (1938)[1] gave the following definition of rhythm:-

> '. . . an instinctive disposition to group recurrent sense impressions vividly and with precision, mainly by time or intensity, or both, in such a way as to derive pleasure and efficiency through the grouping.'

[1] p.139.

His list of the effects of rhythm includes several that are of interest. Rhythm:-

Favours perception by grouping.

Adjusts the strain of Attention. We acquire a feeling of ease, power and adjustment when the measure fits the attention wave.

Gives a feeling of power. It carries into the future and results in a motor attitude or projection of the self in action so that one must feel one is "acting" it - an exhibition of the principle of empathy.

Enables movements to be foreseen and even forefelt, as rhythmic periodicity is instinctive.

Stimulates and lulls. In dancing and marching, after the initial stimulation to action, there is a pleasurable adjustment and obliviousness of effort.[1]

Finally, Henkin (1955) identified two clear cut and independent factors in music - melody and rhythm, later finding them to be independent mathematically and psychologically, and Thackray (1969) in his study of Rhythmic Ability, listed eight subsidiary concepts associated with rhythm: pulse, tempo, number, timing, duration, loudness, metre and phrasing.

Rhythmic Perception Theories

Most theories may be grouped under one of three main headings. They may be dealt with quite briefly as much of the basic ground has been covered above:-

(a) Mental Activity or Instinctive Theories

Although Meumann (1894) was an early supporter, the Instinctive Theory had its most influential proponent in C. Seashore (1938), whose view is made clear in the quotation given in the previous section. Many later commentators, including Lundin (1967), consider the theory mentalistic and contrary to the facts.

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[1] Seashore(1938) pp.140-145.

(b) Physiological Theories

These stem from McDougall (1902a), who believed that rhythm must be correlated with some internal nervous or physiological mechanism for the impression of rhythm to arise. Isaacs (1920) also strongly supports the physiological theory of rhythm, and Lashley (1951), from the quotation given earlier, appears to take a similar view.

(c) Motor Theories

Supporters of these take the general view that rhythmic response is dependent on the action of the voluntary muscles, and not the involuntary physiological rhythms associated with the previous theories. Unfortunately, some authors, while supporting a motor theory, confuse the issue by referring both to motor and to physiological activity. Nevertheless, theories of this type are the most generally accepted today.

An early writer points the way towards a motor theory:-

> 'It is doubtful if a rhythm is really perceived before a certain degree of facility or skill in the movement is attained.'
> (Smith, 1900)

Stetson (1905), however, was the first to propose a Motor Theory and stated that we perceive rhythm as such because we have bodily machinery that can be trained to react. Later he affirmed that our sense of rhythm could not be explained in terms of judgements of time intervals: the conception of a rhythmic unit-group as an organised group of movements whose conditions are muscular came nearer to the facts (Stetson and Tuthill, 1923). Titchener (1910) associated rhythmic perception with kinaesthetic sensations due to contractions in the middle ear, and Weld (1912) believed the perception of any music feature was associated with minute muscular adjustment or delicate contraction, which the listener only notices after intensive introspection. Ruckmick (1913), another pioneer in the development of the theory affirmed:-

> 'Kinaesthesis was essential for the establishment of a rhythmical perception. That perception, once established however, rhythm might be consciously carried, in the absence of any sort of kinaesthesis, by auditory or visual processes.'

> 'Kinaesthesis on the accent is more intensive and is felt as strain or tension, while kinaestheis on the non-accent is less intensive and is felt as relaxation.'

Further support for the motor theory comes from Vernon (1935), who included certain Gestalt principles in his view and added that musical perception develops far more rapidly among instrumentalists for whom music is a matter of muscular performance than in those for whom music remains chiefly cognitive and emotional. Thackray (1969) who found strong support for the theory in his work with children, also noted that many physical education and dance students were inclined to perceive rhythm in a purely visual way. In addition, rather surprisingly, there was no specially high correlation between rhythmic perception and rhythmic performance.

A motor view, rather more overtly physical, was taken by Dalcroze (1921), who founded the school of eurhythmics that became popular in the nineteen twenties:-

> 'By means of movements of the whole body, we may equip ourselves to realise and perceive rhythms.'

Even he referred to physiological processes such as heart beat and respiration in connection with rhythmic responses, but his inclusion of the importance of a regular gait and voluntary movements make him one of the strongest supporters of a motor theory.

Experimental work apparently refuting the motor theory comes from Renshaw (1932). He found that subjects who sought to improve their auditory discrimination by tapping hands or feet made poorer judgements than those who remained alert yet immobile. Generally, however, it is the Motor Theory that has received the most support and this is not surprising in view of the common tendency among musicians to make explicit or implicit sympathetic movements when listening to or recalling music.

Finally, two individual points of view must be mentioned. Fraisse (1948) put forward a complex theory in which different levels of rhythmic activity are postulated, and Lundin (1967) considered rhythm was a learned response of the whole organism - hence general fatigue after a performance. He believed the response to be both perceptual and motor, with a perception of the pattern also occurring in the performance of rhythm.

Rhythmic Imagery

> 'Rhythmic features should be vividly imagined before performance.'
> (Thackray, 1969)

Rhythmic Imagery is obviously closely interrelated with the Motor Theory of Rhythm as many writers have noted the presence of explicit or implicit kinaesthesis in all forms of imagining. Colvin (1908) and Mainwaring (1933) both observed the ease with which laryngeal and other kinaesthetic processes were unwittingly substituted for so-called true auditory imagery. Jacobsen (1932) found that the same nerve impulses to muscles occurred when imagining movements as when actually performing them, and Knight (1948) observed that incipient movements of the vocal cords and tongue often accompany our mental processes. Eysenck (1947)[1] sums up as follows:-

> '. . . experimental evidence is overwhelmingly in support of the contention that an idea, or image of a movement tends to produce the precise movement imagined, or a modified form of it.'

Although Helmholtz (1877), contrary to most authors, regarded auditory imagery as a fundamental activity, the general concensus, and certainly the experience of the writer, is that kinaesthesis, explicit or implied, is a necessary component of both rhythmic and pitch imagery. As the principal subject in the experimental programme, the writer became increasingly aware of the motor aspects of rhythmic imagery in the necessary "rehearsal" before tempo initiation.

1, p.196.

CHAPTER TWO

Physiology, Personality and Movement Speeds

As a preface to the various topics under this heading it will be well to consider briefly the two very different ways they may impinge upon musical tempi. The first, to which various references will be made during the chapter, concerns the possible role played by physiological periodicities, movement speeds and preference generally in the movements of musical performance. The second relationship is more subtle, and concerns the composer as well as the performer. If it be allowed that the creative musical experience often begins as a rhythmic stirring of the body, and not just in the case of dance-based musical ideas, then it may be possible for a performer to recapture the appropriate feeling by finding the right movement. This particular thesis has been expressed best by Blacking (1973)[1], who in the following was concerned both with the music of other cultures and with past ages:-

> 'So often, the expressive purpose of a piece of music is to be found through identification with the body movements that generated it, and these in turn may have their origins in culture as much as in the peculiarities of an individual. There are so many different tempi in the world of nature and the body of man that music has endless possibilities of physical coordination with any one of them, or several of them together. Without this kind of coordination, which can be learned only by endless experimentation, or more quickly by direct aural transmission, there is little possibility that music will be felt. When we know the associated dance step, we may know whether  should be thought of as 1-2-3-123, 1231-2-3-, or 1-2-3-4, or whatever. It may be necessary to slow down one's breathing in order to "feel" a piece of Korean music, whose unique elegance and refinement are hard for a European to appreciate. A similar control of the body makes it easier to catch the innigster empfindung of Beethoven's Piano Sonata, Op 109, last movement. Just breathe slowly, relax the body completely and play - and the empfindung comes through the body. It is no longer an elusive mysterious Teutonic quality!
>
> . . . .
>
> but to feel with the body is probably as close as anyone can ever get to resonating with another person. I shall not attempt to discuss the issue of musical communication as a physiological phenomenon; but if music begins, as I have suggested, as a stirring of the body, we can recall the state in which it was conceived by getting into the body movement of the music and so feeling it very nearly as the composer felt it.'

1,pp.110/1.

Movement generally, then, may be said to have relevance both in connection with individual performing tempi and with the composer's creative impulse. The latter, as Blacking suggests, is an interesting possibility but inevitably the emphasis in this chapter will be on possible relationships between movement and musical performance.

The Physiological Effects of Music

Before considering the effect various physiological factors may have on movement speeds and musical tempi, it will be useful first to consider the reverse process. A great deal of conjecture is involved in eliciting the origins of tempi from physiological periodicities, but there is no doubt that music and musical tempi can affect physiological functions. Very few, however, would admit to being affected to the following degree:-

> 'Music causes a strange commotion of my circulation: my heart beats violently; tears usually announce the end of the paroxysm and are sometimes followed by muscular trembling, shaking of the limbs, swelling of the feet and hands . . . I see no more; I scarcely hear; giddiness and almost fainting follow.'
>
> (Berlioz, in Savill, 1958)

Many authors have studied the effect of music on our various physiological activities. It is generally agreed that listening to some music at least, particularly the more rhythmic variety, affects heart rate, most usually making it faster (Binet and Courtier, 1896; Gibaud, 1898; Bingham, 1910; Weld, 1912; Hyde and Scalapino, 1918; Diserens, 1926; Washco, 1933; Ellis and Brighouse, 1952). Blood pressure changes, not necessarily consistent, were also noticed by Hyde and Scalapino (1918), Diserens (1926) and Washco (1933). In a curious experiment by the Belgian composer Grétry (in McLaughlin, 1970), he noted that his pulse accommodated itself to his own singing tempo, getting both slower and faster as necessary. Coleman (1921), too, believed heart rate could adjust, within reasonable limits, to the tempo of an external stimulus. The most recent work, by Hunter (1970), included a concern for the effect of different kinds of music upon the interesting phenomenon of Sinus Arrhythmia, the normal slight irregularity of the human heart pulse that decreases with increased attention. She concluded that the decreased SA in predictable music suggested a higher general level of arousal in the listener.

The effect of listening to music on respiration has also been studied. Binet and Courtier (1896), Gamble and Foster (1906), Weld (1912), Diserens (1926) and Ellis and Brighouse (1952) all found that music generally caused a faster rate, while Weld and Diserens further noted that breathing became less regular. Guibaud (1898) observed that dissonances and minor keys had the greater effect on respiration, the irregular breathing thus caused becoming more regular with the return to a major key. It would certainly be profitable to study the relationship of any breathing changes or attempts to phase with musical phrasing or accentuation in both listening and performing situations. The writer was aware of regular patterns in his breathing, even during the non-breath-based experimental performances.

Changes in muscular condition have also been reported. Jastrow (1900), noted that subjects listening to metronome beats had corresponding periodic contractions in hand and arm muscles, and Hunter (1970), reported that muscular tension was often experienced in her listening experiments. Of particular interest is the work of Weld (1912), who found that attention to the beginning of a musical phrase not only affected circulation and respiration but modified the tension and equilibrium in various muscles. The resolution of the phrase led to a relaxation of these tensions, except in the case of an incomplete or illogical ending, which left an expectant attitude of muscular dis-equilibrium.

Further miscellaneous effects noted have been increased metabolic rate (Diserens, 1926) and a change in the stomach's peristaltic waves (Sugarman, 1954). Finally, the use of music to stimulate, lull or persuade must be mentioned in passing, together with its undoubted therapeutic value, where among its uses is the treatment of poor muscular coordination and the stimulation of proper breathing patterns.

Fundamental Physiological Periodicities, Circadian and other Variations

Reference has already been made in Chapter 1 to the various possible internal clocks and their relationship to Time Psychology parameters. It is not unreasonable to look for the origin of any clock, and perhaps ultimately through it, all movement speeds and musical tempi, in the fundamental elementary periodicities of the human organism:-

> '. . . the time units we use in our actions are functions of the speed of deep-seated organic responses conditioning metabolism and various vital activities such as the propagation of the nervous discharge. There is a time appropriate to the organism, of which the units are a function of the speed of the biological processes. Now this speed is essentially controlled by the temperature level, on which depends the chemical activities forming the sub-stratum of life.
>
> Within certain limits compatible with the functions of life, a temperature rise produces an acceleration.'
>
> (Piêron, 1951)

Whatever the ultimate basis of the internal clock proves to be, the evidence given in this and previous sections strongly supports Piêron's assertion that it accelerates with a rise in body temperature. The crucial timing periodicity remains a matter of conjecture, and as Solberger (1965) gave the frequency range of all the various biological rhythms as extending from 2,000 cps to one per day, month, year and even longer, it is obviously far beyond the scope of this study and the writer's competence even to identify all such periodicities, let alone to do more than speculate on the identity of the fundamental timing source. However, without denying the possible prior importance of other perhaps more fundamental periodicities, it will be realistic to concentrate on the one that has not only received the most attention, but is also one of the more likely candidates; namely the alpha frequency. This, the first of the so-called "brain waves" to be identified, was found by Berger (1924). Subsequently, further periodicities in the brain's electrical activity have been observed, Grey Walter (1953) classifying them as follows:-

Delta	frequency	0.5 - 3.5 cps
Theta		4.0 - 7.0 cps
Alpha		8.0 - 13.0 cps
Beta		14.0 - 30.0 cps

Grey Walter associated alpha waves with the process of scanning for a pattern - the waves relaxing when the pattern was found, and this suggests the possibility of a chosen tempo being a multiple of this scanning mechanism. As the alpha frequency, which varies between individuals, is generally taken as being approximately 10 cps, the value of 100 msecs appears yet again. The view of Sanford (1971), already given in Chapter 1, that the experimental evidence gives little support for alpha rhythm being the primary factor used in duration estimation, must not hide the fact that a number of investigators have reported a relationship between alpha frequency or phasing and several aspects of time behaviour. Heuse (1957) and Mundy-Castle and Sugarman (1960) found that there was a positive relationship between alpha rhythm and tapping speeds. Sanford (1971) stated that the above results suggested that the alpha cycle might represent a time unit in the organisational processes of perceptual-motor acts, and Surwillo (1961) explicitly put forward just such a theory. Certainly both his work in connection with reaction times (Surwillo, 1963), and that of Kristofferson (1967) show a marked correspondence between alpha frequency and performance measures. In this and other papers Kristofferson gave evidence that the quantum involved in reaction time may be a half or smaller fraction of the alpha period. Reaction Time distributions have also sometimes appeared to be multimodal as though a periodic process underlies the possibility of response occurring at any given time; Venables (1960) and White and Harter (1969) finding peaks 100 msecs and 25 msecs apart respectively. Although Sanford (1971) stated that results of this kind suggest many, possibly independent, periodic mechanisms may influence behaviour, the possible relation of the latter figure to a quarter alpha cannot be completely ignored. A periodic influence on performance as rapid as this does however weaken the theory of a Psychological Moment four times as long. Although the connection between reaction time and actual movement speeds may be rather tenuous, within the total context of the subject, any evidence of quantal or periodic behaviour characteristics is of interest.

Some attempts have also been made to discover whether reaction times are affected by the position in the alpha rhythm phase in which the stimulus occurs, but thus far no clear picture emerges. Bates (1951) and Lansing (1957), however, found that the motor response initiation in reaction time tended to be related to the alpha phase.

It would simplify matters if the alpha frequency could be linked causatively with all the data involving multiples or fractions of 100 msecs. However, despite the considerable encouragement of some of the above, it is still a very speculative area. Indeed, Ornstein (1969) quotes studies that were unable to relate time experience with any brain rhythms.

With regard to nervous rhythms generally, the writer leans heavily on Fraisse (1964) who in turn quotes extensively the work of Sherrington (1906), Adrian (1934), Fessard (1936) and Bethe (1940).

Rhythmic oscillation seems a characteristic of the functioning of the nervous system and even nervous tissues not spontaneously rhythmic respond rhythmically when exposed to a constant stimulus. In all cases, both centres and fibres have their own period of response - as in the scratch reflex of the dog, only corresponding within certain limits to the rhythm or intensity of the stimulus.

Fraisse also noted how nervous rhythms tended to synchronise with each other, the period of one part very often acting as a pacemaker for other pulsations. For example, the sinus node in the heart is believed to be a pacemaker for other centres which all have their own periodicity. According to the most acceptable hypothesis the regularity of the pulsation of any organ or centre is mainly due to the coordination of a large number of elementary pulsations. Even more important, certain periodic activities such as the alpha rhythm can be synchronised with stimuli which are themselves periodic.

Fraisse[1] continued:-

> 'Synchronization is also frequently apparent in alternating movements. These owe their regularity to the phenomenon of successive induction. The contraction of the flexors leads to the contraction of the extensors, and so forth. This succession has its own tempo, as has been proved by a number of experiments concerning the spontaneous tempo of mastication, of walking, of the swinging of a limb or the swaying of the trunk, etc. The most interesting fact established is that these alternating movements can be induced by rhythmic stimuli. This induction can be effected in a child of nine months, and it is this aptitude which makes it possible for large military formations to march in step, although the individual tempo may vary from one soldier to another.'

All these facts, Fraisse affirmed, demonstrated two properties of the nervous system. First, the tissues and nervous centres either have a spontaneous rhythmic activity or a natural rhythmic response to stimuli. Second, whether spontaneous or triggered, a centre's rhythmic activity has its own resonance frequency which can only be modified within certain limits by any regulation, stimulus or synchronisation. The tendency for physiological rhythms to synchronise is similar to the principle of rhythmic entrainment first noted by Huygens (in Oatley and Goodwin, 1971) in the eighteenth century. He observed that when two clocks running at different speeds were hung on the same thin wooden board, they became synchronised.

The point must now be stressed that any fundamental origins of perceptual and motor time experience, not only almost certainly vary between individuals but are also probably subject to modification. This modification has most often been observed in connection with circadian or induced changes in body temperature, but it is possible that further circadian or other exogenous or endogenous fluctuations may also affect our time behaviour.

> 'Since body temperature varies in such a striking way throughout the day, and since it is known that many other physiological processes exhibit similarly marked circadian changes, it appears more than likely that the functioning of the brain will also vary,

[1], Fraisse(1964) pp.30/1.

> in that its operation must clearly be supported by some at least of these processes. There are therefore strong grounds for expecting that the speed and accuracy with which all manner of activities involving nervous functions are executed will fluctuate throughout the day.'
>
> (Colquhoun, 1971)[1]

The circadian body temperature rhythm observed by Colquhoun makes a rapid rise from a minimum at 0500 hrs to 0900 hrs, followed by a more gradual rise to the maximum in the early evening. From about 2200 hrs the descent is rapid to the early morning minimum. The relationship between body temperature and any internal "clock" has already been noted several times, but several studies have also observed a positive relationship with performance measures such as reaction time and efficiency (eg Kleitman, 1963 and Colquhoun, 1971). However, a post lunch dip in the performance of some tests not paralleled by a corresponding temperature dip has led to speculation that performance is related to the level of arousal rather than the body temperature. Blake (1971) certainly supports this view and he makes the additional observation that his results show that intraverts have higher arousal levels than extraverts in the morning and that the arousal increases at a greater rate in extraverts during the day. Kleitman (1963) suggests that this dip may reflect the rest phase of an underlying rest-activity periodicity of 80-90 minutes and this certainly corresponds neatly with the similar pattern observed during sleep. The obvious explanation that the post lunch sleepiness can be ascribed to the digestion of the meal would be readily accepted but for the fact that one is, if anything, less sleepy after breakfast tea and dinner. Other short and long term fluctuations in our physiological periodicities, body temperature and apparently dependent perceptual and motor abilities are known to occur. The menstrual cycle is an obvious example, and Kleitman (1949) found evidence of a weekly change in body temperature. Interesting possibilities emerge from the contraversial work of Fleiss (1906 and in Kleitman, 1949), Swoboda and Teltscher, who between them believed they had identified three so-called biological rhythms

1, p.42.

which start simultaneously at birth. These three cycles, one of 23 days associated with fluctuations in physical condition, another of 28 days influencing the nervous system and emotions and a 33 day cycle concerned with the intellect, proceed uninterruptedly throughout life. Critical days are said to occur when two, and especially all three cycles change phase simultaneously, and may therefore be predicted. Finally, Surwillo (1963), in showing that older subjects tended to have slower alpha rhythms, raises the interesting possibility of a changing musical tempo preference with age. All the above suggests that the circadian variations may be superimposed on cycles of various longer periods. It also posed problems for the writer's experimental programme, where, although time of day could be made a constant, no other aspects of the circadian or other cycles could be controlled. There is some evidence from the experiments that both short and long-term variations in tempo behaviour may occur.

Physiological Factors and Movement Speeds

Many authors have also been concerned whether movement speeds could be related in an absolute or relative way to the frequency or level of physiological parameters such as the circulation, respiration, blood pressure and body temperature itself. As the fundamental frequencies just dealt with may well control the tempo of other periodic physiological activities, this section is closely related to the previous one. Inevitably, therefore, some data, both from the previous section and associated aspects of Time Psychology, will be appearing again. In any case, as many experiments concerned with perceptual parameters involve some sort of movement response such as tapping, much other previous data has implications for Movement Speeds. Because of the undoubted effects music can have on certain physiological activities, uncertainty as to which is cause and which effect must arise when considering the possibility of these same activities affecting Movement Speeds. Also, the part played by an increase in body temperature is not yet clear. It appears to make the "internal clock" go faster, but it could also make its effect more directly at a later stage, faster movements being the result of a greater muscular fluency when warm. In addition, as a performer can be aware of playing too fast when nervous, that very awareness makes it less certain that a faster "internal clock" is responsible. The situation is therefore complex and in no way clarified by the literature.

With regard to pulse or respiration rate, no modern study has detected an absolute arithmetic relationship with any movement speeds. Seashore (1899), Coleman (1921) and Anders (1928) all believed there was a possible relationship between heart and respiration rate and some movement speeds, but generally their methods were very unsound. In particular, Coleman, basing part of his paper on animal observations made in Regent's Park Zoo, made comments such as:- 'Cheetah, lying on its side with heart beat plainly visible, rate 72. Its rate of breathing was 12 or one fifth. . . . Fog on the breath of polar bears showed one breath for each step.' These authors therefore suggest indirectly that there are individual preferred rates in the modes of movement investigated, and that each rate has an arithmetic relationship with the heart pulse or respiration.

A possible relative relationship with the pulse or respiration is much more likely and easier to establish. However, although Leumann (1889) thought there may be a relationship between both these variables and walking and reading rate, Hollingsworth (1925), Francois (1927) and Dunlap (1934) all reported that faster pulse rates were not consistently associated with faster tapping or movement speeds. In addition, no relationship was found between performance rate and blood pressure (Baxter, 1927) or fatigue and alcohol (Harrell, 1937).

Investigations into the effect of body temperature variation on performing rates have usually found that a higher temperature increases the rate of performance, whether that increase is artificially induced or the result of natural variation (eg.Francois, 1927; Hoagland, 1933). Hoagland also quoted much other work confirming this view, and Baxter (1927) is definitely in the minority in finding no such relationship. Most of the above data is therefore consistent with, or duplicates, the parallel findings in Time Psychology and the previous section.

If there are relationships between any fundamental nervous periodicity, the periodic physiological activities and Movement Speeds, then any variation in a more basic periodicity is likely to have an observable effect in movement. Variations may be due both to occasional causes, exogenous and endogenous, and to circadian and other periodic cycles. Orme (1969), supporting views expressed in the previous section, considered the possibility of there being weekly, monthly or longer period variations in physiological activities, but the variation probably most pertinent to the writer's study is the now well-attested circadian body temperature cycle, with its early morning minimum rising to a maximum in the late afternoon. Implications for tempi are obvious, and indeed, as early as the nineteenth century, Dresslar (1892) noted that speeds were affected by the time of day, with the fastest and slowest rates occurring at 4 pm and 8 am respectively. Scripture (1902) and Fox-Strangways (1929) also thought that the individual natural movement rate and musical tempi respectively varied with the time of day. Although the writer's own experimental performances give limited data in this area, there is evidence that circadian temperature or other changes may affect both mean tempo and the range of speeds performed. It is a topic well worth future study.

Universal Tempo Preference

Whether or not any fundamental physiological periodicity contributes to the fact, one cannot escape from the ubiquity and possible universal significance in both Time Psychology and Movement of the 750 msecs area, and possibly also its multiples and fractions. It has previously appeared in connection with Unitary Pulses of Subjective Time, Duration and Tempo Indifference Intervals, the Absolute Indifference Interval, and its metronomic equivalent of MM80 has long been considered the "just" or "normal" musical tempo. With regard to this, a possible Universal Tempo Preference in relation to music in particular will be considered later in Chapters 3 and 5 and in connection with the results.

In addition, both Oleron (1952) and Fraisse (1964) refer to the psychological significance of 750 msecs as a rate controlling constant of the brain's mechanism. The former noted that subjects reproduced a sound stimulus about 700 msecs after the stimulus had ceased, as if this interval was the optimum for immediate succession. This agrees well with the comment of Fraisse previously given that the spontaneous movements, walking and heartbeats have approximately this frequency. Mursell (1937), however, commenting on previous studies on motor rhythm and skilled movements suggested that at the rather slower rate of 60 per minute there lies a critical speed for coordinated human actions. Waesberghe (1966, 1967 and 1968), although principally concerned with human musical motion, stated that the physical laws underlying 'tempo, rhythm, structures and constructions' in general phenomena are just as well applicable to music, dance, speech and the simple movements of the conductor's beat. He also drew attention to the significance of MM60, associated it not only with ordinary relaxed human "going along", "striding" or "walking", but also the average rate of accentuation in speech and in rocking, whether or not accompanied by a cradle song. In addition he observed that the marching step was twice as fast as the walking step.

However, although there may in a very general and broad sense be a tendency to make various modes of movement at approximately the rates suggested above, it is in no sense a preference within the precise terms of the writer's hypothesis. Nevertheless, the MM60-MM80 area could represent an ideal "average" or "neutral" speed of movement with which all others are unconsciously compared.

Individual Preferred Tapping Rates (By Performing)

Without prejudicing the future discussion of the definitions of "Preference", all data for experiments in which the subjects were asked to tap with the finger at "normal", "neutral", "natural", "most comfortable" or "convenient" speeds are also included. No distinction is therefore made between these terms and "preference", the methods employed, or the data for any different metrical grouping. In many respects, therefore, "preferred tapping" is the performing equivalent of both the Absolute Indifference Interval and Preferred Tapping Rates by Comparison.

		Range of Individual 'Preferences'
Stevens (1886)	[ave. 710 msecs]	530 to 870 msecs
Seashore C. (1899)		300 to 3·5 secs
Miyaki (1902)		340 to 1·35 secs
Stetson (1905)		188 to 281 msecs
Patterson (1916)		250 to 1·65 secs
Braun (1927)		320 to 2·25 secs
Oléron (1952)	[using a very indirect method]	c.700 msecs

Other investigators have observed generally that individuals seem to have a "preferred" rate of tapping (Nurullah, 1927) and the wide individual differences noted above have also been observed by Miles (1937). Miles also stated that some subjects were much more consistent in their preference than others and that any preference appeared to be based on the rate of succession of individual taps and not on the duration of any metrical group. He also found that metrically grouped tapping, as opposed to unaccented tapping, caused the range of rates chosen by an individual to diminish and all individual ranges to become more similar. Thackray (1969) observed that in one of his tests with children, some of them kept a steady tapping pulse which did not fit the music and that this pulse was usually in the MM80-100 range. Most musicians would find this difficult to do and he assumed it was a case of a preferred tempo overriding the external musical stimulus. Although the now familiar 700 msecs area only appears twice in the above data, it is noteworthy that the phenomenon Thackray described was usually at about this frequency.

Admittedly, simple tapping is a more rudimentary movement than that involved in any kind of musical performance, but the wide individual differences that have been found both in any preference and in preferential precision and consistency may well reflect a similar state of affairs in the world of real music. Many musicians, including the writer, would affirm that Scripture's (1902) assertion that the natural rate of tapping varies with practice, fatigue, time of day, health and external conditions of resistance applies equally well to musical tempi.

Individual Personal Tempi

Tapping of course has no intrinsic value, being just the mode of movement most frequently investigated because of its convenience and simplicity. Other less artificial voluntary movements have also been the subject of study. These have included Speech Tempi or Accent Distribution and Timing (Squire, 1901; Wallin, 1901) and Walking Speeds (Schäfer, 1900; Harrell, 1937). However, apart from confirming that wide individual tempo differences exist in these activities as well as in tapping, the generally averaged published data would seem to have no other relevance to this study. Of more interest are the studies investigating intra-individual consistency in motor speeds generally. Cratty (1967), concerned with what he termed "Personal Equations in Movement", called this component the "Personal Tempo". In this respect, the various batteries of activities have often included tapping, as well as walking, miscellaneous arm and leg movements, reading and writing speeds. As complex voluntary movements of this type are more akin to the movements of musical performance, any consistency is going to be of interest.

Reference has already been made to McDougall's (1902a) view that the bodily mechanism reacts rhythmically to a stimulus at its own fairly constant tempo, and all the following authors, in various degrees, support a monistic view of Personal Tempo:- Smith (1900), Meumann (1913), Guttman (1931), Frischeisen-Köhler (1933), Kennedy and Travis (1947) and Jones and Hanson (1961). Frischeisen-Köhler taking a mentalistic view, stated that the "psyche" abhors one tempo as "unsympathetic" and recognised another as "sympathetic". She also believed that personal tempi were largely inherited. Several writers, while finding no evidence of a single pervasive individual personal tempo, postulated either group factors of speed (Allport and Vernon, 1967) or presented evidence that movements with similar actions or using opposite limbs share a common rate (Lewitan, 1927; Harrell, 1937). In the most comprehensive study to date, Rimoldi (1951)[1] also came to similar conclusions:-

> 'Summarizing, we feel entitled to conclude that the monistic view of personal tempo does not seem to agree with the experimental findings, and that the practice of determining an individual's tempo by means of one or several tests of tapping is unsatisfactory. If a general tempo factor exists, its influence is very limited due to the existence of definite clusters of speed . . . Individuals seem to be constant through long periods of time in their tempo characteristics. Each S seems to adopt a certain temporal pattern for a particular group of activities and this is the best definition of his "personal tempo".'

Rimoldi's experiments had suggested that the speed of large movements of the trunk or limbs were independent of the side of the body, muscular group or function and were probably related to individual gait or gesture. There appeared to be different natural speeds for two groups of movements, one group involving the large muscles of the trunk and proximal parts of the limbs, and the other the distal parts of both extremities. However, he did not accept the view that the tempi of different activities were totally unrelated. Fast individuals were consistently fast in all activities over long periods of time, a view generally confirmed by Wu (1935). Adams (1935), however, observed that a person who was quick in one task was not necessarily so in another.

[1] p.302.

On the other hand, Patterson (1916), Braun (1927), Lauer (1933), Harrison and Dorcus (1938) and Harrison (1941) found no significant similarity in tempo between any of the various tasks performed, although the last two studies, in addition to Frischeisen-Köhler (1933), Adams (1935), Rimoldi (1951), Allport and Vernon (1967) and Smoll (1975a and 1975b) all affirmed that individuals are relatively consistent with regard to the rate at which they perform specific motor tasks. Adams, however, noted that Ss consistent in one test were not necessarily consistent in another. The general evidence also suggests that the time between test periods has relatively little influence on the tempo for any activity, although the possible effect of Circadian and other biological variations on movement must always be considered. Swindle (1913) and Allport and Vernon (1967), among many others, found wide tempo differences between individuals for any particular task, and Cratty (1968) observed that this accounted for the difficulty experienced by some dance teachers in encouraging individuals to break out of well-established habit patterns involving rhythm. Colleagues of the writer who are teachers of dance frequently remark that children and students have their own natural tempo - meaning their tempo for any particular dance situation, thus making concerted movement more difficult, although in an early study, Scripture (1902) did suggest that the individual natural movement rate could be modified by practice. In any case, in communal activities like dancing and marching, any individual preferences have to be reconciled into a common ensemble tempo.

Musical performance is more than just a matter of motor activity of course, many other considerations certainly taking conscious precedence, but inasmuch as any given performing situation is a specific complex motor task, so the above research and comments may be applicable to the tempi of music. It is noticeable that few workers in this area have been concerned with the degree of preference precision and consistency that is the writer's main interest. Indeed, some of the findings quoted above were the result of just one immediate sequence of performances of the required task for each S. In this respect however, it is interesting that Rimoldi (1951), Tisserand and Guilhot (1949) and Smoll (1975c) all found that Ss with faster "preferred" tempi were generally more consistent in the performance of tasks including repetitive movements.

The question of ease and economy of effort is also important in preferential movement tempi. It is well known that athletes and swimmers, particularly in long distance events, settle into a tempo they feel is both economical and least fatiguing. Howes (1926), for example, emphasised the importance of striking the right tempo when rowing. Scripture (1899) stated that the natural rate is the one at which an individual can perform the greatest number of movements with the least fatigue, and Austin (in Nurullah, 1927) made the point that rhythm to be enjoyed must lie within the limits of pleasurable exercise.

Tempo Limits and Reaction Times

The above leads to a brief consideration of two parameters which, although by definition, have little obvious relevance to preferential speeds in any activity, may influence musical tempi by setting limits on the note speeds with the beat. Uhrbrook (1928) reported that an individual's maximum tapping speed usually correlated quite highly with other maximum performances, and Lewitan (1927) obtained good repeat reliability and close right and left hand side agreement with maximum speed tapping and body movements. Harrison (1941) found no indication of an individual unitary speed factor characteristic of all maximum rates of movement apart from a few exceptional individuals who were fairly consistent in both their voluntary and maximum speed levels. Both he and Wu (1935) did however find a low, but reliable positive general relationship between voluntary and maximal rates of movement. Of interest to keyboard players in particular is the work of Stetson (1905), who reported that the maximum speed of beats by a single finger was about half the rate possible from a combination of two or more fingers.

A familiar value appears in the work of both Dresslar (1892), who noted that the most rapid tapping rate under voluntary control approached 100 msecs per beat, and Richet (1898), who stated that this same speed was the limit for pronouncing syllables.

Tapping speeds have not usually been considered related to Reaction Times (Eysenck, 1947), although Swindle (1913), in an unconvincing experiment involving the striking of buttons with a mallett, found a high correlation between individual Reaction Time and tempo.

Physique, Mechanical Factors, Expressive Movement and Personality

It is suggested that body lever dimensions, movement extent and other aspects of physique may be related to an individual's tempo characteristics. To some extent the laws of mechanics must apply to human movement, with factors such as the natural swing tempo of our body levers having a possible influence on performing tempi. Many writers have observed that limb movements tend to be pendular; an increase in movement extent not necessarily producing an increase in its duration (Binet and Courtier, in Angell, 1919; Isserlin, 1914; Buytendijk, 1947). In musical practice this may be true for modifications of the extent of a movement once initiated, as in conducting, but general experience would agree with Cattell (1946) that rhythms with a small movement amplitude are usually faster. However, although shorter limbs may tend to encourage faster tempi in walking (Schäfer, 1900) and many involuntary movements, it is not clear if they are associated with generally faster rates in all activities where movement is secondary to other considerations. There is certainly no evidence that conductors with shorter arms favour faster tempi!

Other mechanical factors may also apply. Heavier limbs or limbs loaded with clothing or extended by a baton could also affect tempi, although subsequent indirect evidence is to the contrary. Perhaps even more critical and relevant are the external forces acting against the movements of the body, and in this connection, Scripture (1902) noted that individual natural rate varied with the external conditions of resistance. Stetson (1905), not necessarily contradicting this, observed that an obstacle introduced against an oscillating limb does not affect the character or tempo of the movement. It does appear therefore that a given individual movement situation, when repeated with the same loading and external resistance at least provides the mechanical conditions appropriate for consistent tempi. These matters will again be raised when dealing with the musical variables of instrument, touch and technique.

There have been several attempts to categorise psychomotor or physical types. Kretschmer (1925) first differentiated between pyknic and non-pyknic types, and Enke (1930) in his work on consistency of movement produced the following categories and findings:-

1) Pyknics are essentially slower than leptosomes and athletics.
2) Pyknics are more irregular and variable, while leptosomes and athletics are more mechanical, automatized and stereotyped.
3) Leptosomes and athletics are given to perseveration, finding it more difficult to change their personal rhythm and slowed by distraction.
4) Pyknics are adaptable to external rhythms and their action is speeded by distraction.
5) Finely coordinated activity is best carried out by leptosomes, less well by pyknics and least well by athletics.
6) Pyknics are fluid, free, soft, rounded and uninhibited in their actions. Leptosomes are stiff and angular.
7) Pyknics fatigue gradually, leptosomes suddenly.

In relation to the present study perhaps much of the above is no more than a sophisticated way of stating that fat or clumsy people generally move more slowly or that fast people are generally fast in all their movements (Swindle, 1913).

A more recent system of classifying physical types was devised by Sheldon et al (1940) known as "somatotyping". Endomorphs, having a well-covered large bone structure are generally slow movers, Mesomorphs are predominantly muscular, while Ectomorphs are essentially thin and lean.

Apart from their actual physique and tempi, it has been found that individuals evince consistency in the way they move generally. Their "Expressive Movement" is thus another component of Cratty's "Personal Equations in Movement". Cratty (1967) commented that the available literature indicated a remarkable consistency of personal performance quality in both gross and fine body and limb movements.

Allport and Vernon (1967)[1] also write:-

> 'The evidence indicates clearly that the expressive movements of personality are not specific and unrelated; on the contrary they form coherent, if perplexing patterns.'

The writer's main interest here is in the possibility of relating any consistent individual movement quality, as it affects a musician's physical performing style and technique, to consistency of performance and tempo. Of course we are now in an area where objective measurements are very difficult, and assessing consistency in the more subtle aspects of movement and gesture would probably be impossible. Perhaps it is only with the more mechanical parameters of human movement, such as its extent or body lever dimensions, that any future relationships with musical performance can be established.

Integral with Expressive Movement is the question of Personality:-

> 'Motor acts are not so specific as to be meaningless, and being organized they must reflect to a large degree the organization of the total brain field. There are degrees of unity in mental life and in personality. It is surely not unreasonable to assume that insofar as personality is organized, expressive movement is harmonious and self-consistent, and insofar as personality is unintegrated, expressive movement is self-contradictory.'
>
> (Allport and Vernon, 1967)[2]

1, p.247; 2, pp.181/2.

There is little doubt that musical tempo is affected by the temperament of the executant (Fox-Strangways, 1929). The general calmness or excitability of a musician, together with his passing mood probably affects the extent, style and tempo of his performing movements, just as it affects the interpretation of the music itself. Indeed, C.P.E. Bach (1953) recommends a performing style based on this very phenomenon. Unfortunately, no experimental work appears to have been done in this area and the indirect experimental evidence is contradictory. Although Hiriarteborde (1964) showed there was a relationship between emotional stability and the synchronisation of rhythmic responses, R. Seashore (1926) found no such correlation. The physical somatotyping previously mentioned also has general implications for temperament. Endomorphs tend to be phlegmatic, Mesomorphs and Ectomorphs respectively being extraverts and intraverts.

Finally, Harrison (1941) and Smoll (1975a) found an absence of sex differences in the preferred tempo of performance for several motor tasks. This finding disagrees with that of Hoffman (1969), who reported a significantly faster preferred finger-tapping tempo for males than for females.

Movement Analysis

Some work has been conducted on the analysis and categorisation of types of movements and movement sequences, and as the nature, grouping and control of the detailed actions involved in musical performance are clearly part of the total background, the writer feels justified in the inclusion of this section. However, having drawn attention to its likely ultimate significance, it will suffice in this study to mention only the work coupling Movement Analysis with musical activities. The following two authors were concerned with the relation between movement and what they called the "rhythmic unit group":-

> 'One may say that the unit group is the form in which the various muscle sets and segments of a limb or organ can all work together freely and easily in a single movement cycle.'
>
> (Stetson, 1905)

> 'We shall find that motor rhythm depends upon an integrated pattern of action which we shall call the Movement Cycle, in which separate movements are apprehended always as constituents of a single kinaesthetic unit.'
>
> (Mursell, 1937)

With regard to the muscle-sets at work in a musical rhythm, Stetson was doubtful if the muscles actually producing the tone were the source of the rhythm. So many non-rhythmic actions were concerned in moving up and down the keyboard, passing between levers in wind instruments, bowing stringed instruments, as well as in extraneous activities such as pressing pedals and turning over pages. However, he did make the point that the ordinary unit group does not show wide variations in durations, being a little less than one second, and that multiplying this value by three or four represented the maximum duration for the slower, automatic regular movement which produces the measure.

Stetson's (1905) experiments included the analysis of up and down rhythmic movements of the arm and hand with baton, finger tapping on a key or tambour, and foot tapping on the floor. He found that the duration of the beat stroke was surprisingly uniform and independent of either the tempo or the length of the stroke. This beat stroke he called a ballistic or free-thrown movement and he added that he found no beat strokes longer than 125 msecs, suggesting to the writer that the average duration might be close to the ubiquitous 100 msecs value. Stetson adds:-

> 'Changes in tempo are due to voluntary hastening or retarding during the relaxation process. This fact is of considerable importance in conducting. A chorus or orchestra depend quite as much on the backstroke as they do on the beat stroke for direction. Conducting at the organ or piano is always unsatisfactory, and an angular style of beating which suppresses the back stroke is almost as ineffective.'

He certainly strongly suggests that the tempo of a movement is aimed or predetermined and not affected by the duration of a fairly uniform beat stroke, or by subsequent resistance:-

> 'An obstacle against which the limb strikes does not affect the character of the movement. At the end of the normal interval the

> negative muscle-set contracts and withdraws the limb, as if the limb had shot to the end of its course unimpeded. It is simply as if the lower part of the oscillation had been cut off by the obstacle and its place taken by a pause at the obstacle. If one closes ones eyes and beats a rapid rhythm with the arm and hand, at first in the air, and then approaches an obstacle whose position is not exactly known until the hand strikes the obstacle at each beat, one will find that the character of the movement and the rhythm is quite unchanged by the intervention of the obstacle.'

Recent work by Marsden et al (1972) confirms this, coming to the conclusion that muscular movements are under the control of a servo similar in many ways to those in engineering control systems, including an automatic gain compensation for altered loading. They found that if a voluntary movement met an unexpected obstruction, additional muscular power was very quickly exerted to overcome it.

Implications for musical performance certainly suggest themselves, where the touch and resistance of one instrument may be very different from another. However, it must be pointed out that an instrument is not changed during a performance, and presumably the touch factor is normally taken into account when setting the original tempo. Where the above work may impinge upon this study is in suggesting that musical movements of a ballistic type, such as in piano staccato, may not have their intended tempo affected by the subsequent touch of the instrument, even if that instrument had not previously been tested by the performer. Indeed, this was borne out by the results generally, where even the tempo of legato playing appeared to be unaffected by a different piano.

Mursell (1937) used some of Stetson's terms in describing the various types of movement in the Movement Cycle. In relation to beating time, the stages involved in each beat cycle he gave as follows:-

1) The ballistic down beat - the accentual element.
2) Preparatory or terminal subsidiary movements dynamically integrated with the down beat.
3) The Relaxation Phase - when the muscles prepare for the next cycle.

Finally, Thackray (1969) makes the following distinctions between fine and gross body movements and rhythms as exemplified by dancing and instrumental performance respectively:-

1) The type of coordination required is different.
2) Dance movements normally involve the control of the whole body whereas instrumental performance is more limited.
3) Dance movements involve weight transference from foot to foot, and the factor of static and dynamic balance to a far greater extent than that demanded by instrumental performance.

Movement Training and Memory

An aspect of Movement Training that must be mentioned is the possible integral part played by tempo in the learning of any skill or sequence of movements. A very recent study by Summers (1974) makes a useful contribution here:-

> 'The timing of events rather than being independent of sequencing appears to be an integral part of the motor program, particularly for rhythmic time structures.'

Swindle (1919), making a rather similar point, stated that the amplitude of movements in a group can be more easily influenced than tempo or direction. One educational implication from this is that tempo, or perhaps more accurately, the timing relationship of each action, is not something added on to performing technique but should be learnt simultaneously with it. In addition the memory and recall of a performing tempo may necessitate the kinaesthetic "imagining" of the original performance. This is an accord with Mainwaring (1933) who stated that the recall of music requires a process of "thinking" in recurred kinaesthetic experiences. This was qualified however by his assertion that the medium in which a tune was presented was rapidly forgotton, the melody being recalled by motor processes as a "mere tune". R. Seashore (1926) also stressed the importance of taking and retaining a muscular set of the rhythmic pattern as a whole for a sufficient length of time in order to be able to reproduce it. C. Seashore (1938) even went further, in stating that at the moment of recall, the organic responses throw the organism as a whole into muscular tension, affecting digestion, perspiration, pose, stability, breathing and circulation. Further references to the importance of kinaesthesis in rhythmic imagery, and therefore, the writer maintains, rhythmic recall, have previously been made in Chapter 2.

The effect of training on memorising and absolute tempo has also been considered, with conflicting results. Nurullah (1927) reported no improvement whereas Renshaw (1932) noted improved accuracy after practice. There is no evidence from the writer's experiments that repeated performances, whether in immediate or intervallic succession, unconsciously become more consistent and precisely alike in tempo. However, the general literature in Chapter 5 includes interesting cases of musical tempi being memorised very accurately.

Rhythmic Ability

The one specific skill common to all Rhythmic Ability test batteries in either an explicit or implicit form is the ability to maintain a steady tempo. For this reason, the following studies are of some relevance.

There has been no general agreement about the possible training of Rhythmic Ability. Seashore (1938) considered it, like all discriminative abilities, an elemental quality, not changing with practice, training or age. Henderson (1931) and Coffman (1951) however both believed it could be improved with training, and Swindle (1913) took the extreme view that it was acquired and not inherited. In the latest study to date, Thackray (1969) thought the evidence suggested that rhythmic performance could be improved by training, but was unsure if this implied an improvement in perception. With more specific regard to steady tempo maintainance, Thackray considered this ability showed the least improvement with age, noting that even experienced musicians were shown to be unreliable and erratic in this respect.

Tempo steadiness is particularly pertinent with regard to the writer's experiments, not only because preference implies some form of steadiness, but because the timing method employed presupposed that the subject maintained a steady tempo. On the other hand, if any tempo control is based on units longer than one beat, rubato, by definition, should have cancelled itself out over the 40 beats duration timed in the Main Experimental Programme performances.

The writer believes that within the material of Chapters 1 and 2 lies the origin of all movement and performing speeds. The next chapter will be concerned with the more directly musical and performing factors that may play a part in the selection or variation of any available individual tempi.

CHAPTER THREE

Musical and Performing Tempo-Affecting Factors

This is the writer's speculative list of all those musical and performing factors that could control or affect tempi in any way. Support from the experimental or general literature is included where appropriate. It must be made clear that although an exhaustive list is attempted, only a small number of the factors could be selected for the Experimental Programme. Taken in totality, they are the criteria upon which a performer consciously or unconsciously bases his interpretation.

I FACTORS DEFINING COMMON BROAD RANGE OF APPROPRIATE TEMPI

These are the criteria governing the broad range of acceptable tempi for all musicians in any given circumstances, which, in the writer's opinion, are capable of being taken into account before the performance is initiated. Any resultant tempo range arising out of the interaction of any of these factors is not to be confused with preference. It is merely the range within which any individual preferences may manifest themselves.

General Factors - Usually constant for any piece or movement.

(a) Tempo Words

The tendency today is to link the Italian tempo terms with metronome equivalents. Piéron (1951) however reminds us that the usual values of artistic rhythms have their origin in heart beats - as originally affirmed by Aristotle, and that it is possible to link musical tempi with the motor activities of locomotion:-

funeral pace	-	adagio
walking	-	andante
quick march	-	allegro
running	-	presto

Another point of view is taken by Donington (1974)[1]:-

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[1] p.386.

> 'Time words are notoriously vague. They often relate strictly to mood, not to tempo: eg largo (broadly), grave (gravely), adagio (at ease), maestoso (with majesty), allegro (cheerfully), etc. Tempo is a function of mood, rather than the other way about.'

(b) Metronome Mark

Taken literally this is of course a precise tempo indication and not a broad range. However, it is usual to regard any metronome figure as the centre of a reasonably wide range of acceptable tempi. In any case, the difficulty many musicians experience when attempting to synchronise with an accurate metronome is indirect support for a view of preference that is both individual and precise. On the manuscript of one of his songs Beethoven wrote:- '100 according to Maelzel. . . . for feeling also has its tempo and this cannot be entirely expressed in this figure' - (in Dorian, 1942).

In the light of the discussion in the Introduction concerning the definition of musical beat and tempo, it is clear that a metronome figure is not necessarily an indication of true physiological musical tempo. As Sachs (1953) points out, the gamut of tempi shown on the metronome implies a ratio of about 1:8 between its extremes. Such a range he says cannot exist as it conflicts with the physiological conditions of tempo, with the range accessible to marchers' and dancers' steps and conductors beats. No person is able to stretch or shorten steps or beats within so large a range. Sachs goes on to state that the actual change of real tempo is possible only in much narrower limits, suggesting the two extremes are probably closer than a ratio of 1:4.

Although a reliable method of notating tempi has only been available since the Maelzel metronome was perfected early in the nineteenth century, the present writer will follow the practice generally adopted of transcribing the tempi referred to by earlier writers in terms of MM values.

(c) Period, Style and National Characteristics

Despite the suggestion to the contrary in (a) Italian tempo terms do not have a fixed value. For example, a Haydn andante would normally be played faster than one by Brahms. Thus, the period and style, including the musicological evidence outlined in (d), are important factors in defining the possible tempo range for any piece. National temperament may also affect the range of acceptable tempi for the performer. For example, British performers have tended to play the German repertoire faster than they do themselves. C.P.E. Bach (1753) also noted that adagio and allegro in Berlin implied greater tempo extremes than were customary elsewhere.

(d) Standardisation of the Beat

In different musical periods there have been attempts to standardise the musical beat. Despite the complexities caused by a gradually changing notational system, the assumption of metronome numbers to pre-Maezel data and other matters detailed below, the metronomic equivalent of 750 msecs is much in evidence:-

> 'One by-product of the introduction of the metronome and of clock-measured tempi has been to relieve the notes themselves of the duty of implying any tempo at all. In medieval music . . . semibreve = 80 has been suggested as the norm round about 1350. We can also trace the evolutionary process in which note values became steadily devalued, . . .'
>
> (Cole, 1974)

Dart (1964) stated that the latest research suggested that the metronomic equivalents of the note values in the Middle Ages were of the following order:-

c. 1200 long = 80

c. 1250 breve = 120

c. 1280 breve = 80

c. 1320 semibreve = 120

c. 1350 semibreve = 80

1400-1500 semibreve = 50 in O or C

100 in ⦶ or ₵

70 in C 3/2

140 in C 3 or ₵ 3/2

In the Renaissance in particular, tempo was related to the tactus, the down-up motion of the hand or baton made by the directing musician. This movement consisted either of two equal time-units as in modern duple conducting, or of a long two time-unit down stroke followed by a single time-unit up stroke. Most authorities believe that there existed a fairly uniform "normal" tactus tempo from which only minor deviations were possible, changes of actual pace being achieved by using different note values in relation to this tactus. According to this view the note values had near absolute durations, and tempo words were accordingly both unnecessary and practically unknown before the seventeenth century. Sachs (1953) gives the tempo of this "normal" beat as between MM 60 and MM 80. However, without the mechanical means generally available to ensure an objective standard, the concept of a fixed tactus tempo in early music must always be viewed with caution. Indeed, a recent study by Bank (1972)[1], although first acknowledging the biological significance of c. MM 60 in relation to walking, regular speech accentuation and rocking, and c. MM 80 to pulse rate, concludes with the following:-

> '. . . analysis of many musical examples of musica mensuralis, dating up from c. 1200 to c. 1520, shows a general tendency towards two main tempi. These coincide with c. MM 60 and c. MM 72, congruent with the main tempo of biological rhythm on the one side, and with the rhythm of the pulse on the other hand. In certain circumstances these basic tempi can be doubled into c. MM 30 and c. MM 36 respectively, beaten in a "tactus maior", or in an undiminished "tactus proportionatus". But this is not the only possibility. There are indications of tempo-shifts to either side, eg in "diminutio per tertiam partem", or in "augmentatio" based on prescriptions or special note-symbols. Differentiations from the basic tempo, chosen for a given composition, are realised in the parts only by strictly mathematical ratios. For this long period THE THEORY OF ONE TACTUS OF INVARIABLE SPEED CANNOT BE SUSTAINED.'

Nevertheless, much evidence remains that the general tempo area of MM 60 to MM 80 had some significance in the Middle Ages and Renaissance and despite notation changes, continued to do so in the Baroque. Machatius (1955) gave MM 70 as the average basic tempo for two minimae in 1600, Praetorius (1615-19) stated that ♩ = 80 was a good average speed, and Quantz (1752)[2] specified four main categories of tempo, all related to the same standard beat:-

1, p.259; 2, pp.284/5.

> 'The Allegro assai is thus the fastest of these four main categories of tempo. The Allegretto is twice as slow. The Adagio cantabile is twice as slow as the Allegretto, and the Adagio assai twice as slow as the Adagio cantabile. In the Allegro assai the passage-work consists of semiquavers or quaver triplets, and in the Allegretto, of demisemiquavers or semiquaver triplets. Since, however, the passage-work just cited must usually be played at the same speed whether it is in semiquavers or demisemiquavers, it follows that notes of the same value in the one are twice as fast in the other. In alla breve time, which the Italians call tempo maggiore, and which, whether the tempo is slow or fast, is always indicated with a large C with a line through it, the situation is the same, except that all the notes in it are taken twice as fast as in common time.'

Later in the same work Quantz[1] established eighty beats per minute as the norm. Metronomic equivalents of his suggestions include the following for his four main tempo categories:-

	Common Time	Alla Breve Time
Allegro assai	𝅗𝅥 = 80	𝅝 = 80
Allegretto	♩ = 80	𝅗𝅥 = 80
Adagio cantabile	♪ = 80	♩ = 80
Adagio assai	𝅘𝅥𝅯 = 80	♪ = 80

The relationship of Quantz's standard to human pulse rate will be shortly discussed.

Bedos de Celles (1766) provides empirical evidence of actual speeds in the 18th century. He found that marches, minuets, 6/4 and 6/8 movements of 24 bars and 2/4 movements and quick allemandes of 32 bars commonly last about 20 seconds. This would give us whole bar metronome values of approximately MM 72 and 95 respectively, neither of which, allowing for the uncertainty of the timing method, are far from the MM 80 figure.

Sachs (1953) remarked that Handel's era was aware of a Tempo Giusto, and that MM 80 had been a normal tempo in different cultures for a very long time, adding that the leisurely stride of a man provided its physiological basis. This was also the view of McLaughlin (1970), who asserted that most people have a concept of tempo giusto at approximately MM 80-90.

Although progressively smaller note values have been employed for the

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[1] 1, p.286.

beat, coupled with some associated gradual changes in their durations, much of the historical evidence suggests that the 750 msecs area that has appeared so often in the literature of Time Psychology once represented also some kind of general standard tempo for musical expression. Sachs (1953)[1] also explains how even a gradual change of note value durations is not incompatible with this concept of a fairly static standard tempo:-

> 'This process of gradual elongation would have been simple and continual but for the fact that tempo (when not considered from a psychological viewpoint) depends upon a human, physiological motor unit, from which it cannot deviate too much without losing its kinetic power and musical usefulness. True, the slowing-down movement affected the motor unit. It might start from, say, MM 80 and subsequently slacken to less than MM 60 under the pressure of recent smaller values. But it could hardly drop too far below MM 60. For if it did so, say, to MM 53, the next-smaller time-value, then at 106 MM, would draw closer to the physiologically established starting point of MM 80 and succeed automatically to the rank of motor unit. This is why within a few centuries the long inevitably yielded its position to the breve, the breve to the semibreve, the semibreve to the minim, the minim to the semiminim.'

Naturally, this does not imply that one common speed for all music is a desirable and normal aim. Indeed, Sachs adds that the concept of a normal motor unit, of a Tempo Giusto independent of personal interpretation, had disappeared by the nineteenth century. Kolisch (1943) quotes a letter Beethoven wrote to his publisher in 1826:- 'We can hardly have any tempi ordinari any more, now that we must follow our free inspiration.'

In any case, as mentioned above, the various rates of movement for fast and slow tempi can easily be obtained by the multiplication and subdivision of a basically similar "normal" beat, as in the Renaissance. Also, as McLaughlin points out, musical expression involves the building up and resolution of tensions; one such legitimate tension being created when the musical pulse is faster or slower than this "normal" tempo.

Many theorists and composers have attempted to relate the human pulse to a "standard" tempo. Indeed, before an accurate objective measure was freely available in pre-Maezel days, the heart pulse was both a standard and a measure. This dual function is therefore a source of some confusion and

[1] p.201.

uncertainty. Much modern literature, including the translations of early works, when quoting early tempo data, does not make it clear if the MM numbers ascribed to earlier writers are a subsequent interpretation in terms of the heart pulse originally referred to, or objective reporting of numerical data - albeit itself probably related to a heart pulse of 70-80. There is in fact often no means of knowing whether even the original authors were thinking in terms of an "ideal" preference only coincidentally similar to the pulse, actual musical practice, a numerical convenience related to the one commonly accessible standard measure of tempo, or romantically predisposed to associate the pulse of life with that of music. Whatever the case however, the frequency with which multiples and fractions of this valu occur in this and the following section is accounted for, although the MM 80 area may be less of a real preference and more of an artefact associated with the average human pulse tempo.

Nevertheless, some early writers unequivocally considered the human pulse to be a standard for musical tempi, and not merely a measure. Stevens (1957) quotes Nathaniel Tomkins' annotations in one particular set of his father's Musica Deo Sacra part books at Tenbury:-

> 'Sit mensura duorum humani corporis pulsuum, vel globuli penduli, longtitudine duorum pedum a centro motus.'

Assuming a pulse rate of 72 per minute, this gives a musical tempo of 𝅗𝅥 = 72. From the same century, Simpson (1665) writes:-

> 'Some speak of having recourse to the motion of a lively pulse for the measuring of crotchets, or to the little minutes (ie seconds or MM 60) of a steddy going watch for quavers.'

Ramos (1492), Gafurio (1496), Lanfranco (1533), Zacconi (1592), Mersenne (1636-7) and Quantz (1752) were also among those who tried to establish the heart pulse as the standard of tempo.

Quantz[1] however was aware of the difficulties associated with this:-

> 'One might object that the pulse beat is neither constant at each hour of the day, nor the same in every person, as would be required to accurately fix musical tempos with it. It will be

[1] 1, p.288.

> said that the pulse beats more slowly in the morning before meal-time than in the afternoon after meal-time, and still faster at night than in the afternoon; likewise that it is slower in a person inclined to melancholy than in an impetuous and jovial person.'

Later[1] he sheds some light on the ubiquity of the MM 80 tempo, referring again to the four tempo categories mentioned earlier:-

> '. . . I will be still more explicit. Fix approximately eighty pulse beats to a minute as the standard. Eighty pulse beats in the fastest tempo of common time constitute forty bars. A few pulse beats more or less make no difference in this regard. For example, five pulse beats more in a minute, or five less, in forty bars shorten or lengthen each bar by only a semiquaver. This amounts to so little that it is imperceptible. Those with more or less than eighty pulse beats in a minute will then know how to proceed with regard to decreasing or increasing the speed. Even if it were admitted, however, that my proposed device could not, in spite of everything, be presented as generally and universally applicable, regardless of the fact that I had proved it with the beat of my own pulse and with many other tests with various people in connection with my own compositions and those of others; my device would still serve to keep everyone who, in following the method discussed above, had gained an understanding of the four main categories of tempo, from departing too far from the true tempo of each piece.
>
> . . . .
>
> Beyond this, if someone could discover a simpler, more accurate, and convenient device for learning tempos and establishing them, he would do well not to delay in communicating it to the public.'

The following writer does just this, relating tempo standard to a more objective system:-

> 'Scholar: - - - Sir, of what length must I make a pendulum, in order to beat the true time of the several Notes of Musick; as the Semibreve, the Minim, the Crotchet etc?
>
> Master: - - - I then suppose the pendulum to be about 30 inches long, which Pulses are said to be almost the 60th part of a Minute, or nearly the space between the beat of the Pulse . . .'
>
> (Tans'ur, 1746)

Galileo (1581), Mace (1676) and Loulié (1696) also attempted to standardise tempi by relating it to the swing of a pendulum, while Buchner (between 1513 and 1532) compared the duration of the tactus with the stride while walking normally.

1, Quantz(1752) p.288.

Nevertheless, despite the similarity of the average pulse to MM 80 and the evidence of the above, the Psychophysical and Movement literature gives little support for heart rate being a part of the tempo controlling mechanism. If the MM 80 tempo is in any way the "normal" one, then its relationship with the pulse is certainly not direct. It may even be coincidental or further evidence of a common more basic time-keeping mechanism affecting not only heart rate and musical tempi, but also walking and many other activities. Perhaps however, Sachs (1953)[1], whose own "personal standard tempo" he thought was near MM 80 but whose pulse was in the sixties, has the true explanation of the apparent pulse-musical beat equation when he says:-

> '. . . that in determining musical tempo, civilizations without a mechanical metronome have always availed themselves of the ticking clock that nature has given to the heart. The pulse can certainly measure music, just as certainly it does not rule it.'

To which, the present writer would add just one more possibility, namely that the heart beat, although not controlling tempo, may give to an individual an unconscious idea of a "normal" tempo with which all others are compared.

(e) Tradition and Precedent

Tradition precedent and current fashion, sometimes contrary to authenticity, can also play their part in setting an acceptable broad range of tempi. We are only now shaking off the 19th century tradition of slower tempi for the allegro movements of "Messiah", and today's passion for light dancing allegros may well become a future tradition. The ready and frequent reproduction of the performances of leading performers and conductors now possible also helps nowadays quickly to define the current acceptable range of tempi for any particular work.

(f) Dance Tempi

In Dancing and Ballet, movement speeds and musical tempi literally meet. Despite the undoubted inter-individual differences and intra-individual consistency in movement previously discussed, certain ranges of tempi become

[1] pp.33/4.

established for the dances of any age, and although Pavlov (1927) linked the various dance tempi with processes such as the pulse and respiration, it is much more likely that they are based on the average natural movement speeds for each dance routine. Indeed, in some dances, the nature of the steps makes a performance only possible between narrow tempo limits.

Various theorists have quoted figures for the tempi of different dances, but never with complete agreement. Not surprisingly a periodicity at MM 80 is again evident in the Quantz tempi:-

Affilard (1694)		Quantz (1752)
♩. = 116, 100	gigue	♩. = 160
	canarie	♩. = 160
♩ = 106	passacaille	about ♩ = 180
	tambourin	about ♩ = 180
♩ = 156	chaconne	♩ = 160
	furie	♩ = 160
𝅗𝅥. = 70	menuet	♩ = 160
	bourrée	♩ = 160
𝅗𝅥 = 120	rigaudon	♩ = 160
	rondeau	about ♩ = 140
𝅗𝅥 = 120	gavotte	about ♩ = 120
♩ = 95	marche	♩ = 80
	musette	♩ = 80
𝅗𝅥 = 90	courante	♩ = 80
	entrée	♩ = 80
	louré	♩ = 80

Finally, Farnsworth et al (1934), in a study misleadingly entitled "Absolute Tempo", found that the subjectively correct tempo for the waltz, as obtained by controlling a variable speed pianola and also by tapping agreed well on average with the tempi of ♩ = 116 proposed by the Recording Department of the Aeolian American Corporation.

(g) Marching Speeds

Again a direct relationship with movement is involved, in this case the various speeds of locomotion. Regimental drill books quote figures such as MM 120 and 60 for quick and slow marches, but, apart from the information given by bandmasters in Chapter 5, as far as the writer knows, no band has ever been objectively timed to ascertain consistency in either marching or concert performance. As in dancing, any different individual natural rates of movement have to be reconciled.

(h) The Text as a Whole

The mood and general content of any text and the response to it must invariably restrict tempi to within the limits imposed by current commonly accepted good taste.

Structural Musical Factors - Continuously variable and immeasurable in most cases, but often sensibly constant, within limits, for any given section or short piece. It may be that in addition to helping to define or modify the broad range of acceptable speeds, a subsequent consistent change in any of the following musical variables may also cause a slight change of tempo - possibly unconsciously.

> 'It is the content that settles the pace. Full harmonies, harmonies that change oftener than the beat, elaborate figuration that would easily become vulgar if hurried, poised melody that relies on contrast of pitch rather than of accent, all make for a slow tempo.'
>
> (Fox-Strangways, 1929)[1]

Like the General Factors detailed above, and of course depending upon the degree of individual musical perception, the structural musical factors are all capable of being at least partly apprehended, and therefore taken into account, before tempo initiation.

(i) Harmony - Individual Chords, Progression and Harmonic Rhythm

Three closely related aspects of Harmony may influence tempo:- Individual Chord Sound, Chord Progression and Harmonic Rhythm.

The nature, texture, style and colour of the individual chords, perhaps

[1] 1, p.39.

considered in relation to the acoustic environment, are likely to play a part in adjusting the range of suitable tempi. For example, almost by definition, because harmony is meant to be savoured, full, unusual or subtle chords, together with decorative devices such as the suspension and appoggiatura, require more duration for their aural effect to be better appreciated.

Nevertheless, the little experimental evidence from the literature generally seems to contradict this view, although the apparent unawareness of the many variables involved and the introspective explanations offered make the following authors very suspect. In a study by Judd (1899), a piece played on the piano with full accompaniment was faster than when unaccompanied or executed on a dummy keyboard. The explanation suggested is that in both slower cases the S is forced to supply the missing parts by an increased effort of imagination. Similar results were obtained by Ebhardt (1898), but his explanation in the first case was that feeling enters in as the determining factor of tempo, an accompaniment increasing the emotional effect; and in the second that the increase in physical activity takes more time, and the feelings rise less quickly without the full tonal sensations. However, Sears (1902), using a reed organ, noted that not all his Ss performed hymns faster when harmonised. In any case, the present writer maintains that the complete omission of either harmonic support or the actual sound is not the same as a comparison between different degrees of harmonic fullness, and his position is not necessarily invalidated by the above data.

The second aspect to be considered, the chords in progression, is most applicable to tonal music. It is harmonic tension, tonal direction and relationships that helps to give such music its movement and momentum. The more predictable and conventional the progression, the faster it will tend to be performed, and, as in the case of single chords, unusual events or a generally unpredictable or less tonal chord progression will tend to make a slower tempo appropriate.

The most potent aspect of Harmony however is Harmonic Rhythm. This, although a continuous variable, may for practical purposes be regarded as discrete. The more common types of harmonic rhythm, which remain virtually constant in most short simple pieces, are detailed below. Even longer movements, without maintaining any absolute consistency, will often have the same approximate rate of harmonic change throughout. There is however a tendency in tonal music towards a faster harmonic rhythm, and possibly an associated rallentardo, at cadence approaches.

Average rate of chord change	Example
Crotchets, with some passing quaver chords or suspensions	Bach chorales
A new chord or position every beat or half bar	Hymn tunes
Iambic and Trochaic Rhythms ♩|𝅗𝅥 and |𝅗𝅥 ♩|	Minuets
A new chord every bar - Waltz tempo	Chopin Waltzes
A new chord every bar - fast "one in a bar"	Beethoven Scherzi
Multi-bar rhythm - but chords always changing at cadences	Classical expositions

Musicians would agree that the above list, in descending order of rate of chord change, also represents an approximate ascending order for tempi. The more frequent the chord change, the slower the tempo required to appreciate it: the more static the harmony the greater the need to create interest in some other way. Although the composer usually creates his own interest with thematic devices or decorative figuration, faster speeds are not only a possible additional source of interest, they are also more easily and musically achieved with a slow harmonic rhythm. Acoustical considerations enable broken chord and other figuration, when decorating a slow harmonic rhythm, to be played at a faster pace without blurring the harmony.
Harmonic Rhythm was a factor selected for investigation, and the experiments

showed that it plays a vital part in tempo choice and confirmed the general views expressed above.

(j) Melodic Rhythm

Common sense suggests that the greater the rhythmic interest between the beats, always taking into account the criteria mentioned in (i), the slower the appropriate speed. This would be both for the performer's convenience and the listener's appreciation of detail. Fox-Strangways (1929) supports this view, but contradictory principles may also be at work. Continuous regular figuration could give increased momentum and encourage a faster speed than when the beats are undecorated, sporadic and irregular figuration possibly having the opposite effect. Thus, the relative effects of even and dotted figuration and the disturbing influence of syncopation must also be considered. These were also among the factors investigated experimentally and some interesting results will be discussed.

The fastest notes, the opening, or the most memorable thematic group or rhythm, often in the mind when initiating a performance, may also be potent individual tempo setting factors.

(k) Melodic Shape

Melodic shape can never be a truly consistent factor in any piece, but inasmuch as there may be a preponderance of one or more characteristic features such as conjunct movement, wide leaps, rising scales, broken chords, ornamentation, so the broad range of acceptable performance speeds may be affected. For example, rising scales suggest excitement and a greater pace than wide leaps which need more duration, not only to execute, but also to perceive. In particular, the melodic shape, character and intervallic tensions of the opening phraise may also have a decisive part to play in tempo initiation.

(l) Texture

Apart from suggesting that the more dense musical textures will require generally slower tempi, most aspects of texture have been dealt with under other headings. However, two related points in connection with tempo have not yet been specifically mentioned. Firstly, the tempo must allow for the proper projection of the melody, particularly when it is an inner part and secondly, it is necessary to perform at a speed at which no detail is lost.

> 'The pace of a composition, which is usually indicated by several well-known Italian expressions, is based on its general content as well as on the fastest notes and passages contained in it. Due consideration of these factors will prevent an allegro from being rushed and an adagio from being dragged.'
> (C.P.E. Bach, 1753)[1]

There is also the effect of counterpoint to be considered. A polyphonic texture needs a slower tempo than a monophonic one, not only to give time to perform or appreciate the different parts, but also because the former usually involves a more complex harmonic rhythm.

Finally, while the inability of a poor technician to perform difficult music fast enough is not the concern of this study, the inherent difficulty of some music cannot avoid being a controlling factor in setting the appropriate tempo range. Indeed, the sense of strain when projecting music such as Beethoven's Grosse Fuge is a legitimate component of the piece.

II FACTORS AFFECTING TEMPO WITHIN ANY APPROPRIATE BROAD RANGE

The writer suggests that these factors, while not exercising a major influence on the broad range of acceptable tempi, affect choice of tempo within that range, although individual response to each will be different.

Expressive Structural Musical Factors

- These include both continuous and discrete variables.

(a) Phrase Structure and Touch

If tempo is concerned with the duration of longer musical units and not just beat speed, then the type of phrase structure may be a relevant factor. Speculation suggests that regular and predictable phrasing would encourage a more natural and regular flow and therefore rather faster tempi. Regular phrasing, as in the hymn-like structure of the experimental music, would also seem to encourage sympathetic breathing in phase with the musical phrasing,

1, p.151.

whether the performance is vocal, breath-based or purely instrumental. The likely contribution to tempo of the speed or control of respiration was frequently in the writer's mind during his own experimental performances.

In addition, the possible relative effects of short and long phrases and the presence or absence of an anacrusis must also be considered, together with the use of legato and staccato, which, although a performing factor, is closely related also to phrase structure. In the experiments, very significant tempo differences were obtained between the legato and staccato performances.

(b) Volume and Dynamics

There would appear to be contradictory elements at work here. Loud music, both for acoustical reasons and because of the greater extent of movement and effort often involved, would first seem to promote a slower speed, yet the evidence from the psychophysical literature, namely, the apparent increased duration of louder sounds, could indicate a compensatory increase in speed. The average amateur choir's tendency to accelerate in ff and retard in pp perhaps supporting the prior claim of the latter principle in some cases at least. Again, this acceleration could instead be caused by the greater excitement engendered by more volume.

The effect of accent must also be considered. Both Ebhardt (1898) and Sears (1902) found that accents in tapping or playing single keyboard notes usually gave rise to an increase in actual duration, and this is rather at variance with the above. Unfortunately, neither author informs us whether the increased duration was a supplementary agogic accent or whether, to the performer, the note durations were subjectively equal.

Accent frequency may also exert an influence; fewer accents facilitating rapid movement, and an accent on most beats or syncopated accents exerting a retarding effect. Further more psychological aspects of volume and accent will be discussed below under (h).

(c) Mode and Expressive Intervals

The common tendency to equate the major system with pleasure and the minor with pain has been discussed by Meyer (1956) and Cooke (1964). The former identifies the many associated factors inseparable from any given tonality, some of which have already been included in the present writer's survey:-

> 'The minor mode is not only associated with intense feeling in general but with the delineation of sadness, suffering, and anguish in particular. This association, which as we have seen is also connected with chromaticism in general, appears to arise out of two different though related facts: 1) States of calm contentment and gentle joy are taken to be the normal human emotional states and are hence associated with the more normative musical progressions, ie, the diatonic melodies of the major mode and the regular progressions of major harmony. Anguish, misery and other extreme states of affectivity are deviants and become associated with the more forceful departures of chromaticism and its modal representative, ie, the minor mode. 2) Marked or complex chromatic motions common in the minor mode-melodic lines which move conjunctly by semitones or disjunctly by unusual skips and uncommon harmonic progressions - have tended to be accompanied by tempi which were slower than those which accompanied more diatonic music. This was, of course, particularly true of the earlier use of chromaticism during the Renaissance and the baroque period. This coincidence of chromaticism and its modal representative with slower tempi can be explained at least in part on technical grounds. For not only are the instruments constructed with the diatonic norm in view so that it is more difficult to play chromatic passages rapidly, but musical training, both instrumental and vocal, is based upon the normality and simplicity of diatonic progression.'
>
> (Meyer, 1956)[1]

Cooke developed a thesis that tonal composers have used the various intervals within major and minor keys to express different moods and ideas quite consistently over many centuries. Famous examples, such as Mendelssohn's rapid minor key movements, where the general trend is contradicted, cannot nullify the general principle that a major key suggests pleasure rather than pain, and presumably a faster tempo than a minor key. In addition modal music with its frequent minor third and flattened seventh, takes on the general character of a minor key. Very recent work by Gabriel (1976) investigating the validy of Cooke's thesis, suggests that although the basic major/minor key-pleasure/pain equation stands up to

[1] 1, pp.227/8.

empirical investigation, the effect of the melodic intervals and formulae is not as catalogued by Cooke. He also accuses Cooke of being selective in his musical examples. However, Gabriel's experiments isolated the melodic units from any tonal or rhythmic context, and the writer is of the opinion that the addition of potent tonal and rhythmic position and accent to Gabriel's procedure would have produced results much more in agreement with Cooke and with common usage. For example, a minor 6th ambiguously presented tonally and rhythmically, or in a major chord context, takes on the quality associated with its inversion, the major 3rd. The same interval in a minor chord context will have a very different effect.

The writer therefore believes that mode, in conjunction with potent melodic intervals and harmonic tension at the beginning of a piece is another factor affecting precise individual tempo initiation.

(d) General Pitch Level and Key

A lower general tessitura or key, with its associated greater resonance, makes a rather slower tempo necessary. This assertion receives complementary support from the literature of Time Psychology, where it was noted that lower sounds seem shorter. The compensatory principle mentioned in a previous section, and to be more fully dealt with under (h), would thus also indicate a slower tempo. As Key and Mode are the only absolutely discrete and fully controllable musical variables, they were inevitably among those factors selected for experimental investigation. The generally predictable effect they had on tempo will be discussed in due course.

The psychological effect of sharps and flats in the key signature may also be a subtle factor in tempo initiation, as may the actual feel of the instrument in different tonalities, particularly with keyboard instruments. Also significant could be the tendency for keyboards to have a lighter action in the treble register.

(e) Words

In addition to the effect of the text as a whole on the appropriate broad tempo range previously dealt with under I(h), the actual production and sound of the words at the beginning of a piece may bring about a fine adjustment to tempo initiation. The language, the syllabic structure of the opening phrase, the associated articulation of the singer and the need for clarity of words all contribute here.

Performing Factors - If the data and possible preferences discussed in connection with Movement Speeds apply to the actions used in musical performance, then those actions must be taken into account when considering individual tempo initiation. Particularly relevant may be the movements involved in conducting, bowing and playing repeated or alternating notes on keyboard, wind instruments and percussion.

(f) Conducting Movements

The writer contends that conducting is a genuine "performing" method, even when there are no performers to be conducted. Unhampered by external performing considerations, technical problems or inhibitions, restricted only by the movement possibilities of the arms, it expresses an "ideal" tempo. The method was used extensively in the writer's early experiments. Its principal weakness, when no performers are present, is that the absence of actual sounds creates yet another dimension of artificiality.

The literature of Movement Speeds has already provided some points of interest. Stetson (1905), when analysing conducting movements, found that the duration of the beat strokes was not affected by their length, and Buytendijk (1947), who was concerned with movements generally, also noted that an increase in movement extent did not necessarily cause an increase in its duration. Reference has also previously been made to Stetson (1905) and Mursell (1937) in connection with the Movement Cycle. Both analysed the movements of beating time in relation to this cycle, suggesting that the preparation, downbeat stroke and relaxation phase were all grasped as a single entity. This is possibly further support for a view of tempo control where the crucial duration is not the single beat but a group of beats or larger musical unit.

Sachs (1953), referring to tempo limits, suggested that the minimum conducting tempo, with no beat subdivision, was about MM 32, with an approximate maximum at MM 132: above this tempo the conductor would fidget and not beat. Finally, the previous literature on the effect of increased weight on movement speeds would indicate that the use of a baton, or its size, does not affect the conductor's beat.

(g) <u>The Movements of Instrumental and Vocal Technique</u>

The movements of performing technique may be categorised as follows:-

1) Involving physical manipulation of an instrument only, as in keyboard, string and percussion playing.
2) Combining (1) with tonguing or lip technique, as in wind and brass playing.
3) Involving no physical manipulation and solely concerned with the movements of articulation, as in singing.

A simpler and possibly important alternative classification could distinguish between the breath-based performing of (2) and (3) and the solely mechanical manipulation of (1). However, it is also possible that the phases of breathing and musical phrasing may be related in all three categories.

As musical performance involves so many kinds of movement, the general movement data dealt with in Chapter 2, including the maximum, minimum and preferred or economical speeds for any particular limb or combination may still apply even when the actions are ostensibly the servant of musical criteria. If so, the different types of touch or technique associated with legato, staccato, use of pedal and the style, extent and strength of the performing movements will all affect an individual's tempo. However, the simple tapping involved in many psychophysical and movement experiments is hardly comparable even with the most elementary performing situations; in addition, the resistance, action, loading or voicing of the instrument add further mechanical and acoustical variables. More realistically related may be those experiments investigating maximum tapping rates. Rieff (1900) and Rieger (1903) both found that the maximum rate of playing repeated keys with a single finger could not exceed a beat of 125 msecs. When, however, two or more fingers were used in alternation, the maximum rate was approximately doubled. Reference to Chapter 2 under Tempo Limits and Reaction Times shows that comparable results were obtained by Dresslar (1892) and Stetson (1905) for simple tapping and beating. Meumann (1894) suggested that the use of both hands generally in playing may make for a greater precision of tempo. These apart, there appears to have been no other research relating movement speeds, articulation habits or respiration speed and phasing to musical tempi.

It must be made clear again however that the technical or vocal deficiencies, lack of confidence or nervousness of the performer, although a reality on occasions, play no part in the writer's study of preference.

(h) Psychophysical and Psychological Factors

Certain interesting possibilities emerge from the literature of Time and Rhythm Psychology, most of which have been mentioned in connection with other topics. Although much psychophysical data has been drawn from the passive comparison type of experiment, it is possible that if objectively equal durations or tempi can be made to sound unequal through the variation of other aspects of their presentation, then those same variations may correspondingly mislead a musical performer as to his own tempo. The general principle applying in all cases would appear to be that any subjective impression of greater or lesser degree will tend to affect the performer in the opposite direction. For example, Time Psychology data suggesting that both higher and louder tones seem longer, carries the implication that generally or relatively high or loud music may be performed faster in order to compensate for the apparent greater duration of the tones. The complementary principle of the agogic accent, that longer seems louder, is interesting in relation to this.

However, the general compensatory principle outlined above may have to be applied within the context of an overriding psychophysical phenomenon affecting most of the musical tempi spectrum. The writer refers to the tendency for durations longer and shorter than the Absolute Indifference Interval to be under and overestimated respectively. This situation is further complicated because the different experimental methods used in determining the relevant data also suggest alternative implications for tempo. For example, in relation to the underestimation of longer durations, either of the following may apply:-

(i) If underestimation means that a reproduced long duration is shorter than the standard, then an immediate attempt to copy a slow musical tempo could result in a faster speed. This may even apply to the relationship between the "mental" rehearsal of any slow tempo and its subsequent realisation in performance.

(ii) If underestimation means that long durations seem shorter than they really are in an absolute sense, they may be made longer (slower) in compensation.

Section II(b) suggested other contradictory factors may also be concerned. For example, the acceleration of inexperienced performers in a crescendo gives credence to the psychological general principle mentioned in the first paragraph, while the physical and acoustical factors involved in louder music would seem to favour slower tempi. Further, the psychological effect on tempo of accentuation must not be ignored. The apparent fast tempi of some conductors such as Toscanini can sometimes be attributed more to extreme precision or fewer accents rather than objective pace. The question then arises as to whether the performer in such cases assesses the tempo similarly and performs at an objectively slower pace than he realises.

Other less subtle factors are also prompted by the ground covered in Chapters 1 and 2. The so-called Internal Clock, much referred to in the psychophysical literature, is likely to be significant in relation to musical tempi, particularly with regard to the factors causing it to run at a different speed. For example, the generally attested accelerating effect of higher body temperature could affect both actual movement speeds and the assessment of those speeds, whether that higher temperature is caused by circadian variation, warmer environment, illness or nervousness. Our assessment of tempo may also be affected by our unconscious acceptance of the first performance we hear or give of any work as the standard by which we measure all aspects of subsequent performances. In this respect, the anchor effect of an often heard signature tune is an interesting future research topic.

There are thus a number of potential psychological/acoustical tempo-affecting factors in any performing situation. The writer, without hazarding a resolution of the many compensatory and contradictory elements, presents them as an essential although uncertain part of the total tempo background.

The actual passing mood of the performer has sometimes been deliberately exploited in the past, both in composition and performance. C.P.E. Bach (1753) even urged the performer to "languish and grow sad" in sad music in order to move his audience more. Music from the "Storm and Stress" period and fantasias, toccatas and improvisatory pieces by composers from other periods, such as Liszt, were sometimes written so that a wide variety of tempi are possible. The character of the music then depends very considerably on the mood of the executant, and is an exaggeration of what happens to a lesser extent in nearly all musical performance.

Some miscellaneous points remain to be made. Wallin (1911) suggested that persons who chiefly enjoy the melody and harmony in music will favour slower tempi than those who appreciate more the rhythmic element, and in this connection it is perhaps significant that Henkin (1955) found melody and rhythm to be independent mathematically and psychologically. Finally, sex differences, both physical and psychological, may affect the tempi performed by men and women.

Instrumental Factors - Concerned with variables outside the performer's control; in most cases constant throughout a given performance.

(i) Type of Instrument, Orchestration or Registration

As the instrument, the characteristic melodic or harmonic ideas associated with it, together with its individual sound are all concerned in the composer's original conception, it has already indirectly played a part in defining the broad range of acceptable tempi. More particularly however, the timbre of an instrument projected into an acoustic environment may affect tempo. For example, an instrument such as the flute where the tone contains few harmonics may encourage rather faster speeds, quite apart from the related considerations dealt with below under (j). On the other hand, a more resonant timbre will often sound more comfortable at a slower tempo. The experimental results confirmed expectation that the different instruments used would appreciably affect the tempi performed. Unfortunately, it was impossible to assess the relative contributions made to the tempi differences observed by movement factors, technique, touch and timbre. The writer's speculation that the passing of the melody from one instrument or section to another, or a change of organ registration, may also unconsciously and imperceptibly modify on-going tempi receives some support from a study by Turner (1938), described in Chapter 5 II(d), and the experimental results.

(j) Action, Touch and Voicing of Instrument

The mechanical action of an instrument, its resistance, balance, response, and repetition capability all interacting with the player's touch, are likely to affect and certainly limit tempi. Previous mention has been made of a possible relationship between movement speeds and instrumental loading. A further factor is the speed of speech in instruments such as the organ, clarinet and oboe, where any delay so often results in a slower tempo. With regard to the experiments involving a change of piano, the results were both interesting and partly unexpected.

<u>Environmental and Social Factors</u> - Continuous variables, generally constant for any performance.

(k) <u>Acoustics</u>

The size and reverberation period of the performing situation together with the presence and size of an audience are the chief criteria, but the resonance of the instrumental or vocal sound itself is obviously linked with the former parameters and part of the total acoustical system. Experienced performers no doubt take the obvious factors into account before beginning, but the actual projection of the sound into the acoustical space may well reveal an unanticipated element requiring an unconscious minor adjustment to the tempo. Generally, larger halls with a longer reverberation period make a slower tempo desirable in order to avoid sound congestion and to promote clarity of any words, particularly with a large ensemble or volume. Correspondingly, a dry acoustic makes faster speeds possible.

(l) <u>Psycho-Social Factors</u>

In this category come the performer's reaction to the type, mood, receptivity and response of an audience, the position of the music in any programme and the nature and requirements of the musical occasion. For example, a children's concert may necessitate faster or slower speeds in order to prevent boredom and increase clarity respectively. Very practical matters such as the need to end the concert by a certain time, or the distance to be marched by a band may also be taken into account when initiating a tempo.

(m) <u>Ambient Conditions</u>

Foremost here is ambient temperature, mainly because of its effect on body temperature, but possibly also because changing temperatures affect instrumental action, pitch and the actual speed of sound. Speculation suggests that humidity and the general weather conditions may also be involved, but perhaps only indirectly through an associated change of mood.

(n) Ensemble Size and Nature

For reasons of mechanical and human inertia, and the acoustical considerations previously considered under II(k), rather slower speeds are generally more appropriate with larger ensembles, orchestras, choirs, congregations and longer marching columns. The time lag between the conductor and the farthest players will also contribute here.

The reconciliation of any individual preferential tempi with the conductors "ideal" initiation tempo will be discussed later.

III METRE

Although a Structural Musical Factor, Metre is fundamentally different from all previous factors in that it is not principally concerned with sound but with grouping. It is treated separately here as the writer contends that metre is not only the decisive factor in tempo initiation but also (and this is probably not unrelated) the most essential and distinctive component of conventional tonal music. The pervasive metrical division is a vehicle for every other structural musical factor, and the one usually absolutely integral with the composer's conception.

It is likely that each metre generates a different series of tempi covering the complete range from the slowest possible to the fastest possible musical speeds. There may also be a relationship between metre and a performer's natural or accommodated breathing tempo or phasing, and not only in breath-based performances. Relationships with the background literature also suggest themselves, particularly the most favourable tempi for grouping subjectively in twos, threes and fours, Movement Analysis and Movement Speeds. Indeed, the completely different movement attitude adopted between duple and triple metres, especially in relation to the sequence of actions and associated momentum towards the next accent, draws the writer's attention again to the apparent unimportance to the performer of individual beat succession. What does seem critical during performance is the position of the longer-term temporal "goals", particularly the next strong beat, and all the action is concerned with reaching for them. Thus, the different modes of accentuation, grouping and phrasing associated with each metre affect tempo in a fundamental way.

Cooke (1964) also made the point that, other things being equal, there is an expressive antithesis between duple and triple metres. Its basic effect being seen in the contrast between the regular, rigid masculine movement of the two feet in marching or running, and the longer, swinging or lilting feminine movement of the dance. All traditional metres can be resolved into one of these two groups.

A different consideration is the psychological effect of the appearance of the time signature and the note values most in evidence. When confronted with 4/2 as opposed to 4/4, the minim beat of the former and the generally "whiter" musical notation will tend to encourage slower tempi even when no tempo implication is intended, as in older music or some hymn books. Since the Renaissance, composers have had different habits in this respect. Beethoven, for example, invariably using a minim beat for fast movements and a quaver for slow ones. The more subtle distinctions between, for example, ¢ and C, and simple and compound subdivision will undoubtedly also affect choice of tempo.

Some general points remain to be made. While all the Musical and Performing Factors can be taken into account in large or small measure before tempo initiation, it is not until the actual sound is heard and any instrument addressed that a complete aural and tactile perception takes place of every factor individually and of their interaction with each other. A quick revaluation after tempo initiation therefore may cause a slight modification of that initial speed, just as a subsequent significant momentary irregularity or longer-term change in any variable may also respectively cause temporary rubato or a general and also probably unconscious tempo change. It is further suggested that unexpected events or irregularities in any factor need more time for their performance, proper effect and appreciation by the listener, and are thus a further reason why a basic tempo may be momentarily retarded.

The initial tempo is of course one of the vital components of the performer's interpretation, and within this basic underlying tempo, the subsequent temporary deviations, from whatever cause, are indicative of his expressive intentions. Meyer (1956)[1] in fact sees deviation from the regular as a universal principle and an expressive necessity for all performing parameters:-

> 'In music and speech pure tone, true pitch, exact intonation, perfect harmony, rigid rhythm, even touch and precise time play a relatively small role. They are mainly points of orientation for art and nature. The unlimited resources for vocal and instrumental expression lie in artistic deviation from the pure, the true, the exact, the perfect, the rigid, the even, and the precise. This deviation from the exact is, on the whole, the medium for the creation of the beautiful - for the conveying of emotion.'

While concurring with the above writer, it is necessary to re-emphasize the importance of an underlying or background absolute regularity, without which the concept of deviation would be meaningless. Indeed, with regard to tempo, it is generally accepted that rubato should not affect the basic overall tempo established for any section of music, and the timing method employed in the experiments assumes this is so. However, it was considered sensible to ensure that the music provided for each experiment gave no encouragement to rubato, by contriving an almost absolute internal consistency in the various musical factors previously described. This also enabled a more controlled comparative investigation of the selected continuous or discrete variables to take place.

[1] p.202.

CHAPTER FOUR

Possible Tempo Origins; Choice and Preference

Possible Origins of any Available Musical Tempi

It seems likely that the speed of all motor activity has its ultimate origin in one or more fundamental nervous periodicities, which may manifest themselves first in the various discriminatory and preference parameters of Time Psychology. These, or the multiples of any basic periodicities, would then work through the various levels of human movement from involuntary movements and reflex actions, through simple voluntary movements and finally the complex movements of musical performance. However, this view raises several interesting questions:-

1) Are the fundamental origins of tempi universally identical and constant, or are there inter-individual differences and intra-individual variations perhaps associated with body temperature?
2) Are Perceptual and Movement parameters related or determined by a common fundamental origin?
3) Is there a resulting constant or varying discrete series of possible or more likely individual movement speeds based on a periodicity related to a fundamental pulsation, or is there instead a continuum within which all movement speeds are equally possible?
4) Are any resulting available tempi for each musician the consequence of individually different fundamental nervous periodicities or of one universal nervous tempo acting through differing physiological systems?
5) Do individual physical parameters such as body lever dimensions and weight contribute to the total system producing available speeds?

6) In addition, do the mechanical factors created by the loading of an instrument in the total performing situation also affect tempi?
7) If they do, is any range of available movement speeds completely modified and/or do they affect the selection of the precise tempo from any available range, perhaps also putting limits on the maximum and minimum movement speeds physically possible in any situation?

These academic questions may never be answered for certain, but the model of tempo proposed by the writer postulates the availability of a different discrete range of movement tempi in each total situation, having its ultimate origin in a fundamental nervous periodicity. It must be emphasized however that these tempi are almost certainly not all "preferences". The final detailed discussion and extension of this view in relation to the results will be given in Chapter 9.

The subjective tempo initiated from all the speeds individually possible within the broad range deemed artistically appropriate by the relevant criteria is presumably an intuitive response. It is suggested that this response is determined by a combination of those factors listed in Chapter 3 that can at least be partly apprehended before the instrument is addressed or the sound projected, together with the musician's temperament, mental and physical state, passing mood, reaction to the apparent mood or words of the music, previous activity, knowledge, perception, experience, maturity, taste and current interpretative view. All these variables, often contradictory in effect, contribute to a resultant total response situation; inasmuch as a different character can be given to music by different tempi, so any performing tempo is partly an expression of the performer's own character.

> 'Taste is the true metronome.'
>
> (Bemetzrieder, 1771)[1]

1, p.68.

> 'Practical musicians have, during long periods of musical history, been content to find the right tempo by intuition rather than by measurements - perhaps sensing that the choice of a "right tempo" is closely bound up with the acoustics of the playing space, the timbre of the particular instruments involved, and the articulation habits of the players.'
>
> (Hugo Cole, 1974)

Differing temperaments may also decide which factors predominate in the mechanism of tempo initiation. For some musicians, psychological, physiological or movement factors may override the more subtle musical ones, while for other and possibly better performers, musical or performing factors are more potent. Indeed, the true position generally, or for any individual, could lie anywhere between the following extreme views:-

1) Performing movements in any situation are limited to a fixed discrete series of possible tempi: the musical and performing factors merely determine the "choice" of the appropriate speed from those available.
2) Performing tempi are determined solely by the nature of the musical material. This would presuppose a continuum of available speeds, and could result in a similar speed for all musicians for some pieces.

The first extreme is possible and indeed with the admittance of the modification of the available tempi by some of the factors also concerned in the "choice", is the writer's present position, being compatible both with the experimental results and the everyday facts of performance. The second extreme is very much less consonant with the evidence, although any sensible variation in a structural or musical factor is likely to modify tempi consistently. There can however be no question of musical criteria always generating a similar speed for all musicians. Nevertheless, the more potent, or suggestive musical material may occasionally encourage a fairly uniform tempo response from different performers. Indeed, several writers have suggested that in some cases, and within limits, the musical content may settle the pace:-

> 'Every melodic piece includes one phrase at least from which the variety of tempo needed by the music can be clearly recognised. This phrase, if other considerations are taken into account, often compels one into its own natural speed. Bear this in mind, but also realise that for this sort of intuition long experience and fine sensibility are required. Who will contradict me if I regard this as among the highest accomplishments in the art of music?'
> (Leopold Mozart, 1756)[1]

> 'In music like this there never seems to be any question of the tempo; that is inherent in the sounds themselves.'
> (Fox-Strangways, 1929)[2]

> 'Some movements allow a much narrower margin of tempo than others. Perhaps there is always just one interpretation, and therefore just one tempo, which most musicians will find more convincing than any other; or perhaps interpretation is always relative. In either case, the only way of finding the tempo is by responding to the music itself, with a sensitiveness not given to every musician alike nor to any metronome at all.'
> (Donington, 1974)[3]

Tovey (in Fox-Strangways, 1929) made an interesting observation indirectly related to the above views:-

> 'In true music a slow theme is not the same as a quick theme played slowly. Slowness is Bigness.'

One final contribution comes from Mursell (1937), who believed that the absolute tempo for a piece depended on the setting of the entire tonal-rhythmic structure upon the true beat or takt.

While no author indicated the limits of the tempi to be regarded as the "same speed", the writer would not go so far as to suggest, with Leopold Mozart and Fox-Strangways, that some or all music generates an absolute tempo for itself. However, it is demonstrable that certain dance steps quite narrowly limit the possible range of some dance tempi, and the tempi of music explicitly or implicitly related to dancing movements may also be similarly restricted. Although in this sense there may be preferential tempi from the music's point of view, in all others, the music is but one part of the total performing situation governing tempo. The writer therefore repeats that although musical criteria, modified by performing, instrumental, environmental and psychological factors govern the interpretation, including tempo "choice", that "choice" is restricted to the movement speeds available at any given time.

1, Violinschule,I,ii,7; 2, p.39; 3, p.383.

Whether the "long experience" or "fine sensibility" mentioned by Leopold Mozart is necessary, and whatever the crucial factors in tempo initiation, it may not be correct to call the intuitive response the "right" or "ideal" tempo, or even the desired one, even when it is experienced through the performing media. When the performance commences, and all the factors previously incompletely taken into account make their full effect, the tempo may be changed. This change may take place, quite unconsciously, by the reselection of another available movement tempo, or by the modification of the initiated one.

Perhaps a theoretical ideal or pure "intention" tempo independent of movement considerations does not exist. After all, the literature of Rhythmic Imagery suggests that an imagined performance cannot completely eliminate those movements, explicit or implicit, required in actual performance. Whatever the case, the only tempo that can ever be measured is the one that settles down after initiation, and is clearly the only one with which the experimental study is concerned.

Tempo Choice and Preference

A general discussion of these terms is now necessary as they have been much used without qualification in the literature. As the writer believes a range of tempi is available in any given musical situation, the term "choice" is therefore applicable to a performing tempo on every occasion irrespective of other considerations. "Choice", then, is bound up with interpretation, but must not necessarily be regarded as synonymous with "preference". Most musicians will affirm that it is quite possible to regret a starting tempo, perhaps because of the miscalculation of the effect of some musical, instrumental or performing factor, and this tempo, although "chosen", is assuredly not "preferred".

Preference therefore is much less easy to define, and involves more complicated issues. There are certainly two related concepts involved here, namely subjective and objective preference, which need to be differentiated. Subjective preference is manifested in a listening situation when a comparison is involved and in a performing situation when the performer "prefers" his present tempo to previous ones or uses words like "normal", "satisfying", "economical of effort", "feels right", "most comfortable", "relaxed" or "ideal" when describing the tempo. Objective preference on the other hand can only refer to the speeds at which one goes most often, presumably assuming other tempi are available but not "chosen" so frequently. Previous writers, unfortunately, have used the term preference indiscriminately for many modes of behaviour and have rarely discussed a definition, even when publishing data under that heading. The above therefore indicates the writer' present position with regard to the distinctions between and within "choice" and "preference" and is to be considered in relation to the Experimental Definition of Preference given in Chapter 7.

However, any attempt to define a term such as preference is bound to raise contraversial matters, and it will therefore be useful to offer additional comments and speculation. They are given in note form, without further discussion or conclusions drawn:-

1) As it is never possible to repeat the exact circumstances of any performance, particularly the temporal and psychological circumstances, it can never be known for certain if a "natural" performance could have gone at a different speed. If other "natural" speeds are in fact impossible on any given occasion, the concepts of "preference" and "non-preference" are perhaps meaningless, together with any distinction between "choice" and "preference".
2) If the exact circumstances of performance can never be repeated, then the conditions condusive to any "preference" will never occur again, making the concept of a static preference untenable.
3) It will never be possible to discover if a different tempo is due to a change of "preference" or to the performance of a non-preferred speed.

4) Similarly, it may not be possible to know if any given tempo is determined by psychological, physiological, movement or musical factors or, as the writer believes, by a combination of them.

5) A subjective preference by listening may not be the same as the same musician's subjective or objective performing preference. The former will be restricted by the number of tempi available in the comparison situation and the latter will be affected by performing and instrumental factors not involved when merely listening.

6) Because of 5, and for many other reasons, it follows that a performer's subjective preference could be an uncomfortable speed for some listeners.

7) It is possible that objectively identical tempi may be subjective preferences on one occasion and uncomfortable on another. Similarly, identical tempi may appear to be different to both performer or listener on different occasions.

8) It is even more likely that objectively different tempi, on different occasions, may sometimes appear to be subjective preferences. Similarly, they may appear to be identical both when the performing or listening conditions are essentially the same and when they are different.

9) The likely part played by memory in tempo preference must therefore not be discounted. It is rarely possible in natural performing situations, and most certainly not in experiments, to be entirely oblivious of past performances, whether the memory of them is accurate or not. Any apparent preference could therefore be the speed remembered, or perhaps, most easily remembered.

10) If a changed musical or instrumental factor affects tempo "choice" or "preference", it is either because the preference is actually altered or because the different sound or touch confuses the memory and the attempt to reproduce a tempo previously made under different conditions. Perhaps these are different ways of saying the same thing.

It has been mentioned several times that the writer believes that tempo may well be less concerned with beat speed than with the unconscious overall duration control of the various units of music from the bar and phrase, right through to the movement, complete work and perhaps even the whole concert programme. There would then be a right moment for every musical "goal", both short and long term, and the reaching for that "goal" would control the general prevailing beat speed, overriding any passing rubato. Indeed, the computation of tempo in the writer's experiments relies upon this very assumption. The ultimate extension of such a view of tempo initiation and control would take into account breaks between movements and even unanticipated interruptions such as tuning and inter-movement applause. These interruptions would then be allowed for unconsciously in faster subsequent tempi. An attempt to reconcile longer-term tempo control with the discrete movement speed availability previously proposed is made in Chapter 9.

With specific regard to intentional tempo changes both within and between movements, another principle may be applied, consciously or unconsciously, by some musicians. Adjacent tempi may be related mathematically, either as a deliberate manoeuvre to facilitate tempo change, or because historical stylistic necessity makes a proportional relationship obligatory. Such a procedure may also be the result of a less calculated and even unconscious subtle satisfaction of the principle of simple ratios which manifests itself in much fundamental musical theory and aesthetics.

Finally, brief mention must be made of ensemble or conducting tempi in relation to tempo choice. The views expressed in this chapter concerning individual preference, particularly if that preference is contained within fine limits, appear to contradict the inescapable phenomenon of unified ensemble performance. However, reconciliation of different preferences could occur in several ways. The process of induction mentioned in the quotation of Fraisse (1964) in Chapter 2 is one possibility, and the rather similar concept of entrainment, that followed it, is another. The two clocks in the Huygens experiment behaved contrary to their individual mechanical nature when in resonant contact, and the same principle may apply to concerted human performance. If movement speeds are "chosen" from a continuum then synchronization of this kind is obviously no problem. A discrete series would pose more problems but even in this case the available tempo nearest to the ensemble speed may also be modified by the principle of entrainment. Alternatively, the performer could unconsciously modify the performing conditions in order to change the available speeds, perhaps by altering the amplitude of the performing movements. This sympathetic adjustment may contribute to the pleasure obtained from any communal activity involving synchronized movement such as dancing, marching and musical ensemble.

CHAPTER FIVE

Literature and General Views on Musical Tempi, Preference, Consistency and Steadiness

As far as can be ascertained there has been no previous detailed analysis of the possible tempo affecting factors and certainly no attempt to study any precise preferences and preference variation. Most previous views on preferential tempi have been based on experiments involving tapping and other arbitrary or artificial movements and, as in the case of the related fields, there has been an emphasis on general or individual broad preference ranges and averaged data.

The very meagre literature of experimental work directly related to preference, none of it recent or very rigorous, is detailed in Section I. Section II presents general literature and opinion on preference and other aspects of musical tempi.

I Experimental Work directly related to Preference

(a) Preferential Tempi by Listening to Music

As the result of a very primitive experiment in which the criterion of preference was the observed intensity and pervasiveness of spontaneous foot-stamping of an audience while listening to music at various tempi, Wallin (1911) gave the following four grades of response:-

very good (vigorous and pervasive) for	510 msecs average beat	(MM 118)
good	560	(MM 107)
fair	590	(MM 102)
poor	660	(MM 91)

The data suggests that the most probable range for preference is 410 to 700 msecs per beat, with the best grade of responses occurring most often in the 410 to 500 msecs range. Wallin's figures have even less value because a wide tempo range is masked by each average, and duple and triple metre data are combined in those averages. Two findings from this and an additional experiment involving the comparison of clicks may however stand up to more rigorous scrutiny; namely that each grade of responses in triple time music occurred at a uniformly slower rate than in duple time, and people do have a preference when given a choice of tempi. It is also interesting that the average very good response tempo was almost identical to the average preferred click tempo of 519 msecs beats also obtained by Wallin.

In a study mainly concerned with rhythmic preference and memory, Harrell (1937) found a high individual correlation between rates designated as being theoretically preferable for singing "Star Spangled Banner", waltzing and listening to the jig "Turkey in the Straw".

(b) Preferential Tempi by Performance

The only work similar to that undertaken by the writer has been that of Sears (1902), who, in an experiment in which hymns were played on a reed organ, found that both different subjects and the same subject played any given hymn at a variety of speeds when asked to perform in their own natural way. Outside the experimental situation, however, there have been occasions when objective timings have been made of several performances of a given work both by the same and different performers, and these will be detailed in Section II.

(c) Tempo-Affecting Factors

(d) Tempo Memory

No experimental work using music has apparently been done previously in these two important areas.

(e) Tempo Steadiness

Sears (1902) noted that the difference in duration between successive measures was frequently greater than 200 msecs. Unfortunately, no attempt was made to ascertain whether the inaccuracies of individual bars were overridden by a compensatory rubato or longer-term duration control. Much more recently, Thackray (1969) in his work on Rhythmic Ability, observed that even experienced musicians could be erratic in tempo maintainance, and that this ability improved very little with age.

With regard to the immediate repetition of a piece of music, Ebhardt (1898) found that the variations in total playing time for piano pieces were rarely greater than 300 msecs, while Sears noted that music repeated without pause tended to be slower the second time. No consistent trend of this kind was observed in the writer's results.

II General Literature and Opinion on Preference and Tempi

The limited available literature has been supplemented by the collective and individual answers to a questionnaire sent to eminent musicians in a variety of musical fields. Inevitably there is some duplication of views expressed by the writer in previous chapters. The relevant part of the questionnaire is now given, the general order of the topics that follow being based on it:-

The Questionnaire

1. How would you define "Preferential Tempi"? (This is not necessarily the obvious question it seems. I shall assume your definition applies to your subsequent answers.)

2. Do you believe musicians can have Preferential Tempi?

3. Do you believe you have any preferential speed(s) in musical performances?

4. Have you ever felt uncomfortable at a tempo you have chosen?

5. Have you ever felt uncomfortable (because of the tempo) when listening to a performance?

6. If YES to 3, are your preferential speed(s) related to specific pieces?

7. If YES to 4, please give examples and any timing information:-

8. If YES to 3, are your preferential speed(s) related to Time Signature?

9. If YES to 8, please give any available details:-

10. Do you think any of the following factors affect your speeds:-
    (a) Your Mood? (b) Acoustics? (c) Audience Size?
    (d) Instrument Action/Touch? (e) (Conductors) Weight/size of baton?
    (f) (Conductors) Size/Nature of Ensemble?
    (g) Any other factor(s): Musical, environmental etc? (Please give brief details.)

11. Before performing, conducting, marching etc, do you have any "mental" or "physiological" rehearsal in order to set the tempo? (Please give brief details.)

12. Can you "aim" accurately for any required tempo? (Please give any degree of accuracy.)

13. Can you memorise a tempo over a long period? (Please give any brief details.)

14. If you know you have preferential speed(s):-
    (a) Give any evidence that they have remained the same over the years:-
    (b) Give any evidence that they have changed:-

15. Give any evidence that your tempi, subjectively the same as years ago, are (a) still the same, or (b) faster or slower:-

16. Do you believe the various tempi in a multi-movement or sectional work should ever be related mathematically? (Give details of any views.)

17. Do you believe you and/or others can have an unconscious time control over the total duration of a movement or complete work? (Please give any evidence, if available.)

18. (Ensembles only) If you can, briefly explain how you initiate your tempi:-

19. (Ensembles only) Please give any evidence of your ensemble's consistent tempi, or lack of them:-

20. Kindly note any theories you have with regard to tempo choice or preference and/or briefly quote anecdotes/views of other musicians on the subject:-

Replies were received from the following, some of whom are mentioned later in connection with particular views or experience:-

Conductors

Adrian Boult
John Currie
Neville Dilkes
Ian Humphris (Linden Singers)
Raymond Leppard
David Willcocks

Military Bandmasters

E. Ball
T. Kenny
A.J. Richards
P.A. Sumner
D.N. Taylor
C.L. Tyrrell
R.E. Wilkinson

Instrumentalists/Singers

Herrick Bunney
Ralph Downes
Peter le Huray
Gervase de Peyer
Robert Tear

University/Teachers

Kenneth Abbott
Alan Angus (Ardingly College)
Peter Aston (Univ. East Anglia)
Victor Bradley (Ardingly College)
Antony Hopkins
Ian Parrott (Univ. Wales)
John Paynter (Univ. York)

Record/Radio Producers/Critics

John Culshaw (ex Decca, B.B.C.)
Peter Gammond
Paul Myers (C.B.S. Records)
Lionel Salter

(a) Definitions of Preference

In the experimental literature many facile statements about "Preferential Tempo" have been based on one or more specific movement situations very often completely divorced from music. Certainly the present writer has found no author who has ever suggested that the term itself is very difficult to define, let alone conducted controlled musical experiments. The general literature has usually taken a much more realistic and imaginative view of preference than the experimental psychologists. Donington (1974)[1], anticipating the writer's hypothesis, asserted that any "preference" is different for different musical situations:-

> 'The familiar story of Beethoven's irascible inability to believe his own previous metronome markings illustrates very well the fallaciousness of assuming that a good tempo at one performance is a good tempo for every performance. It is not so; there are too many variables which affect the case.'

The views of the responders to the questionnaire on this topic are of interest. It was evident that few musicians who replied had ever seriously thought about the matter before. Several replies suggested that the question was almost too obvious to answer, eliciting tautologies such as "the speed I prefer". Boult would not use the term, asserting that the tempo is either "right" or not. The most common reply however was of the form "feels right at the time". Only two answers hinted that preference might involve more than just individual mood or musical and performing factors, by referring to psychological and physiological make up. No responder defined preference with respect to any degree of precision or consistency in given circumstances.

(b) Universal Musical Tempo Preference

The possible significance of the 750 msecs area for movement and the general acknowledgement from mediaeval times onwards of a "Just Tempo", variously given as between MM 60-80, its metronomic equivalent, have already been discussed in Chapter 3. It remains to be seen how far actual musical practice today is consistent with this concept.

1, p.382.

McLaughlin (1970) commenting on the acceptance of MM 80 as the "normal" or "just" tempo, added that the actual preferred tempo may vary from one individual to another, such differences arising from physiological or mental causes. For example, he suggested that the evidence from Hoagland (1933) showed that a $1^{o}c$ difference in body temperature could make a difference of 12 metronome units in our assessment of moderate tempi. It is interesting to note that the average human pulse rate is about 100 at age four and does not slow down to about 80 until the late teens. This could account for a young person's notion of "normal tempo" being faster than that of a mature adult, although it has been shown already that there is little likelihood that a faster pulse actually causes a faster speed.

Hallock (1903), from a study of tempo indications in four editions of Beethoven piano sonatas determined more or less by musical traditions going back to the composer, reported that in all movements, slow or fast, it was always possible to identify a "true beat" which might or might not be indicated by the time signature. This beat invariably fell within the limits of MM 60-80. In the same study, the replies to a questionnaire from seventeen orchestral conductors further showed that they set their beat between MM 64 and MM 72. She however also pointed out that much music, fast and slow, can be played at approximately MM 60 without any feeling of delay or haste - presumably the predominant note value, giving a multiple or fraction of this standard, creates the effect of faster or slower pace. This is in exact accordance with Mursell (1937) who believed the normal speed of the true beat or takt lay, within rather narrow limits, close to this figure. Ebhardt (1898) also commented that slow and fast music both have fairly similar beat speeds after allowance had been made for subdivision. It is interesting that Sachs (1953) found that the average tempi of different movements of Bach's B minor Mass timed over several performances could all be analysed, in terms of actual note movement, as being close to MM 80. Indeed, it has already been noted that Sachs believed that figure to be his "personal standard tempo".

Nevertheless, any "just tempo" or universal preference undoubtedly covers a broad area of speeds, in order to accommodate both individual differences and musical criteria. This, together with the possibility of its appearing as a multiple or fraction of the prevailing beat, make both universal and individual preferences not necessarily incompatible concepts. It is noteworthy that none of the answers to the writer's questionnaire contained any references either to "just tempo" or any other universally "preferred" tempo. There is certainly no evidence of a precise universal preference, although any individual precise preferences, or multiples or fractions thereof, may well fall within a suitably broad concept of "just tempo".

Finally, the recent work of Waesberghe (1966, 1967 and 1968) must be mentioned again. He found that tempi in musical movements and dance were related to those of human movements generally in walking, rocking and other activities. The tempo underlying all these activities he believed to be in the region of MM 60.

(c) Individual Preference

Dunton Green (1929)[1], although referring to this "just tempo", was obviously aware that on occasions only one precise tempo will satisfy an individual:-

> 'Tempo giusto, a most provoking indication. What is "just"? Who would stay for an answer? Only scales of the utmost aesthetic finesse can weigh these imponderabilia, scales of justness more sensitive by far than those of justice: a drachm on the wrong side inclines greatness to the merely second rate.'

With one exception, all the responders to the questionnaire answered Yes to Questions 2, 3 and 6. It is likely then that most musicians believe an individual preferential tempo of some kind can exist, although subsequent answers made it clear that they also generally believe any preferences change with differing circumstances. Two musicians went so far as to state that

[1] p.42.

for every piece on every occasion there will be a different preference. This view, which the writer has already suggested is the ultimate in preference sensitivity, really denies the existence of preference at all, and certainly prohibits any confirmation by experiment. It is necessary here however to distinguish between two types of preference change. Firstly, there is the subjectively same "preference" that changes objectively over a short or long period. This is of course to do with Tempo Memory and will be dealt with under that heading. Secondly there is the conscious change of tempo preference that can arise through greater experience from change of taste or other factors. Unfortunately, the responders to the Questionnaire and the literature generally often do not make the distinction clear between the two types of preference change. Some of what follows ostensibly concerned with objective preference change, may therefore more properly belong in the Tempo Memory section.

Myers, referring to Szell's tempi as marked on his scores by secretaries since 1919, in some cases found no two performances of the same duration. He also referred to Boulez as another conductor who never repeated his tempi in any work. Common musical experience, the psychophysical and movement literature, as well as the above, would suggest that any preferences may well change with time of day and over longer periods. However, it is never possible to know if the phases of the variables involved, apart from time of day, are identical in any subsequent performances. In addition, it is interesting that one responder, who was satisfied with his tempo at the time of recording, thought it was too slow at a later playback. Most likely, the different acoustical and physiological conditions of playback were the cause of this, but the possibility of an actual change of preference cannot be ruled out even here. Culshaw however made the following comment:- 'Most professional musicians who perform regularly are astonishingly consistent in tempi over a short period of time. But this year's "Moonlight" may be different from last year's by the same artist.'

With regard to Question 14 which concerned both Preference and longer-term Tempo Memory, very few of the responders gave any objective evidence of a preference changing with age. Those who believed their speeds had changed thought they chose rather slower speeds as they got older, some attributing it to maturity, greater control or improved projection. Boult however quoted his timings as annotated on B.B.C. scores as evidence of consistent tempi over the years, and Salter also found a basic consistency in his own recordings. The well known example of Toscanini, whose later recordings were generally faster, appears to be somewhat exceptional in this respect. Neither the Szell timings referred to above, nor the observations of Guttmann (1932) given below, showed any consistent trend either way over many years.

From the literature, the most valuable information and comments, mostly concerning tempo consistency, come from Sachs (1953)[1]. Quoting the work of Guttmann (1932), who had timed the performances of numerous conductors over many years, he summarises his findings thus:-

> '1) The inherent tempo of a certain piece is stronger than the temperament of the performing conductor. When the latter dominates, the piece appears in distortion.
>
> 2) The individual tempo of a conductor changes from performance to performance, but its latitude is much smaller than the span between conductors slow and rapid by temperament.
>
> 3) In symphonies and similar cyclical works, the largest variance occurs in the first movement.
>
> 4) The greatest variability found in performances of the same work under the baton of the same conductor - in Guttmann's case, of Beethoven's Fifth Symphony directed by Richard Strauss - was 20 per cent. The greatest variability of the same work directed by several conductors - Wagner's Siegfried Idyll - was 32.2 per cent.
>
> 5) The conflicting claims, frequently voiced, that individual conductors grow progressively either slower or faster with age could not be substantiated.'

Sachs also quotes the Kirkpatrick edition of Bach's Goldberg Variations (1938a), in which the harpsichordist has added his tempi both at the time of publication and eighteen months before. The earlier tempi were in most cases

1, pp.377/8.

up to 14 per cent faster, only a few being slightly slower. He goes on to say that Kirkpatrick's unassuming notes are probably more valid than Guttmann's heterogeneous observations, criticising the latter's findings for resting on the assumption that tempo is a quality in its own right. Sach's adds that a performing tempo depends not only upon personal temperament and interpretation, but also on a number of ponderables and imponderables. The same metronomic speed might be correct, too fast, or too slow, depending on the medium in which it materializes. The various tempo-affecting factors he enumerates are included at the end of the next section.

An indirect indication of the existence of a permanent or temporary preference is of course the feeling of pleasure or discomfort that can be experienced when performing or listening to music at certain tempi. All the responders except two answered Yes to Questions 4 and 5, and there were many references elsewhere to tempi "feeling right". One musician stated that he had only ever heard one performance of the first movement of Schubert's fifth symphony in which the tempo did not seem "wrong", and another commented that the last movement of Mozart's Prague Symphony was nearly always taken too fast.

Several remarked that the composer does not necessarily know the best tempo for his works, quoting, among others, Beethoven and Bartok as examples of composers whose own MM markings are sometimes unreliable or even impossible. Although Bartok timed every piece in his Mikrokosmos in minutes and seconds, Schoenberg, in the preface to his Fourth Quartet, noted that his metronome marks must not be taken literally. Wagner, indeed, eventually discontinued using MM indications, so uncertain was he as to the appropriate tempi. Fox-Strangways (1929) also made the same point, quoting both the leader of the Hungarian Quartet, who said that at a rehearsal with the composer present the latter preferred their tempo to his own, and a similar case concerning the Ries Quartet and Beethoven. He concluded that the tempo is not necessarily part of the composer's conception and therefore not sacrosanct.

Stadlen (1967) remarked that Beethoven gave evidence that the tempo of his musical ideas was as liable to decisive alteration as any other feature. Temperley (1966) sums up the matter well, at the same time casting doubt on the validity of one of the writer's experimental performing methods:-

> 'A composer in his study, beating time to a few imaginary bars, may decide on a metronome mark quite at variance with the speed which he himself would adopt in performance.'

Temperley also quotes Sir George Smart, who visited Beethoven at Baden in 1825:-

> 'Beethoven gave me the time, by playing the subjects on the pianoforte, of many movements of his symphonies, including the choral symphony, which according to his account took three quarters of an hour in performance . . . This I deem to be totally impossible.'

Nevertheless returning to the questionnaire, although a composer may not be the best judge of a suitable tempo for his music, especially in the translation of his "ideal" conception to practical reality, the greatest discomfort due to listening to a "wrong tempo" appeared to be felt by the responders who were composers - particularly when listening to performances of their own music.

Finally, Preference is so closely linked to both Short and Long-Term Tempo Memory that much of what shortly appears under that heading at (g) may be regarded as a supplement to this section.

(d) Tempo-Affecting Factors

As the writer considers Metre to be the most potent influence in setting the tempo, this factor was given a separate number on the questionnaire. It therefore came as a surprise to find over seventy per cent of the responders indicating NO in Question 8.

A possible common preference generated by the music itself was mentioned by two responders. One affirmed that there was an optimum tempo for some pieces while others would be satisfying at very different speeds. Another went further, believing there was an instinctive universal "correct" tempo for every piece capable of about five per cent variation either way.

With regard to Question 10 and the other factors affecting tempo, very nearly all the musicians affirmed that Mood, Acoustics and Instrument Action/Touch affected their speeds. Over half the responders also believed that Audience Size was a factor to be considered. Supporting comments included:- "nervousness makes a performance faster than the rehearsal", "larger and more reverberant halls require broader speeds", "allow for the echo in cathedrals". One organist gave his timings of Liszt's "Ad Nos" Fantasia in different cathedrals as 28 and 31 minutes respectively.

Additional factors given in answer to 10(g) were musical texture, type of audience and the occasion - functional pieces such as dances and marches being played quicker in concerts. In addition, one responder made the point that only the very insensitive would not have their tempo modified by the factors enumerated.

With regard to 10(e), very nearly all the conductors believed that the weight or dimensions of the baton had no effect on their tempi, two adding that it would be a poor conductor whose tempi were so affected. They were all agreed however that the size and nature of an ensemble were factors to be considered when setting a tempo. One bandmaster remarked that sheer physical distance between the baton and the farthest player and the associated sound time lag compelled a slower tempo. Some surprising tempo factors specifically concerned with marching bands were also given, including gradient, footwear, length of marching column and distance to be covered.

Returning to Sachs (1953)[1], the list of tempo-influencing factors he gives includes some interesting points:-

> Orchestration - the same melody staccato on the xylophone would need to be faster than when played legato on the organ.
>
> Tessitura - low registers often need a slower tempo.
>
> Density - a bare monophonic setting is necessarily faster than a polyphonic one.

[1] pp.378/9.

Ensemble Size - the density provided by bigger forces and the multiple harmonics they create necessitate slower tempi.

Acoustics - echoes, so frequent in churches, impose a slower tempo.

Broadcasting and Recording - the different effect of a piece heard "three dimensionally" in a tone-reflecting hall and even seen with the concurrence of the performing bows and conductor's baton has to be compared with the same piece heard "two-dimensionally" in the flattening projection of microphones and loudspeakers and without the concurrence of visual impressions. The latter situation requires a slightly faster tempo.

Nevertheless, Sachs considered that the above "outer conditions" are the "lesser powers" in deciding tempo, and proceeded to quote Schumann (1835) concerning the movement's "inner measure" being the sole determinant of tempi. The view of Wagner, as summarised by Turner (1938) is also interesting, raising as it does the question of tempo variation within a basic speed.

> '. . . if the music is all melody it cannot be too slow, if it is all rhythm it can hardly be too fast; when the two are mixed careful judgement is continuously required to decide which of the two preponderates at any given instant and by what proportion, the tempo being raised or lowered accordingly to correspond.'

This quotation supports Turner's main thesis, based on his study of many of Elgar's performances of his own works (including unpublished recordings), that tempi change slightly with change of theme, even although the MM mark remains the same. He also mentions the following view of Brahms, quoted originally by Henschel:-

> 'Tempo is elastic; a single number can be of no value.'

(e) Miscellaneous Views and Criteria for Appropriate Tempi

So many valuable comments, not specifically elicited by the questions, were made that the writer regretted not including this heading in the questionnaire.

The relative importance accorded to tempo in musical interpretation varied between an absolutely vital role and the least important factor. Various interesting criteria for appropriate tempi were mentioned. One responder stated that the tempo must not be too fast for proper phrasing and the completion of notes, or too slow for musical momentum. Other criteria included the necessity for the music to "breathe", a consideration of the density of the notes, clarity of words and comfort. With regard to piano performance one responder believed the tempo was an instinctive response to the touch of the instrument.

Two musicians, including Boult, stated that it was important to find out what is important about the music, and another thought that the natural flow of the music emerged when it was well known. Boult also supplied the following helpful suggestions concerning pace in music:-

> 'Performance must not be too slow:-
>
> 1. for the tunes to be easily grasped in their entirety by the listener.
> 2. for the players to bow and breathe naturally and in comfort.
> 3. for the whole movement to be clear to the listener as one entity.
>
> Performances must not be too fast:-
>
> 1. for the subjects to be easily and comfortably heard.
> 2. for the players to express the music easily and naturally without a scramble.'

Several musicians described various circumstances in which the same tempo could be made to appear different or have a different effect, which raises again the question of psychological factors, dealt with in Chapter 3. A conversation between Vaughan Williams and Boult was quoted in which the latter was accused of setting too fast a tempo. Boult replied that the composer did not think so when he conducted his piece for him ten years previously. Vaughan Williams agreed, but stated that then he was not sure if the public would like it. Now he was more assured and knew it could stand going more slowly.

More than one responder quoted conductors such as Beecham, Toscanini and Solti whose extreme precision made their tempi seem faster than they actually were. Boult referred to Richard Strauss's famous performance of Mozart's fortieth symphony in which the sparse accentuation of the outside movements also made deliberate tempi feel quite fast.

The question of precedent was also raised. One musician believed that the first performance heard or performed oneself of a new piece became established as a norm for tempo.

(f) "Mental" or Physiological Rehearsal

Question 11 was included in the questionnaire as the writer has always been interested in the "mental" or "physiological" processes just prior to tempo initiation. Although most responders answered Yes to the general question, no musician appeared to have indulged in the degree of introspection necessary to describe any process in detail. Expressions such as counting, hearing or "mentally" playing the first bar, main theme, most significant or difficult passage really sum up all the information given. One responder added that care must be taken to ensure that nervous tension does not make any "mental" playing too fast, and another stated that the "rehearsal" occurred when conducting but not when playing.

In treatises on conducting the topic has been raised, particularly in connection with the preparatory movements of the baton, but the writer has found little information in the literature generally about what could be an important factor in successful tempo initiation.

(g) Short and Long-Term Tempo Memory

As Question 14, in addition to Questions 12, 13 and 15, also has implications for Tempo Memory, the relevant answers and views given under these numbers will be combined in this section. The very closely related topics mentioned, all involving Tempo Memory, included absolute tempo sense and training, aiming for a given MM or previous tempo, attempting to repeat a tempo and short and long-term conscious or unconscious tempo consistency in any given music. The writer would also point out that Tempo Memory, by definition, is closely related to Preference, and in this connection it is significant that responders usually attributed even unconscious tempo consistency to memory rather than preference. As far as possible, the writer has ensured that the evidence in this section concerns the accuracy of recall of tempi subjectively the same, and not the conscious change of preferred speeds.

Although most responders answered YES in Questions 12 and 13 very few, apart from those concerned with marching bands or recording, gave any objective evidence of short or long-term tempo memory. The subjective degree of accuracy included expressions such as "extremely accurately", "fairly accurately" and "near enough". One musician stated that he was correct ninety per cent of the time and always knew when he was wrong. Some attributed any inaccuracy to inexperience, one musician related all tempi to the duration of one second and another "held" two standard tunes in his mind as reference tempi. Only one responder mentioned an absolute tempo sense, and added that few musicians possessed it.

The more objective evidence is clearly of greater use. One bandmaster found his performances changed very little in total duration over an eight week performance run, and the military bandmasters generally, quoting the various MM numbers for the different regimental marches, certainly believed they were accurate and the writer must assume they had to make frequent objective checks on their tempi. However, the most significant and accurate information came from those active as producers or performers in the recording or broadcasting studio. Culshaw made the following observation:-

> 'Under recording conditions the majority of conductors can reall tempi with great precision even after a gap of some days (most operas, for example, are recorded out of sequence). There are some cases where a gap of several months has separated one bar from another. I used to remind myself of the earlier tempo in case the new one turned out to be different (in which case the tapes would not of course have spliced together). It was only very occasionally that either (i) the conductor himself wanted to hear what he had previously recorded, or (ii) that I had to tell him that his new tempo would not match.'

Salter, when conducting for films, found he was able to time sequences to within one second over, say, four minutes, never being more than three seconds out. In his role as a radio producer however he did not always meet the same consistency:-

> 'I have often noted how even experienced artists seem to find difficulty in supplying accurate timings for the works they perform; yet for the most part they are consistent as between studio rehearsal and performance; i.e. in the same conditions they do not vary much (except for certain unpredictable artists whose minds have not been fully made up or who believe in remaining totally flexible in their reaction to the circumstances of the moment). The presence of an audience at the performance however brings about a change in acoustics to which they may react.
>
> As a record critic one is frequently struck by apparent instabilities of tempo arising from the splicing of different "takes" at marginally different speeds - which points to some lack of control, not only by the players but by the recording supervisor.'

Myers, another recording producer, also noted how difficult it was, when rerecording parts of a movement, to match the tempo between different "takes", and this supports the view of another responder who remarked that absolutely identical tempi are rare.

Question 15 dealt specifically with the possibility of subjectively identical speeds changing in later years. The case of Stravinsky was mentioned who believed that his performances of his own music had remained unchanged in tempo over the years. They were in fact shown to be slower in his old age.

The question of tempo training arose in connection with the military bandmasters. Several used terms like the "ingraining" of their particular regimental tempi over the years, and all implied that they had to learn them. One conductor who changed regiments from the cavalry to the infantry retained the previously "ingrained" cavalry march tempo of MM 116 in his concert performances even after he had learnt the new infantry march tempo of MM 120 for parade purposes.

(h) Tempo Steadiness

This refers to internal accuracy of tempo during the performance of an essentially steady speed. The question was not included in the questionnaire as any answers would have been purely subjective, except in the unlikely event of a kymographic or otherwise recorded analysis being available. The matter will be raised again later as the writer's timing procedure assumes a steady beat in all performances. However, just one responder, Willcocks, mentioning the topic in connection with another question, believed a slight acceleration was necessary in all "strict" music.

Meumann (1894) suggested that a musician could have an automatic steady tempo control, thus enabling him to concentrate on interpretation. In the experiment of Sears (1902) previously described, he found that the kymograph recordings of the performances revealed not only that the relative length of the notes were not exactly in accord with the notation, but that the duration difference between successive measures was frequently longer than 200 msecs.

(i) Inter-Movement/Section Tempo Relationships

While not necessarily directly related to the initiation of the opening tempo of a work, the writer was interested to see if there was any support for the idea suggested in Question 16. However, all except four responders indicated NO in this section. Some identified pieces where the proportional relationship of tempi was asked for by the composer, or might be useful, but the general consensus was certainly against any conscious or general application of mathematical relationships between tempi. Nevertheless, Currie, conductor of the Scottish National Chorus, and the writer's first supervisor, certainly supported the view that in sectional works such as a Mozart Opera, the speeds could be related within a kind of "tempo tonality", with the final tempo being a satisfying "recapitulation" of an earlier speed. In the Marriage of Figaro for example, he suggests one basic speed, through its multiples and subdivision, can be adapted to all the changing tempi and that the final tempo should match the speed of the overture. Apart from early proportional systems, however, it may be questioned whether a composer ever consciously plans this possibility, and whether the selection of related tempi in any such cases is obligatory.

(j) Longer-Term Duration Control

Opinion was equally divided in Question 17 between those who answered YES, NO and DON'T KNOW, and the only comments added were "of course" and "not important".

Some views and indirect evidence suggesting that the unconscious reaching for short and long-term musical "goals" may control beat speed, or that the total length of a work or even the concert may affect a performer's tempi come from a number of sources. Temperley (1966) commented on Sir George Smart's collection of programmes in the British Museum giving the timings of some 140 performances between 1819 and 1843, perhaps the first objective evidence of early nineteenth century performing speeds. In nearly every case Smart timed the duration of the whole work, presumably including the variable inter-movement gaps; Temperley incidentally commenting that Smart's tempi were not consistently faster or slower than those acceptable today. More particularly, the following timings in minutes of performances of the same work show a surprising consistency:-

		Parts			
Handel's Messiah		I	II	III	Whole
	1819	81	75	43	199
	1822	82	76	50	208
	1824	85	78	41	204
	1831	83	76	40	199
	1835	81	72	-	-
		Part I			
Haydn's Creation	1819	50			
	1822	50			

The above is even more surprising when one considers that cuts or encores may well have been a feature of these performances. Currie has also timed successive annual performances of Handel's Messiah, finding an even greater total duration consistency than in the Smart performances. He noted that this duration tended to remain the same even when there was considerable variation in the extra-musical events within the work such as applause and intervals. Currie also remarked that Ormandy was able to "start" an imaginary performance of a Beethoven symphony while engaged in an entirely different activity such as conversation, and at the appropriate moment indicate when the performance had ended. A subsequent comparison of this duration with his actual performances showed a remarkable accuracy. Perhaps the commonly experienced ability of being able to wake up at a predetermined time is another aspect of this same long-term duration control. Bünning (1967), in this connection, also referred to the phenomenon in which a hypnotist can cause a subject to wake up or perform an action at a certain time with great accuracy.

Finally, Boult (1963) drew attention to the "tempo" of the concert as a whole, in particular to the link between movements even when musically it is indiscernible.

(k) Ensemble Tempi

Although Questions 18 and 19 were particularly directed at quartet and ensemble leaders, conductors of orchestras and choirs also share the problem of reconciling any different individual tempo preferences. Very little information was in fact elicited. Humphris remarked that tempi were only arrived at after much trial and error, and often heated discussion, while Dilkes expressed amazement at the unanimity of tempi in a professional orchestra.

Despite the degree of contradiction regarding many aspects of tempo shown even by experienced professional musicians, the general consensus of views expressed both in the questionnaire replies and elsewhere gives support for the alleged potency of many of the possible tempo-affecting factors detailed in Chapter 3. The great majority of musicians from all ages have also agreed

that tempo is a vital and possibly also a mysterious and complex factor in musical performance. There has however been a surprising and almost total absence of any references to the possibility of psychophysical and physiological factors being involved in tempo. Nevertheless, these aspects of tempi, although probably fundamental, can play no major part in the following experimental section, being far beyond both the scope of the study and certainly the competence of the writer. The concern of Part B must be with what actually happens in the given performing situations. Unfortunately, the different Musical, Performing and other factors listed in Chapter 3 that contribute to any total situation have also been shown to be too numerous and complex for one study. It was therefore decided to investigate individual and general preference and tempo behaviour using a small selection of these factors.
The initial possibilities were so vast that the writer first conducted a series of Pilot Experiments. As a result of the open-minded inspection of tempi in the repeated performances of some easily contrived musical situations it was hoped to make a more rational selection of the factors and areas to study in the Main Experimental Programme. It was also hoped to obtain preliminary support for the hypothesis and valuable experience in experimental design, setting up, administration and data presentation.

PART B

EXPERIMENTAL WORK

CHAPTER SIX

The Pilot Experiments

General Aim

To investigate individual or general tempo characteristics in given simple musical situations, using the performing methods of singing "lah" or words and conducting.

Subjects and General Procedure

Twenty-one subjects in all were employed; nineteen female college music students, the male college tutor accompanist (BB) and the writer (PB).

Experiments P_1 to P_6 were conducted in the same small college practice room with each S standing. In P_7 the writer performed in his lounge, standing by the piano. No music was provided, and before the first session the writer confirmed that each S could perform the relevant music fluently and without strain in the given key. The students were not told the general aims of the experiments and only the writer heard the performances of any other subject. The experiments took place over five months, and on the rare occasions when a S other than the writer performed in two sessions on the same day they were at least two hours apart.

Timing and Data Recording

The same stopwatch, calibrated in 1/10 seconds was operated and read by the writer for all Ss; it being held in his right hand even when performing himself and conducting with that hand. The total duration for twenty-five beats was entered on the standard form designed for these and all subsequent experiments immediately after each single performance, reading up to the higher calibration where necessary. The switching-on point was never at the very beginning, so any erratic opening tempo had time to settle down before timing commenced; the timing method assuming the tempo to be steady over the duration concerned. When required, the duration for twenty-five heart pulses was taken immediately after the musical performance. All other Ss took their own pulse, verbally indicating the rate to the writer. Any irregular pulses were noted as such according to the writer's subjective assessment. Ss were asked to classify their "mood" according to one of the following three categories:- happy/exhilarated, content/relaxed and sad/tense.

Scale Interval

A single beat duration of 20 msecs was arbitrarily chosen as the Duration Scale Interval, and the raw timing data were subsequently transformed into single musical beat or heart pulse durations, using the following scale of equivalence, shown here with the corresponding metronome values:-

Durations		MM	Durations		MM
25 Beats (seconds)	Single Beat (msecs)		25 Beats (seconds)	Single Beat (msecs)	
6.2- 6.6	240-260		19.2-19.6	760-780	
6.7- 7.1	260-280		19.7-20.1	780-800	75
7.2- 7.6	280-300	200	20.2-20.6	800-820	
7.7- 8.1	300-320		20.7-21.1	820-840	
8.2- 8.6	320-340		21.2-21.6	840-860	70
8.7- 9.1	340-360		21.7-22.1	860-880	
9.2- 9.6	360-380		22.2-22.6	880-900	67
9.7-10.1	380-400	150	22.7-23.1	900-920	
10.2-10.6	400-420		23.2-23.6	920-940	
10.7-11.1	420-440		23.7-24.1	940-960	
11.2-11.6	440-460		24.2-24.6	960-980	
11.7-12.1	460-480		24.7-25.1	980-1000	60
12.2-12.6	480-500	120	25.2-25.6	1000-1020	
12.7-13.1	500-520		25.7-26.1	1020-1040	
13.2-13.6	520-540		26.2-26.6	1040-1060	
13.7-14.1	540-560		26.7-27.1	1060-1080	
14.2-14.6	560-580		27.2-27.6	1080-1100	55
14.7-15.1	580-600	100	27.7-28.1	1100-1120	
15.2-15.6	600-620		28.2-28.6	1120-1140	
15.7-16.1	620-640		28.7-29.1	1140-1160	
16.2-16.6	640-660	90	29.2-29.6	1160-1180	
16.7-17.1	660-680		29.7-30.1	1180-1200	50
17.2-17.6	680-700	86	30.2-30.6	1200-1220	
17.7-18.1	700-720		30.7-31.1	1220-1240	
18.2-18.6	720-740		31.2-31.6	1240-1260	
18.7-19.1	740-760	80	31.7-32.1	1260-1280	

Experimental Terms

Attempt

A single performance of the music provided.

Sequence

An immediate succession of different tempi (usually slow to fast), or of subjectively similar tempi.

Session

An experimental trial at which one attempt, sequence or other procedure takes place.

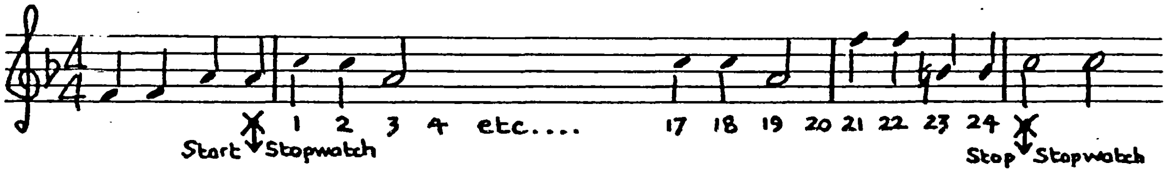
"Preference"

A non-rigorous and undefined use of both this term and "same speed" will be made in the Pilot Experiments. They will, however, be given precise definition for the Main Experimental Programme.

The Experiments

Pilot Experiment P_1

Aim:	To investigate any individual or general tempo preferences in the given musical situation, and further to note whether any tempo variations are associated with the other variables recorded.
Subjects:	Five female music students (FW, BS, RB, RF, KC). Twelve sessions each, usually about one week apart.
Instructions:	Sing the following Haydn melody opening to lah at the most natural speed. Do not rall. at the end. Starting pitch F given.



Record:	Duration of twenty-five music beats and heart pulses. Date, Time of day, Previous activity and Mood.

Pilot Experiment P_2

Aim: As P_1.

Subjects: Five further female music students (RV, EM, GS, GJ, BC).
Ten sessions each, usually about one week apart.

Instructions: As P_1 except no starting pitch given.

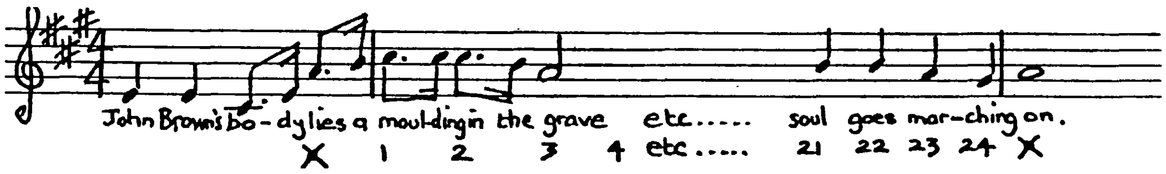
Record: As P_1. In addition record actual starting pitch.

Pilot Experiment P_3

Aim: As P_1.

Subjects: Five further female music students (PN, RW, KJ, PR, AB).
Twelve sessions each, usually about one week apart.

Instructions: Sing the given opening of "John Brown's Body" with words at the most natural speed.
Do not rall. at the end.
Starting pitch E given.



Record: As P_1.

Pilot Experiment P_4

Aim: As P_1.

Subject: One further female music student (CS).
Twenty sessions, about two per week.

Instructions: As P_3 except no starting pitch given.

Record: As P_1. In addition record actual starting pitch.

Pilot Experiment P_5

Aim: As P_1. In addition to note (a) any effect on tempo of the different performing methods, and (b) the movements made in "mental" performance.

Subjects: Three further female music students (AC, SH, JS) the writer (PB) and BB.

Sixteen sessions, about two per week.

Instructions: Perform the opening of "John Brown's Body" in the two ways indicated in the following session schedule. In every case perform at the most natural speed without a rall. at the end:-

Session (1) Lah aloud, Sing words aloud
(2) Lah "mentally", Sing words "mentally"
(3) Sing words aloud, Sing words "mentally"
(4) Sing lah aloud, Sing lah "mentally"
(5) As 1) reverse order
(6) As 2) reverse order
(7) As 3) reverse order
(8) As 4) reverse order
(9)-(16) Repeat (1)-(8)

(In order to record the "mental" performances the S tapped the beat with a finger.)

Starting pitch E given (PB and BB 8ve lower).

Record: As P_1 (with the exception of heart pulse). In addition record (a) nature and degree of any further body movements made during "mental" performance, and (b) the tempo relationship of both performances at each session as "faster than", "slower than" or "similar".

Pilot Experiment P_6

Aim: To make a preliminary investigation into the possibility of there being a range of "preferred" tempi in the given musical situation.

Subjects: As P_5.

Sixteen sessions, about two per week and intermixed with Expt P_5.

Instructions: At each session, in immediate succession, sing the given opening of Offenbach's "Can Can" to lah in the following three ways:-

(1) At the slowest reasonable musical speed.

(2) At the speed that seems ideal.

(3) As fast as possible for good musical effect.

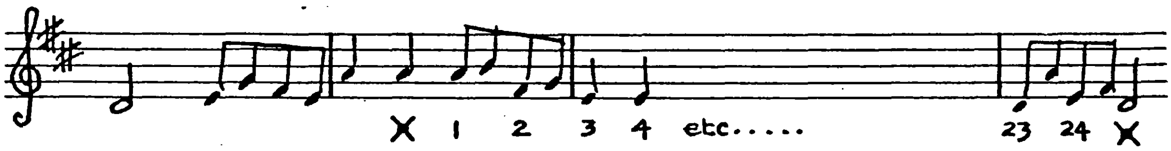
Do not rall. at the end of any performance.

At alternate sessions the Ss were asked:-

(a) to make extensive conducting movements.

(b) to make no intentional conducting or body movements.

Starting pitch D given (PB and BB 8ve lower).



Record: As P_1 (with the exception of heart pulse). In addition, record nature and approximate degree of body movements made during non-conducting performances.

Pilot Experiment P_7

Aim: To investigate (a) the possibility of there being a discrete series of tempo "preferences" in any musical situation, and (b) the effect on tempo of change of metre.

Subject: The writer (PB).

Twenty sessions for each piece, many sessions, in random order, on some days.

Instructions: Perform the given music openings, softly vocalising lah through the breath while conducting in an expressive rather than formal way with the right hand. At each session give a sequence of performances of any one of the pieces, as follows:-

(1) At the slowest reasonable musical speed.

(2) etc. At the next slowest speed etc until the fastest possible musical speed (beyond which the music would feel one in a bar).

Do not rall. at the end of any performance.

No session to be commenced until all apparent trace of the previous tempo has left the writer's mind.

Each performance to be made after the timing has been noted for the previous one (an interval of about 10 seconds).

Key chord and starting pitch, given before each single performance, to form the tonal basis of the "breathed" performances.

(In order to achieve a measure of uniformity, the keys selected were all sharp and also kept each melody within the same approximate compass.)

<u>Record:</u> Duration of twenty five music beats.

Presentation of Results

Although some statistical procedures were considered appropriate, as the experiments were comparatively unsophisticated and the number of sessions in each was limited, the principle reliance is upon graphical presentation, generally in the form of histograms. In the case of sequence experiments it is exclusively so, as the resulting extensive multimodal distributions were not amenable to conventional tests for significant preference points or areas.

The same graphical format but with a scale interval half as wide will be used in the Main Experimental Programme, thus facilitating a subsequent visual comparison with the Pilot Experiment data. The simultaneous use of a beat duration and MM scale, together with Italian tempo words relates the visual presentation to more musical terms. The so-called "normal" tempo of MM 80 will be indicated by a red line. Inclusive dates of each experimental period are included with the graphical material.

The following symbols are consistently used:-

Music Tempi Data: ⁝ oriented: faster ↔ slower

Heart Pulse Data: ⁚ a superimposed double scale is used to facilitate comparison with Music Tempi

Starting Pitch: ⊙ oriented: higher ↔ lower

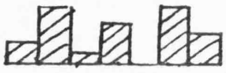
Chronological Cumulation:
[Enabling both chronological trends and strong relationships between data to be observed visually]

Music Tempo > twice Heart Pulse: ●——●

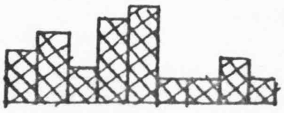
Heart Pulse > twice Music Tempo: ●——●

Irregular Pulse noted: ✗

Combined Data of one Subject:



Combined Data of > one Subject:



Statistical Tests

In Expts P_1-P_4 the Spearman Rank Order Correlation (r_s) was used to estimate the degree of relationship between Music Tempo and Heart Pulse or Pitch. In Expt P_5 the Binomial Test of Probability (p) was applied to some of the time-order and performing method relationships. Significance was set at the 5 per cent level. All values obtained are appended to the graphical data; those at the 5 per cent level or beyond being so noted and commented on further in the Observations and Discussion.

In order to avoid confusion with musical connotations, the term "occurrences" will be used instead of frequency, and modal and non-modal values or areas in tempi distributions will be referred to as "peaks" and "troughs". The references to "peaks" and "troughs" in the text are based solely on unqualified observational criteria. The writer is also aware that the small number of sessions and elongated occurrence (f) scale make apparent "preferences" highly suspect.

FIG P1 EXPT P1 SINGING LAH(Haydn): SINGLE TEMPORALLY SPACED ATTEMPTS AT NATURAL TEMPO(Pitch given)

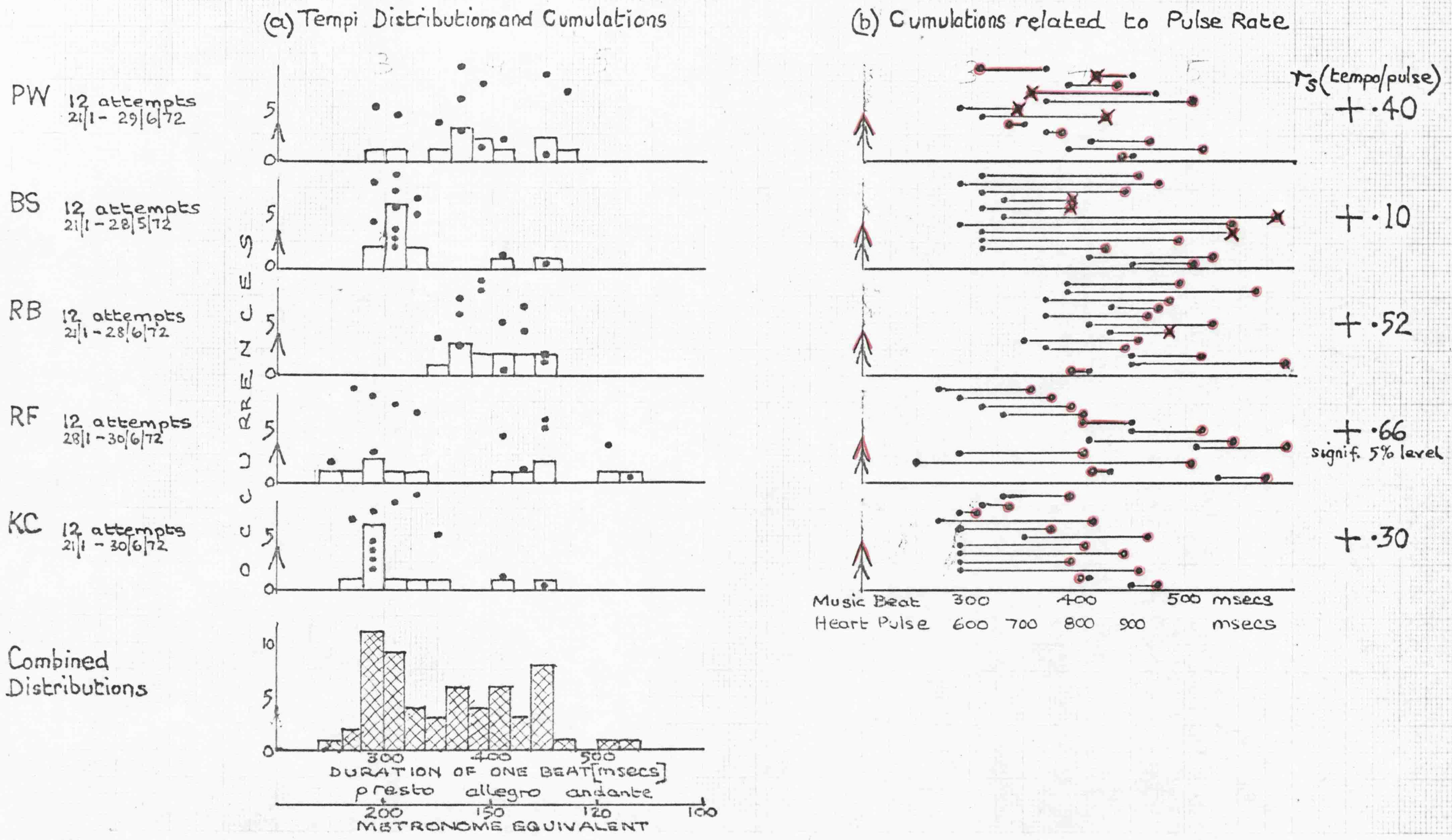


FIG P.2 EXPT P_2

SINGING LAH (Haydn): SINGLE TEMPORALLY SPACED ATTEMPTS AT NATURAL TEMPO (Pitch not given)

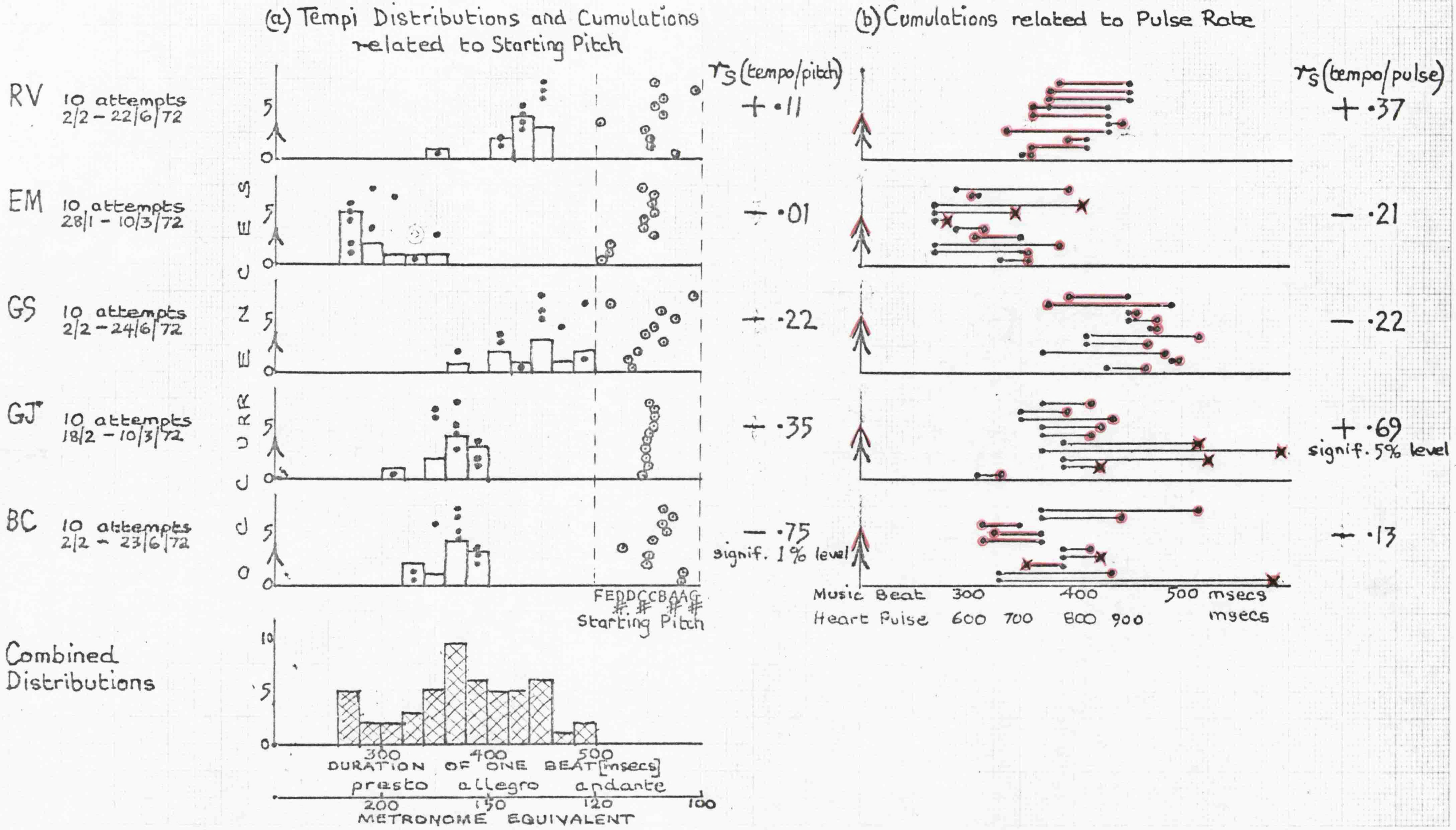
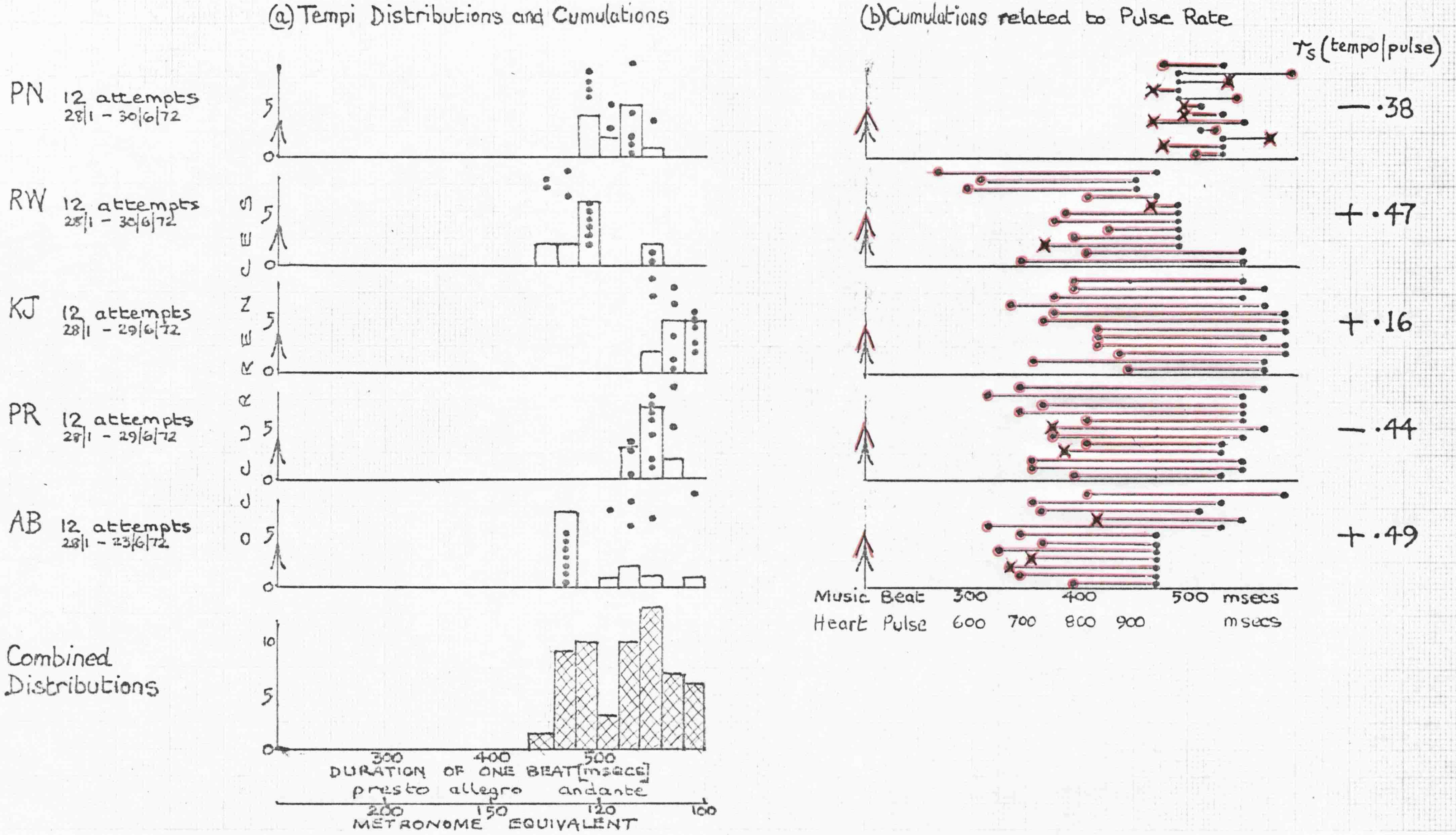


FIG P3 EXPT P3 SINGING WORDS (John Brown's Body): SINGLE TEMPORALLY SPACED ATTEMPTS AT NATURAL TEMPO (Pitch given)



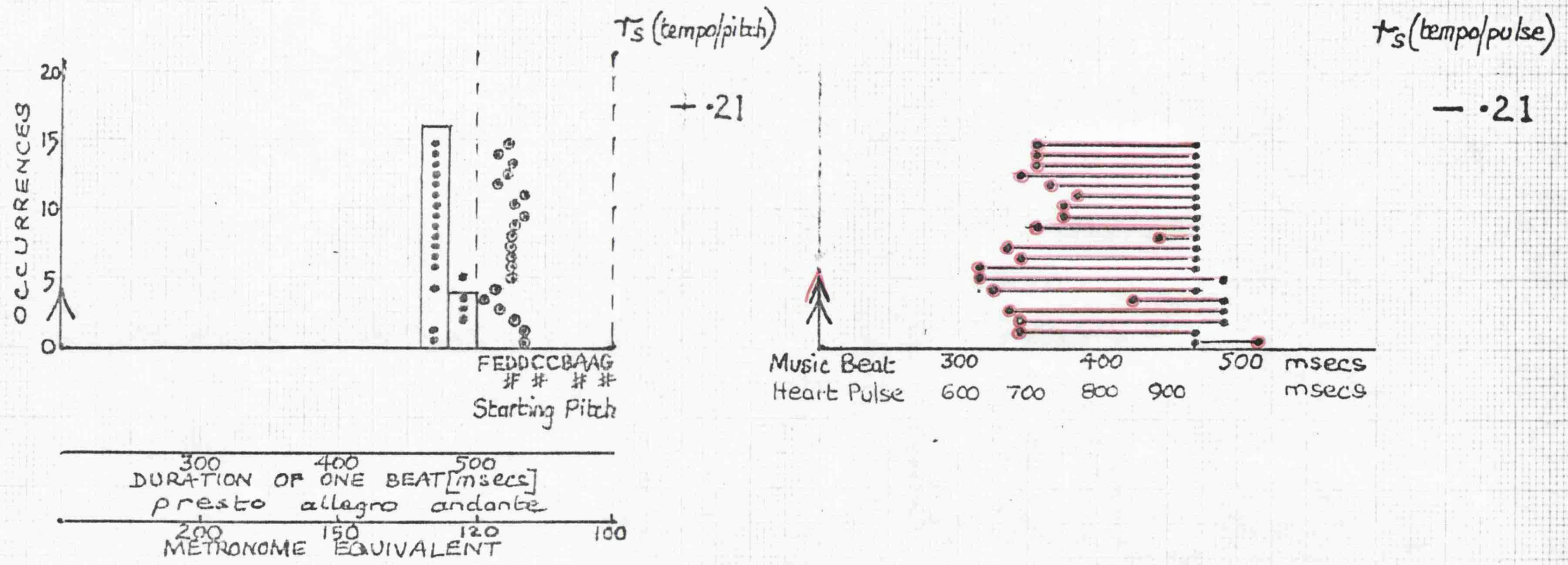
(a) Tempi Distributions and Cumulations

(b) Cumulations related to Pulse Rate

FIG P4 EXPT P4

SINGING WORDS (John Brown's Body): SINGLE TEMPORALLY SPACED ATTEMPTS AT NATURAL TEMPO (Pitch not give

CS 20 attempts
25/1 - 20/6/72



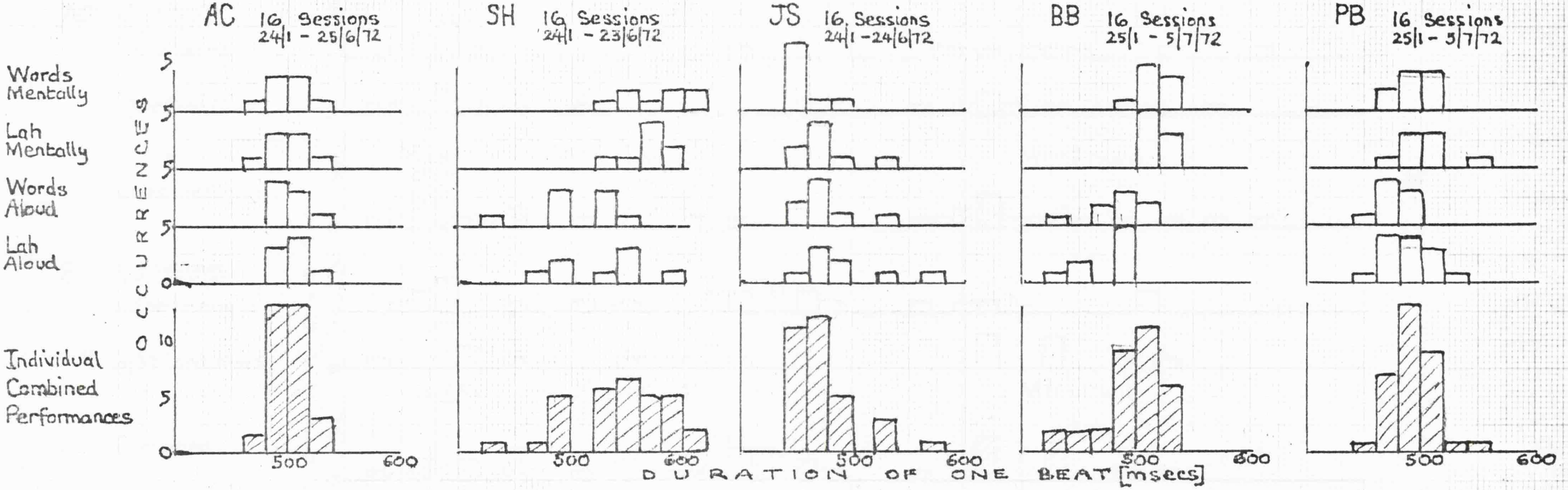
(a) Tempi Distribution and Cumulation related to Starting Pitch

(b) Cumulation related to Pulse Rate

FIG P_5 EXPT P_5

SINGING, AS INDICATED (John Brown's Body): PAIRED ATTEMPTS AT NATURAL TEMPO

(a) Individual Tempi Distributions for each Performing Method



(b) Analysis of Total Tempo Relationships for each pair of Performing Methods

LA	cf	WORDS	'Performances FASTER THAN'	
La Aloud	before →	Words Aloud	1	7
La Aloud	after ←	Words Aloud	6	4
LA ALOUD	cf	WORDS ALOUD	7	11
La Mentally	→	Words Mentally	0	8
La Mentally	←	Words Mentally	7	3
LA MENTALLY	cf	WORDS MENTALLY	7	11
LA	→	WORDS	1	15
LA	←	WORDS	13	7
LA	cf	WORDS	14	22 [p=·12]

ALOUD	cf	MENTALLY	'Performances FASTER THAN'	
Words Aloud	→	Words Mentally	6	4
Words Aloud	←	Words Mentally	7	3
WORDS ALOUD	cf	WORDS MENTALLY	13	7
La Aloud	→	La Mentally	5	4
La Aloud	←	La Mentally	8	2
LA ALOUD	cf	LA MENTALLY	13	6
ALOUD	→	MENTALLY	11	8
ALOUD	←	MENTALLY	15	5
ALOUD	cf	MENTALLY	26	13 [p=·027]

1st cf 2nd PERFORMANCE

'FASTER THAN'

24 51

[p = ·0013]

FIG P_6-1 EXPT P_6

SINGING LAH (Can Can): GROUPED ATTEMPTS AT 'MINIMUM' 'IDEAL' AND 'MAXIMUM' TEMPI

(a) Tempi Distributions

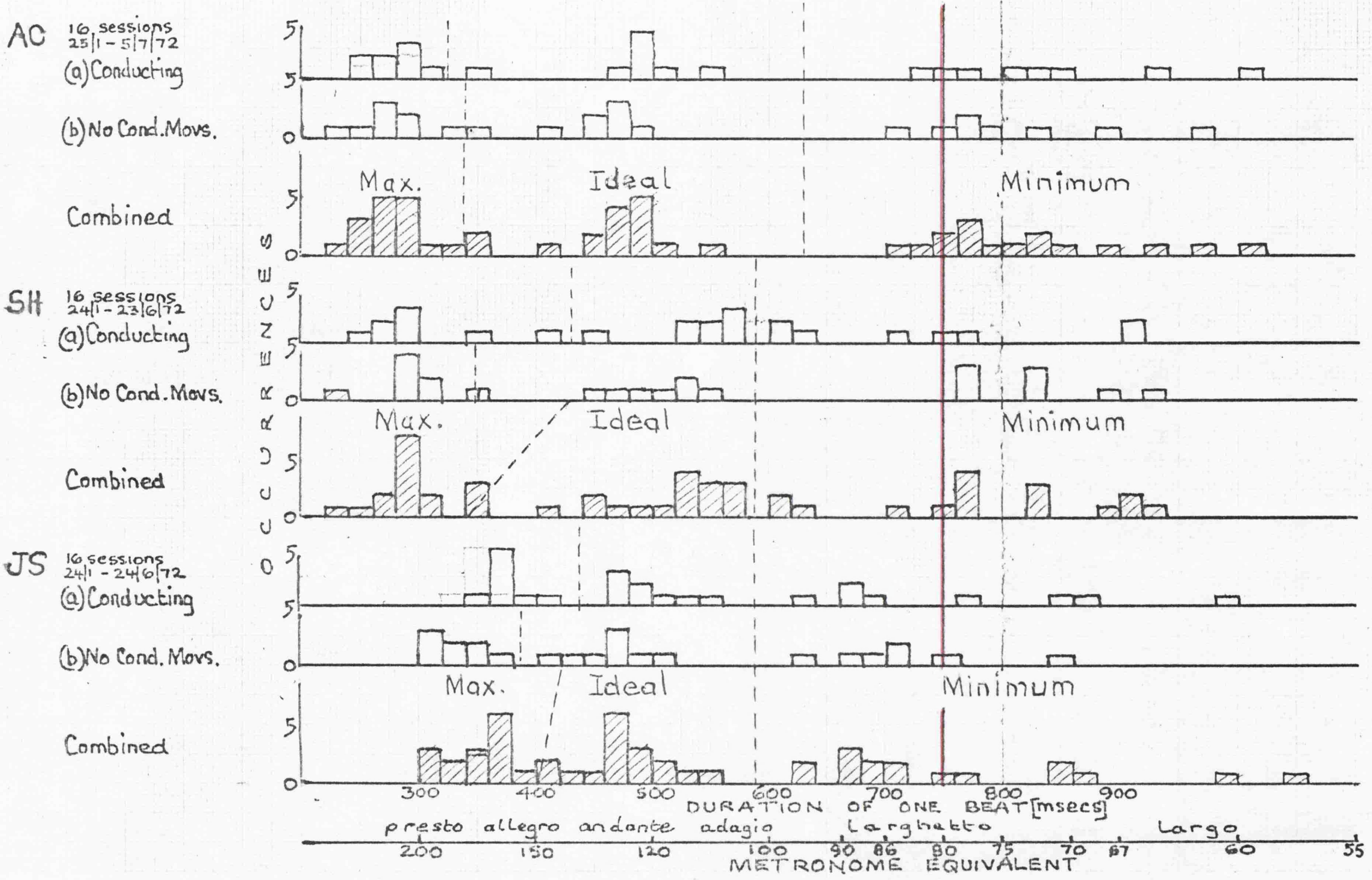


FIG P6-2 EXPT P6 CONTD.

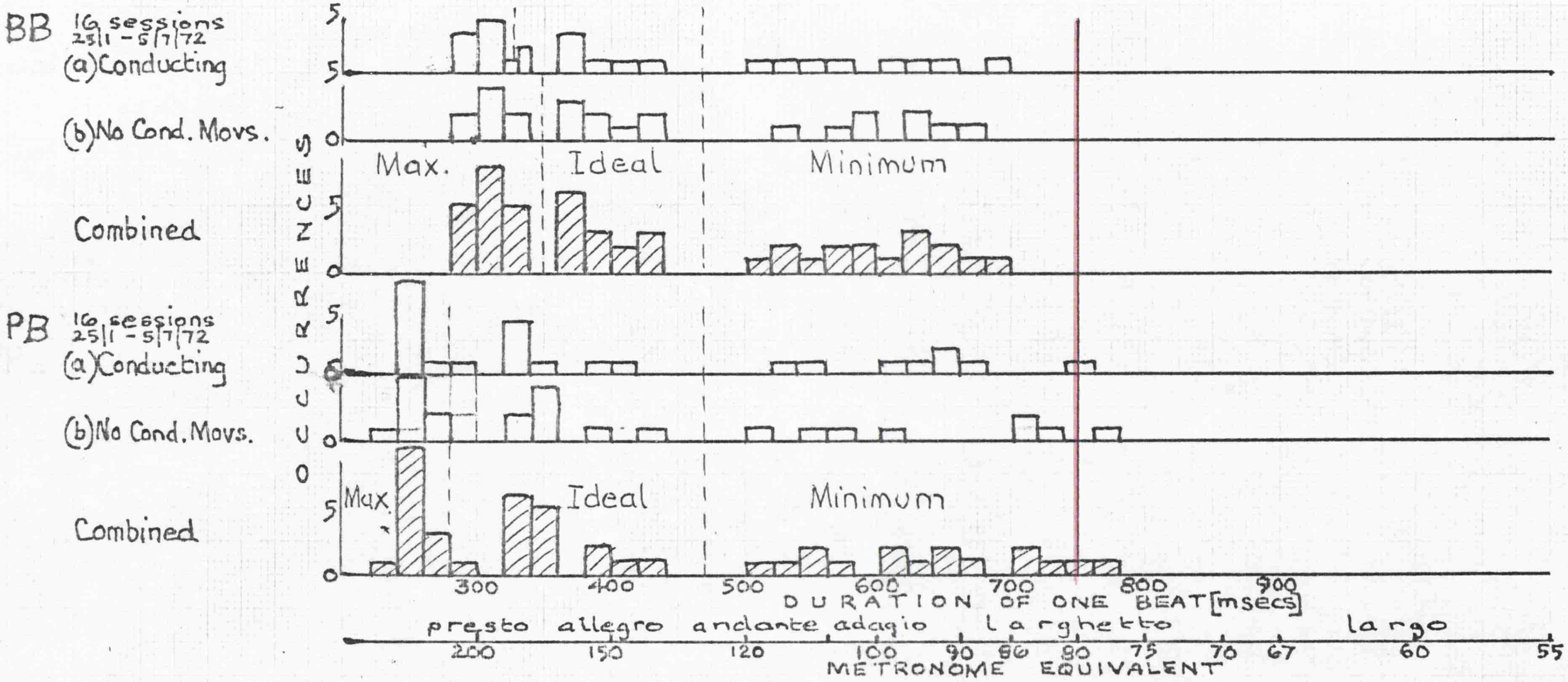
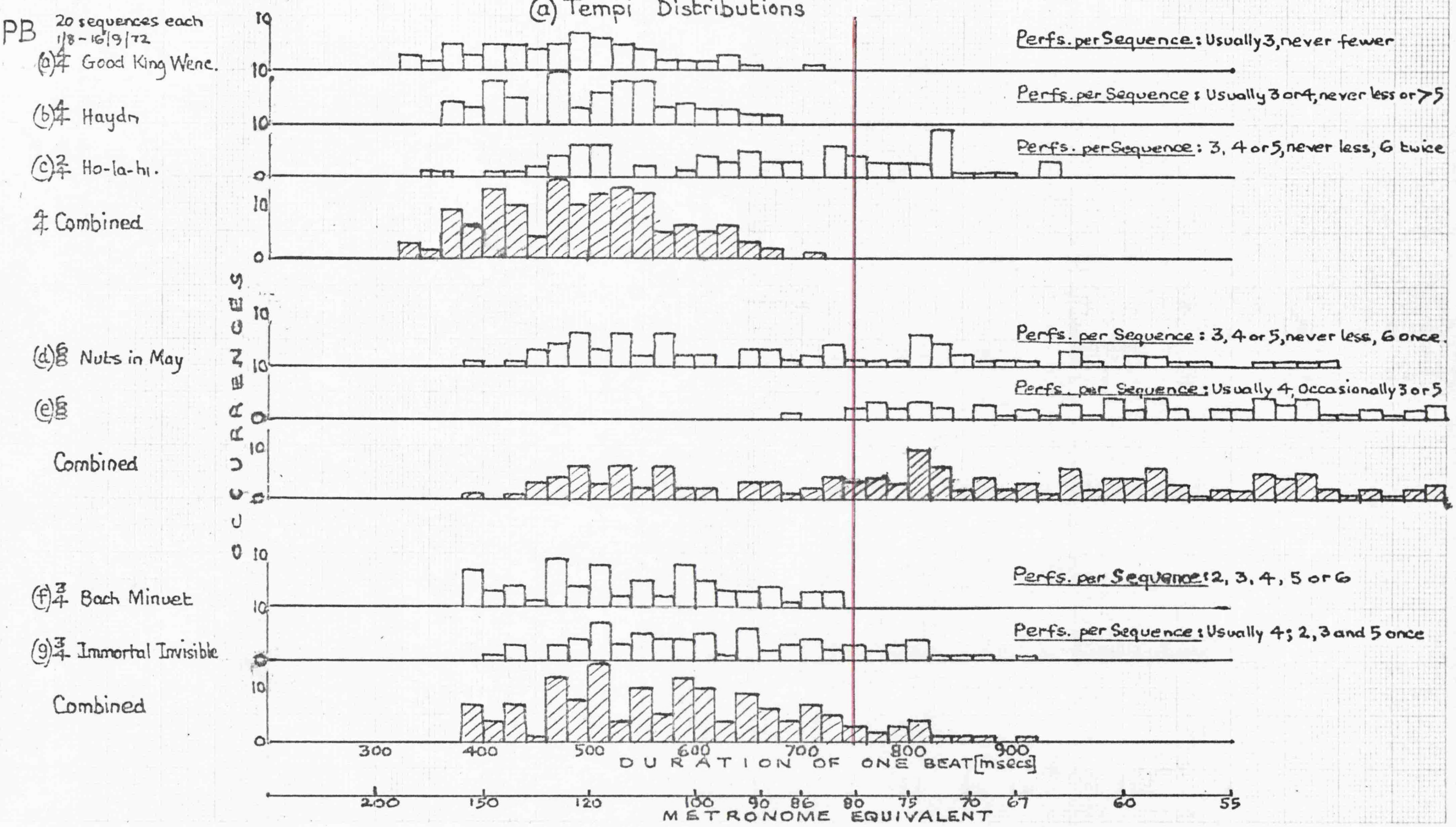


FIG P7 EXPT P7 CONDUCTING (Melodies as Indicated): SEQUENCES SLOW-FAST


(a) Tempi Distributions

Observations and Discussion

The following tentative observations may be made, mainly from a visual inspection of the data.

General

1) There is no common or individual preferred tempo for all the musical situations or for melodies in the same metre, and certainly no evidence of a "just tempo" in the 750 msecs area.

2) Only in P_5 is there any suggestion of a common preferred tempo for any given piece (AC, BB, PB).

3) Without prejudicing the Main Programme experimental definition of the terms "same speed" and "preference" and the associated question of fineness of duration interval scale, it does appear that many Ss have a degree of "preference" in each of the musical situations experienced. (P_1: BS, KC, P_2: RV, GJ, P_3: RW, KJ, PR, P_5: AC, BB, PB), while CS in P_4 has an outstandingly precise "preference" within one duration scale interval. (This interesting distribution, together with its cumulation using a finer scale interval, will be shown again in the Main Experiments section where a comparison is made with the writer's performance in a similar experiment.) Many Ss, however, appear to have no strong "preferential" tendency at all.

4) A small number of Ss suggest they may have more than one discrete "preference" peak - (P_1: RF, P_3: RW, AB, P_5: SH, JS).

5) The tempi profiles are very varied, although both BS and KC in P_1 and PN and RW in P_3 have similar cumulation sequences.

6) There appears some tendency to perform any "preference" in successive performances, even though each performance was usually a week apart (P_1: KC, P_3: RW, AB, P_4: CS).

7) The first performance usually proved to be at an extreme tempo with the next one in the direction of any ultimate "preference". Nevertheless, apart from (6) above, there appears no evidence that tempi gradually settle down and become more consistently close to any eventual "preference" centre.

Indeed, the last few performances were often the most erratic and seem to discourage any suggestion that learning or tempo memory are factors to be considered (P_1: KC, P_3: RW, KJ and particularly AB).

8) As there appears to be no readily observable relationship between tempo variation and Previous Activity, Mood and Time of Day, these variables have not been shown in the data and will not be commented on again in the Pilot Experiments. The first two were difficult to control and quantify and in retrospect should not have been included. However, as the literature gives a degree of support for a circadian influence on movement speeds and other activities, some attention will be given to that in the Main Programme

Experiments P_1-P_4

With regard to the relationship between music and heart pulse:-

9) Figs P_1-P_4 show no clear indication of any general positive or negative relationship between music and heart pulse in respect of absolute value, ratio or direction. However, with regard to a rank order relationship, the majority of Ss gave positive r_s values; two (P_1: RF, P_2: GJ) within the 5 per cent significance level.

10) A consistent heart pulse does not appear to be condusive to a particularly consistent musical tempo choice, although the S with the most precise tempo "preference" also had the most consistent pulse (P_4: CS).

11) There is no general tendency for a fast or slow heart pulse to be associated with a fast or slow musical tempo.

12) An irregular pulse is not associated with a greater inconsistency of tempi, neither is it associated with the exceptional speeds of any distribution.

With regard to any relationship between pitch and tempo when a starting pitch is not imposed:-

13) With one exception, Figs P_2 and P_4 show no relationship. The quite remarkable rank order relationship shown by a single S, (P_2: BC), in which a faster tempo is associated with a lower pitch within the 1 per cent

significance level, is contrary to the expectation that any relationship would be in the opposite direction.

14) The two Ss who evinced the most consistent starting pitch (P_2: GJ, P_4: CS) were also the most consistent in tempi.

In making any comparisons between experiments the writer is aware that the different Ss concerned make any observations very suspect. With the considerable possibility of any apparent trends being solely a function of the different performers, the writer very tentatively makes these further comments:-

15) It appears from P_1 and P_2 that the imposition or otherwise of a starting pitch does not affect tempo consistency.

16) The generally more precise preferences in P_3 and P_4 may be due to the more rhythmic nature of the test music or to the singing of words instead of lah.

Experiment P_5

It was not thought necessary to record heart rate for Expts P_{5-7}. The writer continued holding the stopwatch in his right hand when performing himself, after first ensuring that its accuracy was not affected by the movements.

17) An inspection of the totals in Fig P_5(b), together with the application of the Binomial Test of Probability (p), suggest that time order and other factors may influence tempi in sequential performance. Namely:-

(a) The first of two successive performances tends to be slower. The Binomial Test applied to the combined total 1st and 2nd performances shows the probability of the given or more extreme figures occurring due to chance to be P = .0013, well inside the 1 per cent significance limit. Although this time order effect appears to be the most potent factor affecting immediately successive performances, it may be eliminated from the other compared totals because of the compensatory performing sequence employed.

(b) Mental performance is more often slower than overt performance.

Here again the probability p = .027 of this being due to chance is well within the 5 per cent level.

(c) Lah tends to be slower than words. However, in this case, p is not within the required significance limit.

18) There is some sign of a broad common tempo preference for this piece. It could be argued, however, that circumstances were favourable to consistency and similarity in the case of BB and the writer. They alone among all Ss knew the aims of the experiments, and therefore possibly consciously or unconsciously attempted to satisfy experimental expectation and repeat previous tempi. In addition, the writer may have "learnt" any generally favoured tempo while timing the performances of other Ss. Nevertheless, two other Ss (AC and JS) are at least as consistent and precise in their "preference".

19) No performing method can be said to produce a generally sharper preference peak.

20) The preference shifts due to different performing methods are not consistent between Ss. AC remains steady while JS and BB shift in opposite directions.

21) Each subject made individually consistent body movements throughout the course of the experiment. The three students moving knees, feet and arm respectively, to the same approximate extent each time.

Experiment P_6

The stopwatch was held in the writer's right hand even when conducting with that hand. The literature in Part A gives no clear indication that the extra loading would have affected the tempi in any way.

22) Fig P_6 shows no sign of the presence of a common maximum, "ideal" or minimum tempo. The "ideal" tempo of AC coincides with the absolutely clear "troughs" of BB and PB.

23) The individual "ideal" tempi are consistently closer to the maximum side of each tempi range.

24) Some very slight overlapping occurs between some maximum and "ideal" tempi (SH, JS, BB). There is always a clear gap between the "ideal" and minimum tempi, but this gap would presumably have been filled if more than three tempi had been called for each session.

25) Some maximum and "ideal" tempi are equally precise in "preference" suggesting the possibility of a discrete range of several "preferences", together with their associated troughs, in any individual performing situation. The minimum speeds cover a very much broader range, although here again the separated peaks in some of the profiles suggest that any discrete series of preferential tempi may extend across the complete range of musically possible speeds (particularly SH).

26) All the separate and combined individual tempi profiles are different in respect of precision of preference and absolute and proportional deviations of the maximum and minimum tempi from the "ideal".

27) The chronological sequences of minimum speeds (not shown) tend to get faster for each subject.

28) As in Experiment P_5, the writer is conscious that his tempi may have been affected by listening to the performances of the other Ss.

With regard to the effects of Conducting:-

29) Conducting movements do not appear to affect the precision of any preferences, although in most cases the individual maximum, "ideal" and minimum speeds shift consistently one way or the other as a result of them.

As the Ss were the same in P_5 and P_6, and a quadruple melody was performed in each experiment, the lah performances of P_5, may reasonably be compared with the non-conducting "ideal" tempi (lah) performances of P_6.

30) The individual "preferences" or distribution profiles in these two experiments show no obvious similarities or relationships.

31) The body movements made when not conducting were similar in each case to those made in P_5.

Experiment P_7

32) An individual broad "preference" area in several metres can be observed in Fig P_7 at approximately 500 and 800 msecs per beat. There is also a tendency towards a general distribution trough at approximately 450 msecs.

33) Melodies with the same time signature do not have outstandingly similar distribution profiles. Indeed, those for pieces (b) and (f) have more in common than pieces (a) and (b), where both time signature and general phrasing are alike.

34) The question of a discrete series of preferences in every musical situation remains unresolved. The distribution profiles of pieces (b), (c), (d), (e) and (f) in their different ways possibly support the proposition.

35) Change of metre, and indeed change of piece, tend to change the "preference" profile, but no clear pattern emerges from any observation of the data.

36) There seems no relationship between profile or number of peaks and the usual number of performances in a sequence. The first and last performances for each piece can each occur over a wide range of tempi.

Appraisal and Criticism

In retrospect these experiments now seem rather naive and uncontrolled. The small number of performances merited no statistical analysis with regard to individual "preference", and the different subjects, music and performing methods employed in the Pilot programme as a whole precluded the possibility of making any confident assertions about tempo characteristics generally.

Therefore, all the foregoing comments, based as they are mainly on the observation of rather meagre data, are only very tentatively advanced at this stage.

However, as one object of the Pilot Experiments was to gain experience and insight, omissions and defects were inevitable. In this respect much of the data contributed to the writer's thinking and suggested promising directions and procedures for future work.

Other more specific criticisms also come to mind. Taking the heart rate after each performance, and not by direct coupling during it, presupposed that it remained steady through the session. Although this is an interesting area, it was decided not to investigate the effect of heart pulse in the Main Experiments.

In P_5, so-called "mental" performance was contradicted by the timing requirement of tapping, and as a pure "mental" tempo, untramelled by movement or instrumental factors can never be properly measured, this performing mode will not be used again. A possible additional weakness in P_7 is that the writer, knowing the experimental aims and having both an unavoidable subjective impression of previous performances and the knowledge of his actual timings, could attempt to relate his tempi to patterns believed to be becoming established.

The writer remains satisfied with the timing procedure and will use the same basic method in the Main Programme, although the undesirability of any subject knowing his tempi after each performance or even during the experimental period will have to be considered. Dividing the total duration by the number of beats gives a more realistic assessment of true pace and is less inhibiting than directly coupling a performance to a kymograph recorder and measuring individual beats. It also prevents short-term rubato from substantially affecting the data. At the same time, inaccuracies from whatever cause, whether real tempo variation or timing or reading inaccuracy, although tending to smooth out any sharp preference peaks, will also make those that remain even more significant. The scale interval was rather wide but was necessitated by the small number of performances in each experiment. Although unlikely, it is possible that this interval is wide enough to mask more than one very fine preference. It will therefore be halved in the Main Programme.

Summary

Despite the shortcomings of these experiments, there seems little evidence that musicians share a common preferential tempo for any given piece, and certainly none for any general tempo preference or "just tempo". There are however some suggestions of other common tempo features as well as interesting individual characteristics. Whether the various degrees of individual preference previously commented on would have been maintained throughout a more extensive experiment is a matter for conjecture. These preferential tendencies appear to change with musical content but less so with a change in performing method. Perhaps this is not surprising as the performing methods were limited to varieties of vocal performance. There is also a little encouragement for the view that an individual may have more than one "preference" in any specific musical situation.

As to the factors affecting tempo, there is some evidence that the second of two immediately successive performances tends to be faster, as does overt singing compared with "mental" performance. However, there appears to be no indication of any general relationships between musical tempi and pulse rate or starting pitch. The striking correlations shown by a few Ss may be indicative of personal rather than universal trends.

Much of the above is therefore in general agreement with the literature and the writer's speculation and gives at least tentative support for the working hypothesis.

CHAPTER SEVEN

Basis of Main Experimental Programme

Experimental Terms

The procedural definitions of Attempt, Sequence and Session will be as given for the Pilot Experiments. Series will refer to the different sets of 25 Sessions necessitated by the test and retest procedure or to complete single experiments. Where the writer performed in two series concurrently, the same number is used with a different suffix. It is now essential however that both "Same Speed" and "Preference" be given final precise definitions before proceeding further.

Experimental Definitions of "Same Speed" and "Preference"

These terms are extensively treated as they are integral both with the hypothesis and any analysis of the results.

"Same Speed"

Speed in this context refers to the tempo of the beat as defined in the Introduction. Distinction must be made between three different concepts of "Same Speed", namely:- (i) A subjective definition, (ii) An objective statistical definition, and (iii) An empirical definition for this experimental study, reconciling (i) and (ii) with the rather less rigorous demands of musical "preference" over a long period of time.

(i) A subjective "same speed" can only be the speed thought to be the same in an immediately successive performance. However, even in immediate repetition, the question of memory arises, and for increasingly longer intervals between performances, whether those performances are subjectively the same or "preferences", tempo memory will play an ever increasing role.

(ii) As an absolute objective "same speed" can only be achieved by a machine, an arbitrary limit for human musical performance will always be set by the duration scale interval chosen. The selected interval defining the limits of "same speed" statistically must not be so broad as to make the term an indication of a mere general tempo trend masking any more precise preferences, or so narrow that few of the performances in any one series fall within the same scale interval. In addition, the accuracy of the timing mechanism and procedure also sensibly limit the fineness of any interval scale. The interval must also be reasonably consistent with any psychophysical data for tempo and duration sensitivity, and in this connection the writer considered using a logarithmic scale in order to conform to the possible Weber-Fechner relationship between sensory experience and magnitude of stimulus. However, it was finally decided that this was not practicable. A linear scale is therefore used, in terms of the duration of one beat. The scale interval, fixed at 10 msecs, represents not only the maximum deviation of beat duration possible within statistically similar tempi, but also limits the precision of preference investigated.

(iii) The relationship between subjective and statistical "same speed" was investigated in a special experiment (Expt 13). Reference to Fig 13 and the associated Results and Observations shows that the range of speeds subjectively the same in immediate succession varies according to the tempo repeated. "Fast" and "Natural" speeds, although phasing usually causes them to occupy two adjacent scale intervals, are each generally contained within a 10 msecs range of raw values. In the relevant tempo area, the selected interval is thus commensurate both with the range of subjectively similar tempi and the generally accepted 2-3 per cent limen for tempo sensitivity, - the much greater slow speed variation also being in accord with the Weber-Fechner relationship. The appropriateness of the scale interval defining the range of tempi statistically the "same" is thus confirmed both experimentally and with respect to the Psychophysical Literature.

For practical purposes, the above certainly suggests that "same tempo" in an experimental programme may be defined as those speeds contained within any two adjacent duration scale intervals. However, although a 20 msecs interval proved to represent the limits of "Natural" tempo "same speed" variation in the most favourable performing situation for generating a sequence of them, it was not necessarily adequate for "preference" experiments taking many months to complete. In any case, in most experiments, the question of a subjective "same speed" was not intentionally involved; Ss usually being asked to perform either a sequence of different speeds or at a "Fast", "Natural" or "Slow" speed. The writer was surprised however to find that in many cases the tempi distributions showed that a range of two adjacent scale intervals was also appropriate as a realistic "same tempo" ideal in "preference" experiments, thus reconciling subjective, statistical, psychophysical and practical criteria. Therefore, when examining the data for "preference", this 20 msecs "same tempo" interval will be used as a standard, with which narrower or wider distributions of tempi will be compared.

It must be pointed out, however, that just as subjectively similar tempi may differ objectively over a period of time, so the tempi within any arbitrary 20 msecs "same tempo" interval may not all have been subjectively the same for any given S.

Preference

The distinctions between Choice, Subjective and Objective Preference have already been discussed in Chapter 4. However, Choice and Subjective preference, although inevitably involved to some extent in any performing situation, cannot be admitted in relation to the hypothesis or experimental programme, where pure objectivity must be the aim. For this reason, Ss were asked to perform at a "Natural" - not a "preferred" speed. The writer was also aware that any tempo performed under this condition in a preference experiment may not automatically be called a "preference" in either a subjective or objective sense. As in the case of "same tempo", the experimental definition of "Preference" must be statistically based, concerned with the tempi actually performed more often, rather than with what is necessarily "preferred".

Two aspects of objective preference must now be discussed. The first concerns the degree of tempi similarity required in relation to a single tempo distribution before the term preference may be applied to it. The ideal in this case must of course be the range of speeds admitted as being the "same tempo" - that is, those tempi falling within two adjacent scale intervals as previously decided. However, in the experiments, as the single distributions rarely correspond exactly to this ideal, it is usually a question of whether the given distribution is a realistic approximation of a "same tempo" for preference purposes.

The above aspect might be termed absolute objective preference. Many of the experiments however are equally concerned with significant differences between tempi distributions - whether or not each distribution itself is realistically confined within a single "same tempo" scale interval. Any distribution, however wide, if significantly different from another, may be said to be a comparative or relative preference in relation to it. Comparative preference may then be applied to the different tempi distributions produced by one S as a result of variations in some instrumental, performing or musical factor, or by more than one S in the same musical situation. As very few distributions approached the "same tempo" ideal, most of the experimental observations and discussion in the next chapter will be concerned with relative objective preference and the statistical significance of the observed tempi distribution differences. In any case, it was not found possible to apply normal statistical procedures to ascertain the significance of single distributions in relation to a "same tempo" ideal.

It was also not possible to apply statistical tests to the sequence experiments data. The prime interest here was whether, in a multimodal sequence distribution, one or more discrete "same speeds" occurred a significantly greater number of times in relation to the adjacent tempi.
As a substitute for statistical procedures, the writer relied here on extensive test and retest and a visual examination of the data.

The above outlines the two aspects of objective preference that are the experimental programme's main concern. Related issues must also be raised however, including inter-series or long-term consistency and the secondary characteristics of tempi distributions such as deviation and general profile.

Although any resulting significant absolute or relative preferences, trends or characteristics are ostensibly concerned with the tempo of the beat, whether they are really concerned with the speed of beat succession or with the duration of the beat or longer musical unit cannot be answered in this investigation. That the duration of a single (average) beat was computed from a total performance duration reflects not only a practical convenience but also the writer's position with respect to the question just raised.

Finally, references to distribution "peaks", "troughs" and "preference" hereon will now relate solely to the relatively greater number of performances occurring at any given "same tempo" or within comparatively narrower or wider limits, whether considered significant or not at that stage. In addition, despite the emphasis on the two types of objective preference detailed above, it is inevitable that the term "preference" will also have to be used occasionally in a generally descriptive way. When a more rigorous connotation of absolute or comparative preference is intended it will always be associated with the significance of the relevant data.

General Aims

Using one basic specially composed melody, to investigate:-

(a) The possibility of there being a discrete series of individual preferable tempi in any given total musical situation.

(b) Tempo change in association with the variation of the selected musical, performing and instrumental factors.

Rationale of Main Experimental Programme

For reasons given in the Introduction, the entire programme is based on versions of this one specially composed triple metre melody, using one principal S in all experiments (PB) with confirmatory work with other Ss in many of them.

Therefore, although the writer believes metre to be the most potent tempo affecting factor, and one urgently requiring a detailed investigation of its own, it remains constant in all the experiments. With regard to the music used, it was decided that the following criteria had to be satisfied:-

The Standard E flat Melody must be:-

(i) previously unknown to all subjects (This eliminates any tempo tradition).

(ii) consistent in its crotchet beat melodic movement.

(iii) free from memorable rhythmic or melodic interest (There is then less chance of unidentifiable structural factors affecting individual tempo or generating a common tempo).

(iv) capable of being sung and performed on different instruments.

(v) capable of being supported by various discretely different harmonic rhythms.

The Standard E flat Version (Keyboard) must be:-

(vi) consistent in its crotchet beat harmonic rhythm and style (Standard E flat Harmony).

(vii) capable of being transposed into any major or minor key (Standard Versions).

The Standard E flat Harmony must be:-

(viii) capable of supporting discretely different melodic rhythms based on the Standard E flat Melody.

Within the context of a constant Metre and fundamentally similar musical material, the above enables many of the factors detailed in Chapter 3 to be investigated in a controlled situation. The normally continuous variables of rhythm and harmonic rhythm, now contrived to be discrete, may be added to the intrinsically discrete variables of key/pitch, mode, instrument and performing method. In relation to the Standard E flat Melody, Standard E flat Version and Standard E flat Harmony, a study may now be made of the tempo behaviour associated with a consistent variation in each of the above factors.

However, with the weaknesses of the Pilot Experiments in mind, the writer was aware of the need to keep the factors not being investigated as constant as possible. Some, such as instrument, room and acoustics were clearly unchanged, but others created problems. One difficulty concerned the interrelationship of some factors. For example, a change in harmonic rhythm is difficult to contrive without a corresponding change in melodic rhythm. Nevertheless, the differentiation and control in cases like this was achieved within practical limits. Other factors posed bigger problems. In particular, the temporal variables, by their very nature, are impossible to control simultaneously. Any attempt to standardise time of day would have necessitated every performance attempt of any given experiment being at least a day apart, thus causing the ever present possibility of physiological periodicities greater than the circadian to have an even greater effect. In any case, making time of day a constant in all experiments would have limited the number of experiments possible or severely extended the already long total experimental period. It was therefore decided generally to ignore physiological and psychological variables such as heart rate, respiration rate and phasing with the music, body temperature and mood of the subject from whatever cause, unless extremes were patently obvious, in which case the session was postponed. Any effects due to circadian variations may however be eliminated from all intra and inter-experiment comparisons as the sessions for each subject took place at random times between 0800 and 2200 hrs, although the possibility of longer-term periodicities affecting behaviour must always be in mind when interpreting results. This does mean therefore that the data for any series, and certainly the combined data, arising from the very necessary test retest procedure, while confirming the broad preference areas, may well mask the more precise preferences existing at any given time, but which change with some circadian or longer periodicity. It was clearly desirable for the different series of any experiment and for related experiments, particularly when involving the same S, to have as close a chronological proximity as possible in order to avoid the worst effects of any long-term biological variations. Many experiments were in fact conducted simultaneously over the same general period, as the total chronological programme of PB experiments in Fig 16 shows.

Although the general outline of the Experimental Programme necessary to satisfy the two General Aims was clear at an early stage, the actual selection of experiments for it and their chronological order was not in toto planned in advance. Expt 1 was suggested as a starting point by the final Pilot Experiment, and this in turn led to subsequent closely related investigations. It was not until much experimental work had been done that the complete programme was finalised. After the Results and Observations for each experiment the writer has added, where necessary, brief details of the thinking and speculation that led to the immediately following or later experiments.

The experimental rationale for the majority of the experiments may be summarised thus:-

(a) For experiments investigating any discrete series of preferred tempi it was necessary to contrive a situation where no musical, performing or other factor was varied, and in which all tempi between very slow and very fast were equally possible. To this end the Ss were instructed to perform the given music in immediate sequence, usually from the slowest possible musical speed, then at the next slowest etc until the fastest possible triple metre speed was reached, beyond which the music would feel one in a bar.

Within this procedure the two chosen performing methods were:-

(i) Conducting while vocalising lah (as in Pilot Expt P_7).
Standard E flat Melody.

The elimination of an instrument and other external tempo-affecting factors makes the performing method suitable for expressing a conductor's "ideal" tempi.

(ii) Piano legato. Standard E flat version.

(b) For experiments investigating tempo change in association with the variation of selected musical, performing or instrumental factors, the Ss were instructed to make one attempt at a "natural" speed in each session. The variables finally selected, all either intrinsically or constructively discrete, and which necessitated appropriate modifications of the Standard Melody, Version or Harmony were:-

(i) <u>Instrumental and Performing Methods</u>

Piano legato, Piano staccato, Glockenspiel, Organ, Organ Dummy Keyboard, Organ Dummy Keyboard + Noise, Singing Lah, Singing Words, Treble Recorder.

(ii) <u>Structural Musical Factors</u>

Harmonic Rhythm, Melodic Rhythm, Key/Pitch and Mode.

It is necessary to restate here that the total duration timing procedure employed again throughout the programme makes the assumption that the tempo remains steady within that duration. Thus the switching-on point was never at the beginning of the performance in order that any tempo uncertainty could settle down. The writer had considered a kymograph recording of each performance but decided, as in the Pilot Experiments, that not only would the mechanisms involved inhibit natural performance, it would be no more accurate measuring the duration of a single or average beat than the method actually employed. However, the writer would again point out that any significant results arising from a total duration procedure, with the attendant possibility of its masking tempo fluctuation, make those results even more impressive. Despite the apparent concern of the data with the duration of one beat, that significance would of course really be related to average tempo or the control of that tempo by the total duration measured rather than to individual beat duration or momentary tempo.

In order that fair visual comparisons between data may be made, the number of sessions in both sequence and single attempt experiments was always twenty-five.

Subjects and General Procedure

The writer (PB) was the principal subject in all experiments. The college tutor accompanist (BB) was a second subject in a number of them, and twelve female music students assisted by being subjects in selected confirmatory series.

All Ss except the writer gave their performances in the same college practice room. The writer performed in his own lounge, with repeat series in the college practice room to enable more valid comparisons to be made with the other Ss. In all experiments an attempt was made to control or monitor subsidiary factors. The writer, who heard the performances of all other Ss, ensured that the music was always played or sung at a moderate volume with normal triple metre accentuation and without observable rubati or rallentandi, and only on rare occasions was it necessary to ask a S to repeat a performance because of a failing in one of these respects. Methods of performance not requiring a keyboard were undertaken standing by the respective pianos, with the music placed at a convenient height. As far as possible it was ascertained that the S had not been playing or listening to music, or engaged in any physical activity, immediately before any session. Music was always provided and the S was asked to read from the score even if it had been memorised. No series was commenced until the S could play or sing the required music fluently.

Although the writer heard all other performances and BB heard those of the writer that he timed, no other S heard another's performance; all taking care that their practising and performing were private. No S except the writer knew of the precise aims of any experiment or the specific or cumulative timings until the complete programme was finished. However, as the act of timing the duration of each performance was not concealed from the S, the concern of the investigation with tempo was self-evident. It was however necessary to limit the writer's knowledge of his own timings in order to prevent any conscious or unconscious attempts to perpetuate promising trends. This was achieved partly by self-imposed restrictions with regard to access to previous data and partly by the general procedure outlined here. In sequential performance the writer was unaware of the various timings until the end of the session, and the overall experimental design was organised to inhibit any tempo memory. In no case was the temporal interval between attempts less than 5 minutes, the writer always ensuring that in his case no session was undertaken until the memory of the previous trial's tempo had apparently faded. In addition, as many different experiments undertaken by the writer and BB often ran simultaneously over the same period, it was also usually possible to arrange that the sessions were intermixed as to music, experimental method and instrument. This had the additional advantage of eliminating time-order effects, but introduced the possibility of tempi being affected by interaction between experiments. The chronological period and interrelationship of the various series is shown in Fig 16.

<u>Rooms and Musical Instruments Used</u>

(a) <u>Writer's Lounge</u> 24' x 22'

Piano: Blüthner Grand 6' 3"

Recorder: Schott's Concert Treble

Glockenspiel: Sonor Soprano

Organ: Scala Royale electrically blown harmonium

(b) College Practice Room 6' x 5' (door closed)

Piano: Rudi Ibach Sohn Upright

Recorder: As above

Glockenspiel: As above

Instrumentation, Timing and Data Recording

The duration of forty beats was timed by hand stopwatch or Centisecond Timer as indicated in the respective experiments.

Stopwatches (1) and (2): Nero Lemania

Centisecond Timers (1) and (2): Griffin and George

The former were calibrated in 1/10 second and read to the higher calibration when in doubt; the centisecond timers were also always read up to the next 1/10 second. Electrical timing was introduced to eliminate a suspicion of watch-reading prejudice, and to enable the writer to time his own instrumental performances. The former was found to be unfounded and stopwatch timing was retained for all experiments in the college practice room.

When timing himself by stopwatch the writer's method was as previously described in the Pilot Experiments. Any other operator of the stopwatch, who always stood beside the S, is indicated for each experiment. The centisecond timer was situated in a distant room so that its clicking was inaudible. It was activated by means of two simple spring contact floor switches placed to the left of the piano pedals and operated by the writer's left foot in all cases. In order to confirm the accuracy and practical correspondence of the different mechanisms and procedures, the stopwatch and timer were periodically started and stopped simultaneously, each in their respective ways. As the difference between them over a typical duration was never greater than 1/10 second the writer was satisfied that any errors or differences due to their respective mechanisms, or inherent in the different physical switching procedures, were negligible in relation to the scale interval used. The different stopwatches and timers, occasioned by availability, were also checked in this way. In addition, possible errors due to individual reaction times affecting stopwatch switching were almost eradicated by ensuring that only the writer timed all other Ss, and limiting the stopwatch timing of his own performances to just two college colleagues. The centisecond timer was always operated by members of the writer's family. In sequence experiments the writer or other assistant operating the stopwatch or centisecond timer, after immediately recording the duration and resetting the device to zero, indicated verbally that the next performance could commence. The temporal interval between the different performances of a sequence was therefore of the order of 10 seconds. The raw data in all experiments was recorded on the standard form provided.

Scale Interval

The appropriateness of the 10 msecs Duration Scale Interval in connection with the definitions of "same speed" and "preference", the subsequent data distributions and the limen for tempo sensitivity has already been discussed.

All raw duration data were subsequently transformed into single beat durations according to the following scale of equivalence, shown again with corresponding metronome values:-

Durations		MM
40 Beats (seconds)	Single Beat (msecs)	
9.7-10.0	240-250	
10.1-10.4	250-260	
10.5-10.8	260-270	
10.9-11.2	270-280	
11.3-11.6	280-290	
11.7-12.0	290-300	200
12.1-12.4	300-310	
12.5-12.8	310-320	
12.9-13.2	320-330	
13.3-13.6	330-340	
13.7-14.0	340-350	
14.1-14.4	350-360	
14.5-14.8	360-370	
14.9-15.2	370-380	
15.3-15.6	380-390	
15.7-16.0	390-400	150
16.1-16.4	400-410	
16.5-16.8	410-420	
16.9-17.2	420-430	
17.3-17.6	430-440	
17.7-18.0	440-450	
18.1-18.4	450-460	
18.5-18.8	460-470	
18.9-19.2	470-480	
19.3-19.6	480-490	
19.7-20.0	490-500	120
20.1-20.4	500-510	
20.5-20.8	510-520	
20.9-21.2	520-530	
21.3-21.6	530-540	
21.7-22.0	540-550	
22.1-22.4	550-560	
22.5-22.8	560-570	
22.9-23.2	570-580	
23.3-23.6	580-590	
23.7-24.0	590-600	100
24.1-24.4	600-610	
24.5-24.8	610-620	

Durations		MM
40 Beats (seconds)	Single Beat (msecs)	
24.9-25.2	620-630	
25.3-25.6	630-640	
25.7-26.0	640-650	
26.1-26.4	650-660	90
26.5-26.8	660-670	
26.9-27.2	670-680	
27.3-27.6	680-690	
27.7-28.0	690-700	86
28.1-28.4	700-710	
28.5-28.8	710-720	
28.9-29.2	720-730	
29.3-29.6	730-740	
29.7-30.0	740-750	
30.1-30.4	750-760	80
30.5-30.8	760-770	
30.9-31.2	770-780	
31.3-34.6	780-790	
31.7-32.0	790-800	75
32.1-32.4	800-810	
32.5-32.8	810-820	
32.9-33.2	820-830	
33.3-33.6	830-840	
33.7-34.0	840-850	
34.1-34.4	850-860	70
34.5-34.8	860-870	
34.9-35.2	870-880	
35.3-35.6	880-890	
35.7-36.0	890-900	67
36.1-36.4	900-910	
36.5-36.8	910-920	
36.9-37.2	920-930	
37.3-37.6	930-940	
37.7-38.0	940-950	
38.1-38.4	950-960	
38.5-38.8	960-970	
38.9-39.2	970-980	
39.3-39.6	980-990	
39.7-40.0	990-1000	60

Presentation of Results

As in the case of the Pilot Experiments, a varied graphical presentation of all data is a necessary and valuable supplement to the statistical analysis. Again the sequence experiment data is presented solely in graphical form; any claims for significant peaks and troughs being made in the light of the experimental definition of "preference" and the visual observation of the results from extensive test and retest procedures. Included with the graphical presentation of all results are the inclusive dates of the experimental period, the room and any instrument used for each S.

The linear duration scale employed in the Pilot Experiments, again in conjunction with MM and Italian tempo word equivalents, has been used throughout, together with the same graphical symbols and conventions. As the duration scale interval is also half that used previously, a ready visual comparison may therefore be made both between each Main Experiment and with the Pilot Experiments. Again, the "Normal" tempo of MM 80 will be indicated by an unbroken red line. In a very few cases it has been necessary to omit some extreme values from the graphical data in order to preserve uniformity of format. All values have however been taken into account in the statistical calculations.

For the reason stated in the Pilot Experiments the term "occurrences" will be used instead of frequency, and modal and non-modal values or areas in tempi distributions will usually be referred to as "peaks" and "troughs".

Statistical Tests

The following statistical tests were applied to the data when appropriate. Significance was again set at the 5 per cent level, and all values obtained, whether significant or not, are shown in the various Figures and Tables, with the 5 per cent and 1 per cent significant values underlined as indicated:-

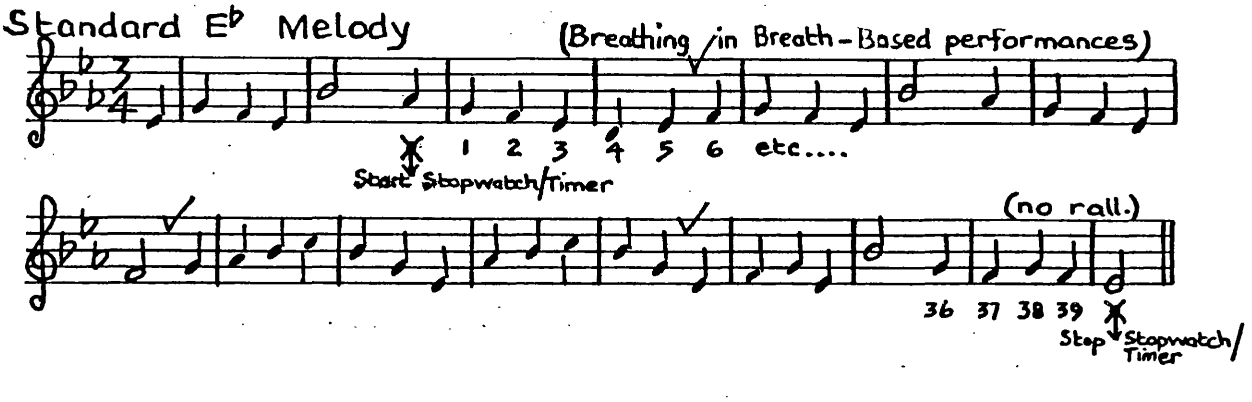
Order of Means - oriented with Standard E flat Version, and giving directional relationships to the t ratios
t test for significant difference between two distributions
Trend test for discrete series
Spearman Rank Order Coefficient
Analysis of Variance
Variance Ratio for cf distribution profiles

CHAPTER EIGHT

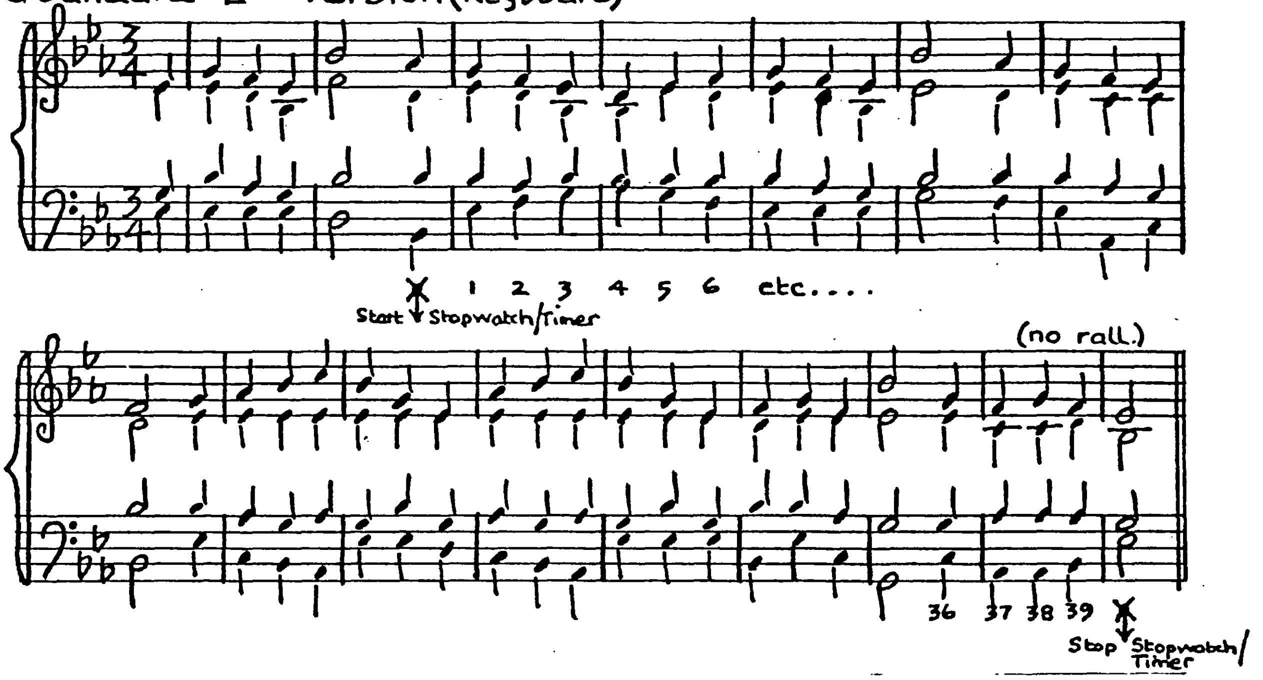
Main Experimental Programme

As so many different experiments are involved, it was decided that clarity of presentation would be better served if the Results and Observations associated with each experiment were also included immediately after its description. This will include graphical data, statistical analysis, the writer's introspection during performance and continuing speculation. The general discussion of the Results as a whole and the relationship of them to the literature, writer's speculation and hypothesis will then follow in Chapter 9.

The presented order and numbering of the experiments is a compromise between the chronological and the logical order deemed appropriate for the complete programme seen in retrospect. The first experiments, mainly concerned with discrete preferences in sequential performance, are followed by those investigating some of the factors believed to cause a variation in any "preference".



Standard E^b Version(keyboard)



Experiment 1

Description

Aim: To investigate possible discrete preferential tempi in the given sequential performing situation, in which all speeds are theoretically equally possible.

Subjects: The writer (PB): Eight series. Three sessions per day average (maximum ten).
College tutor accompanist (BB): Four series. One session per day average.
Five female music students (RA,EE,EH,AC,SH): One series each. One session per week average.

Experimental Rooms: PB Series 1-8: Writer's lounge.
BB and students: College practice room.

Instructions: Looking at the score, softly vocalise the given music to lah through the breath, while conducting in an expressive rather than formal way. At each session give a sequence of performances as follows:-

1) At the slowest reasonable musical speed.
2) etc. At the next slowest speed etc until the fastest possible musical triple metre speed (beyond which the music would feel one in a bar).

	Do not rall. at the end of any performance. Starting pitch E flat, given before each single performance, to form the tonal basis of the "breathed" performances.	
Music:	Standard E flat Melody.	
Record:	Date, Time of day, Duration of forty music beats (In PB Series 7 and 8, First "dynamic" conducting).	
Timing:	PB Series 1-4:	Stopwatch (1) Operated, read and recorded by PB.
	Series 5-8:	Centisecond timer (1) Read and recorded by assistants.
	(Series 7, 8:	PB also held stopwatch in conducting hand).
	BB and Students:	Stopwatch (1) Operated, read and recorded by PB.

Results and Observations

(a) Tempi Distributions

As subsequent sequential analysis of PB Series 7 and 8 (Fig 1-8) shows that the tempo difference between successive performances tends to get smaller towards the fast end of the sequence, the general skew to the right merely indicates that there were more performances at fast tempi than at slow ones. This may therefore be significant in connection with tempo discrimination but not with any precise preferences. We now have to consider the profiles of the distributions in the context of this general slope.

A study of the distribution of each PB series (Fig 1-1) shows a consistent but not readily obvious peak tendency in the 400 msecs area. The combined distributions for two sets of series (Figs 1-3, 1-4) confirms this peak, together with its general restriction to the required "same tempo" duration scale interval of 20 msecs. This is particularly true for Series 5-8, where peaks at 270-280 msecs, 330-340 msecs, 750-770 msecs and possibly other values are also observed. These are rather less in evidence in Series 1-4, although the total combined PB data (Fig 1-4) does indicate broader peak tendencies that include these values, together with a further

FIG 1-1 EXPT 1

CONDUCTING (Standard E^b Melody): SEQUENCES SLOW-FAST

(a) Tempi Distributions

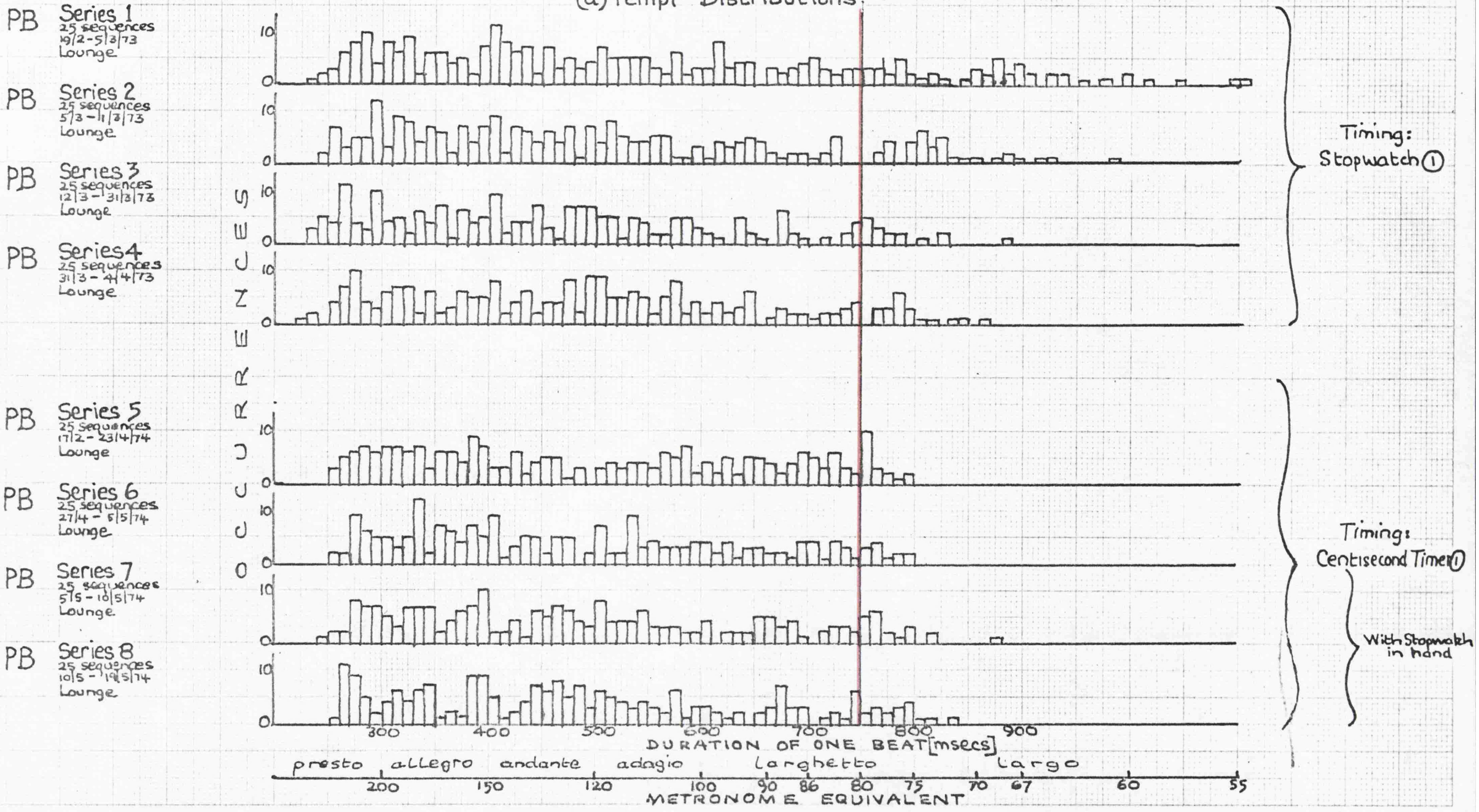


FIG 1-2 EXPT 1 CONTD

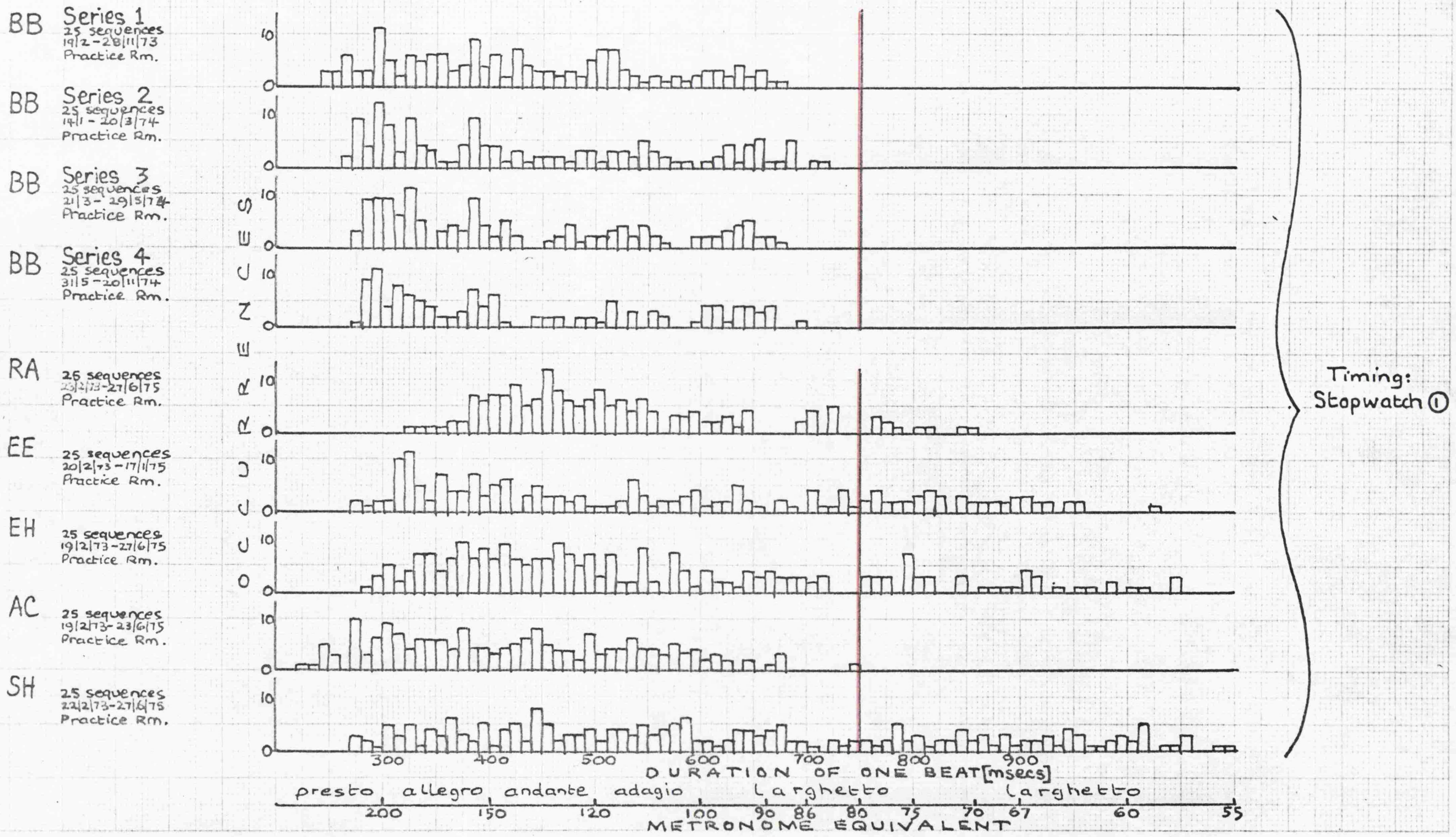


FIG 1-3 EXPT 1 CONTD

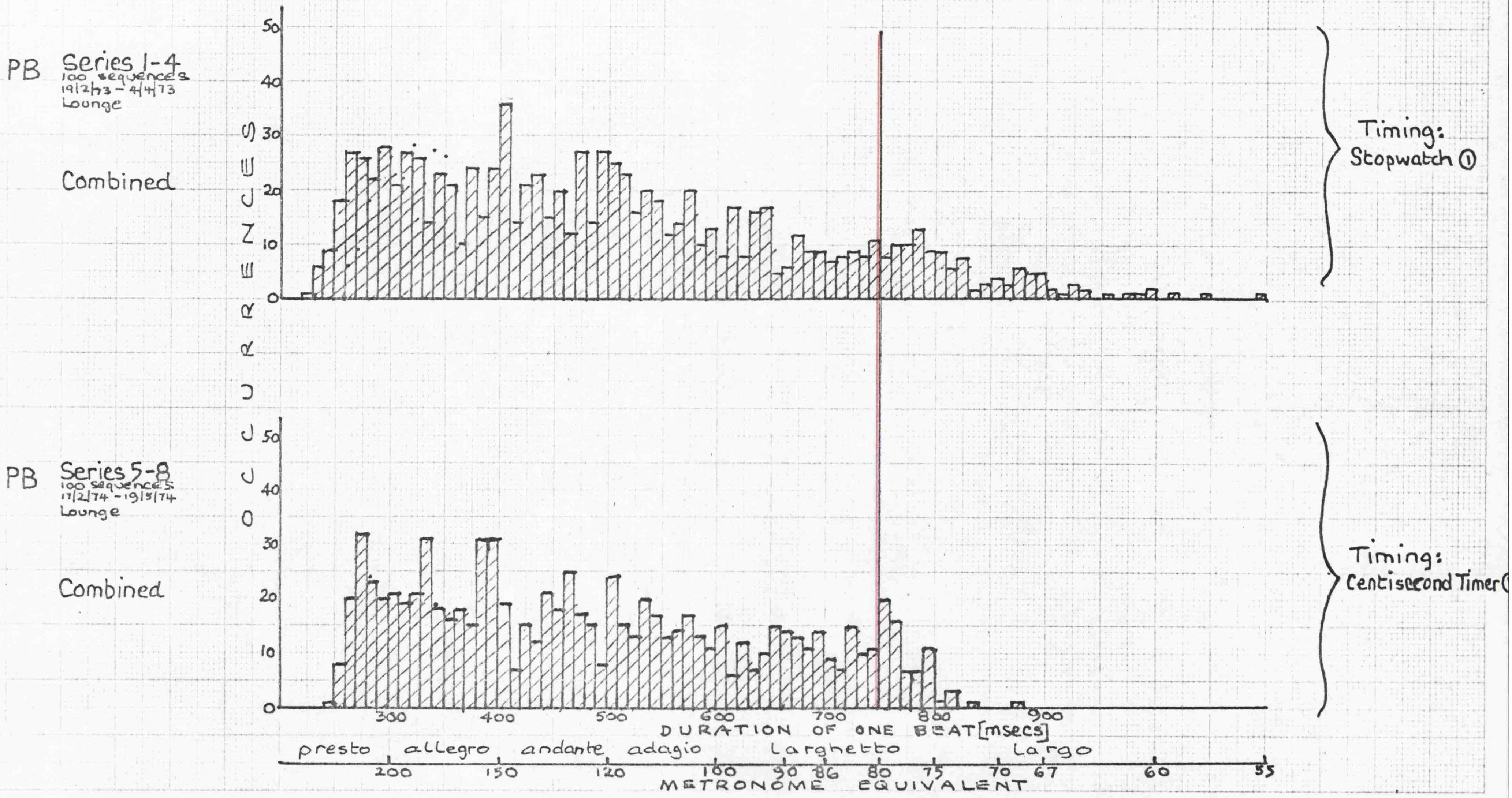
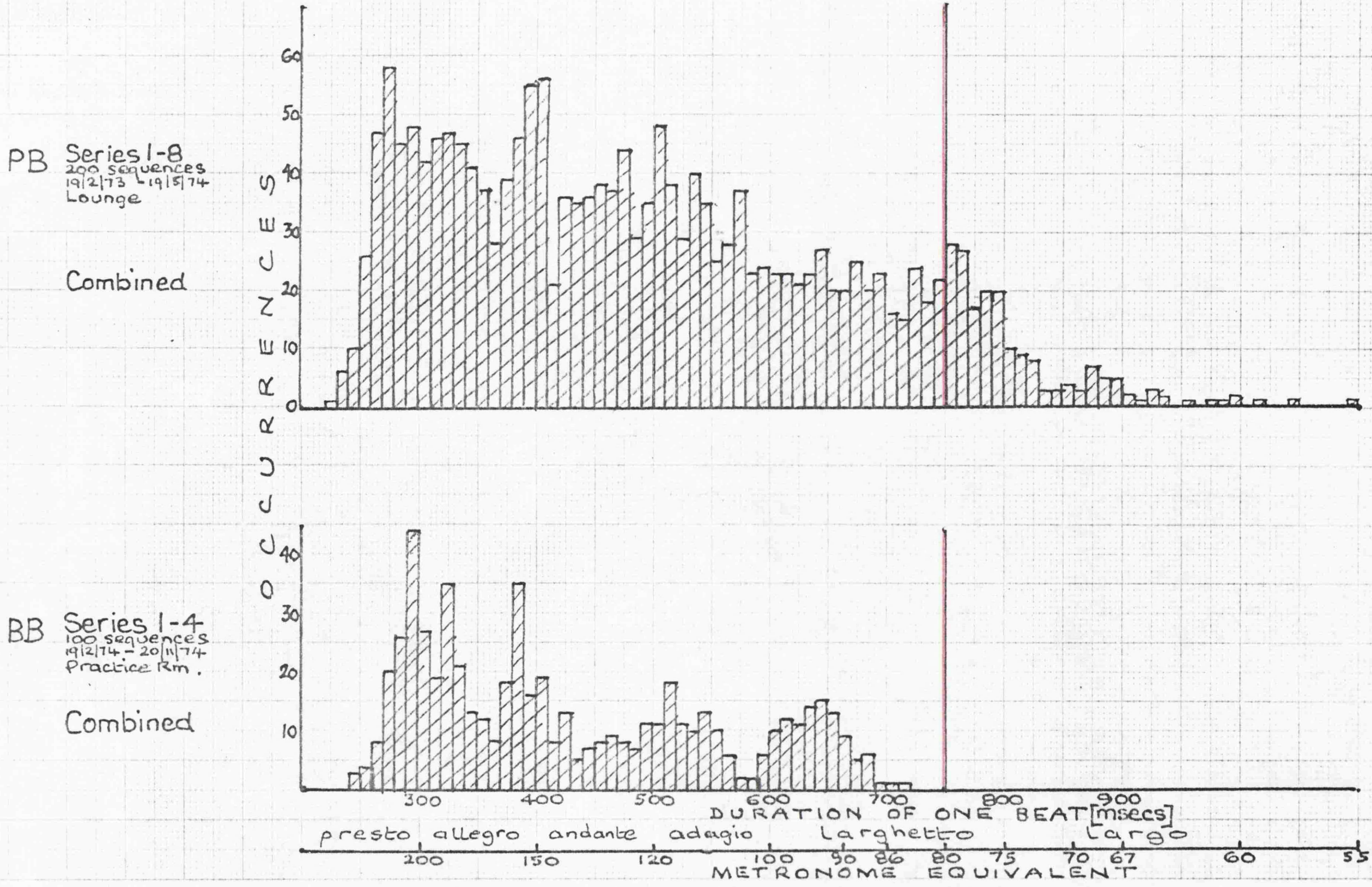


FIG 1-4 EXPT 1 CONTD



very broad peak area centred on 500 msecs. The most outstanding feature however from the combined PB data (Figs $1-_3$, $1-_4$) remains the apparent "same tempo" "preference" around 400 msecs, together with an associated trough just one scale interval wide to its right.

The data for the BB series, both single (Fig. $1-_2$) and combined (Fig $1-_4$) shows the same general distribution profile as for PB, but with more precise peaks, each only one scale interval wide. Three sharp peaks at 290-300 msecs, 320-330 msecs and 380-390 msecs, associated with marked surrounding troughs, and broader peak areas around 520 msecs and 650 msecs make the BB combined data an exaggerated and constricted version of the PB distribution profiles. Another interesting feature is the almost total absence of any performances between 570 and 590 msecs, and this too is reflected in a similar tendency for the PB data to include a trough in the same approximate area. Nevertheless, the most striking common feature within the basically similar profiles is the sharp peak in the 400 msecs area, which, like the other BB peaks, is well within the 20 msecs limit for "same tempo". Although no statistical tests could be applied, the test-retest procedure gives weighty support for the significance of this approximate value for the tempi of PB and BB in this performing situation.

However, the student distributions for single series (Fig $1-_2$) bear no resemblance to those of PB, BB or to each other. The quite sharp peaks observed in some of the distributions may be individual preferences, but without the confirmation of any retesting no significance can be attached to what may be chance concentrations of tempi. There are certainly no common preferences, although the profiles of most Ss give further tentative support to a discrete preferences hypothesis.

Closer examination of the PB data shows slight shifts in many of the features between series. For example, it looks very much as if the 400 msecs area peak shifted from 400-410 msecs in Series 1-4 to a generally faster tempo in Series 5-8 (Fig $1-_1$). As the change in timing procedure was shown to have no effect, the possibility of a long term physiological change must be considered. The writer held the stopwatch in his beating hand in Series 7 and 8 although operating the centisecond timer, but this attempt to repeat the exact mechanical conditions of Series 1-4 failed to have any observable effect. In addition, the sharp cut off to the right of this peak observed in Series 2-4, which led rise to the suspicion of watch reading prejudice, was found to be generally maintained with the electrical timing.

It is suggested that the abrupt cut off frequently observed at the fast end of the distributions of all Ss, representing the point beyond which triple beating is unmusical, may also be a limiting tempo for comfortable movement speed when beating a triple metre. In which case, any tendency to peak there is solely the result of movement rather than musical criteria. Within the general positive skew there is little evidence that the peaks in each single series distribution are less sharp for the slower tempi, which is surprising when any tempo fluctuations in performance or a less fine discrimination at slower speeds would be expected to multiply their effect over a longer duration. The fact that generally broader peaks are not observed in the slower portion of each distribution gives some support to the view that a duration longer than individual beat succession controls tempo.

Finally, apart from PB Series 5-8 combined data (Fig 1-3) there is no other suggestion from any S that the 750 msecs (MM 80) area is a "normal" tempo for this method of performance. In any case, as far as the writer was concerned, this end of the distribution represents subjectively slow tempi, and certainly not a "just" or "normal" standard.

(b) Effect of Starting Tempo on Subsequent Sequence

The writer selected six of his adjacent starting tempi and examined their effect on the subsequent sequences in Series 1-4 (Fig 1-5). They included the two most common starting tempi of 780-790 msecs and 760-770

FIG 1-5 EXPT 1 CONTD

(b) Effect of starting tempo on subsequent sequence: Comparison of selected sequence distributions

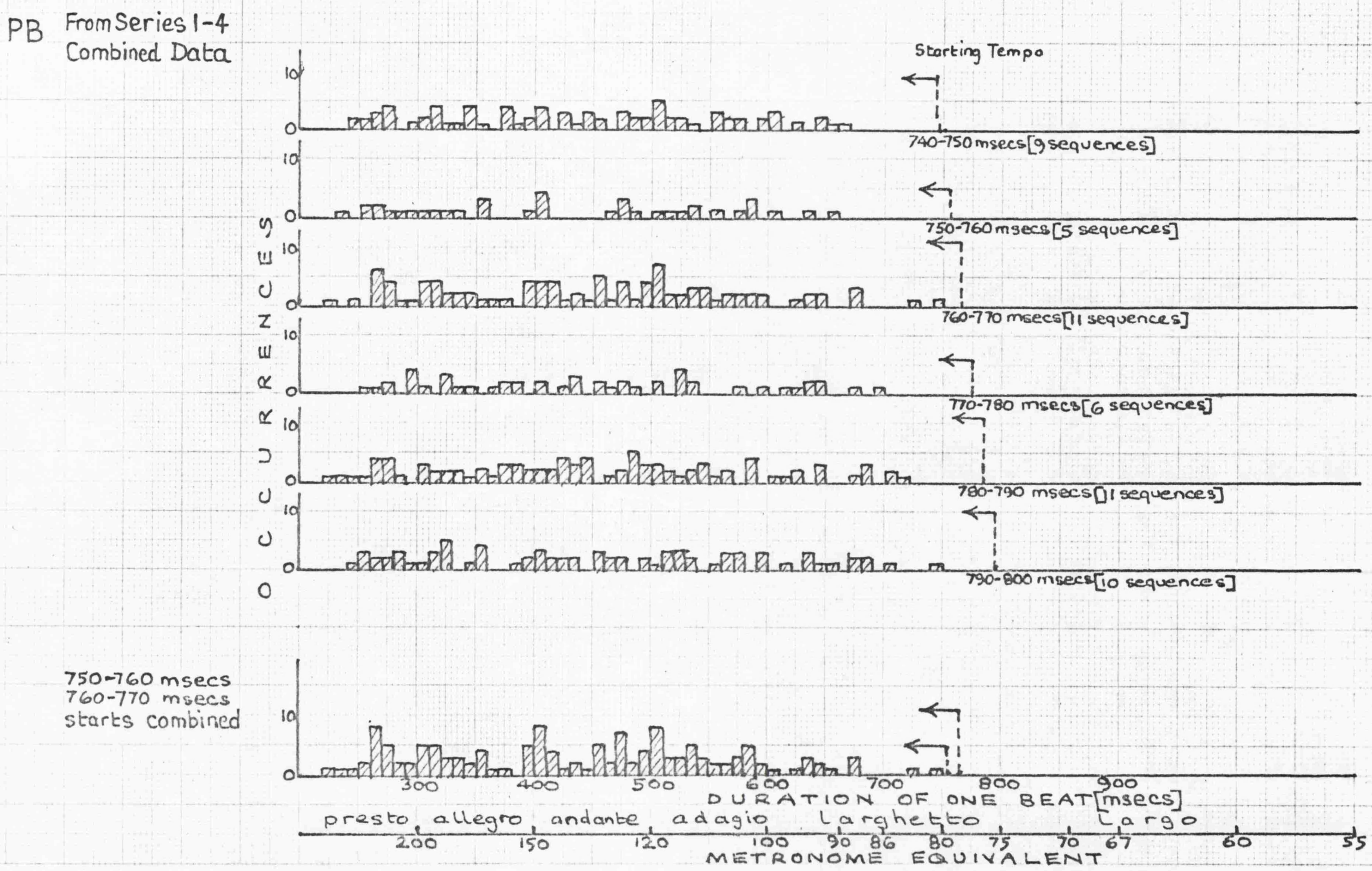
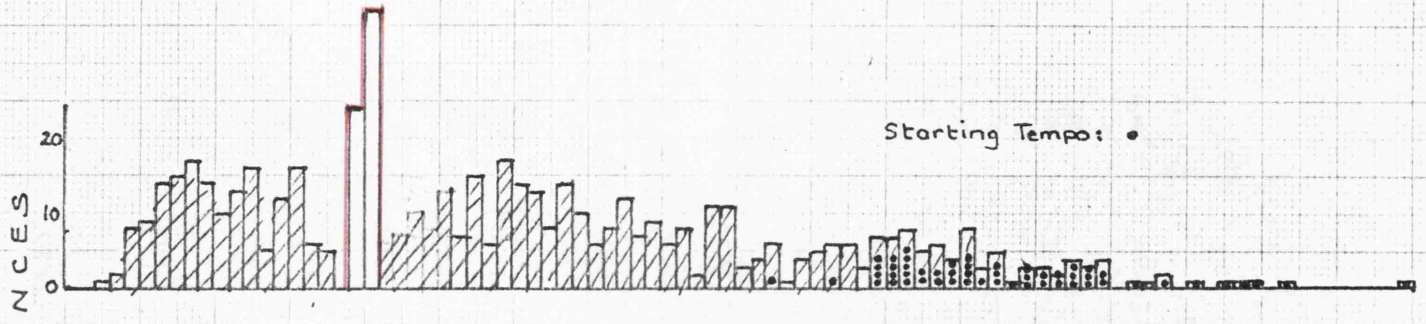


FIG 1-6 EXPT 1 CONTD

PB From Series 1-4
Combined Data

(c) Including only data for sequences containing 390-410 msecs 'peak' (55 sequences)



(d) Eliminating all data for sequences containing 390-410 msecs 'peak' (45 sequences)

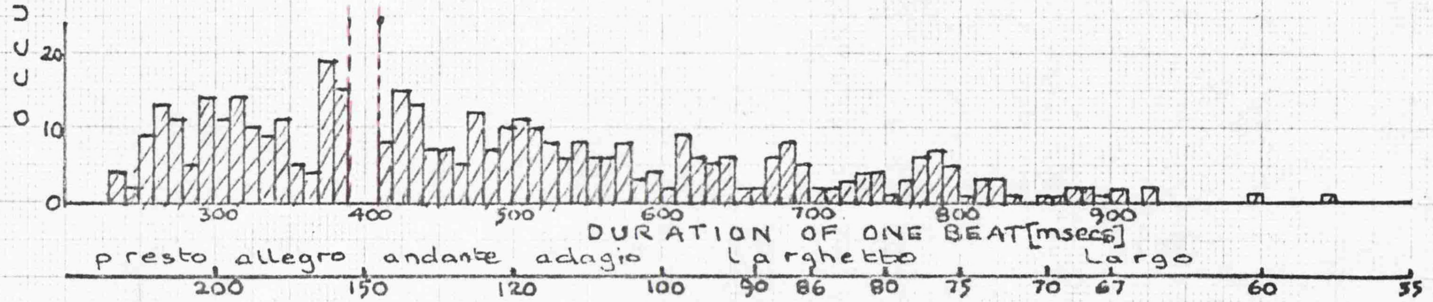


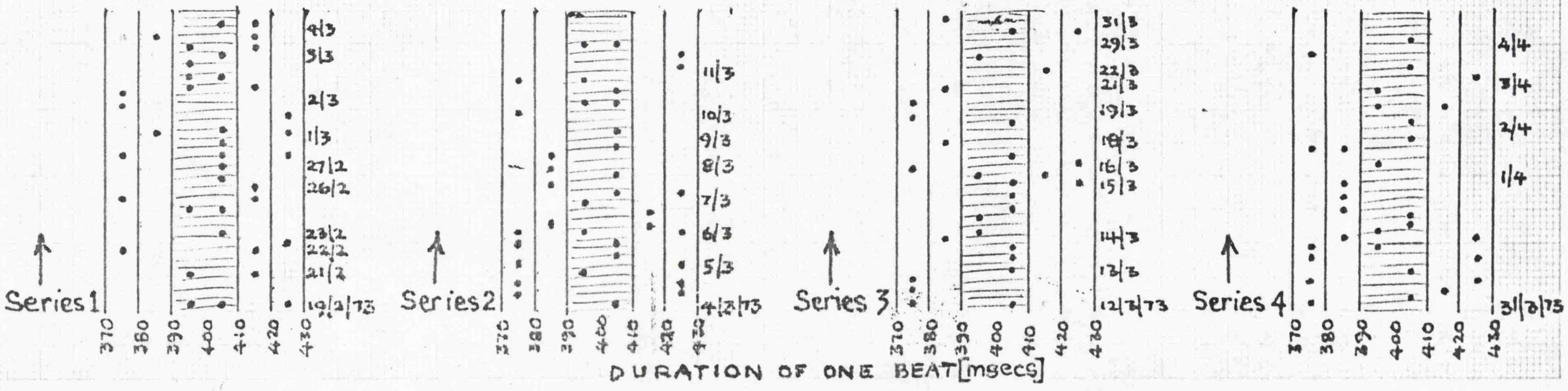
FIG 1-7 EXPT 1 CONTD

PB From Series 1-4
Combined Data

(e) Effect of relatively fast and slow starting tempi on final tempo

(f) Effect of relatively fast and slow starting tempi on number of performances in sequence

(g) Analysis of 390-410 msecs peak area



msecs. Although 750-760 msecs was the least favoured starting tempo of the six, each time it generated a performance in the 400 msecs peak area with wide tempo gaps either side. Further, not only do the combined distributions for this and the adjacent 760-770 msecs starting tempi generate a very prominent and isolated concentration in the 390-410 msecs zone but a similar association may be seen from the reversed viewpoint in Fig 1-6(c).

(c,d) Split Tempi Distributions for sequences containing and omitting 390-410 msecs "peak"

An observation of Figs 1-6(c,d) makes it clear that there is no marked change of profile when the data is divided according to the presence or absence of the 390-410 msecs "peak" tempo. The profile difference immediately surrounding the criterion values was to be expected in the case of (d), given the average tempo difference in this area (Fig 1-8), but it very quickly gets into phase in both directions with the general profile trend for the total combined data for Series 1-4. In (c), the concentration of starting tempi at 740-770 msecs is a helpful complement to the data supporting (b) above.

(e,f) Comparative Effects of fast and slow Starting Tempi

With regard to the effect on the final tempo, Fig 1-7(e) makes it clear that the approximately 30 per cent average difference between the twenty-five fastest and slowest starting tempi had no corresponding effect on the resulting final tempi. However, (f) shows that the number of performances in a sequence does appear to be greater on average when the starting tempo is slower, and that any given starting tempo tends to generate the same number of performances. It is also clear from (f) that the slowest starting tempi were in the first half of the four series being considered and the fastest generally later. Indeed, they were taken almost entirely from Series 1/2 and 3/4 respectively. Not too much must be made of this however, as an examination of the raw data shows that apart from some exceptional first sequences, the number of performances in each sequence maintained quite a steady level throughout not only Series 1-4 but also Series 1-9. There is therefore little suggestion that boredom or impatience during a long programme caused the number of performances to diminish.

BB maintained an even greater consistency in this respect, rarely venturing either side of a five or six performances per sequence pattern. The other Ss were inconsistent, both within and between themselves. Of these, the most eccentric was SH, whose first and last sequences contained four and fourteen performances respectively. The general average between them was approximately nine performances in each sequence.

(g) Analysis of 400 msecs Peak Area in PB data

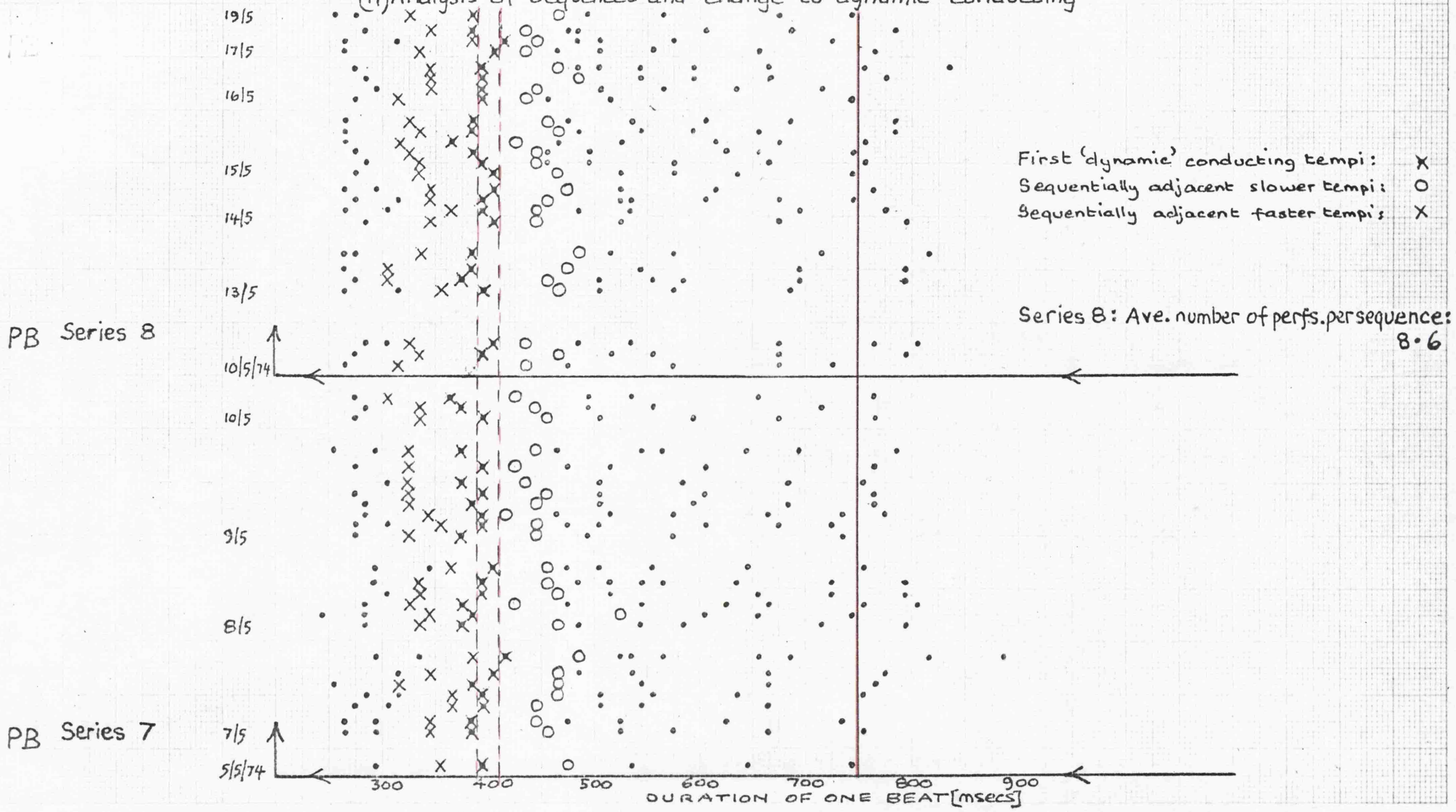
Fig $1-_{7(g)}$ makes it clear that no learning of this peak value took place; in fact, it makes its most prominent appearance in the first series. There is however a tendency for any given value to appear in consecutive sessions, even when the generating sequences occurred on different days. For example, rows of peak and adjacent trough values can be seen in Series 1 26/2-1/3/73 and Series 2 4/3-6/3/73 respectively. This tendency supports the view that there may be minor variations in any preferred tempi, caused by periodic fluctuations longer than the circadian in our "internal clock".

(h) Sequential Analysis

A visual analysis of the PB Series 7-8 data (Fig $1-_{8}$) shows the tendency, common to all subjects and series, for the tempo difference to get smaller towards the fast end of every sequence. There is in fact a very approximate 10 per cent tempo change (in terms of single beat duration) at each step from slow to fast, which is clearly generally in accord with the Weber-Fechner psychophysical relationship. The lack of any correspondence with the accepted 2-3 per cent limen for tempo discrimination can be explained, from the writer's introspection at least. Although the

FIG 1-8 EXPT 1 CONTD

(h) Analysis of Sequences and change to 'dynamic' conducting



instructions asked for the "next slowest speed" each time, the writer was aware that in many cases, certainly away from the fast end of the sequence, finer gradations of tempi were probably possible. During performances two questions came to mind very frequently. "Could I have started the sequence at a slower tempo?" and "Could I have narrowed the tempo difference between successive performances?" Often the answer in both cases was: "Yes, I could have done, but I didn't". Questions of this type recurred throughout the Experimental Programme and the writer suggests that one cannot go beyond the answer given above which is consistent with the experimental definition of preference given in Chapter 7 and its concern with speeds actually performed and no other criteria. In Experiment 15 the possibility of finer tempo gradations will in fact be investigated, but in the meantime, this investigation assumes that those tempi actually performed in any type of experiment are more significant than those that might have been.

The sequences also confirm the appropriateness of the duration Scale Interval selected, as the tempi at the fast end, where they are closest, never occurred within the same interval in these two series and rarely in others.

Another aspect of the sequences shown in Fig $1-_8$ is the point where the conducting changes to what the writer calls a "dynamic" style. This is the change from a smoothly flowing and expressive beat to a jerky and much more positive one. The writer was not aware of the possible significance of this change until after Series 4 and so its position was never indicated in the earlier raw data, but there is no reason to suppose that the pattern observed in Fig $1-_8$ would not have been repeated in the previous series. That the tempo of this first dynamic beat is invariably in the area of the 390-410 msecs peak we have already given particular attention to gives it an even greater significance. From introspection, the writer was always aware, in Series 7 and 8, of the impending change to "dynamic" beating just before its performance, and subsequent conversation with BB revealed that he too was aware of this qualitative change in his conducting at a certain point. The question to be discussed again later, is whether this tempo is just a physical "gear change" associated only with beating time sequences or whether there is an identical or corresponding tempo in sequences involving orthodox musical performance with voice or instrument.

With regard to the tempi immediately preceding and following the first "dynamic" beat, there does appear to be a rather larger gap between them and this beat than the general sequential trend would suggest, particularly on the approach to it from the slower tempo. A concomitant trough either side of any preference was to be expected, but the 400 msecs area peak also probably affected the whole of the profile to its left. As there were always just two or three performances after this change to "dynamic" beating it was perhaps inevitable that the observed double peak profile to the left should result.

The vertical spacing of the sequences makes some attempt to convey their temporal proximation. It will be seen that the tendency, previously noted in other data, for successive sequences to generate rows of similar tempi, appears throughout the full sequential range. It is also clear, that with the writer at least, there was no great overall change in the sequential pattern during a series. Finally, within the 225 sequences performed by PB during Expt 1, there were only eleven occasions when successive tempi were not in fact faster, and instead were the same or slightly slower speeds. The tempi at which this occurred were spread over the whole range and presumably were the result of a loss of concentration.

There then appears to be some evidence to support the discrete preference hypothesis. In the cases of PB and BB a quite remarkable similar profile of narrow and broad peaks and troughs can be observed, which, although not reflected in the different distributions exhibited by the other Ss, was so consistently confirmed by test and retest that the writer presents it as data of some significance. Evidence that the intra-subject consistency was not caused by learning has already been given. Inter-subject learning was also not possible as the pattern had already been established in PB's early data before BB commenced his first series and the latter never heard the writer's performances.

The most notable features of this profile similarity between the data of PB and BB seem to be:-

a general positive skew.
a sharply cut off peak area at the fast end.
a broader peak near the slow end.
an apparent "preference" around 400 msecs coinciding with the
  change to "dynamic" conducting.
a peak between this point and the fast cut off peak.
a common tendency for a broad peak centred on 500 msecs.

During Expt 1 an additional line of enquiry suggested itself as a result of the continuing presence of the 400 msecs area peak in successive PB series. It was therefore decided to delay the necessary investigation of sequential tempi in a more genuinely musical setting and pursue instead several possibilities connected with the apparent PB preference in this area. For this reason, and to facilitate inter-graph comparison, the 390-410 msecs "same tempo" interval is highlighted by red dotted lines in Fig 1-$_8$ and all the data for Expts 2-4.

Expts 2^{AB}, the first of these supplementary tests, probes the possibility of this tempo being readily performed in single attempt situations while using the same performing method. Fig 16 shows that the respective series of each were undertaken in the period immediately following Expt 1 PB Series 1-4, and before Series 5-8.

Experiments 2^{AB}

Description

Aim: With just one S (PB) and using the same performing method as in Expt 1, to investigate whether the 400 msecs peak area tempo noted in the PB data could be readily performed in a non-sequential situation.

Subject: PB. 2^{A}: Nine series. Up to twenty-five sessions per day.
2^{B}: Two series. Each series during one day.

Experimental Room: Writer's lounge.

Instructions: Using the same music and performing method as in Expt 1 and beating dynamically:-

2^{A}: Make a single attempt at the 400 msecs peak area tempo.

2^{B}: Make a group of attempts at the 400 msecs peak area tempo, stopping when a performance occurs within the 380-420 msecs "target" (Giving a theoretically equal chance of a peak or non-peak tempo occurring in the "target". Subsequent attempts after failure being made in the knowledge of both direction and degree of error).

Music: Standard E flat Melody.

Record: Date, Time of day, Duration of forty music beats (twenty-five in Series 7-9).

Timing:

2^{A}	Series 1-3:	Stopwatch (1)	Operated, read and
	Series 4-9:	Stopwatch (2)	recorded by PB.
2^{B}	Series 1:	Stopwatch (1)	Operated, read and
	Series 2:	Stopwatch (2)	recorded by PB.

Results and Observations

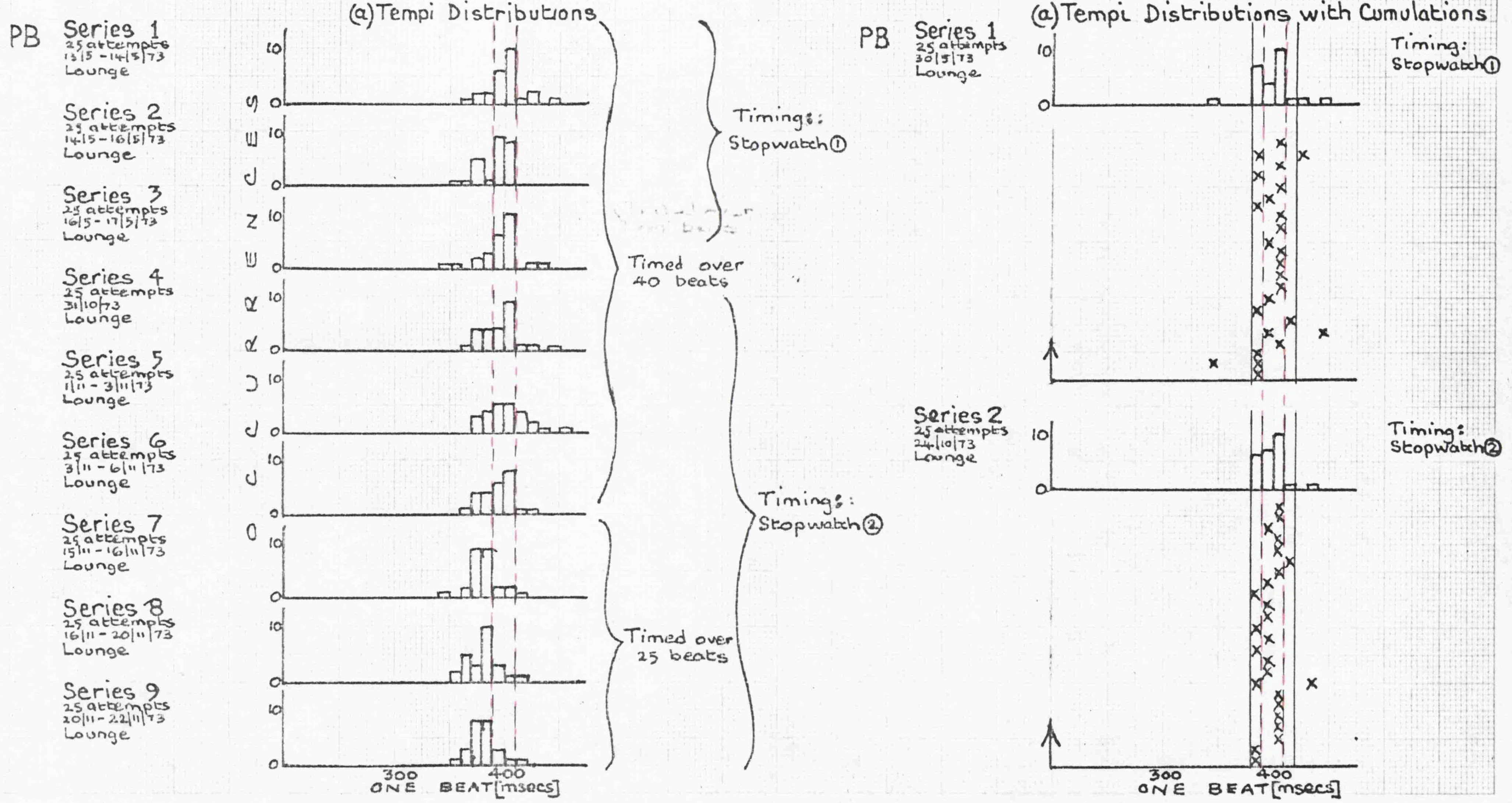
(a) Tempi Distributions and Cumulations

Expt 2^{A}: Fig 2-$_{1}$ shows that comparatively few performances fell

FIG 2-1

EXPT 2A CONDUCTING (Standard E^b Melody): SINGLE TEMPORALLY SPACED ATTEMPTS AT 390-410 msecs 'PEAK'

EXPT 2B CONDUCTING (Standard E^b Melody): GROUPED ATTEMPTS AT 390-410 msecs 'PEAK'



outside the general 400 msecs zone being investigated, and also a profile similarity with the relevant area of most sequence distributions in the PB Expt 1 data (Fig $1-_1$). Although faster "dynamic" conducting was available the writer nearly always accurately selected the tempo corresponding to the sequential "gear change". While it would be wrong to apply the term preference to this particular experimental situation, it does seem remarkable that it was possible to remember either this particular tempo or, perhaps, the movement "feel" associated with the change from flowing to "dynamic" conducting. Further reference to Fig $2-_1$ shows also the same general tendency for distributions to cut off more sharply on the slow side previously noted in Expt 1. The change of stopwatch between Series 3 and 4 clearly made no difference, but the shift of the distribution to the left between Series 6 and 7, paralleling a similar phenomenon in Expt 1 will be further discussed under (b) below.

Expt 2^B: The "target" area, including both two peak and two trough scale intervals as observed in the PB Expt 1 Series 1-4 data, gave an equal theoretical chance of either a peak or trough tempo occurring within it. As both series were undertaken before the time of the tempo shift noted in both Expts 1 and 2^A, not unexpectedly their peaks coincide with those of Expt 2^A Series 1-4 (Fig $2-_1$). In addition the general profiles are again very similar - the almost total lack of performance in the 410-420 msecs scale interval in both 2^A and 2^B being perhaps even more remarkable than the sharp peak to its left.

The cumulative analysis shows that very few "groups" were necessary, the "target" being hit usually at the first attempt, and if not, certainly at the following one. Again the tendency for the same precise speeds to occur in successive trials may be noticed, but, surprisingly, no more so than in Expt 1, where the trials were much further apart chronologically and where the sequential procedure was probably less favourable for it.

It may also be noted that the cumulations show that there was no anchor effect or learning of the first tempo of either series.

(b) Combined Distributions and Comparison with Expt 1

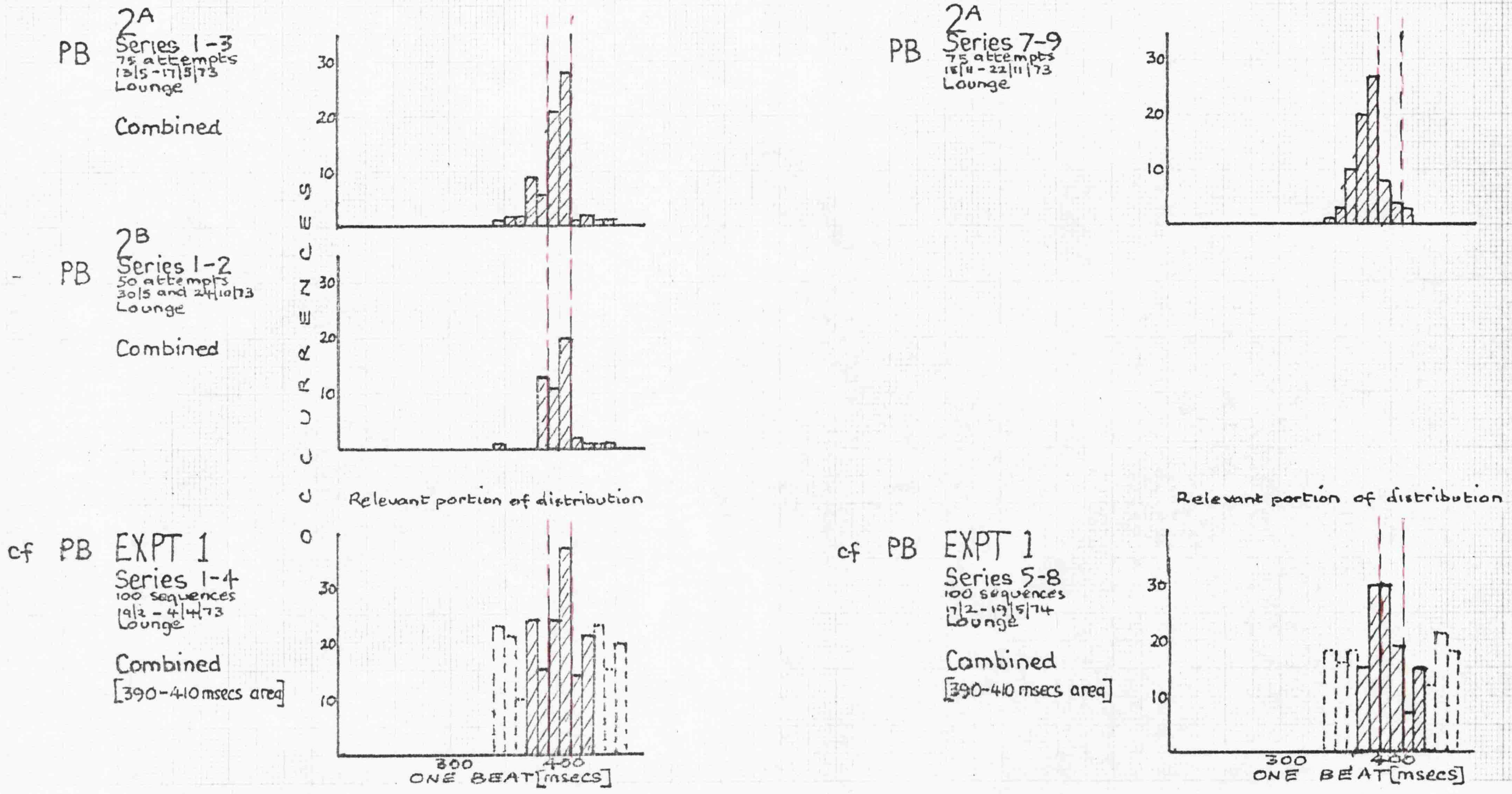
Expt 2^A: The comparison is limited to the combined data of the series of both experiments in closest chronological proximation. Fig 2-2 shows even more clearly the accuracy of the writer's aiming for the 400 msecs peak area tempo and the negatively skewed distributions with their sharp cut-off to the right. The similarity of profile between the Expt 2^A data and the 400 msecs area of the Expt 1 distributions closest to them chronologically may also be seen, together with the parallel shift to the left in the second pair of combined data. However, it must be pointed out that the performances in Series 7-9 were timed over 25 beats and the shift may be due to a different attitude on the part of the writer occasioned by a shorter-term musical "goal". In retrospect, although changing the total duration of the piece is a legitimate and probably fruitful area for further research, it was a mistake to introduce another variable here, necessitating also a difficult adaptation of the raw scores to the scale interval. In any case, although the shift could indicate that some long-term biological variation caused the writer's tempi to be faster in the later series of both Expts 1 and 2^A, it must be noted that the peak tempi of Expt 2^A Series 7-9 are one scale interval further to the left than those of the chronologically later series from Expt 1 also shown in Fig 2-2.

Expt 2^B: The combined data (Fig 2-2) need no further comment as much of the above applies here also.

The results of Expts 2^{AB} certainly suggest that the change to "dynamic" beating peak, whether it shifts slightly or not, has, at least for the writer, a significance of its own quite apart from its crucial position in the slow-fast sequence. However, the writer was not yet satisfied that

Fig 2-2 EXPTS 2^{AB} CONTD

(b) Combined Distributions and cf with Expt 1 PB Sequence Data



the 400 msecs peak area was not an artefact of the experimental programme to date. There was the possibility of a tempo, once established as significant in the performer's mind, being unconsciously memorised, perhaps through the recall of the type of movements and muscular "feel" associated with it. The writer speculated that a different sequential routine might have established a different tempo profile, with the subsequent memorisation of other speeds "confirming" another spurious preference. In any case, although each peak observed in Expts 2^{AB} is clearly generally contained within the 20 msecs "same tempo" limits, it would not be correct to call it a preference, even for this limited performing method, when the total procedure had been so favourable for its execution.

Although Figs 1-5 and 1-6 show little evidence of any relationship between sequential starting tempo and the likelihood of the 400 msecs area tempo being generated, it was decided to initiate a further experiment to see if a change of sequential routine could affect both the 400 msecs peak and general distribution profile. Expts 3^{ABC} were undertaken simultaneously in the period immediately following Expt 1 Series 5-8 and will therefore be compared only with each other and those series.

Experiments 3^{ABC}

Description

Aim:	With just one S (PB), and using the same performing method as in Expt 1, to investigate the effect on the Ss 400 msecs area tempo and general distribution profile of the given different sequential situations.
Subject:	PB: One series each experiment. Sessions well-spaced, intermixed and rarely on same day.
Experimental Room:	Writer's lounge.
Instructions:	In addition to the general performing method as in Expt 1:- 3^{A}: Make the first performance in each sequence coincide with a simultaneously beating Maezel

Metronome set at 710-720 msecs (Accurately adjusted against centisecond timer).

3^B: Start at the fastest possible triple metre speed (not one in a bar) and then perform at the next fastest speed etc until the slowest reasonable musical speed.

3^C: Start at the slowest reasonable musical speed as in Expt 1, but make all the conducting "dynamic" in quality.

Starting Pitch E flat given as in Expt 1.

Music: Standard E flat Melody.

Record: Date, Time of day. Duration of forty music beats.

Timing: Centisecond timer (1). Read and recorded by assistants.
(Stopwatch also held in conducting hand)

Results and Observations

(a) Tempi Distributions

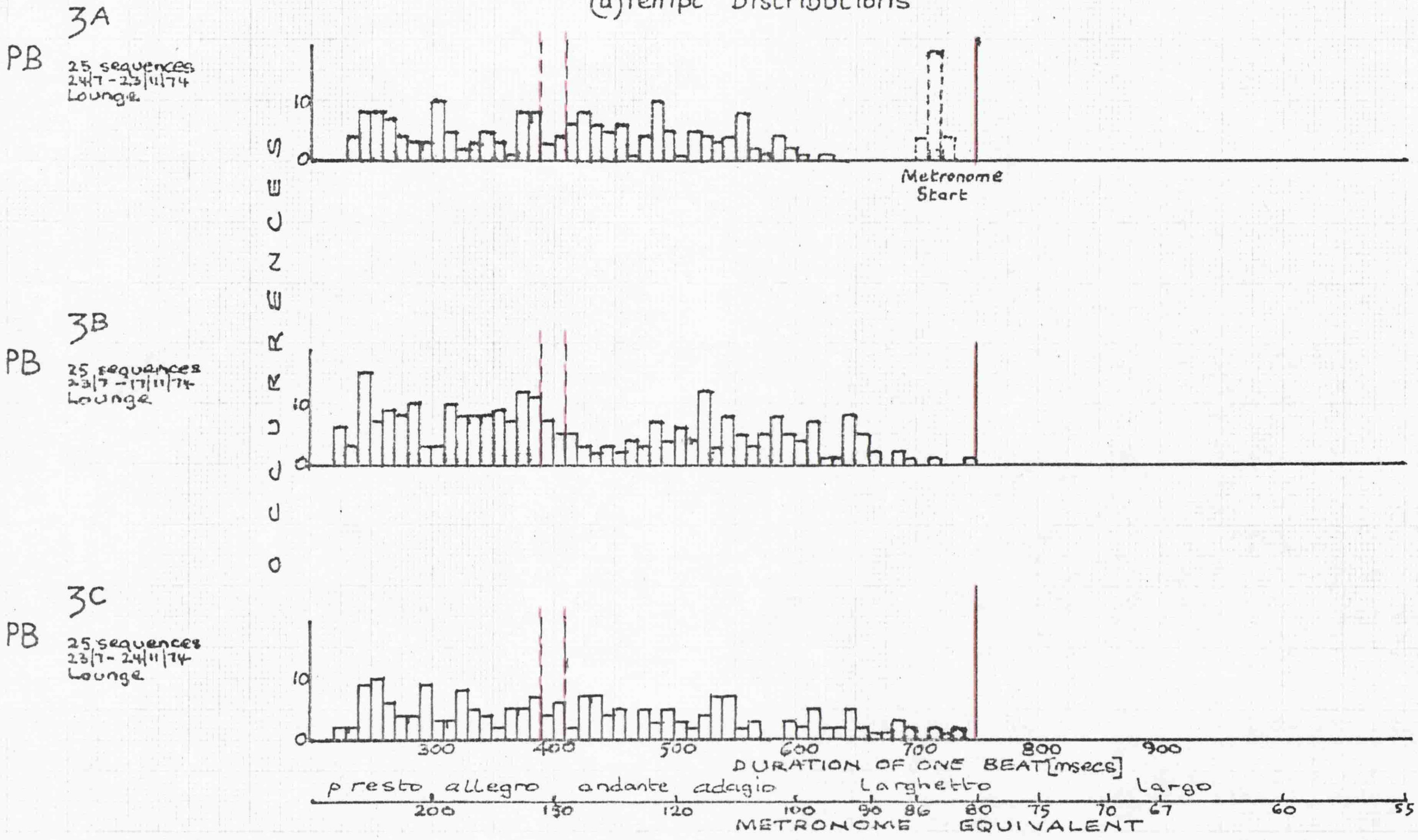
Expt 3^A: If any slow-fast sequence is determined to some extent by the starting tempo, it is likely that the starting tempo most unfavourable to the conditions generating a 400 msecs peak area tempo for the writer will be the one most recently observed as a trough at the slow end of the Expt 1 distributions. Reference to Figs 1-$_1$ and 1-$_3$ shows that the 710-720 msecs tempo imposed at the start of each sequence in Expt 3^A was rarely performed in the last four PB series of Expt 1.

The sequence distributions arising from this imposed starting tempo (Fig 3-$_1$), although showing a general profile similarity with the Expt 1 series in closest chronological proximity (Fig 1-$_1$, Series 8), shows also a consistent shift to the left in several of its features. This is particularly so in the case of the 400 msecs area where a shift of one scale interval is clearly seen in the "same tempo" 20 msecs peak. This may be no more than a continuation of the trend towards faster tempi noted in the previous experiments, but the possibility of its being caused by a rather faster starting tempo than that usually employed in an unrestricted

FIG 3-1 EXPTS 3ABC

CONDUCTING (Standard E♭ Melody): SEQUENCES, 3A: COMMENCING FROM 710-720 msecs 'TROUGH'
3B: REVERSED 'FAST'-'SLOW'
3C: ALL CONDUCTING 'DYNAMIC'

(a) Tempi Distributions



situation must also be considered. However, the evidence from Expt 1 (Figs 1-5 and 1-7(e)) does not give much support for a generally faster or slower starting tempo having much effect later in the sequence.

With regard to the mechanically contrived starting "same speed" at 710-720 msecs, it is interesting that the actual recorded range of tempi is only a little over one scale interval in width, the raw scores in the adjacent intervals being very close to the dividing value. This means that the combined variation due to metronome inconsistency, and, more pertinently, to differences in reaction time and switching and any centisecond timer inaccuracy, was masked by the scale interval and did not affect the results in this or other experiments. This is thus further confirmation that both the 10 msecs scale interval and the 20 msecs "same tempo" interval have very appropriate values for this type of experiment.

One other observation needs to be made on the 3^A sequence distribution profile. Although a gap was inevitable between the 710-720 msecs start and the next tempo, the approximate 20 per cent tempo difference is about twice that generally observed in Expt 1 (Fig 1-8).

Expt 3^B: Reversing the sequences appears to change the Expt 1-type distribution more radically. Not only is the general profile different, but the slowest tempo is much less extreme when it is the final and not the first performance of the sequence. From introspection the writer suspects that the latter may be due to impatience to end an apparently long sequence, or being unable to make the same leisurely "mental" preparation required for a very slow tempo that is possible when it is the first speed performed. The last "dynamic" beat when "changing gear" down to non-"dynamic" conducting does not occur so consistently in the same tempo area as the first "dynamic" beat in the reverse procedure of Expt 1. This will be referred to in more detail under (b). Other features of the distribution are the broad trough area centred on 450 msecs and the narrow "same tempo" 20 msecs trough at 290-310 msecs. Without retest confirmation however these may be no more than chance occurrences.

Expt 3^C: Making all the conducting "dynamic" appears to cause the greatest disturbance to the Expt 1-type distribution, although, as would be expected, not at the fast end where the beating would have been "dynamic" in any case. What is particularly lacking is the Expt 1-type peak around 400 msecs, caused presumably by the absence of any "change of gear" to or from dynamic conducting.

(b) Analysis of change to and from "dynamic" conducting

A comparison with the relevant portion of the Expt 1 Series 7 and 8 distributions (Fig 3-2) shows that the respective areas of the first or last "dynamic" beat and the sequentially adjacent tempi are less well defined and precise in Expts 3^A and 3^B. The change of sequential routine has apparently disturbed the consistency of the "change of gear" point, but not its mean value, which remains close to 400 msecs. As a result, the two clear troughs and equidistant peaks both sides of this apparent "preference", clearly seen in Expt 1 Series 7 and 8 are much less in evidence in Expts 3^{AB}. It is also interesting that in no case is there a non-"dynamic" beat at or to the left of the 400 msecs area, although several slower tempi were conducted in a "dynamic" way.

(c) Sequential Analysis and Comparisons

Fig 3-3 again shows the tendency to perform the same tempo in consecutive sequences, whatever the sequential routine. Only in Expt 3^B were there any tempo reversals or repetitions, and the number of these, compared with their total absence in Expts 3^A and 3^C would indicate that judging a slightly slower tempo is rather harder than the reverse process. The writer would confirm that at the fast end particularly, it was often very difficult to force the tempo to go slower, but this may have been due to change of routine after many series of slow-fast sequences. The average tempo difference at the fast end of the sequences is quite clearly

FIG 3-2 EXPTS 3^{ABC} CONTD

(b) Analysis of change to and from 'dynamic' conducting and cf with Expt. 1 PB Series 7 and 8

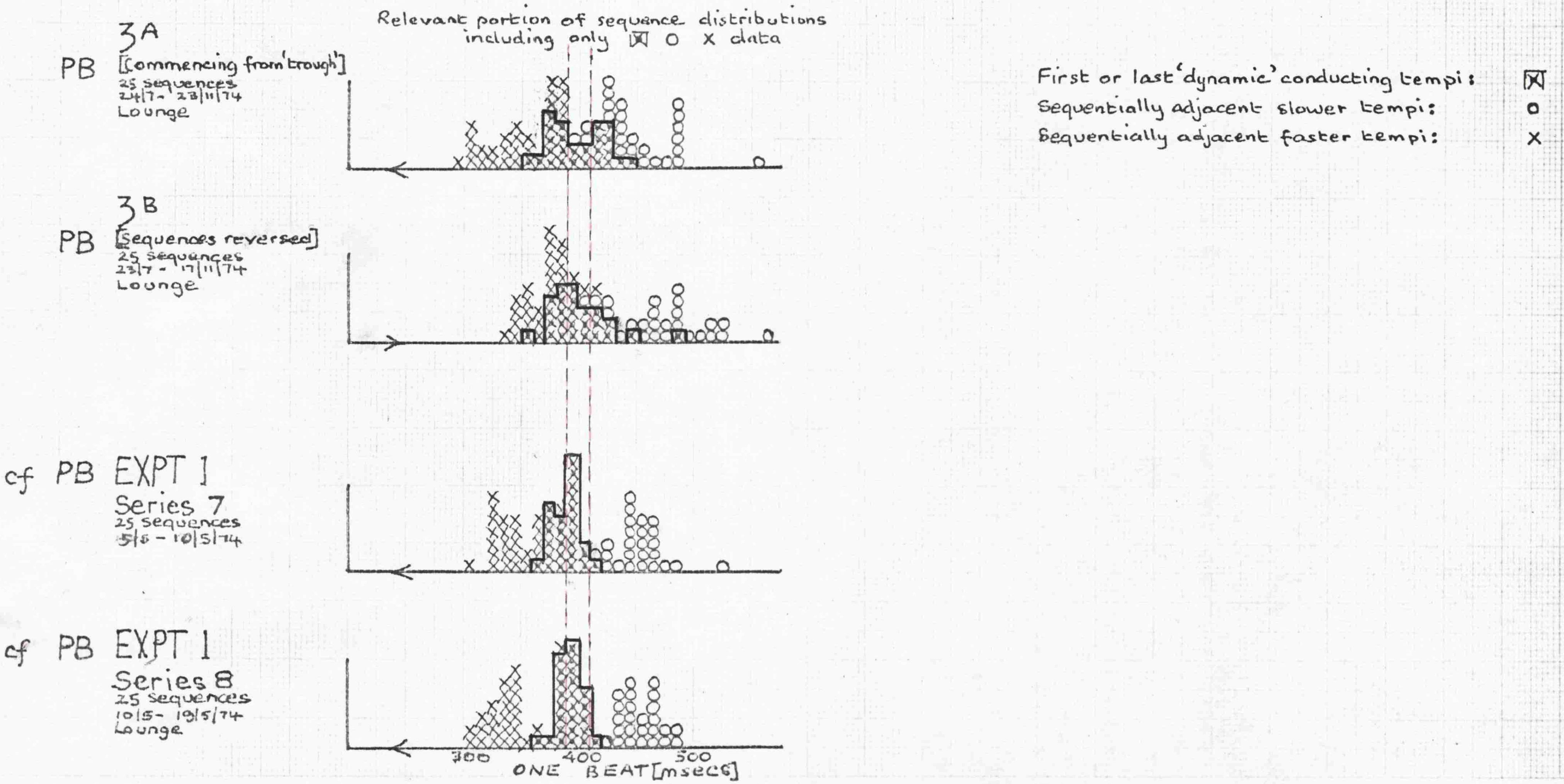
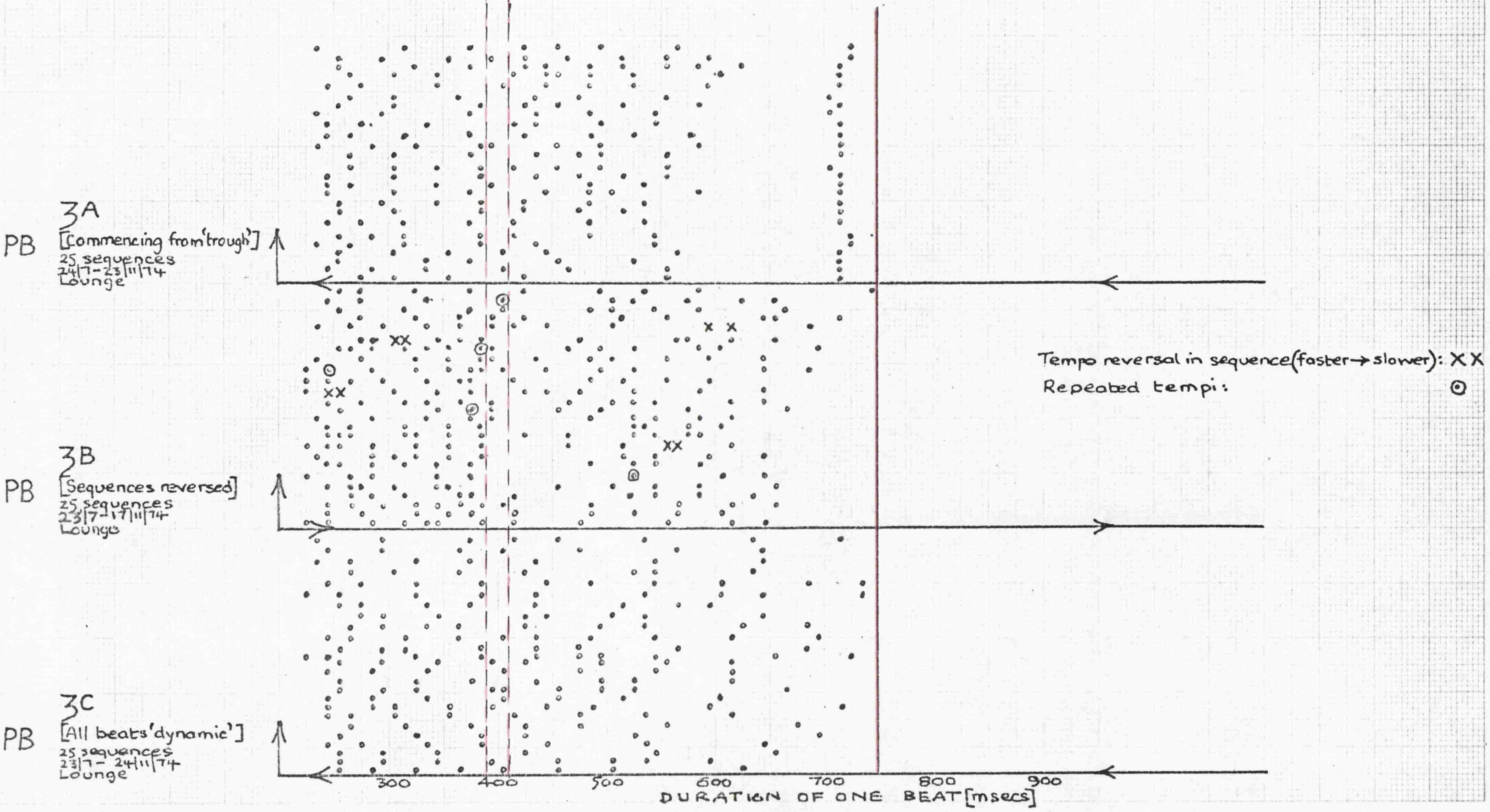


FIG 3-3 EXPTS 3ABC CONTD

(c) Analysis and cf of Sequences



smaller in Expt 3^B. Finally, the sequences for Expt 3^C again make apparent the generally more even nature of that distribution.

Taking the data of Expts 3^{ABC} as a whole, some common features emerge. They all generated some tempi faster than any that occurred throughout Expt 1, they share a common trough in the region of 300 msecs and the imposed 710-720 msecs tempo of Expt 3^A was obviously not learnt and subsequently reproduced in the concurrently running Expts 3^B and 3^C. For some reason however this tempo did mark the approximate tempo limit at the slow end for both these experiments.

All the above certainly suggests that the distribution profiles may be a function of the sequence or routine employed. In particular, Expt 3^C indicates that the peak observed in the 400 msecs area in Expts 3^A and 3^B and throughout Expt 1 could be due to a "change of gear" in the writer's conducting movements, and that where no "change of gear" can occur, as in Expt 3^C, no peak is observed.

Nevertheless, Expts 2^{AB} have shown that during the experimental period this tempo apparently had some sort of individual existence quite apart from its significant sequential position. It could be readily and accurately performed by the writer, at least when the sessions took place in close chronological proximity to some of the sequences that first brought his attention to it. One final experiment was required to ascertain whether the significance of this tempo for the writer extended beyond the limited performing method thus far employed. In the following experiment it was necessary to attempt to contrive that the circumstances at first were no more nor less favourable for reproducing the 400 msecs area tempo than in Expt 2^A. Reference to Fig 16 shows that this was almost the case for Expt 4 Series 1, which, following quite soon after Expt 2^A Series 2, may best be compared with that data. It was however decided to conduct

Expt 4 Series 2 concurrently with Expt 1 Series 5-8 to see if a more closely coincident experience of the sequential conducting performances, and therefore recent and vital reminders of the 400 msecs area conducting tempo in particular, caused these later Expt 4 performances to reproduce it more accurately.

Experiment 4

Description

Aim: With just one subject (PB), to investigate whether the 400 msecs peak area tempo could be as readily performed as in Expt 2^A while using different instrumental and performing methods.

Subject: PB: Two series. Twenty-five sessions for each method. Up to twenty-five sessions per day, but usually far less, in random order of method.

Experimental Room: Writer's lounge.

Instructions: Using one of the given performing methods and looking at the score, make a single attempt at the 400 msecs peak area tempo:-

Keyboard: Piano legato with sustaining pedal
Piano staccato

Breath-based: Singing lah) with no conducting
Singing words) movements
Treble recorder

Starting pitch E flat given as in Expt 1 for singing.

Music: Keyboard: Standard E flat Version

Breath-based: Standard E flat Melody (written 8ve higher for treble recorder.Sung 8ve lower

The text sung to the Standard E flat Melody was the hymn:-

"New every morning is the love
Our wakening and uprising prove;
Through sleep and darkness safely
brought,
Restored to life, and power, and
thought."

Record:	Date, Time of day, Duration of forty music beats.	
Timing:	Series 1:	Stopwatch (1), Operated by assistants but read and recorded by PB.
	Series 2:	Centisecond timer (1), Read and recorded by assistants.

Results and Observations

(a) Tempi Distributions

Several related features emerge from a study of Fig $4-_1$. It is clear that a greater between-series consistency occurs in the case of the breath-based performances. In addition, these distributions are not only more alike than those produced by the two keyboard methods, they also more accurately reproduce the 400 msecs area tempo aimed for. Also noteworthy is the tendency for both types of keyboard performances in Series 2 to produce both narrower concentrations and a general tempo shift closer to the 400 msecs area. This was predicted, and may have been caused by the memory of the required tempo being reinforced by the concurrence of Expt 1 Series 5-8 with Series 2 of this experiment.

For the purposes of statistical comparison, Series 6 was selected from Expt 2^A, as Series 7-9 may have been influenced by being timed over twenty-five beats instead of forty. The Order of Means in Table 1 clearly confirms the graphical evidence noted above, with the average Recorder tempo in particular showing an exact correspondence to the given conducting tempo from Expt 2^A. The Order of Means in this and subsequent experiments of course also gives a directional relationship to the associated t ratios.

The t ratios given in Table 2 further confirm the graphical presentation. Only in the case of the keyboard performances are there significant values for the inter-series distributions for the same performing method. Also, the inter-method t values are generally lower and often insignificant between the breath-based performances of the same series. On the other hand, the tempi differences between the two types of keyboard performances

FIG 4-1 EXPT 4 PERFORMING AS INDICATED (Standard E^{b} Versions): SINGLE TEMPORALLY SPACED ATTEMPTS AT 390-410 msecs 'PEAK'

(a) Tempi Distributions

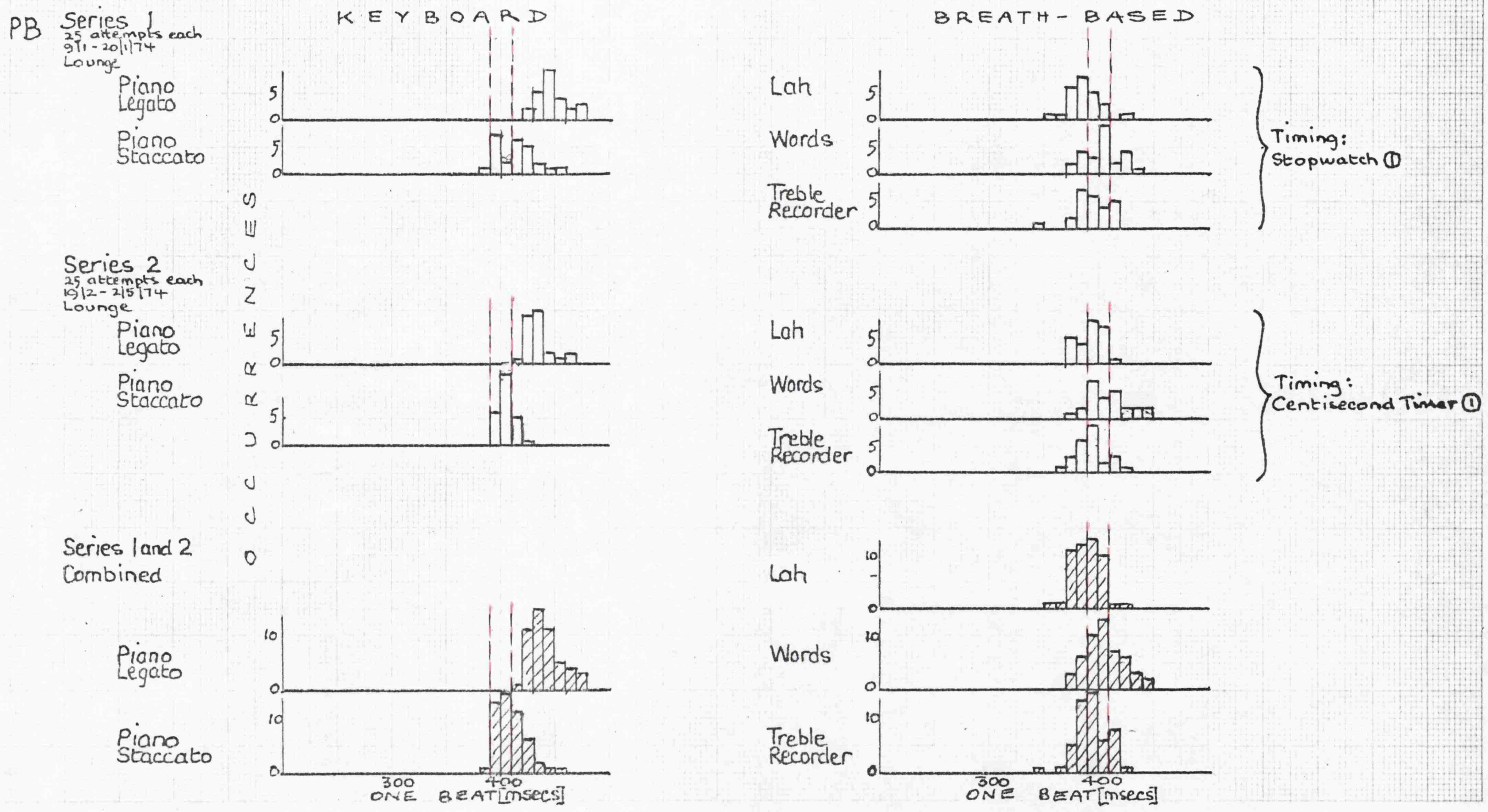


Table 1 Order of Means [Beat dur. in msecs] and cf Expt 2^A Series 6

	PB SERIES 1		PB SERIES 2		
FASTER	Lah	391	Lah	398	
↑	Treble R.	399	Treble R.		
↓	CONDUCT.	399	CONDUCT.	399	cf EXPT 2^A Series 6
SLOWER	Words	408	Staccato	410	
	Staccato	419	Words	414	
	Std. E^bV.	453	Std. E^bV.	440	

Table 2 Inter-Method, Inter-Series and cf Expt 2^A Series 6 t Test Values

PB Data only
1 per cent signif. 2·7
5 per cent signif. 2·02

		Treble R. 1	Treble R. 2	Words 1	Words 2	Lah 1	Lah 2	Std. E^b V. (Staccato) 1	Std. E^b V. (Staccato) 2	Std. E^b Version 1	Std. E^b Version 2
Treble R.	1		1·9								
	2										
Words	1	2·0			1·1						
	2		3·2								
Lah	1	1·7		3·8			1·7				
	2		0·1		3·5						
Std. E^bV. (Staccato)	1	4·2		2·2		6·0			2·4		
	2		3·6		0·9		4·3				
Std. E^b Version	1	12·6		10·4		15·0		7·6			3·6
	2		10·8		5·8		12·2		10·2		
cf EXPT 2^A Series 6		0·0	0·2	2·1	3·1	1·8	0·3	4·4	3·3	13·2	10·6

and between either keyboard and any breath-based performances are invariably significant, often well within the 1 per cent level.

With regard to the comparative success of the various methods in achieving the desired tempo, the t values between the Expt 2^A data and the keyboard and breath-based performances confirm the previous general observation that the latter were more successful. However, they also exhibit another interesting consistent tendency. Reference to Expt 8 shows that the "natural" speed tempi for the performing methods common to both experiments were never in the 400 msecs area, and the respective shifts away from that tempo in this experiment represent attempts to approach these "natural" speeds both in direction and degree.

An explanation must be sought for the significant tempo differences observed both within this experiment and between it and Expt 2^A. These differences are particularly surprising as the instrumental action was not felt or the actual sound heard before the performances started. The initiated 400 msecs area attempt, therefore, should have been based on the same criteria that initiated the Expt 2^A conducting performances. However, the literature and speculative list of tempo-affecting factors in Chapter 3 suggest why the writer may have been deceived in his attempts to reproduce the required tempo. It seems likely that those factors affecting choice in unrestricted situations will also modify attempts of this kind, certainly immediately after the true nature of both instrument and sound have been experienced. In other words, the initiated tempo, even if the desired one, may be modified at the start. Those same factors may also cause that different tempo to appear to be subjectively equal to the desired one. In any case, although the writer was attempting to recall the muscular feel of a conducting tempo, it was not really possible to eliminate the anticipation of the factors associated with the actual performance.

Every type of performing situation may also have a corresponding but different "change of gear" tempo from smooth to "dynamic" type movements. The different loading and movements associated with the respective Expt 4 instrumental performances, and consequent different "change of gear" tempi, may then have confused the writer's attempts to reproduce the 400 msecs area tempo. As the movements of staccato playing are more like the jerky action of "dynamic" conducting, this could explain why that method more closely approached the required tempo than the smoother movements of legato performance. Similarly, lah and treble recorder playing would be more likely to produce the same tempi because they are based on the simple and similar articulations of "lah" and "tu" respectively.

A more detailed comparison of the distributions in Figs 2_{-1} and 4_{-1} shows however two aspects of the breath-based distribution profiles that are consistently different from those produced by conducting. Firstly, the former have peaks rather less sharp and in no way comparable to the "same speed" criterion of 20 msecs. Secondly, they do not show the sharp cut off to the right and negative skew generally exhibited by the Expt 2^{AB} data. Unfortunately, apart from citing the different movements involved, no other explanation can be offered for this profile contrast.

With regard to the extreme variation from the desired tempo in the legato keyboard performances, it must be stated that the writer was not aware of any discrepancy during his playing. Indeed, he would have stopped any performance if he had been, and the subsequent timings always surprised him. It is certainly possible that the desire to correct this also contributed to the faster tempi in Series 2, but even this failed to bring the tempi to the desired pace. The results therefore show that tempi subjectively the same can be objectively quite different when different instruments or performing methods are used.

It is perhaps not surprising that the breath-based tempi were very similar to those in Expt 2^{A} as the method in the latter also included a softly breathed lah. As the absence of conducting movements in Expt 4^A apparently made little difference to the tempi it would seem that vocal articulation and breathing may be the more potent tempo-affecting factors in Expts 1-3 and the unifying influence between those experiments and the breath-based performances here.

Whatever the reasons for the tempi variations, it is clear that for the writer at least, tempo judgement is considerably affected by performing method. It is also apparent that the conducting method and sequences employed in Expts 1-3 in no way produced data absolutely valid for musical performances generally. There is however the possibility that conducting patterns and trends may, in a relative sense, apply to other music and performing methods. The next experiment therefore investigates sequential performance, using one of the performing methods employed in Expt 4.

Experiment 5

Description

Aim: To investigate tempi in the given sequential performing situation with regard (a) to possible discrete preferential tempi and (b) to the patterns and trends observed in previous conducting experiments.

Subjects:
PB: Two series }
BB: One series } Rarely more than one session per day.

Experimental Rooms:
PB Series 1: Writer's lounge.
Series 2: College practice room.
BB: College practice room.

Instructions:
Looking at the score, play the given music on the piano in a slow-fast sequence as in Expt 1.
Play with moderate volume, legato and with sustaining pedal.
Do not rall. at the end of any performance.

Music: Standard E flat Version.

Record: Date, Time of day, Duration of forty music beats.

Timing: PB Series 1: Centisecond timer (2) Read and recorded by assistants.

Series 2: Stopwatch (2) Operated, read and recorded by assistants.

BB: Stopwatch (2) Operated, read and recorded by PB.

Results and Observations

(a)(b) Tempi Distributions and Comparison with Expt 1

A comparison with the PB and BB sequential conducting distributions in Figs $1-_1$ and $1-_2$ and the combined data included in Fig $5-_1$ shows no striking profile similarities, apart from a "trough" in the BB data for both keyboard and conducting performances in the area of 580 msecs. In the case of both Ss, the fast end cut off occurs at a slower speed when playing the piano, but with the more complex movements and instrumental action involved, this was to be expected.

With sole regard to Expt 5, there is a degree of peakedness in the 400 msecs area for both Ss, but the general concentrations here are certainly no more prominent than those observed in many other parts of each distribution. Perhaps there is no other common peak area in the three distributions, and certainly no other features, apart from the broad trough in the BB data noted above, sufficiently striking for particular comment to be made without the confirmation of retest procedures.

A more detailed comparison of the PB Series 1a and 1b data does however show a considerable profile similarity between 530 msecs and 620 msecs, and the general peak centred on 490 msecs in Series 1a may have shifted one scale interval to the left in Series 1b. Indeed, Fig $5-_1$ shows that the upright piano and the smaller room used in Series 1b apparently caused the complete distribution to shift to the left, thus covering a similar range to that of BB. This interesting trend could not have been caused by a long term variation in the writer's "internal clock" as the two series ran approximately concurrently. The same tendency was observed in Expt 6, where further discussion will take place.

FIG 5-1 EXPT 5- PIANO(Standard E♭ version): SEQUENCES SLOW - FAST

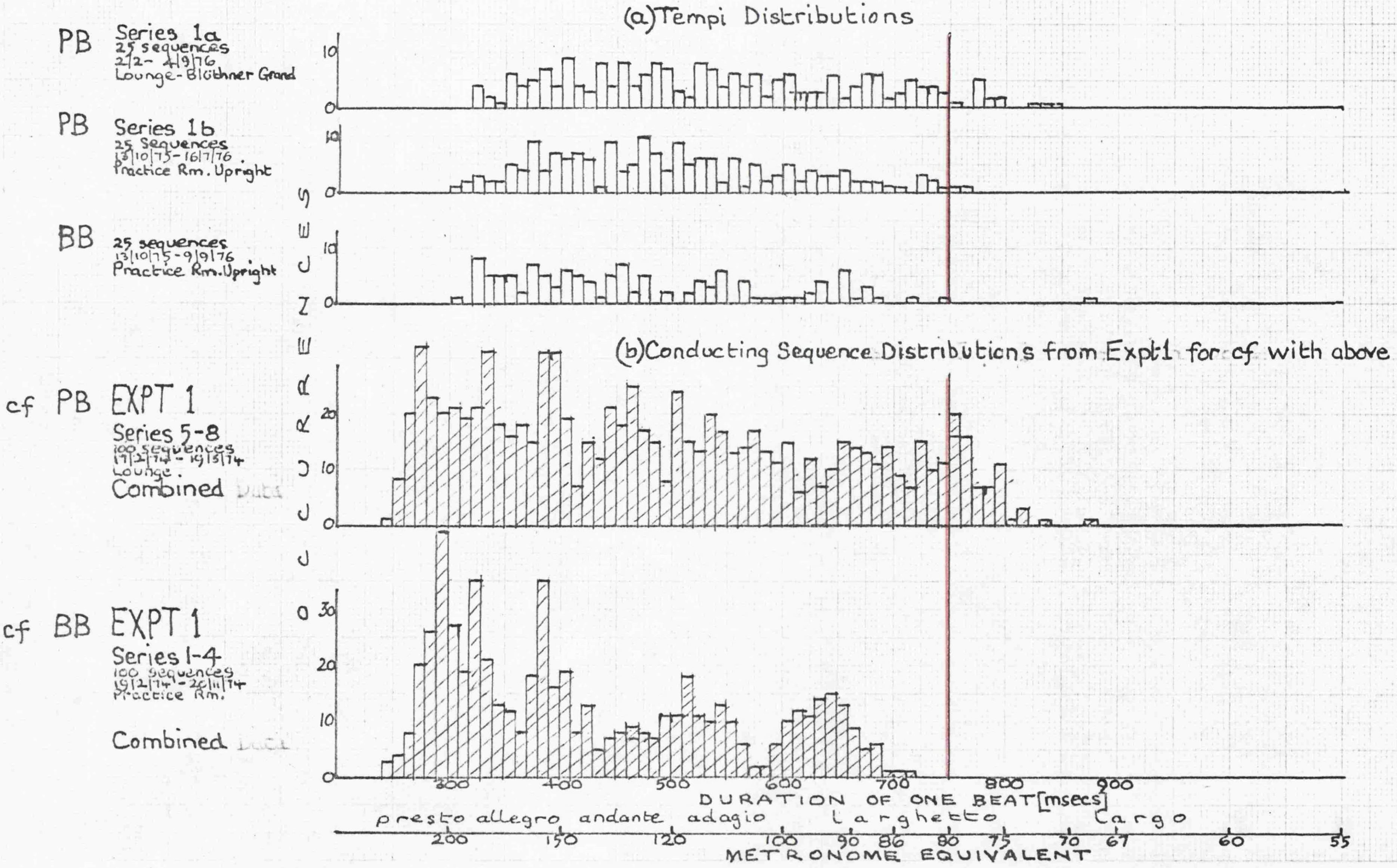
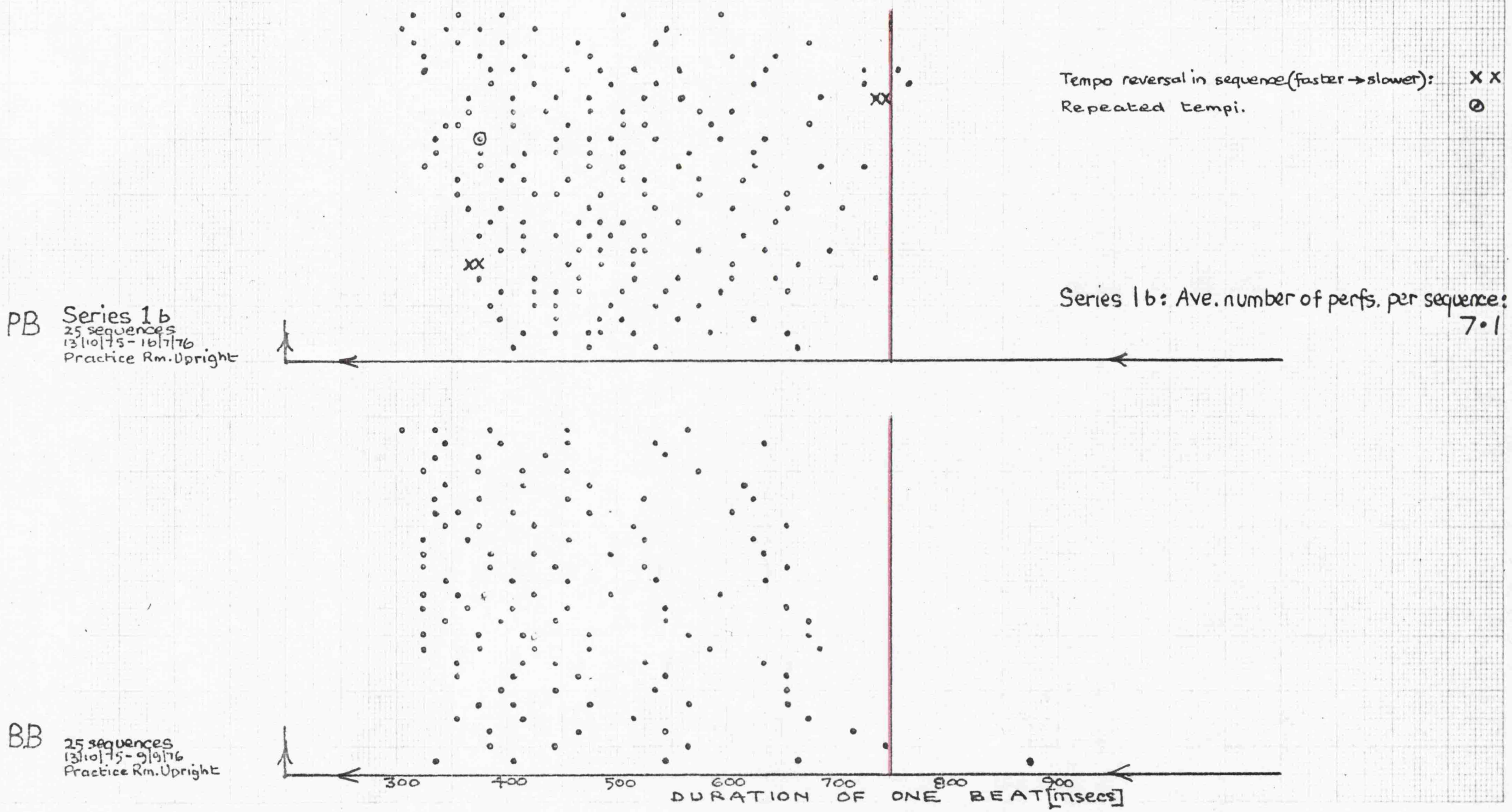


FIG 5-2 EXPT 5 CONTD

(c) Analysis of Sequences



(c) Sequential Analysis

Only the PB sequences for Series 1b are shown in order that any comparison with BB concerns performances made under the same experimental conditions.

A visual examination of Fig 5-2 shows the tendency, previously noted in Expt 1(h), for the tempo difference to diminish towards the fast end of the sequences. As the average number of performances per sequence in PB Series 1b is only 1.5 less than that in Expt 1 Series 8 (Fig 1-8), which covered a considerably wider tempo range, the tempo differences must be rather less than the 10 per cent estimated for the latter. The BB sequences, although containing generally fewer performances, also show the increasingly smaller tempo differences towards the fast end. Thus, in a very general way, Weber's Law may be said to hold for performing tempo sensitivity in this rather artificial sequential situation. The sequences shown in Fig 5-2 also show a gradual chronological shift towards faster speeds in respect of both Ss finishing tempi and BB's starting tempi. That this latter trend is not observed in PB's case is probably attributable to greater motivation. A faster starting tempo quickly becomes associated with fewer performances and a consequent smaller demand on time. Finally, Fig 5-2 shows there were very few occasions when a tempo was reversed in direction or repeated during a sequence (within the discriminatory limits imposed by the scale interval). Reference also to Fig 3-3 shows that these miscalculations tended to occur more often in the 400 msecs region. Unfortunately, contradictory explanations suggest themselves. Both types of error could be indirect evidence of "preference", extreme tempo sensitivity, or, on the other hand, a lack of tempo discrimination in this area of tempo.

Generally, it may be stated that the patterns and trends observed in the PB and BB sequence data for conducting performances do not appear to have absolute or relative validity for sequences produced by another performing method. With special reference to the 400 msecs area peak tempo observed in Expt 1 and further investigated in Expts 2-3, Expt 5 confirms that it has not the significance in the sequence that it had when conducting, although both PB and BB had some concentration of performances in this region. However, both Ss were still aware of a feeling of "change of gear" to a more "dynamic" style of performing during the piano playing sequences, but refrained from noting where this occurred in order to prevent prejudice in favour of this tempo in subsequent experiments. In retrospect, a prejudice of this kind may have influenced the results of Expts 2-4.

The next experiment provides a link between this sequence procedure and the investigation of "natural" speed and "natural" speed variation when a musical or instrumental factor is changed. Using the same performing method and music, it will seek to establish a relationship between single attempts at "fast", "natural" or "slow" tempi and the distributions for sequences produced in Expt 5 (A similar relationship was sought, and found, between the PB conducting sequences of Expt 1 and the single attempts of Expt 2^A). Expt 6 will also provide the standard "natural" speed performance data with which any subsequent variations will be compared. As it was decided that the term "natural", rather than "ideal" as used in the Pilot Experiments, best suited the objective requirements of the experimental definition of "preference", it will accordingly be used for the remainder of the experiments.

Experiment 6

Description

Aim: Using the same music and performing method as in Expt 5, (a) to investigate whether the distributions for single attempts at a "fast", "natural" or "slow" tempo are related to the sequence distributions previously obtained, and (b) to provide the standard "natural" speed data with which the distributions in subsequent experiments, where instrumental or musical factors are varied, may be compared.

Subjects: PB: Three series) BB: One series) Twenty-five sessions in each tempo category. Rarely more than one session per day and in random order of tempo. During the same chronological period and intermixed with Expts 7-13.

Experimental Rooms:
PB Series 1 and 2a: Writer's lounge.
Series 2b: College practice room.
BB: College practice room.

Instructions: Using the same music and performing method as in Expt 5:-
PB Series 1: Make a single attempt at a "natural" tempo.
All other series: Make a single attempt at a "fast", "natural" or "slow" tempo.
Play with moderate volume, legato and with sustaining pedal.
Do not rall. at the end of any performance.

Music: Standard E flat Version.

Record: Date, Time of day, Duration of forty music beats.

Timing:
PB Series 1 and 2a: Centisecond timer (2) Read and recorded by PB.
PB Series 2b: Stopwatch (2) Operated, read and recorded by assistants.
BB: Stopwatch (2) Operated, read and recorded by PB.

Results and Observations

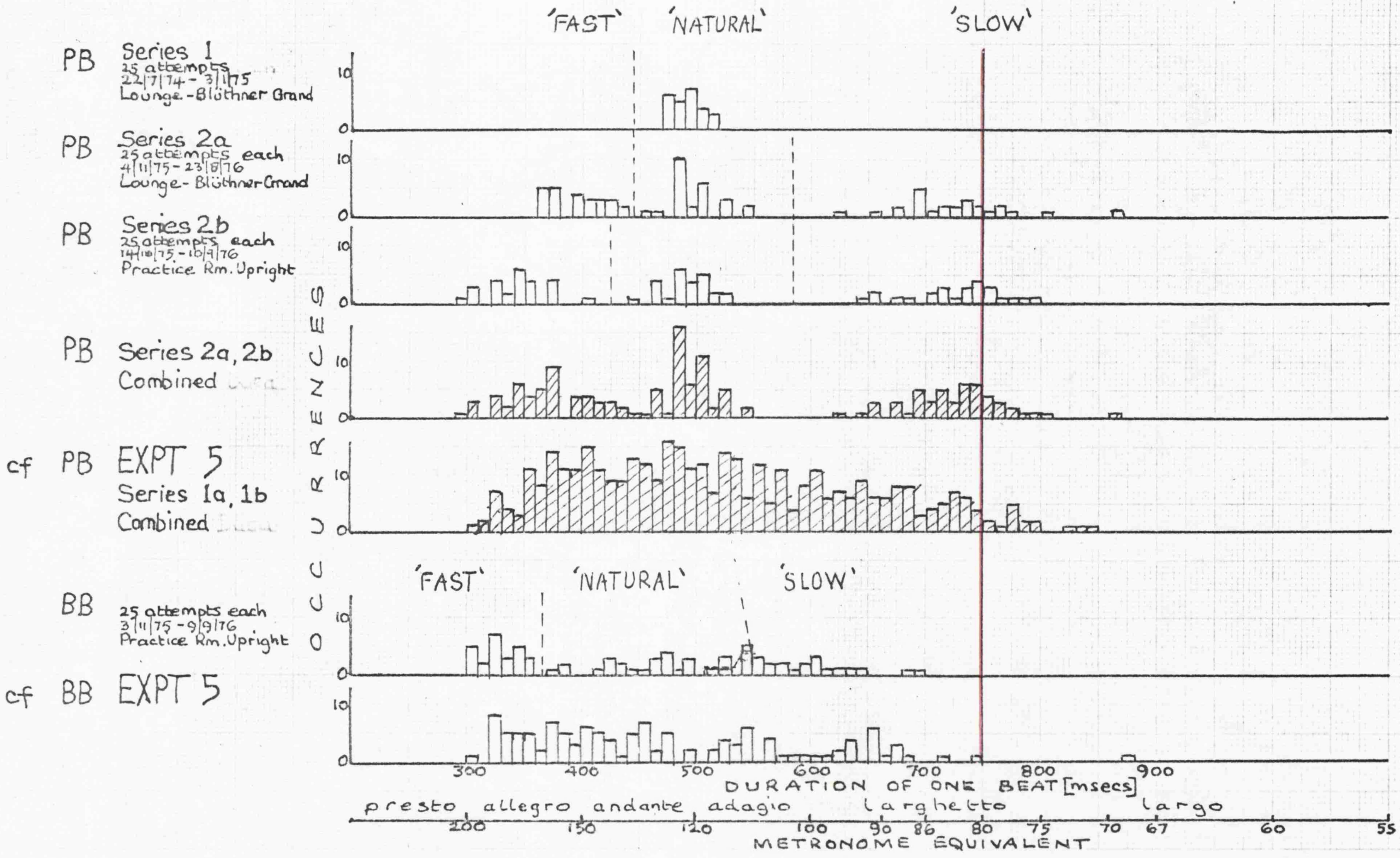
(a) Tempi Distributions and comparison with Expt 5 Sequence Data

It must first be pointed out that the experiment included attempts at "fast" and "slow" tempi, - not necessarily the fastest or slowest musically possible, which were the extreme speeds in the previous sequence experiment. Reference to Fig 6_{-1} shows that between the chronologically comparable series in Expts 5 and 6 the different instructions which the writer gave BB

FIG 6-1 EXPT 6

PIANO(Standard E^b Version): SINGLE TEMPORALLY SPACED ATTEMPTS AT 'FAST', 'NATURAL' OR 'SLOW' TEMPO

(a) Tempi Distributions and cf with Expt 5 Sequence Data



and himself made some difference in the case of the latter but surprisingly little in his own case. The combined "fast" and "slow" data for PB Series 2a and 2b reflects very accurately the position and profile of the fast and slow ends of the PB Expt 5 Series 1a and 1b combined sequence distribution.

With regard to the individual distributions for each category of tempo in Fig 6-$_1$, it is clear that none may be realistically considered as the "same tempo". Even the "natural" tempi distributions, which provide the closest concentrations, are not contained within two "same tempo" intervals, with the near exception of that in PB Series 1. Comparing the Series 2ab combined distribution profiles for "fast", "natural" and "slow" speeds by means of variance ratios gives the following results:- fast/natural: 2.95, fast/slow: 1.5, natural/slow: 4.43. Both ratios concerning the "natural" distribution are significant at the 5 per cent level. The wider distribution for "slow" speeds was predictable due to the expectation of Weber/Fechner-type behaviour, but the greater deviation for "fast" tempi was surprising. Several explanations suggest themselves: the S was predisposed to achieve such a result, the "natural" speed was easier to remember or there was a genuine "preference" in this tempo area. Nevertheless, the range of tempi deemed to be "natural" by the writer covers 110 msecs per beat, but without overlapping tempi in either of the other categories.
On the other hand, BB's "natural" tempi not only deviate across 180 msecs but also overlap some tempi considered "slow" on other occasions (see also Fig 13-$_1$). Perhaps the deviation of each distribution generally should not occasion surprise as the instructions did not require a repetition of a previous speed, although the writer found it difficult not to be conscious of what he thought was his previous tempo. The predisposition mentioned above made this particularly true for the "natural" category. However, a comparison with the distributions of Expts 2^A (Fig 2-$_1$) and 4 (Fig 4-$_1$), where attempts to repeat a given tempo were actually required,

show that much the same range and profile occurred. In addition, the piano legato method included in Expt 4, being exactly as that used in this experiment, makes that particular comparison especially valid. Thus, in the case of the writer, the range of tempi at various times considered "natural" is comparable to the range produced when deliberate attempts are made to reproduce a tempo over a similar chronological period. Unfortunately, no similar comparisons may be made in the case of BB.

The chronological cumulations (not shown) indicated no particular consistent tendency, with the exception of the "fast" tempi in PB Series 2a. The complete absence of performances at 380-390 msecs separates the relatively slower and faster performances in this category occurring almost without exception in the first and second halves of the cumulation respectively.

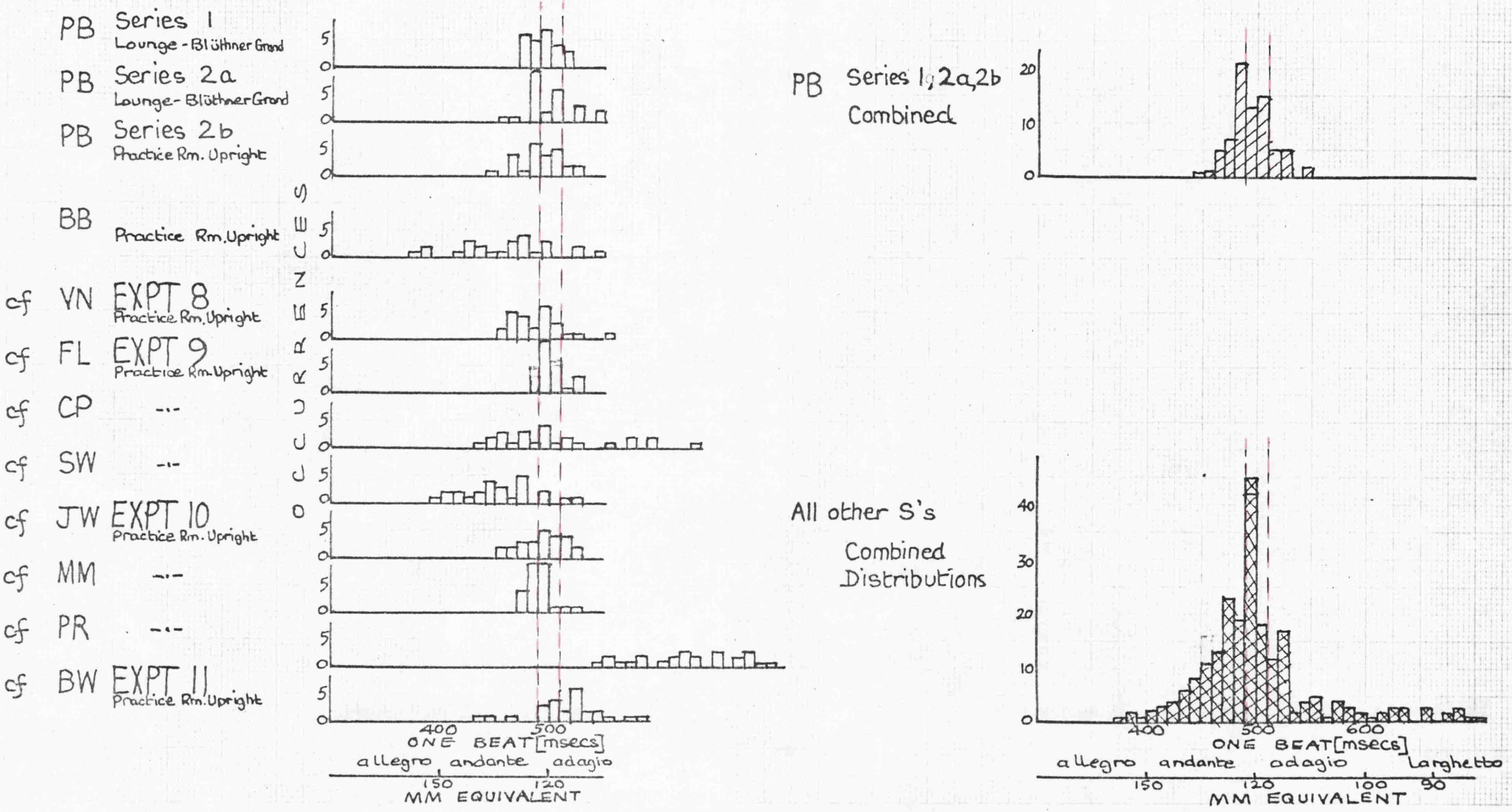
A consideration may now be made of any changes in the writer's Series 2a and 2b tempi distributions associated with a change of piano and room. Although Fig 6_{-1} shows that the "natural" and "slow" speeds were apparently unaffected by being performed in a different situation, the "fast" speeds were very noticeably faster in Series 2b where an upright piano was played in the small college practice room. The statistical difference between the two distributions is significant at the 1 per cent level ($t = 7.38$). However, because several different instrumental and acoustical factors were involved between Series 2a and 2b, it is not possible to identify which were decisive in effecting the observed change in the "fast" tempi distributions. However, there may be some support here for the view, previously suggested in Expt 1(a), that the fast end cut off in a slow-fast sequence represents the limiting tempo for comfortable movement for any given performing method. As a similar but less marked shift to the left has already been noted in Expt 5 between PB Series 1a and 1b, a possible explanation for the more extreme practice room "fast" speeds may therefore be found in the greater facility for comfortable rapid movements provided by the different piano action. It is interesting that the "fast" tempi of PB when playing on the upright piano are much closer to those of BB, playing on the same piano, than to his own "fast" performances during the same period on a grand piano. That the same tendency is not observed between the "natural" and "slow" tempi suggests that the facility for rapid movements may control the position of single "fast" attempts or the fast cut off of a sequence, and not acoustical or more aesthetic criteria. Taking Series 1 also into consideration makes even more clear the consistency of the writer's "natural" tempi, this time over a long chronological period. It must also be pointed out that the PB Series 2a and 2b combined data for "natural" tempi, like the "fast" and "slow" tempi, also matches quite well the relevant profile portion of the PB Expt 5 Series 1a and 1b combined sequence distribution. This area around 500 msecs was also the centre of a very broad peak in the PB conducting data of Expt 1. On the other hand, although reference to Figs $5-_1$ and $6-_1$ shows that BB has a peak near 500 msecs in his Expt 1 data, no such peak occurs in Expt 5 or in this experiment.

(b) Piano (Standard E flat Version) "Natural" tempo distributions for all Subjects

Fig $6-_2$ extracts the PB and BB "natural" tempo distributions for this experiment and shows them in relation to the Standard E flat Version "natural" tempo student data from subsequent experiments. It may be seen that there are essentially two types of distribution in evidence: one quite compact one of approximately five scale intervals (PB, VN, FL, JW, MM), and a much more diffused distribution at least twice as wide (BB, CP, SW, PR, BW). An additional feature of considerable interest is that although the seven more compact distributions all have their modal value within the 480-500 msecs "same tempo" interval, the other distributions each occupy

FIG 6-2 EXPT 6 CONTD

(b) Piano (Standard E^b Version): 'Natural' Tempi Distributions for PB, BB and cf Student S's Data extracted from Subsequent Expts



very different tempi areas. Nevertheless most of these latter type distributions show a number of performances in the 500 msecs area, and the combined distributions for all Ss other than PB still peak around 500 msecs. This combined distribution, representing a single series from each S, together with the PB combined distribution for three series, makes clear the tendency for different Ss to perform the given music on the piano at this tempo. This speed at approximately MM 120 is very far from the so-called "normal" tempo, although the writer's "slow" speeds have a peak close to MM 80. Whether the 500 msecs area tempo represents the writer's "change of gear" for this particular performing method could not be ascertained for certain from introspection either during or after the performances. In any case, BB showed no prominent "natural" tempo peak although he, like the writer, was conscious of a "change of gear" in the previous conducting and piano playing sequences. BB in fact stated that he always gave a "natural" speed piano performance as if it was a hymn tune to be sung, whereas the writer attempted to satisfy natural and relaxed movement criteria.

The performances of this Standard E flat Version legato on the piano at a "natural" speed were arbitrarily made the tempo norm with which all future data could be compared. The relevant "natural" tempo distributions included in Expt 6 therefore appear again in the graphical presentation of most of the remaining experiments.

The aim of these subsequent experiments is therefore generally much more clear-cut, being usually concerned with the observation of any change in the "natural" tempi distribution when a musical or instrumental factor is varied from the keyboard Standard E flat Version legato norm. As this norm in the case of the writer and several other subjects was in the 500 msecs area, in order to facilitate comparison, the 490-510 msecs "same tempo" interval is highlighted by a red dotted line in Fig 6-2 and in much of the subsequent data presentation. Further, it will now be possible to apply statistical procedures more consistently, resulting in a corresponding decreased reliance upon general discussion of the graphical data. To avoid the possibility of a long-term biological rhythm affecting the comparisons, Expts 6 to 13 were conducted over the same chronological period. The effect of any circadian tempo variation was also nullified by conducting these same experiments at random times during the day. However, this potentially important tempo-affecting factor was investigated in the following experiment.

Experiment 7

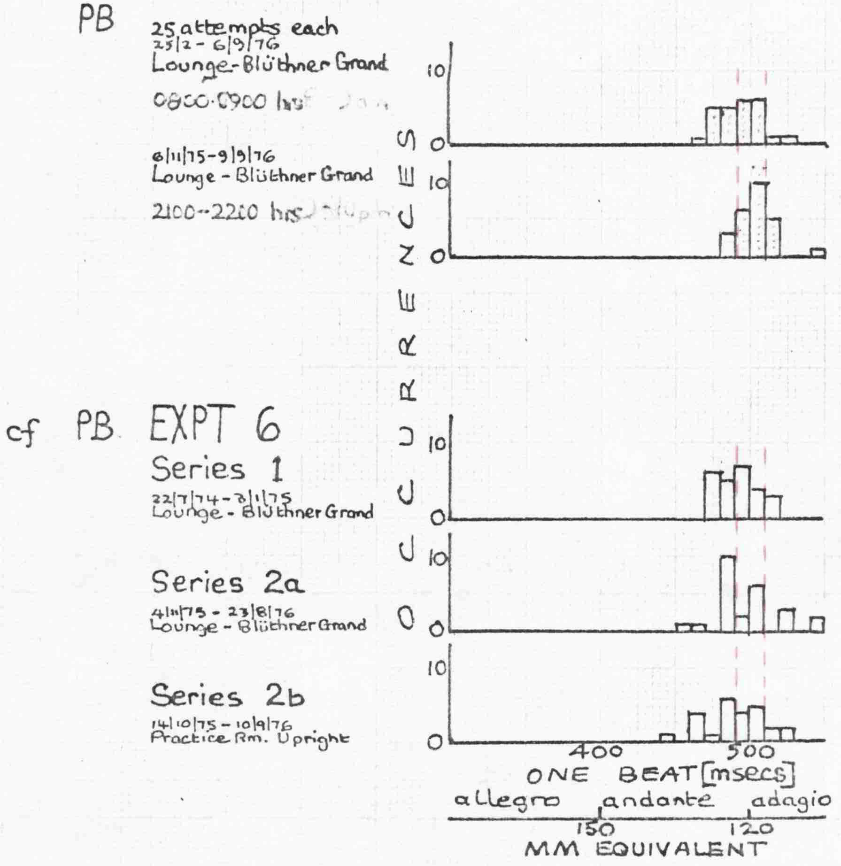
Description

Aim:	With just one subject (PB), and using the same music and performing method as in Expt 6, to investigate the possibility of "natural" tempi being affected by time of day.
Subject:	PB: One series. Twenty-five sessions at each of the times indicated below, never more than one session at each time per day. During the same chronological period and intermixed with Expts 6-13 Series 2ab.
Experimental Room:	Writer's lounge.
Instructions:	Using the same music and performing method as in Expt 6, make a single attempt at a "natural" tempo during one or both of the following times on any day:- Between 0800 and 0900 hrs. Between 2100 and 2200 hrs.
Music:	Standard E flat Version.
Record:	Date, Time of day, Duration of forty music beats.
Timing:	Centisecond timer (2) Read and recorded by PB.

FIG 7 EXPT 7

PIANO(Standard E^b Version): SINGLE ATTEMPTS, AT PRESCRIBED TIMES OF DAY, AT 'NATURAL' TEMPO

(a) Tempi Distributions and cf with Expt. 6 'Natural' Tempo Data



Results and Observations

(a) Tempi Distributions and comparison with Expt 6 PB "Natural" Tempo Data

The respective means of the distributions for morning and evening performances, 497 and 509 msecs, were significantly different at the 1 per cent level (t = 2.97). On the other hand, a comparison of distribution profiles based on ratio of variance gave a result of no significance (F = 1.32). The statistical comparison with Expt 6 is best made using Series 2a, which not only ran concurrently with Expt 7 but was also performed on the same instrument. Given the difference noted above between the distributions for the morning and evening performances, the greater deviations generally observed in Expt 6 data are to be expected, which, as in all other unrestricted experiments, represent performances at random times during the day between 0800 and 2200 hrs. Although neither the morning nor the evening Expt 7 performances produced distributions significantly different from that in Expt 6 Series 2a (t = 1.13 and 1.1 respectively), the distribution profiles are significantly different in both cases at the 5 per cent level (F = 2.26 and 2.98 respectively), with the greater variability occurring in Expt 6.

The Expt 7 distribution for the 2100-2200 hrs performances was in fact the closest approximation to the 20 msecs "same tempo" ideal achieved in any temporally spaced experiments. Even without the confirmation of distributions for other restricted times of day, it does appear possible that repeated "natural" speed performances at the same time each day may be more consistent in tempo than performances at random times. If this is so, then the literature suggests that the circadian body temperature variation may be the relevant factor here. However, as body temperature is at a maximum in the evening, the expectation was for faster and not significantly slower tempi at that time. No explanation for this comes to mind and the matter is one of many requiring subsequent exclusive investigation.

The next four experiments are concerned with the effect on "natural" tempi of a variation in selected instrumental and musical factors. Because of the limitations of time, the methods and versions employed in Series 1 are further reduced in Series 2a and 2b. The various instruments and performing methods used in Expt 8 Series 1 include all those previously employed in Expt 4.

Experiment 8

Description

Aim: To investigate "natural" tempi variation in the context of the Standard E flat Melody, while varying instrument and performing method.

Subjects: PB: Three series. Twenty-five sessions for each method. Up to ten sessions per day, but usually far less, in random order of method. During the same chronological period and intermixed with Expts 6-13.

Three female music students (VN, CD, VL): One series in each of two different selected performing methods. Two sessions per week average.

Experimental Rooms:
PB Series 1 and 2a: Writer's lounge.
PB Series 2b and students: College practice room.

Instructions: Using one of the given performing methods, and looking at the score, make a single attempt at a "natural" tempo:-

Keyboard:
- Piano legato with sustaining pedal
- Piano staccato
- Glockenspiel (one beater in RH)
- Organ
- Organ - Dummy KB
- Organ - Dummy KB + White Noise via Earphones

Breath-based:
- Singing lah
- Singing words (as in Expt 4)
- Treble recorder

Starting pitch E flat given for singing.

Music:	Keyboard:	Standard E flat Version.
	Breath-based:	Standard E flat Melody (written 8ve higher for treble recorder and glockenspiel, sung 8ve lower by PB).
Record:		Date, Time of day, Duration of forty music beats.
Timing:	PB Series 1 and 2a:	Centisecond Timer (2) Read and recorded by PB.
	PB Series 2b:	Stopwatch (2) Operated, read and recorded by assistants.
	Students:	Stopwatch (2) Operated, read and recorded by PB.

Results and Observations

(a) PB Tempi Distributions

Fig 8-1, supported by the Order of Means and t ratios in Tables 3 and 4 show the direction and degree of mean variation between each of the instrumental and performing methods. In all cases, the distributions for the legato performances of the Standard E flat Version are to be regarded as the arbitrary norm for purposes of comparison. In this and subsequent experiments, t values are only given for the same method between series and for the comparison of methods within the same series. Statistical data for the organ performances are also not included in Tables 3 and 4.

Table 3 Order of Means [Beat duration in msecs]

	PB SERIES						STUDENT DATA					
	1		2a		2b		VN		CD		VL	
FASTER ↑	Staccato	450									Treble R.	510
	Lah	458	Lah	464	Glock.	452			Lah	335	Lah	527
	Words	479	Glock.	466	Lah	464			Glock.	342		
	Treble R.	481	Treble R.	468	Treble R.	480						
	Std.E^bV.	497	Std.E^bV.	503	Std.E^bV.	496	Std.E^bV.	492				
↓ SLOWER	Glock.	500					Lah	525				

Fig 8-1 EXPT 8 PERFORMING AS INDICATED (Standard E^b Versions): SINGLE TEMPORALLY SPACED ATTEMPTS AT 'NATURAL' TEMPO

(a) PB Tempi Distributions

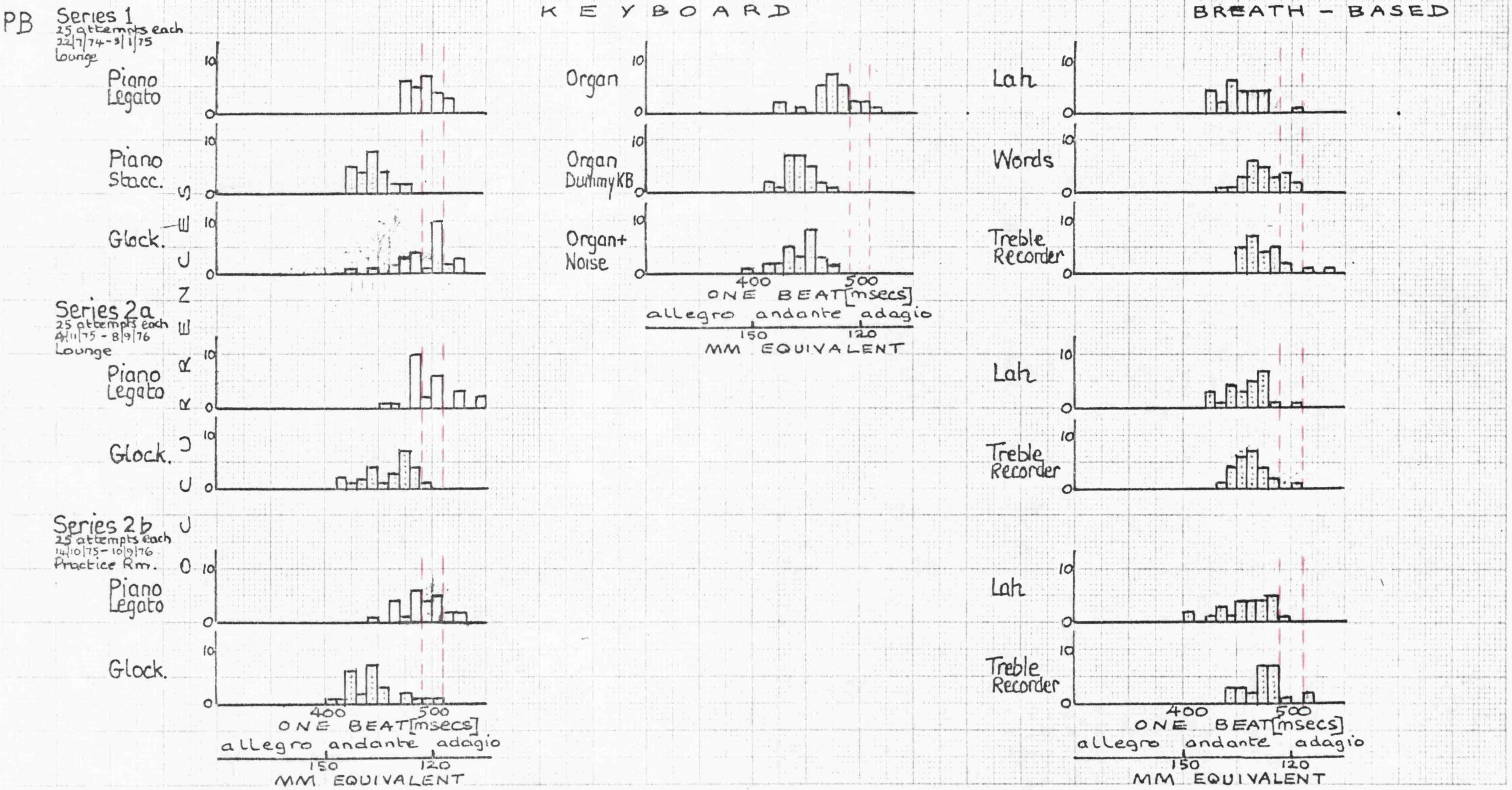


Table 4 Inter-Method and Inter-Series (same method) t Test Values

Student Data circled
1 per cent signif. 2·7
5 per cent signif. 2·02
Organ Data excluded

		Treble R.			Words	Lah						Glockenspiel			Std. E^b Version		
		1	2a	2b	1	1	2a	2b	VL	CD	VN	1	2a	2b	1	2a	2b
Treble R.	1		2·6	0·2	0·3												
	2a			2·4													
	2b																
	VL								2·9								
Lah	1	4·1			3·9		1·2	1·0									
	2a		0·6					0·1									
	2b			2·5													
Glockenspiel	1	3·1			3·5	6·8							5·1	7·0			
	2a		0·4				0·1							2·0			
	2b			4·5				1·8									
	CD									1·2							
Std E^bV.(Staccato)	1	6·3			6·2	1·6						8·8			11·8		
Std.E^b Version	1	3·5			4·0	8·2						0·5				1·2	0·2
	2a		6·5				6·5						5·9				1·2
	2b			2·9				4·9						6·9			
	VN										4·0						

It will first be noted that the trends at "natural" tempi reflect the tempo differences for the same instruments and performing methods previously noted in Expt 4. Also clear is that the Order of Means, Absolute Means and most trends are maintained, within sensible limits, between series. Apart from the interesting and unaccountable reversal of the glockenspiel's position in the Order of Means between Series 1 and 2b, there is no general tendency for faster or slower tempi between Series 1 and the later series.

With regard to any change of tempi between the simultaneous Series 2a and 2b due to room effect, there are some surprising features. No significant t value was obtained for the Standard E flat Version, where the change of piano was expected to make a considerable difference to tempi. Low t values were in fact produced for all other performing methods except for treble recorder performances, where the Series 2a and 2b distributions were different within the 5 per cent significance level. The writer also anticipated that the glockenspiel performances, because they involved movements akin to the "dynamic" conducting method, would produce tempi close to the 400 msecs area investigated in Expts 2-4. They were in fact far from this value.

However, within each series, there are several pairs of distributions that are significantly different, often within the 1 per cent level. Further, as pointed out above, with the exception of the glockenspiel, they are maintained in general magnitude and direction in each series. In addition, the relationship between the lah and treble recorder distributions, although not statistically significant, maintains the same small directional trend in all three series (Table 3). It is also interesting that the faster tempi for lah in relation to words reverses the trend observed in Expt P5. Despite the above, it is also clear that the wind-based performances have a greater homogeneity of tempi than the keyboard methods. This was also noted in connection with the restricted performances of Expt 4. The similarity of the wind-based performances suggests that the vocal or breathing actions they have in common are the more potent factors affecting tempi in this case. The significant tempi differences between most keyboard methods occasion no surprise as they support common sense, musical experience and the expectation arising from the different types of movements involved.

No striking profile differences can be seen in Fig 8_{-1}, and certainly none that are consistently maintained inter-series. In addition, no distribution is realistically confined to the 20 msecs "same tempo" interval. Nevertheless, where significant inter-method differences or consistent trends are observed, there may be said to be individual relative tempo preferences in respect of the various methods employed. Certainly no single individual preference exists, even for this one piece of music.

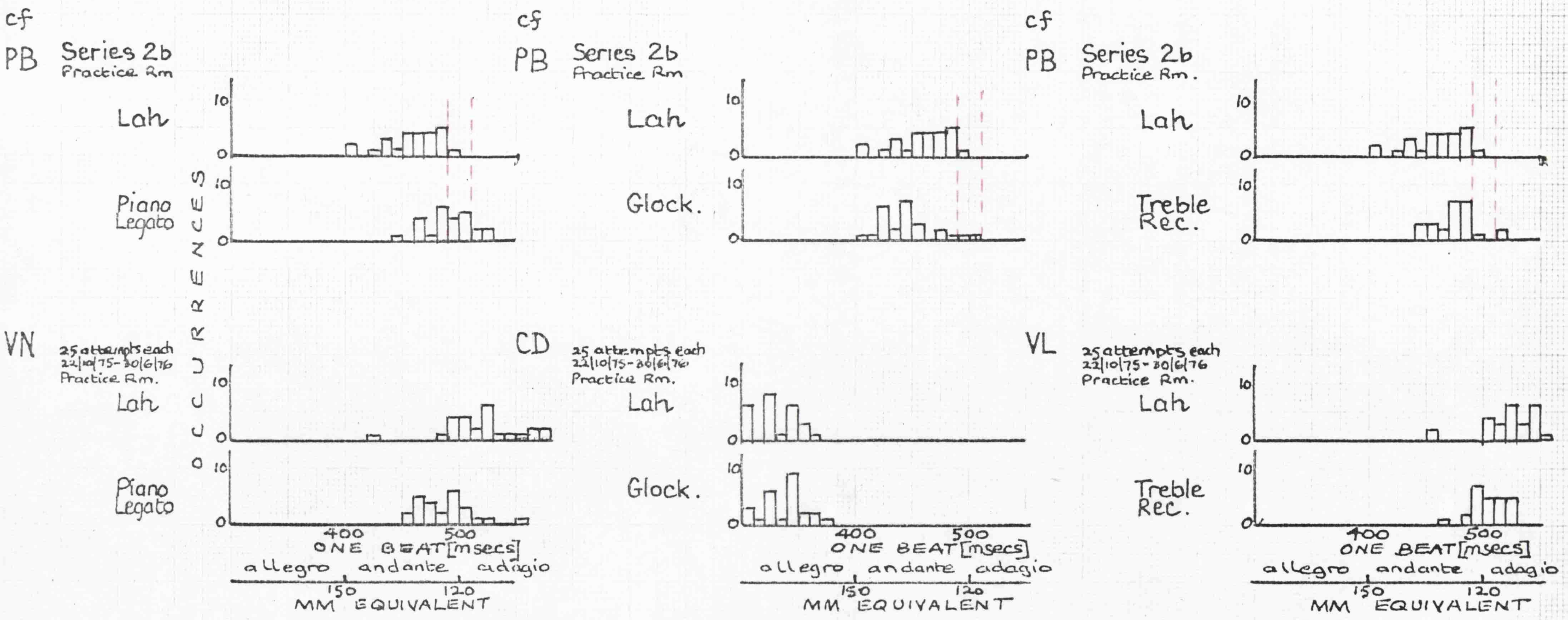
(b) Student Tempi Distributions

Fig 8_{-2} makes clear that there is no commonly preferred student tempo, not even in the case of the lah performances common to each S. Neither is there any similarity with the writer's tempi for the same pairs of methods shown above the student distributions. On this evidence there is thus no question of a common preferential tempo generally, either in the given music or with respect to any particular performing method. Fig 8_{-2} and Table 3 also reveal that each student's direction of mean tempo change is in every case different from the writer's for the respective pairs of performing methods. This was another unexpected result, and while not invalidating the claim and subsequent statistical evidence that the instrumental and musical factors being investigated affect tempi, suggests that some factors may affect different musicians in different ways. The one consistent trend to be noted from Fig 8_{-2} is with respect to the distribution profiles, where changing both subject and performing method made little difference to their general range and peakedness.

The one case of near-identical tempi being produced by the same subject using different performing methods (CD) shows an additional unusual feature. This S's lah and glockenspiel distributions are not only trimodal but also

FIG 8-2 EXPT 8 CONTD

(b) Student Tempi Distributions and cf with relevant PB Series 2 b Data



exactly in phase with each other, suggesting a possible individual discrete preference system operating in this area with a periodicity of 20 msecs. However, there is little support from the remainder of the Expt 8 data for other discrete preferences having this periodicity.

(c) Cumulations

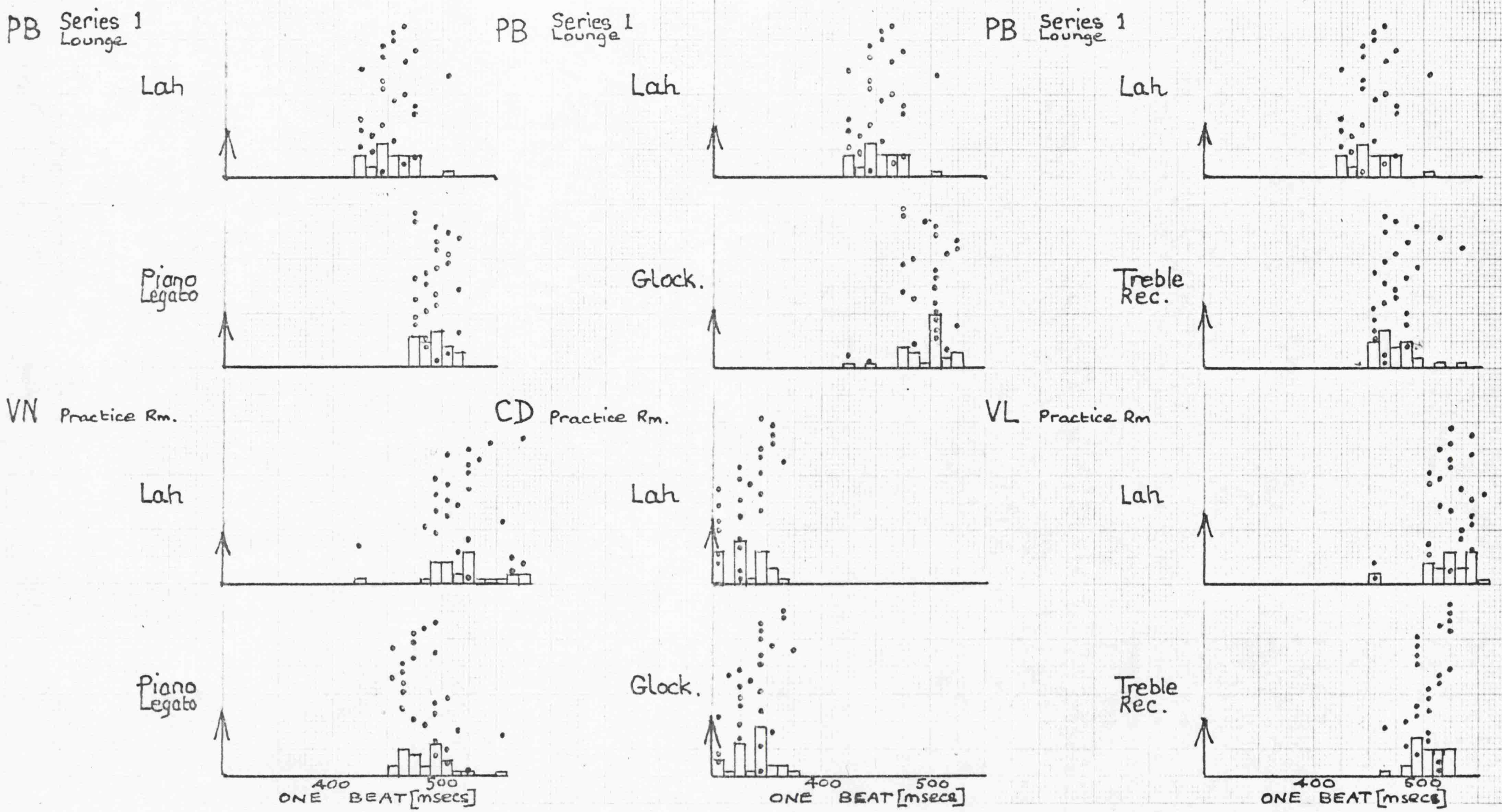
From Fig 8-3 there appears to be no consistent trend with regard to the first performance of any series. That more first performances are at the subsequent modal value is probably only due to the greater number at that speed in any case. The first tempo therefore appears to have no effect on the series that follows. In addition, no learning apparently takes place during the series, as the later tempi do not generally more closely approach the modal value. Indeed, the final attempt of any series is just as likely to be at an extreme tempo. There is also no evidence of any mid-series tempo shift similar to that reported between series in Expts 1 and 2.

Finally, the tendency for the same tempo to occur in successive attempts, noted in some earlier experiments, occurs again here.

Certain difficulties that the writer experienced must now be mentioned. At the beginning of Series 1 in this and the following three concurrent experiments it was rather difficult to forget the 400 msecs area tempo which had previously been so much performed. In addition to this, although the instructions were to perform at a "natural" speed, as the experiment proceeded it became increasingly difficult to avoid trying to repeat what was thought to be the tempo of the previous attempt at that method. Fortunately, the large number of performing and musical variables concerned in these simultaneous experiments ensured that the writer's memory was confused as well as consciously inhibited. From introspection during the performances, the writer often felt that the tempi for different performing methods were subjectively the same, even when the subsequent timings proved otherwise.

FIG 8-3 EXPT 8 CONTD.

(c) Student and relevant PB Tempi Distributions, with Cumulations



This may have been due to the phrased breathing and degree of mental vocalisation that accompanied even the writer's keyboard performances - making them partially akin to the explicit breath-based ones.

From introspection before tempo initiation the writer also sought the origins of the subsequent tempo differences for the different performing methods. This "mental" rehearsal included not only an anticipation of the physical actions soon to be employed, but also an anticipation of the actual sound. There was certainly no conscious awareness of surprise at the actual feel or sound of the instrument once addressed. In other words, as the "rehearsal" was accurate, there was probably less need for the quick modification of the initiated intention tempo presumably required when unpredicted elements of touch and sound make themselves felt. The writer therefore believes that the tempo "existed" in his body before each performance commenced. At the observable "up beat" immediately before commencing, which was also accompanied by an intake of breath in all types of performances, the tempo already appeared to be fixed inexorably.

Experiment 9

Description

Aim:	To investigate "natural" tempi variation in the context of legato piano performances of the Standard E flat Melody, while varying the harmonic rhythm.
Subjects:	PB: Three series. Twenty-five sessions for each harmonic rhythm. Up to six sessions per day, but usually far less, in random order of version. During the same chronological period and intermixed with Expts 6-13. Three female music students (FL, CP, SW): One series in each of the two harmonic rhythms selected. Two sessions per week average.
Experimental Rooms:	PB Series 1 and 2a: Writer's lounge. PB Series 2b and students: College practice room.
Instructions:	Using one of the given harmonic rhythm versions, and looking at the score, make a single attempt at a

"natural" tempo, playing the piano legato with sustaining pedal.

Music:

[Harmonic Rhythm]

(a) ♩ ♩ ♩

Standard E♭ Version

(b) 𝅗𝅥 ♩

(c) ♩ 𝅗𝅥

(d)

(e)

Record: As Expt 8.
Timing: As Expt 8.

Results and Observations

(a) Tempi Distributions

Fig 9-$_1$ and Tables 5 and 6 show less consistent patterns generally than those observed in Expt 8. Not only do the two versions retested by PB very slightly reverse their mean tempo relationship in Series 2b, the distribution profiles of both PB and the three student Ss vary a great deal from the typical Expt 8-type distribution. Indeed, CP and SW give some evidence of having individual discrete "preferences" at different periodicities. It was not thought necessary to seek statistical confirmation of the extreme differences of profile generally observed.

FIG 9-1 EXPT 9-1 PIANO (Standard E♭ Melody-Different Harmonic Rhythms as indicated): SINGLE TEMPORALLY SPACED ATTEMPTS AT 'NATURAL' TEMPO

(a) Tempi Distributions

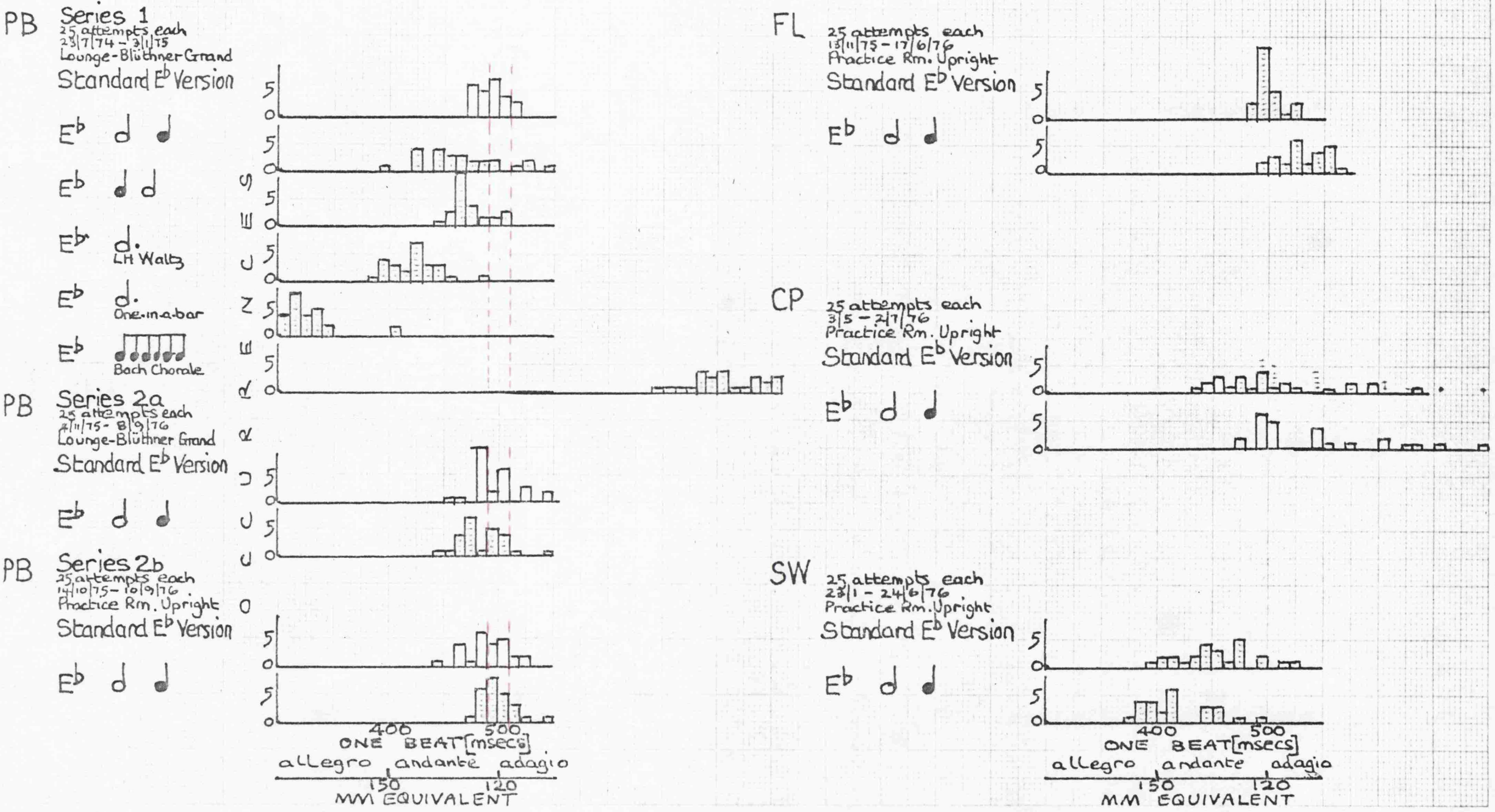


Table 5 Order of Means [Beat duration in msecs]

SLOWER ⟷ FASTER	PB SERIES 1	2a	2b	STUDENT DATA FL	CP	SW
	𝅗𝅥. 333					
	𝅗𝅥. waltz 428					
	𝅗𝅥 ♩ 471	𝅗𝅥 ♩ 490				
	♩ 𝅗𝅥 478					𝅗𝅥 ♩ 424
	Std. E^b V. 497	Std. E^b V. 503	Std. E^b V. 496	Std. E^b V. 505	Std. E^b V. 510	Std. E^b V. 459
	'Bach chor.' 714		𝅗𝅥 ♩ 504	𝅗𝅥 ♩ 536	𝅗𝅥 ♩ 548	

Table 6 Inter-Method and Inter-Series t Test Values

PB Data only
1 per cent signif 2·7
5 per cent signif. 2·02

		𝅗𝅥. one in a bar 1	𝅗𝅥. LH Waltz 1	♩ 𝅗𝅥 1	𝅗𝅥 ♩ 1	𝅗𝅥 ♩ 2a	𝅗𝅥 ♩ 2b	Std. E^b Version 1	Std. E^b Version 2a	Std. E^b Version 2b
𝅗𝅥. one-in a bar	1									
𝅗𝅥. LH Waltz	1	13·7								
♩ 𝅗𝅥	1	21·0	7·4							
𝅗𝅥 ♩	1	20·0	6·3	1·0		2·2	4·2			
	2a						2·7			
	2b									
Std. E^b Version	1	23·8	10·1	2·7	3·8				1·2	0·2
	2a					2·1				1·2
	2b						1·6			

Note:- t values within PB Series 1 derived from ANOVA (F<1%)

Although statistically the PB 𝅗𝅥 ♩ performances became significantly slower between Series 1 and the later series, the writer considers the untypical broad distribution in Expt 1 partly responsible. In any case, as the Standard E flat Version shows no significant change between series, the tendency noted in Expt 8 for inter-series consistency is otherwise maintained. There is also no consistent room effect between Series 2a and 2b. The significant t value (< 1 per cent) for the 𝅗𝅥 ♩ version is counteracted by a non-significant Standard E flat Version trend in the opposite direction. As in Expt 8, the directional relationship of the student means is inconsistent in respect of the two versions performed, again suggesting that the significant t values obtained by both students and writer between the different versions within each series represent differing individual responses to the various versions presented. It is possible that two conflicting factors may have operated in the case of the 𝅗𝅥 ♩ harmonic rhythm. On the one hand, in relation to the Standard E flat Version, the slower 𝅗𝅥 ♩ rate of chord change would seem to encourage faster tempi; on the other, an attention to its greater harmonic interest would have the opposite effect. Differing individual responses or priorities could then account for the inconsistencies observed.

Comment may now be made on the very clear tempi differences observed in PB Series 1; highly significant t values being obtained for many relationships. The closer correspondence between the first three versions in Fig 9-1 is not surprising as they are comparatively similar harmonically. The other versions have not only fundamentally different harmonic rhythms, but also imply quite different performing movements from those used in playing the Standard E flat Version. The Order of Means in Table 5 does in fact support the general view expressed in Chapter 3 concerning the effect of faster and slower harmonic rhythms.

With regard to a common "preferential" tempo irrespective of harmonic rhythm, the contrary evidence is quite clear. A further study of Fig 9-1 and Table 5 does however suggest that for the Standard E flat Version there may be some general degree of preference around 500 msecs for more than one S. Indeed, this has already been anticipated in connection with Expt 6, where an analysis of all performances of this type extracted from Expts 8-11 showed a combined subject distribution peak at this value.

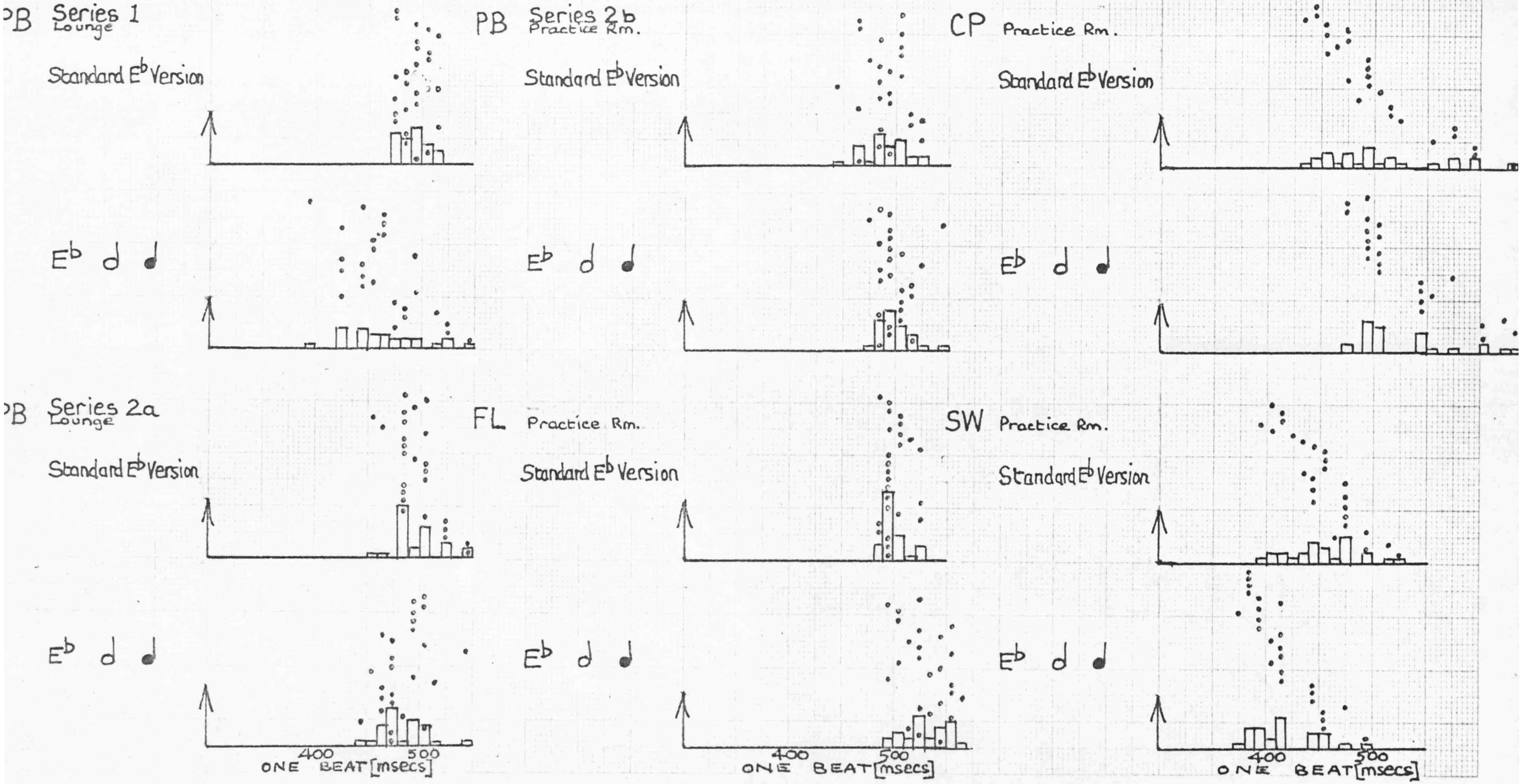
(b) Cumulations

Unlike Expt 8, there do appear to be some consistent cumulation trends, particularly in the cases of the Student Ss. In retrospect, this was to be expected as, unlike the previous experiment, all performances were on the piano and consequently made greater demands on technique. Although the students were adequate pianists, it is clear that with increasing familiarity with the music came progressively faster tempi. Fig 9-2 not only makes this general trend very clear but also further hints at the possibility of a discrete "preference" system. CP in her 𝅗𝅥♩ performances shows this most clearly, but there are indications of similar patterns in other Ss cumulations, including those of the writer. Integral with this trend is the tendency for a given tempo to appear in several successive attempts. This latter characteristic has been noted before in other experiments. There is still no indication that the modal tempo is learnt or that the later attempts in any series are closer to the eventual modal value.

The writer's distributions must always be seen in the light of the difficulties noted at the end of Expt 8. However, previous conducting tempi, if they had an effect on subsequent experiments, almost certainly affected piano performances least of all, particularly the fastest and slowest harmonic rhythms in this case. Here, the performing movements involved, so different from triple metre conducting actions, must have prevented any unconscious attempts to copy the 400 msecs conducting tempo.

FIG 9-2 EXPT 9 CONTD.

(b) Student and Selected PB Tempi Distributions with Cumulations



As far as trying to copy the previous tempo for any given harmonic rhythm is concerned, the comments made with respect to Expt 8 still apply. The 𝅗𝅥. waltz-type performances were the only ones where the writer was tempted to indulge in rubato.

Finally, this experiment illustrates a weakness inherent in investigations of this type, namely the difficulty of controlling all factors not being studied. In this case, it was not always possible to use the same repertoire of chords in the different versions - particularly in the case of the 𝅗𝅥♩ and "chorale" harmonisations.

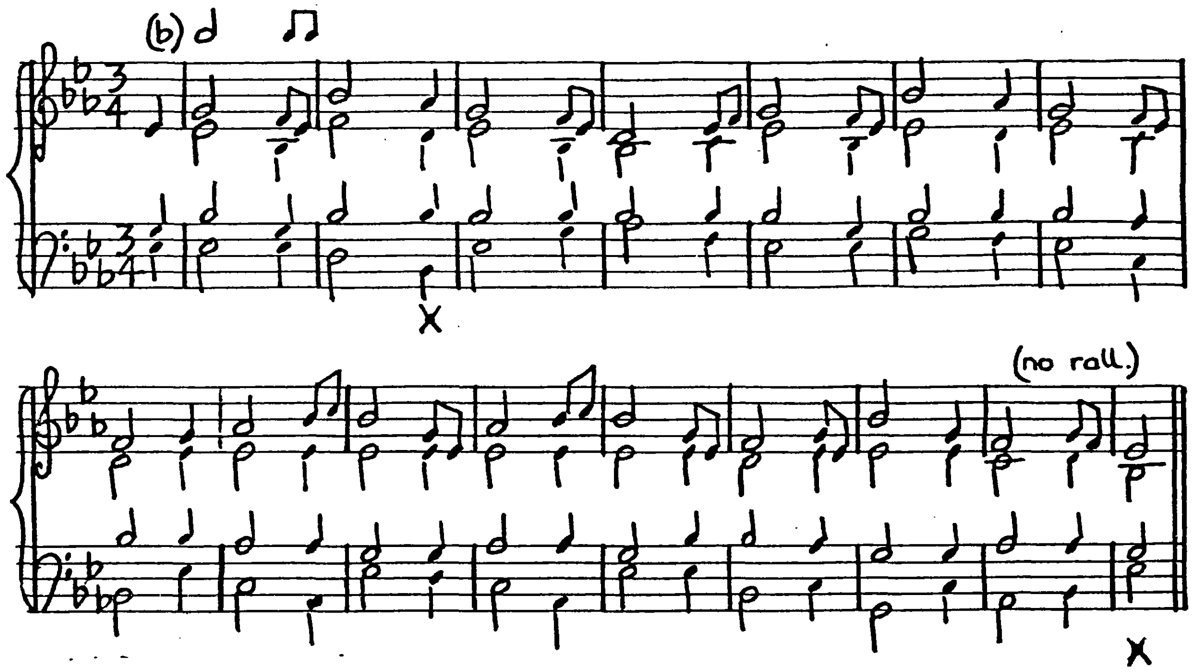
Experiment 10

Description

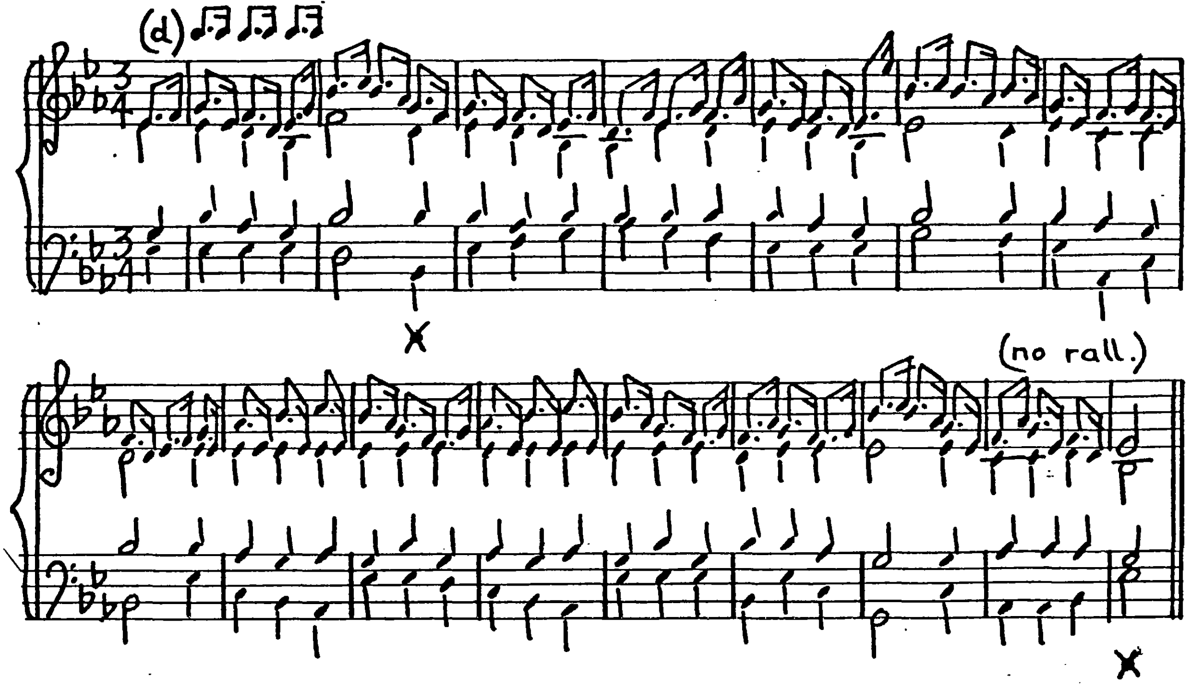
Aim:	To investigate "natural" tempi variation in the context of legato piano performances of the Standard E flat Harmony, while varying the melodic rhythm.
Subjects:	PB: Three series. Twenty-five sessions for each melodic rhythm. Up to six sessions per day, but usually far less, in random order of version. During the same chronological period and intermixed with Expts 6-13. Three female music students (JW, MM, PR): One series in each of the two melodic rhythms selected. Two sessions per week average.
Experimental Room:	PB Series 1 and 2a: Writer's lounge. PB Series 2b and students: College practice room.
Instructions:	Using one of the given melodic rhythm versions, and looking at the score, make a single attempt at a "natural" tempo, playing the piano legato with sustaining pedal.
Music:	

[Melodic Rhythm]
(a) ♩ ♩ ♩
Standard E♭ Version

(b)



(c)



Record: As Expt 8.

Timing: As Expt 8.

Results and Observations

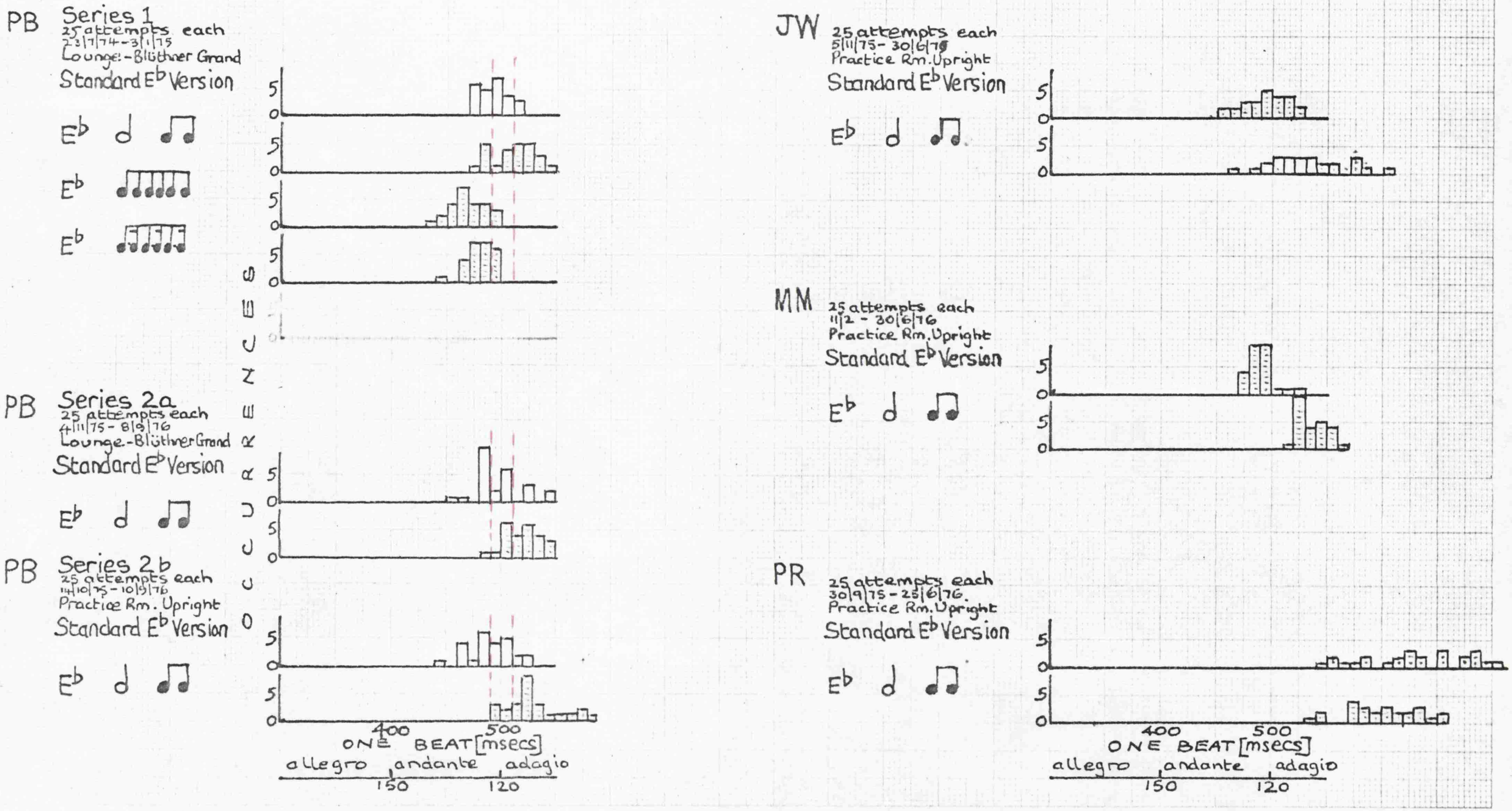
(a) Tempi Distributions

Inter-series tempi relationships were consistently maintained in the three PB series. However, although Fig 10 and Tables 7 and 8 show that no significant absolute tempo shift occurred between series in the case of the Standard E flat Version, the tempi for the 𝅗𝅥 ♫ melodic rhythm became significantly slower (< 1 per cent) between Series 1 and 2b, with a value just outside significance, but with the same directional relationship, also being obtained between Series 1 and 2a. There is a suggestion therefore that a room/piano factor affects some melodic rhythms at least, a view supported by similar t value relationships in Expt 9 for the 𝅗𝅥 ♩ harmonic rhythm distributions (Table 6). In both these cases, the direction of tempo change is towards rather slower tempi on the smaller practice room upright piano. However, reference to Tables 3, 5, 7 and 9 shows that there

FIG 10-1 EXPT 10

PIANO(Standard E♭ Harmony-Different Melodic Rhythms as indicated): SINGLE TEMPORALLY SPACED ATTEMPTS AT 'NATURAL' TEMPO

(a) Tempi Distributions



is no consistent relationship of this kind between the Series 2a and 2b means in the other types of performances. Indeed, in Table 9 the other keyboard performances have a slight although insignificant tendency towards faster tempi on the upright piano. It is possible of course that the far greater number of Standard E flat Version performances occasioned by the complete experimental programme so fixed the tempo in the writer's memory that external acoustical or instrumental factors were overriden.

Table 7 Order of Means [Beat duration in msecs]

	PB SERIES 1	2a	2b	STUDENT DATA JW	MM	PR
FASTER ↑	♫♫♫ 474					
↓	♪.♬♪.♬♪.♬ 485					𝅗𝅥 ♫ 606
	Std.E♭V. 497	Std.E♭V. 503	Std.E♭V. 496	Std.E♭V. 498	Std.E♭V. 496	Std.E♭V. 634
SLOWER	𝅗𝅥 ♫ 516	𝅗𝅥 ♫ 525	𝅗𝅥 ♫ 535	𝅗𝅥 ♫ 537	𝅗𝅥 ♫ 542	

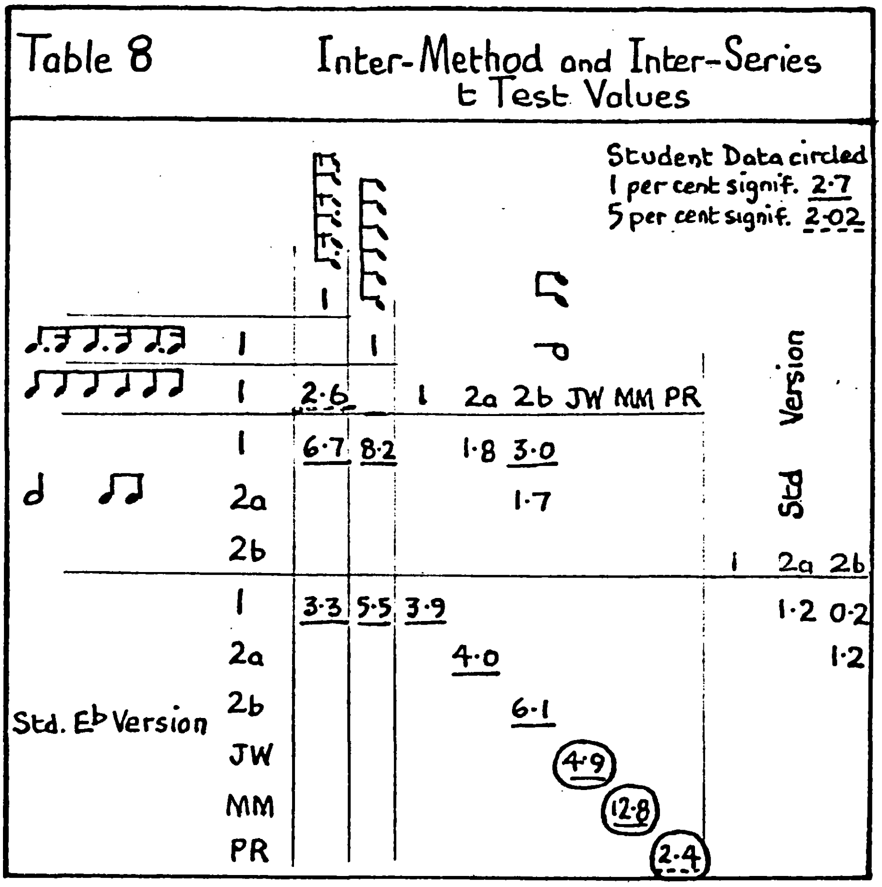


Table 8 Inter-Method and Inter-Series t Test Values

Student Data circled
1 per cent signif. 2·7
5 per cent signif. 2·02

		♬	♫	𝅝						Std Version		
		1	1	1	2a	2b	JW	MM	PR	1	2a	2b
♪.♬♪.♬♪.♬	1											
♫♫♫	1	2·6										
𝅗𝅥 ♫	1	6·7	8·2		1·8	3·0						
	2a					1·7						
	2b											
Std. E♭ Version	1	3·3	5·5	3·9							1·2	0·2
	2a				4·0							1·2
	2b					6·1						
	JW						④·⑨ 4·9					
	MM							12·8				
	PR								2·4			

The graphical evidence, supported by the Order of Means and t scores clearly indicates that the various types of melodic movement selected had a generally smaller effect on tempi than the variations in harmonic rhythm investigated in Expt 9. This supports the writer's view that harmonic rhythm affects tempo more fundamentally than melodic rhythm, which in any case must be considered secondary as it usually decorates the pre-existent harmonic framework.

The directions of the various inter-version tempo changes are of interest. Three of the four S's distributions for the 𝅗𝅥♫ rhythm were slower than for the Standard E flat Version; in every case the t ratio being well within the 1 per cent significance level. It had been expected that the 𝅗𝅥♫ performances would be faster because of the lack of movement on the second beat causing impatience and a desire to reach the third beat earlier. From introspection during performance the writer was aware of a regular breathing movement accompanying the inactive beat and as in this case his tempi were subjectively the same as for the Standard E flat Version, the imagined beat may have appeared to be shorter than it actually was.

The significantly faster speeds performed by the writer in Series 1 for the quaver and dotted quaver movement in relation to the Standard E flat Version were also not according to expectation. It was thought that the addition of between-the-beat "events" would have slowed the performances down. That the reverse was true may have been due to the greater rhythmic excitement and movement engendered by the faster notes. With regard to the relationship between the dotted and undotted quaver melodic rhythms, the principle of greater rhythmic excitement in the former is in conflict with the smoother and easier flow of the latter. In the case of the writer, the second principle may have had priority, as the undotted quaver distribution was significantly faster (< 5 per cent). Further, the observed tendency is in accord with the Time Psychology Literature, where even subdivision of a beat made that beat seem longer than when it was irregularly divided.

Tempi distribution profiles tend to follow the pattern now generally established for twenty-five temporally-spaced attempts. Most of the PB performances of any version fall within two "same tempo" 20 msecs intervals, while it is interesting that the most able student pianist, MM, nearly always performed the Standard E flat Version within the experimental "same tempo" limits.

Once again, there is no one tempo area common to all versions, and although, quite unaccountably, the Standard E flat Version always appears to encourage rather similar tempi for more than one S, there is no common tempo area for the  melodic rhythm.

It was not thought necessary to show the cumulations for this and the following experiment.

Experiment 11

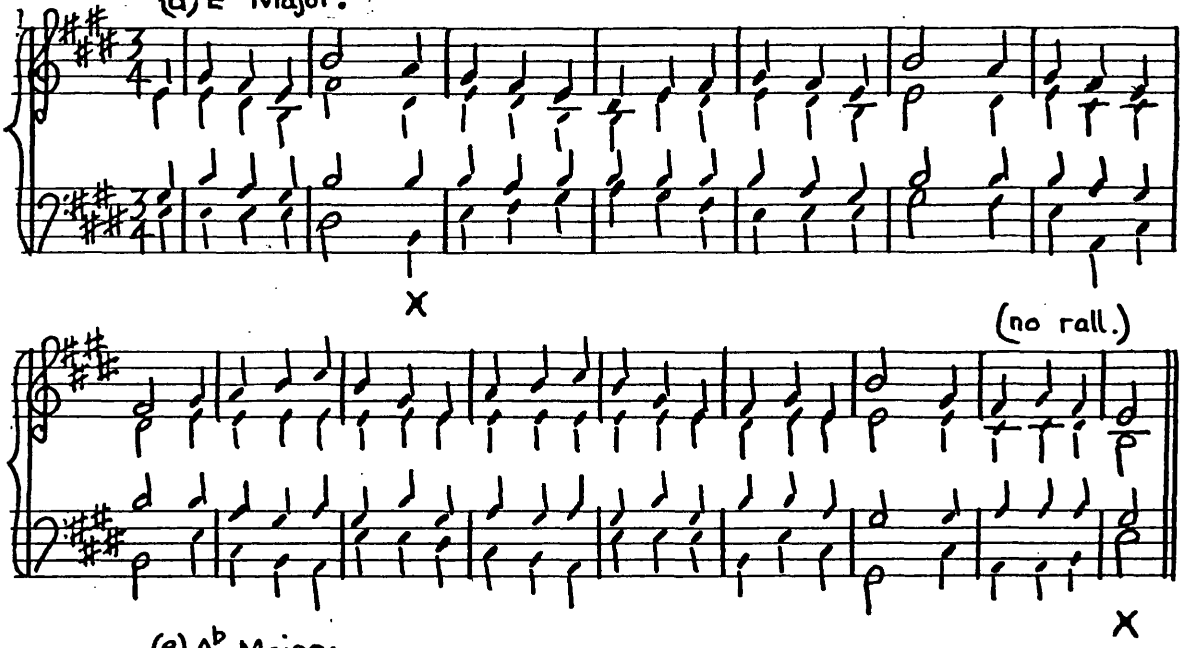
Description

Aim:	To investigate "natural" tempi variation in the context of legato piano performances of the Standard Version, while varying key/pitch or mode.
Subjects:	PB: Three series. Twenty-five sessions for each key/pitch or mode. Up to six sessions per day, but usually far less, in random order of version. During the same chronological period and intermixed with Expts 6-13. Three female music students (BW, SL, AT): One series in each of two different selected keys/modes. Two sessions per week average.
Experimental Rooms:	PB Series 1 and 2a: Writer's lounge. PB Series 2b and students: College practice room.
Instructions:	Using one of the given versions, and looking at the score, make a single attempt at a "natural" tempo, playing the piano legato with sustaining pedal.
Music:	

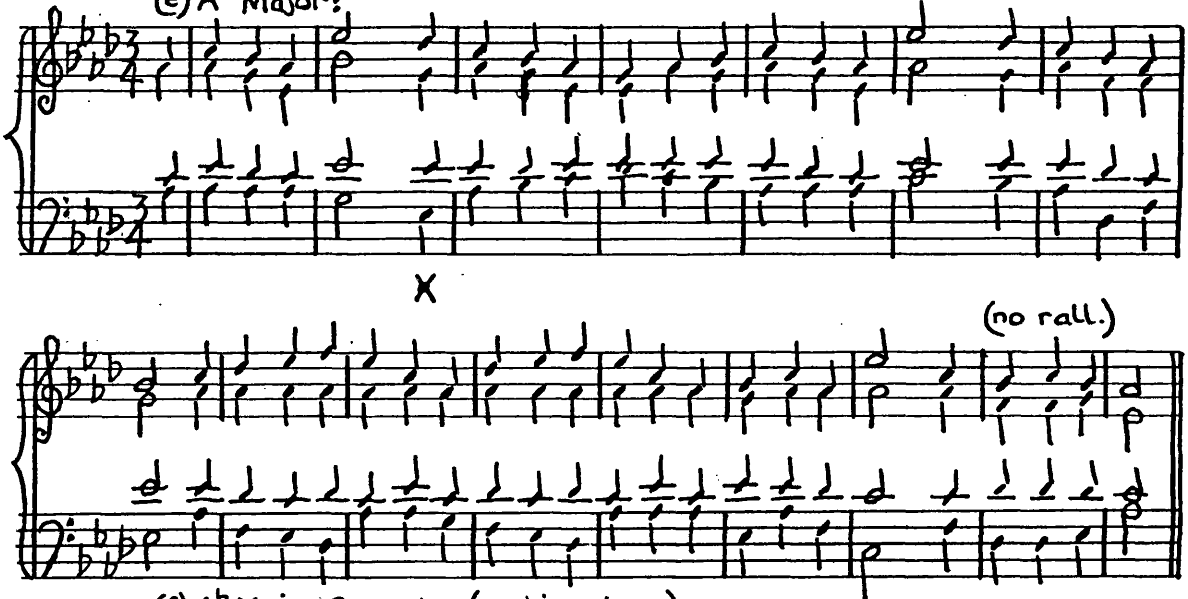
[Key or Mode]

(a) Standard E^b Version
(b) E^b Major (reading E major version)
(c) E Major (reading Standard E^b Version)

(d) E Major:



(e) A♭ Major:



(f) A♭ Major 8ve below (reading above)

(g) E Minor

Record: As Expt 8.
Timing: As Expt 8.

Results and Observations

(a) Tempi Distributions

As more versions were retested in PB Series 2a and 2b of this experiment, the inter-series consistency may be seen very clearly. The inter-series t tests in Table 10 give significant values only in the case of E major performances, although the writer is aware of the dangers of ignoring the possibility of Type II errors. There is certainly no observable general room/instrument effect between Series 2 and 2b, but this was to be expected as any previously noted differences of this kind had concerned performances other than the Standard E flat Version. Perhaps for the reason previously given, this version, even in different keys, will not be affected by external factors. Table 9 also shows that the Order of Means was not essentially changed between the three PB series. The only reversal of adjacent versions concerned Series 2a and 2b, where the same key was read from different music. The student mean tempi relationships given in Table 9 are opposite to the writer's in the two cases where it was considered there would be a considerable measure of agreement. It is difficult to account for SL being faster in e minor than E major, and AT's faster tempi when playing an octave lower. Although the respective t scores for these trends are very low and insignificant, it was the direction of change that occasioned the surprise, contradicting as it did the relevant speculation in Chapter 3.

FIG II EXPT II

PIANO(Standard Version-Different Keys as indicated): SINGLE TEMPORALLY SPACED ATTEMPTS AT 'NATURAL' TEMPO

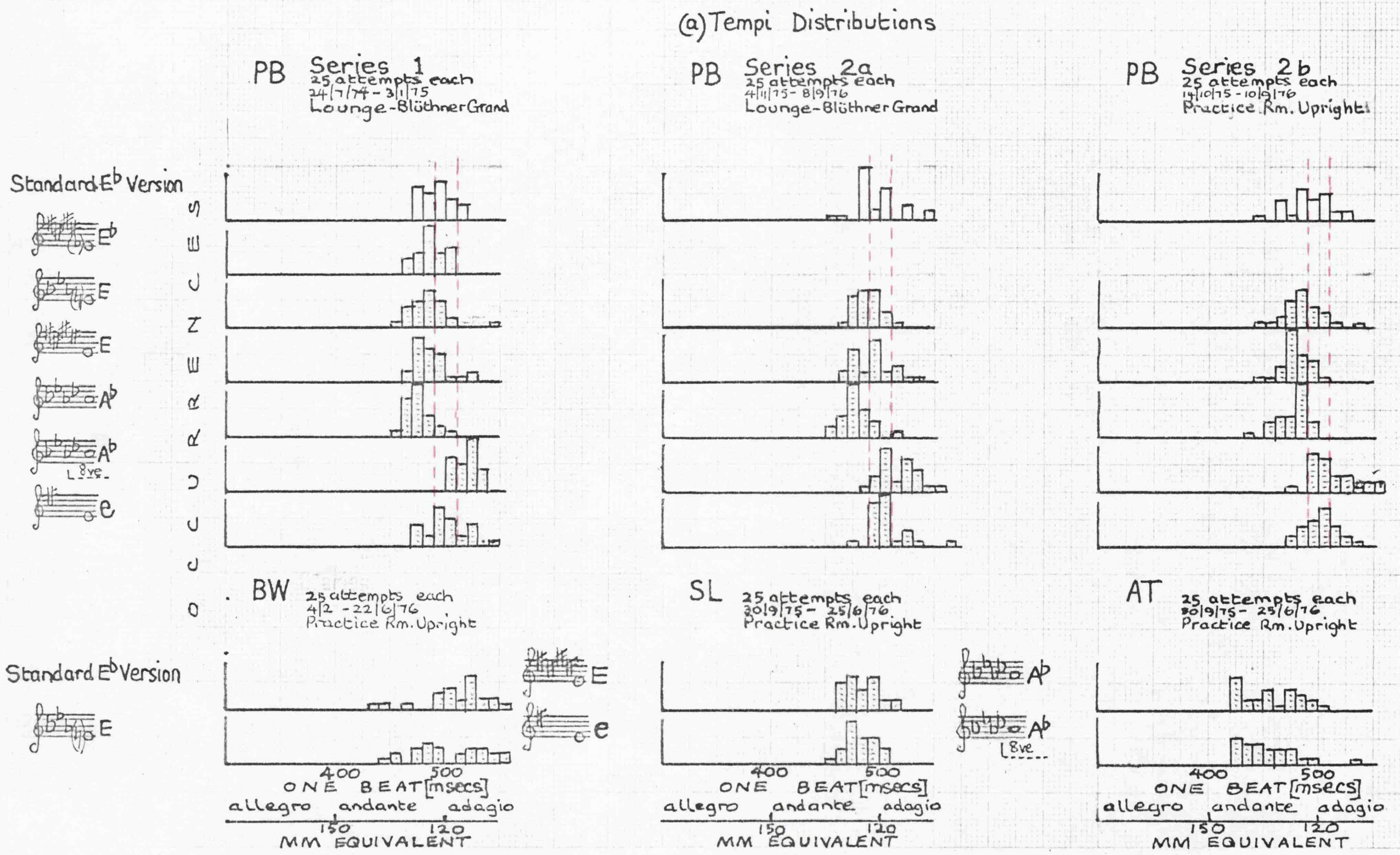


Table 9 Order of Means [Beat duration in msecs]

	PB SERIES						STUDENT DATA					
	1		2a		2b		BW		SL		AT	
FASTER ↑	A^b	481	A^b	483	A^b	481						
	E($b^b b$)	490	E($b^b b$)	493	E	483						
	E	492	E	498	E($b^b b$)	491	E($b^b b$)	510				
↓	E^b(###)											
	Std.E^b V.	497	Std.E^b V.	503	Std.E^b V.	496	Std.E^b V.	521				
	E minor	506	E minor	512	E minor	507			E minor	488	A^b 8ve bass.	459
SLOWER	A^b 8ve bass.	525	A^b 8ve bass.	522	A^b 8ve bass.	518			E	490	A^b	463

Table 10 Inter-Method and Inter-Series t Test Values

Student Data circled

1 per cent signif. $\underline{2{\cdot}7}$

5 per cent signif. $\underset{\text{- - - -}}{2{\cdot}02}$

		E minor				A^b 8ve basso				A^b			E			E($b^b b$)	Standard E^b Version		
		1	2a	2b	SL	1	2a	2b	AT	1	2a	2b	1	2a	2b	BW	1	2a	2b
E minor	1		1·1	0·1															
	2a			1·1															
	2b																		
A^b 8ve basso	1	$\underline{4{\cdot}4}$					0·6	1·5											
	2a		$\underset{\text{- - -}}{2{\cdot}1}$					0·8											
	2b			$\underset{\text{- - -}}{2{\cdot}1}$															
A^b	1	$\underline{5{\cdot}8}$				$\underline{14{\cdot}2}$					0·6	0·0							
	2a		$\underline{5{\cdot}4}$				$\underline{9{\cdot}0}$					0·5							
	2b			$\underline{6{\cdot}0}$				$\underline{7{\cdot}1}$											
	AT								$\bigcirc\!\!\!\!\!\!\!\!\;0{\cdot}5$										
E	1	$\underline{2{\cdot}9}$				$\underline{8{\cdot}3}$				$\underline{2{\cdot}9}$				1·1	$\underline{2{\cdot}2}$				
	2a		$\underline{2{\cdot}7}$				$\underline{4{\cdot}9}$				$\underline{3{\cdot}3}$				$\underline{3{\cdot}2}$				
	2b			$\underline{5{\cdot}8}$				$\underline{7{\cdot}0}$				0·6							
	SL				$\bigcirc\!\!\!\!\!\!\!\!\;0{\cdot}6$														
Std. E^b Version	1	2·0				$\underline{8{\cdot}1}$				$\underline{4{\cdot}7}$			1·1					1·2	0·2
	2a		1·6				$\underline{3{\cdot}4}$				$\underline{4{\cdot}0}$			0·9					1·2
	2b			$\underset{\text{- - -}}{2{\cdot}1}$				$\underline{3{\cdot}8}$				$\underline{3{\cdot}0}$			$\underset{\text{- - -}}{2{\cdot}6}$				
	BW															$\bigcirc\!\!\!\!\!\!\!\!\;1{\cdot}2$			

A trend test applied to the discrete series of keys A^b 8ve, E^b, E and A^b gave significant results ($F < 1$ per cent) for each PB Series.

The order of keys presented in Fig 11 shows the expected very gradual shift to faster tempi from the Standard E flat Version through the progressively higher keys/pitches. As mean tempi differences were clearly generally insignificant between the Standard E flat Version and the keys nearest to it, PB t ratios are only shown in Table 10 for those keys/modes subsequently retested in Series 2a and 2b. To supplement this data a trend test was applied to the discrete series A flat 8ve, Standard E flat Version, E and A flat. The highly significant results (F $<$ 1 per cent) obtained for every PB series confirms the slight but very consistent faster trend visually observed in this ascending series of keys. Significant t scores ($<$ 1 per cent), giving a direct relationship between higher pitch and faster tempi, were also obtained between the Standard E flat Version and key A flat above and below. This degree of mean tempo difference was expected for keys as much as a perfect 4th and 5th apart, but the writer suggests that the consistent trend involving smaller intervals between keys has even greater significance. The PB tempi relationship between E major and e minor also gave the anticipated significantly slower tempi for the latter in each series. The contrary trends to the above observed in the student data has already received comment.

When the experiment was designed the writer speculated regarding the effect of key signature, when the read key was different from that performed. Unfortunately, as the t ratios were insignificant, and these versions could not be admitted into the discrete series used for the trend test, only the very slight but consistent shift to the left observed in the graphical presentation in Fig 11 can be cited as evidence of any tempi change. However, no further comments may be made on this scant visual evidence. The relative effects of key signature appearance and the actual key performed must await further investigation.

With this experiment, the final one investigating tempi variation while just one instrumental or musical factor was varied, it is now evident that not even a very broad common tempo area exists for the music performed. In addition, only with respect to the Standard E flat Version is there evidence of a common tempo tendency for any particular version of the music. Although data for more than one subject's performances of any other version is much more limited, neither this nor the previous experiments give many examples of a student S mean being realistically similar to that of the writer for any method or version of the music.

Finally there is no evidence that MM 80 (750 msecs) represents a "normal" tempo for this piece of music in any of its versions. The 500 msecs area tempo "preferred", at least to some extent, by several Ss is clearly not related in any way to MM 80. Even if the bar length was considered the critical unit of musical movement, the resultant 1500 msecs duration, although exactly twice that required for MM 80, by representing a triple metre subdivision, can only by devious and unmusical arithmetic effect a relationship.

In Chapter 3 the writer asserted that acoustical factors were the primary cause of any higher pitch-faster tempo relationship. It is however difficult to account for the mean tempo differences observed here in terms of the mechanics of tempo initiation. If the initiated tempo is decisive and not modified when the sound is heard, changes of tempo due to key/pitch must be attributable to an anticipation of either the sound of the actual key or the "feel" of the instrument in that key. It must also be pointed out that this inseparability of physical keyboard "feel" and pitch is a further example of the difficulty of isolating one factor only in experiments of this type. However, as the writer does not possess absolute pitch, the true sound at least could not have been mentally anticipated, so perhaps the more likely explanation for changes of tempo in this experiment is that the initiated speed was modified immediately the reality of both instrumental touch and sound was experienced. Presumably this procedure could have caused even the big differences between A flat and A flat 8ve. Of course, in the case of performances in e minor, the true character of the mode change, if not its actual pitch, was appreciated before the sound was heard and therefore taken into account when making the tempo choice.

The need for the next experiment arose from the very unusual data produced by a student S in Expt P_4. The writer was concerned whether the circumstances of this experiment contributed to the very precise distribution obtained.

Experiment 12

Description

Aim: With just one subject (PB), to investigate the effect on Expt 8 Lah-type performances of allowing a freely selected starting pitch in relation to Expt 8 and Expt P_4 data.

Subject: PB: Two series. Twenty-five sessions each. Never more than one per day. During the same chronological period and intermixed with Expts 6-13 Series 2 ab.

Experimental Rooms: PB Series 1a: Writer's lounge.
Series 1b: College practice room.

Instructions: Singing lah, and looking at the score, make a single attempt at a "natural" tempo.
Starting pitch not given.

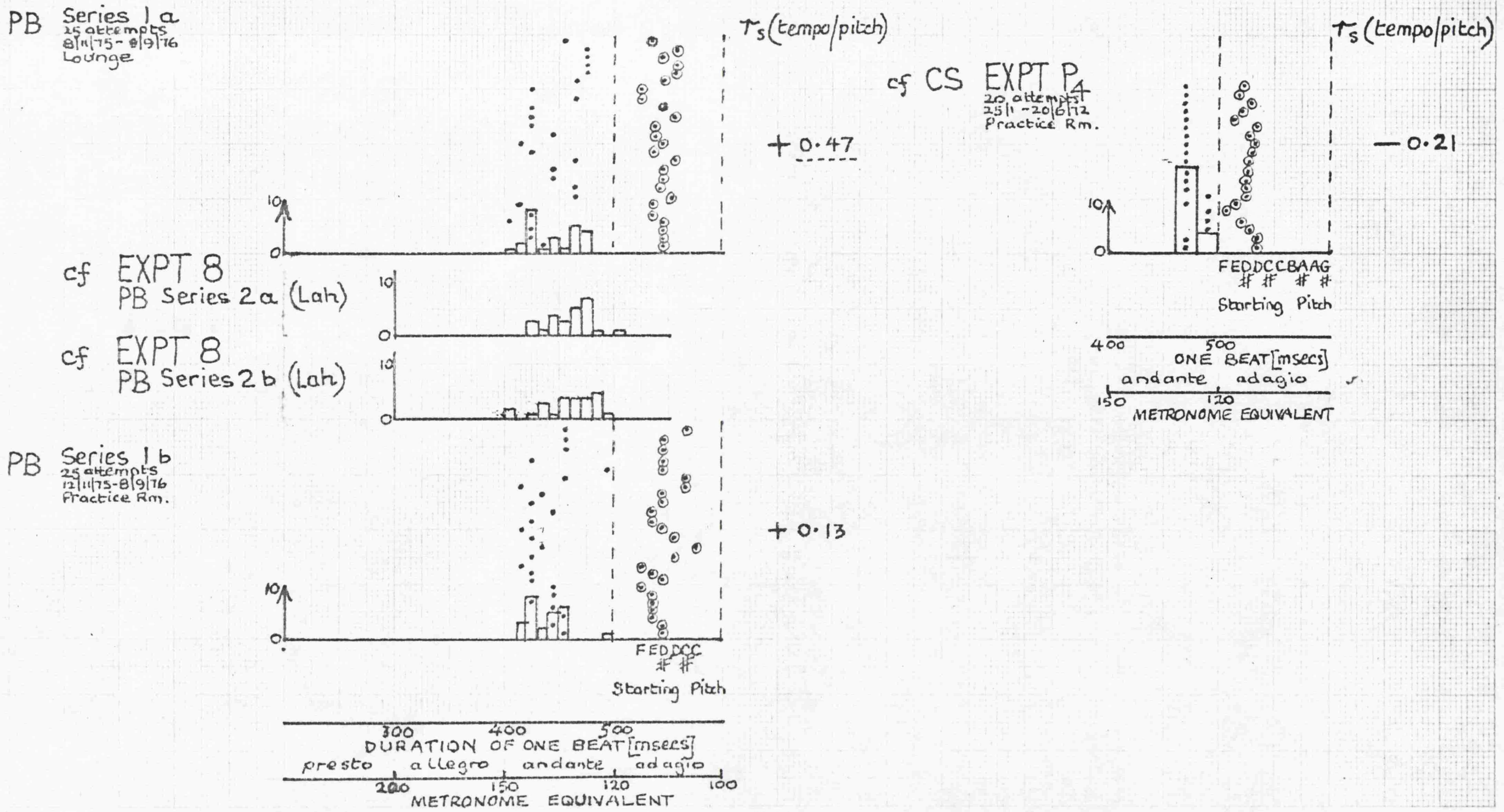
Music: Standard E flat Melody (Sung approximately 8ve lower).

Record: As Expt 8 plus actual starting pitch.

Timing: Series 1a: Centisecond Timer (2) Read and recorded by PB.
Series 1b: Stopwatch (2) Operated, read and recorded by assistants.

FIG 12 EXPT 12 SINGING LAH (Standard Melody - Pitch as indicated): SINGLE TEMPORALLY SPACED ATTEMPTS AT 'NATURAL' TEMPO

(a) Tempi Distributions and Cumulations related to Starting Pitch, and cf with Expt 8 PB lah data and Expt P_4



Results and Observations

(a) Tempi Distributions and cf with Expts 8 and P_4

In order that a more accurate visual comparison could be made with the CS data from Expt P_4, the latter distribution, while retaining the double Pilot Experiments interval scale, is reproduced in Fig 12 with the occurrence (frequency) scale as used throughout the Main Programme. It must be pointed out however that the comparison with Expt P_4 is solely concerned with profile and tempo/pitch relationship. As Expt P_4 involved a different subject, different music and also the singing of words, the absolute values of its distribution are of no concern. What is of interest is whether the writer's lah performances, free from the restriction of imposed pitch, are more consistent in tempo than those in the concurrent series of Expt 8 and become more like the outstandingly consistent data observed in Expt P_4.

The evidence from Fig 12 is inconclusive. There is clearly no appreciable change of profile between Expt 8 Series 2a and Expt 12 Series 1a, although the practice room performances of each experiment gave F = 1.81 in relation to the ratio of the respective variances. This is just outside the required 5 per cent significance value of 1.98, but the greater precision did occur in the room where CS gave her performances. However, even allowing for the visual deceptiveness of the double interval scale used for Expt P_4, the latter data remains unique in its consistency. The comparative effect on tempo consistency of allowing freedom of key in singing performances is thus unresolved. Two possibly opposing factors may be at work here. An imposed key controls one of the possible tempo-affecting factors while introducing the possibility of a varying individual response to that key - an important aspect of which concerns the ease of vocal performance in the required tessitura. Indeed, if the given imposed key invariably imposes a strain on the vocal resources, as was the case in the writer's Expt 8 singing performances, less consistent tempi are easily explained. On the other hand, a freely chosen pitch, while enabling the performer to sing comfortably on every occasion, reintroduces the factors associated with key variability.

With regard to the mean tempi differences within and between the PB lah performances of Expts 8 and 12, Tables 11 and 12 give the relevant data:-

Table 11 Means [Beat duration in msecs] and cf Expt 8 (Lah)

PB SERIES		cf EXPT 8 Lah Perfs.	
1a	1b	2a	2b
448	444	465	464

Table 12 Inter-Series and cf EXPT 8 (lah) t Test Values

				cf EXPT 8 (Lah)	
		1a	1b	2a	2b
	1a		0·7		
	1b				
cf EXPT 8 (Lah)	2a	2·7			0·1
	2b		3·3		

It can be seen that although the different rooms had no appreciable affect on either experiment, the t ratios are significant within the 1 per cent level between the distributions for imposed and unrestricted key in each room. In both cases the trend is for faster tempi when the choice of starting pitch and key is free, suggesting in the writer's case, a greater ease of performance. However, reference to Fig 12 shows that the actual starting pitch chosen was in fact very often E flat, with any divergences from this key just as frequently above it as below. The room did not appear greatly to affect the pitches chosen.

No directional pattern concerning any tempo/pitch relationship can be established from the limited data from two subjects. A significant positive relationship ($r_s < 5$ per cent) between faster tempi and higher pitch occurred in Series 1a, but in the light of a low r_s value for Series 1b and a slight opposite trend in the Expt P_4 CS data, no further comment can be made.

The final three small-scale experiments were initiated in order to confirm certain statistical assumptions and investigate other issues raised during the Main Programme. They also subsequently proved however to have very considerable unsolicited value in relation to the hypothesis. Expt 13 was conducted on various occasions during the period of Expts 6-12 Series 2ab; Expts 14 and 15 were undertaken on the completion of all other experiments.

Expt 13 is an attempt to confirm the statistical assumptions concerning "same tempo" mentioned in Chapter 7. An experiment was contrived to produce distributions for tempi subjectively "the same" in the situation most favourable for generating them.

Experiment 13

Description

Aim: To confirm that a realistic relationship exists between a subjective "same speed" and the empirical definition employed throughout the Main Experimental Programme.

Subjects:
PB: Two series) One session for each tempo
BB: One series) category in each series, in random order of tempo and on different days. During the same chronological period as Expts 6-12 Series 2ab.

Experimental Rooms:
PB Series 1a: Writer's lounge.
PB Series 1b and BB: College practice room.

Instructions: Using the same music and general performing method as in Expt 6: Make twenty-five immediately successive attempts at a "fast", "natural" or "slow" tempo, making the performances subjectively the same at each session.
Do not rall. at the end of any performance.

Music: Standard E flat Version.

Record: As Expt 8.

Timing:
PB Series 1a: Centisecond timer (2) Read and recorded by assistants.
PB Series 1b: Stopwatch (2) Operated, read and recorded by assistants.
BB: Stopwatch (2) Operated, read and recorded by PB.

Results and Observations

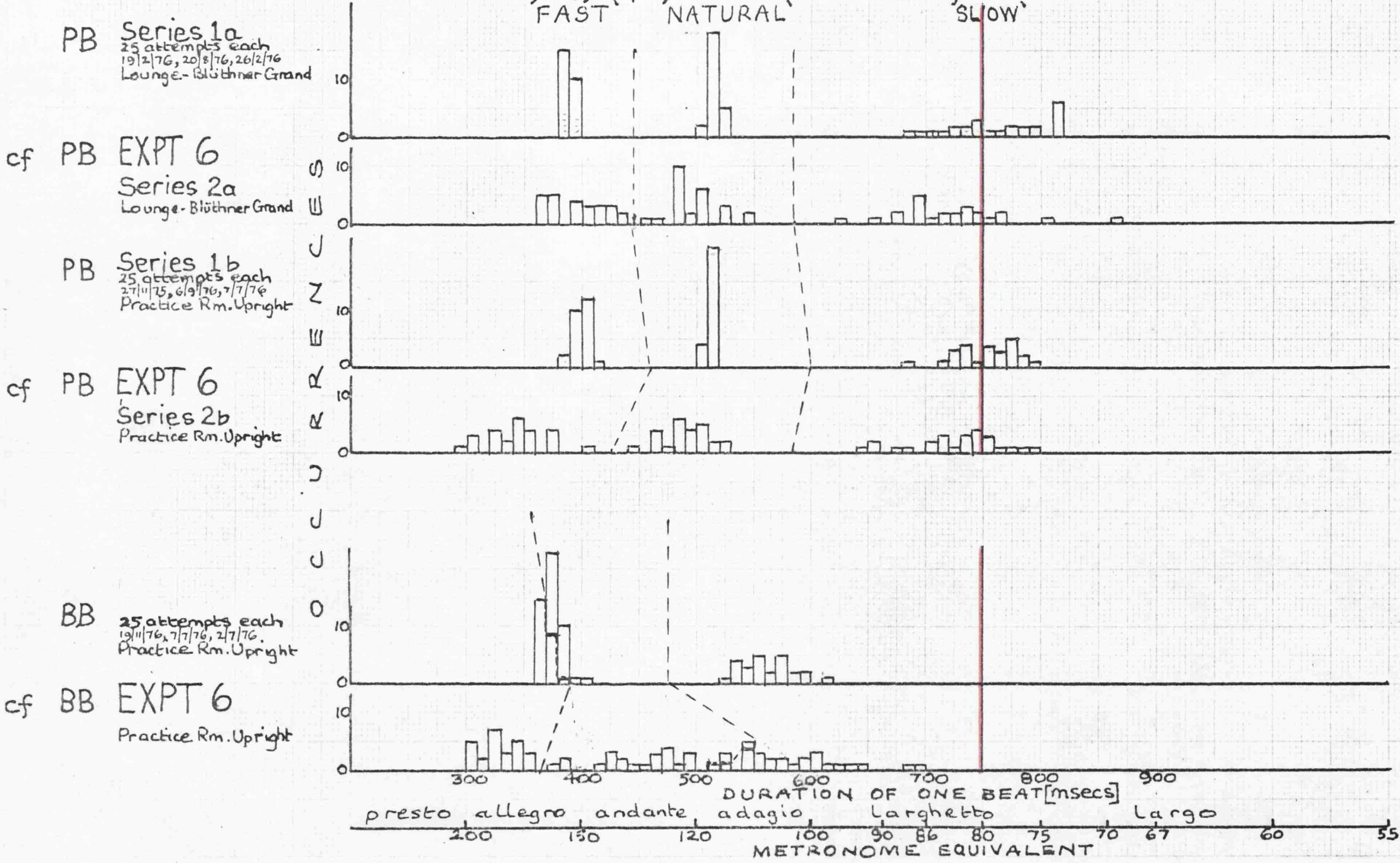
(a) Tempi Distributions and comparison with Expt 6 data

For the first time, the given distributions represent not only immediately successive attempts at the various tempo categories, but also a legitimate copying of each previous tempo. This, together with the observation that any given Expt 13 distribution need not necessarily coincide with the respective modal value in the Expt 6 distributions, must be borne in mind when studying Fig 13-$_1$.

FIG 13-1 EXPT 13

PIANO (Standard E♭ Version): IMMEDIATELY SUCCESSIVE ATTEMPTS AT 'FAST,' 'NATURAL' OR 'SLOW' TEMPO

(a) Tempi Distributions and cf with Expt 6 Data



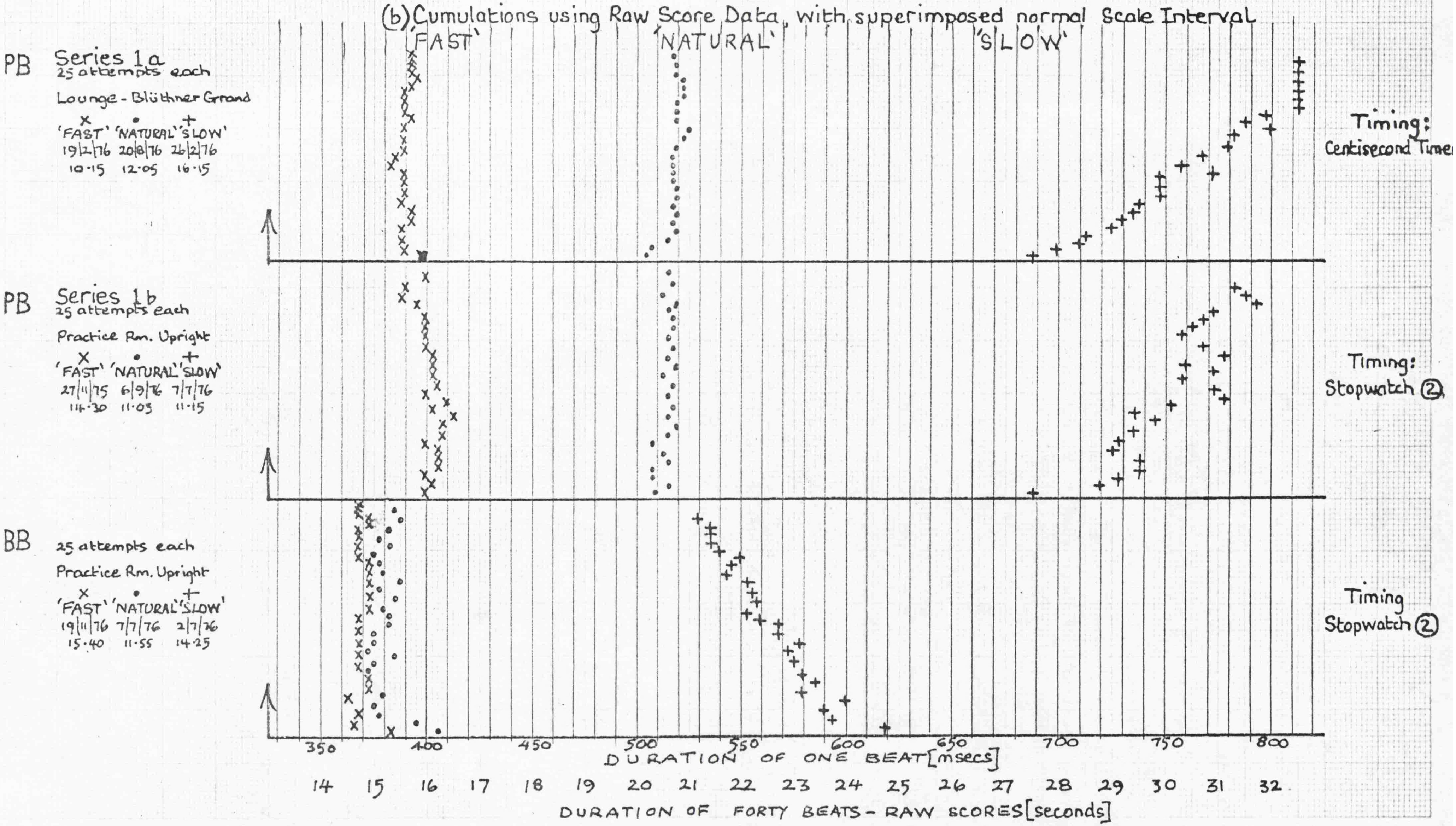
With regard to the appropriateness of the scale interval and the statistical definition of "same tempo", it is clear from Fig 13-_1 that both are amply confirmed in the "natural" tempo area for both Ss. Indeed, sensitivity to tempo change appears to be even more acute at a "natural" tempo than at a "fast" one. Although the range covered by "slow" tempi subjectively the same is surprisingly large in each series, in the "natural" tempo area which is our principle concern, the "same tempo" interval of 20 msecs includes nearly all the performances in each case. With regard to the Weber-Fechner law, it would appear that unless the "natural" tempo area be regarded as an indifference point, on this evidence there may not be a logarithmic type increase in sensitivity to tempo change from slow to fast speeds. On the other hand, as some Time Psychology literature has suggested, "natural" tempo or "preference" may indeed be equated with the tempo indifference point.

Fig 13-_1 makes it again clear that the two Ss do not share "preferences" in any of the three categories. Indeed, the "natural" tempi of BB are generally faster than PB's "fast" speeds. In addition, in the case of BB, tempi subjectively "fast" on one occasion overlap the distribution of "natural" tempi on another.

(b) Cumulations using Raw Score Data

Fig 13-_2, where the usual 10 msecs scale interval is superimposed onto a finer scale utilising the raw scores, makes both the more precise intra-interval variations and the cumulations clear. In both series the raw scores of the writer's "natural" tempi kept generally within an absolute range of 10 msecs, although actually occupying two adjacent standard scale intervals. In fact in Series 1a, in both the "fast" and "natural" speed cumulations, there are many tempi in succession where the total duration of forty beats maintained a consistency within 1/10 second. Comparing this degree of precision (centisecond timer) with the writer's performances in Series 1b (stopwatch) would suggest that the greater raw score variations in

FIG 13-2 EXPT 13 CONTD


(b) Cumulations using Raw Score Data, with superimposed normal Scale Interval

the latter series may be due to stopwatch timing inaccuracies rather than to actual tempo differences. Fig 13_{-1} shows that they were masked by the normal scale interval and may thus be ignored in all earlier experiments. A further interesting feature of the writer's cumulations is the sequence of six identical raw scores at the end of the Series 1a "slow" series, which considering the wide overall distribution is particularly surprising. There is nothing in the Expt 5 and Expt 6 data for this same standard music and performing method to suggest a "preference" in this area, although the writer's conducting sequences in Fig 1_{-3} cut off sharply close to this point.

With regard to any general tendency to get faster or slower during the immediately successive attempts at a subjectively similar tempo, no consistent observable trend occurs in the "fast" or "natural" tempo for either S. Fig 13_{-2} shows however that whereas PB was generally slower in successive "slow" attempts, BB became faster. There were also some occasions when both Ss reversed the prevailing direction, in addition to the absolutely steady conclusion to the PB Series 1a "slow" performances noted above. It is interesting that the writer's immediately successive performances in Expt P_5 usually became faster. Also of interest is that both PB's "slow" cumulations begin on the identical raw score.

In conclusion, both the selection of the normal scale interval and the associated statistical and empirical definitions of "same tempo" are vindicated as far as the relevant "natural" tempo area is concerned.

The next experiment occurred to the writer towards the end of the Main Programme. Speculation during Expt 13 performances suggested that it would be interesting to repeat the above immediately successive performing situation while varying the instrument or a musical factor. Consistency of performance could then be compared with the Expt 13 data. Any greater deviation from consistency while performing subjectively similar tempi could then be attributed to the effect on tempo or tempo estimation of a change in the variable employed. Further, the writer hoped to establish that any greater deviations from the order of consistency observed in Expt 13 were consistently in the direction of the "natural" speed for the respective instrument or music.

In each of the three series undertaken by the writer at the same time of day on three successive evenings, the first performance was always the Standard E flat Version at a "natural" tempo. This was then the norm with which any tempi deviations could be compared. Three other methods or versions from Expts 8, 9 and 11 respectively were then performed with it in repeating sequence, the twenty-fifth performance then being the Standard E flat Version in each case.

Experiment 14

Description

Aim:	In relation to Expt 13 data, to investigate whether tempi subjectively "the same" are affected by the use of different instruments or music.
Subject:	PB: One series. One session for each sequence of performing methods or versions. On three consecutive evenings at 2130 hrs.
Experimental Room:	Writer's lounge.
Instructions:	Make twenty-five immediately successive attempts, performing according to one of the following repeating sequences. Make all tempi subjectively the same as the Standard E flat Version played first at a "natural" speed:-

(Instruments)	(Harmonic Rhythm)	(Key)
Standard E flat Version	Standard E flat Version	Standard E flat Version
(Treble Recorder	(𝅗𝅥. one-in-a-bar	(A flat 8ve
(Glockenspiel	(𝅗𝅥. waltz	(A flat
(Lah	(𝅗𝅥 𝅘𝅥	(E
(Standard E flat (Version	(Standard E flat (Version	(Standard E flat (Version
I	II	III

Music: As indicated above.
Record: As Expt 8.
Timing: Centisecond Timer (2) Read and recorded by assistants.

Results and Observations

(a) Tempi Distributions

The presuppositions of the writer were generally very well supported by the results. Reference to Figs 13-2 and 14 show that the "natural" speed distributions in Expt 13 do indeed deviate less than those obtained here. The assumption may then be fairly made that the greater deviations were caused by the different methods or versions either pulling the intended tempo in the direction of the respective "natural" tempo preferences associated with them or by a parallel effect on tempo estimation. In this respect, the distribution for the key sequence, indicating a more accurate tempo repetition than the other two, suggests that change of pitch/key has a less potent effect on tempo than a change of instrument or harmonic rhythm. This is confirmed both by musical experience and the comparatively smaller inter-distribution differences noted in Expt 11.

(b) Cumulations

The three cumulations emphasise the last point made above. In addition, certain consistent relationships within a sequence may also be noted.

In Sequence I the Standard E flat Versions, apart from the first one, are remarkably similar in tempo to the lah performances that followed them. Also, both glockenspiel and treble recorder performances are invariably substantially relatively faster than the preceding performance on every occasion.

Sequence II shows similar consistent trends. The Standard E flat Version and 𝅗𝅥 ♩ harmonic rhythm that followed it are very similar in tempo, while the 𝅗𝅥. waltz version is always considerably faster than the 𝅗𝅥 ♩

FIG 14 EXPT 14 PERFORMING AS INDICATED (Standard Melody-Various Versions): IMMEDIATELY SUCCESSIVE ATTEMPTS AT INITIAL 'NATURAL' TEMPO

PB 25 attempts using given sequence schedule
Lounge [Blüthner Grand]

(III) Key Sequence:
29/9/76 21·30

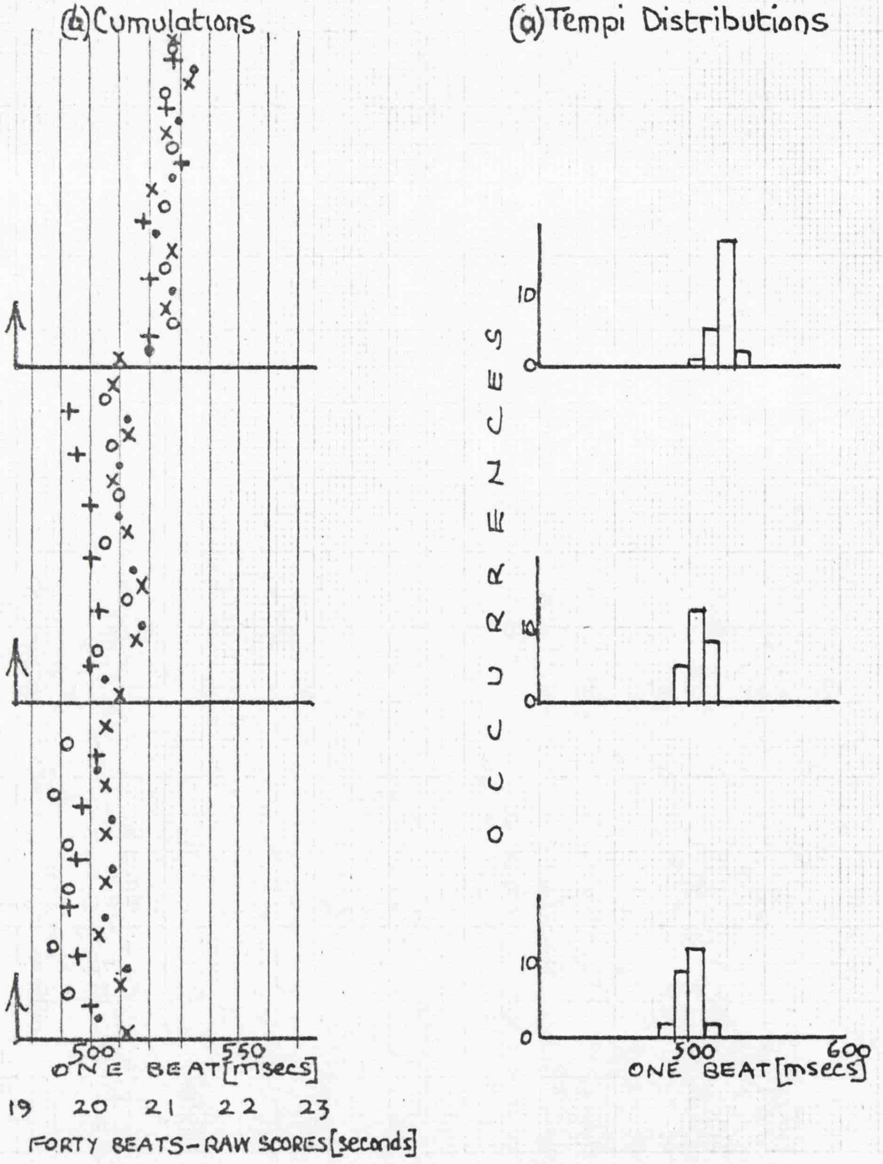
Repeating 6x:
- E etc. ·
- Standard E^b Version x
- A^b 8ve basso o
- A^b +
- E ·
- Standard E^b Version x

(II) Harmonic Rhythm Sequence:
28/9/76 21·30

Repeating 6x:
- d ♩ etc. ·
- Standard E^b Version x
- d. one-in-a-bar o
- d. waltz +
- d ♩ ·
- Standard E^b Version x

(I) Performing Methods Sequence:
27/9/76 21·30

Repeating 6x:
- Lah etc. ·
- Standard E^b Version x
- Treble Recorder o
- Glockenspiel +
- Lah ·
- Standard E^b Version x



harmonic rhythm played before it. Surprisingly, the 𝅗𝅥. one-in-a-bar performances are slower than the preceding waltz version.

It was to be expected that the more precise distribution for Sequence III would not reveal any substantial or consistent inter-key relationships.

Related to the above observations is the tendency for each method to maintain an absolute tempo consistency within the narrow range occupied by the distribution. In Sequence I no single method strays outside a real interval of 10 msecs - the standard scale interval used throughout the main programme and indicated by the additional lines on Fig 14. Also, the recorder and glockenspiel tempi are differentiated from the others. Rather greater absolute deviations are observed in Sequence II and, perhaps surprisingly, Sequence III, although the most consistent tempo, that of the A flat 8ve basso performances, comes from this last sequence.

The distributions for each method are not shown separately, but the mean deviations are quite clearly commensurate with the deviations obtained in Expt 13. With regard to the relationship of the various tempi trends to the direction of the true "natural" tempo for each method, reference to Figs 8-$_1$, 9-$_1$ and 11-$_1$ must also now be made. As Expt 14 immediately followed the completion of Series 2a and 2b in Expts 8-11, comparisons are best made with both those series in each case - there being little evidence of any apparent room/instrument effect. The relationships in Sequence I are generally indicative of the far greater distribution differences for "natural" tempi previously observed in Fig 8-$_1$ in direction, if not always in magnitude.

Apart from the surprising tendency noted in connection with the 𝅗𝅥. one-in-a-bar performances, Sequence II trends are also in accord with the "natural" tempi distributions of Expt 9. In Sequence III the A flat 8ve basso performances were not only very consistent, they were also very often marginally faster than the preceding tempo. This too was unexpected considering the trend noted in Expt 11. However, although it appears that the effect of key/pitch change can be more easily inhibited than that of other factors, the results generally reflect "natural" tempo trends despite the performances attempting to repeat a given tempo. In addition, in an indirect way, they confirm that the differences observed in Expts 8-11 were not the result of expectation and an unconscious contriving of the desired result by the writer.

The writer's introspection during the three sequences may be of interest. By the constraints of the experimental instructions it was never appropriate to say all the subsequent performances after each initial one were at a "natural" speed; indeed, some performances felt uncomfortable at the required tempo. Although during the performances in Sequences I and III the writer usually felt at ease, it was not so in Sequence II, where the waltz and one-in-a-bar rhythms felt very awkward, with difficulty experienced in coordinating the hands and sustaining pedal. The 𝅗𝅥 ♩ harmonic rhythm however, which did in fact produce virtually identical tempi to that of the E flat Standard Version, felt quite natural at the required speed.

Certain general inferences arising from these results may now briefly be repeated or made. Firstly, that pitch/key change is likely to have a smaller effect on tempo or tempo estimation than either a change in instrument or harmonic rhythm. This possibility has of course already been evident from the varying degrees of inter-method variation observed in Expts 8-11. Secondly, the method consistency noted within each sequence, gives considerable support to the view that an individual has a very precise sensitivity or control over tempo. However, the writer favours an alternative explanation concerned with a varying movement speed availability. The case for this will be detailed in the next chapter, where the writer's argument leans heavily on the data from this experiment in particular. Finally, as the writer was unaware of any change of tempo within the sequence, let alone any consistent relative or absolute method trends, any physiological control, sensitivity to change or aesthetic judgement cannot entirely be inhibited even in this contrived experimental situation.

The final experiment, conducted on two successive evenings, attempted to answer a question frequently posed by the writer during the changing speed sequences of Expts 1, 3 and 5. The concern was whether other smaller tempo changes could have been made between the tempi actually performed. Two sequences were therefore performed, both starting from the "natural" tempo, in which the smallest possible tempo changes respectively faster and slower were made. The data presentation uses again the finer raw score scale and superimposed standard scale interval as in Expts 13 and 14.

Experiment 15

Description

Aim: In relation to Expts 1, 3 and 5, to investigate the smallest possible tempo change in faster and slower speed sequences.

Subject: PB: One series. One session for each sequence, on successive days.

Experimental Room: Writer's lounge.

Instructions: Using the same music and general performing method as in Expt 5, play at a "natural" tempo, and then, in Sequence I: at successively faster tempi, and in Sequence II: at successively slower tempi, making minimal tempo changes in both sequences.

Music: Standard E flat Version.

Record: As Expt 8.

Timing: Centisecond Timer (2) Read and recorded by assistants.

Results and Observations

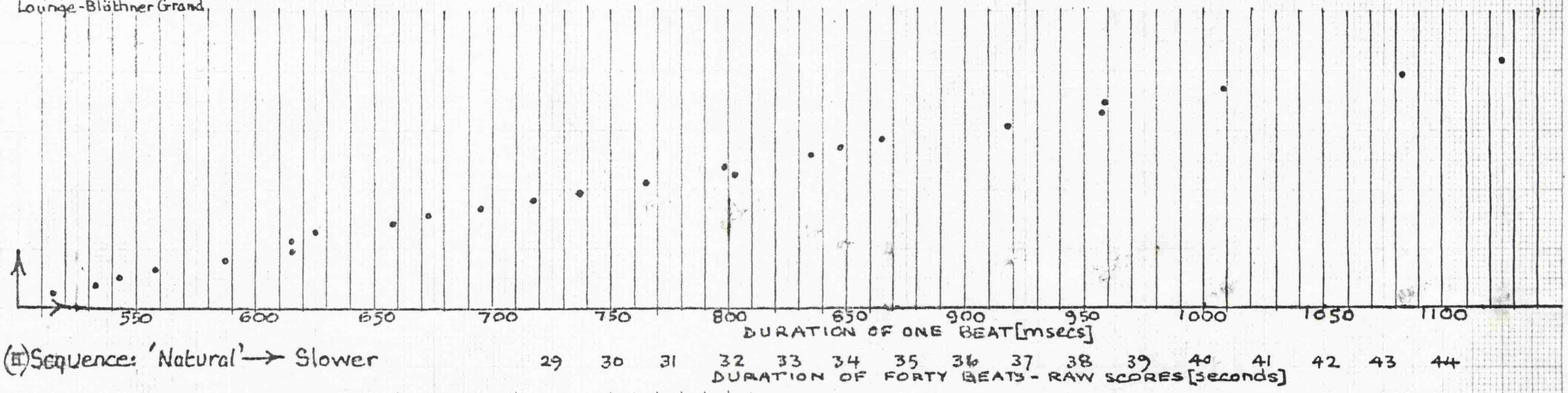
The two cumulations in Fig 15, both starting from a similar tempo may be regarded as one continuous series. Two observations may clearly be made; namely the progressively smaller and greater tempo differences (in terms of the duration of one beat) towards the faster and slower ends of the

FIG 15 EXPT 15 PIANO(Standard E^b Version): IMMEDIATELY SUCCESSIVE ATTEMPTS WITH MINIMAL CHANGES FROM INITIAL 'NATURAL' TEMPO

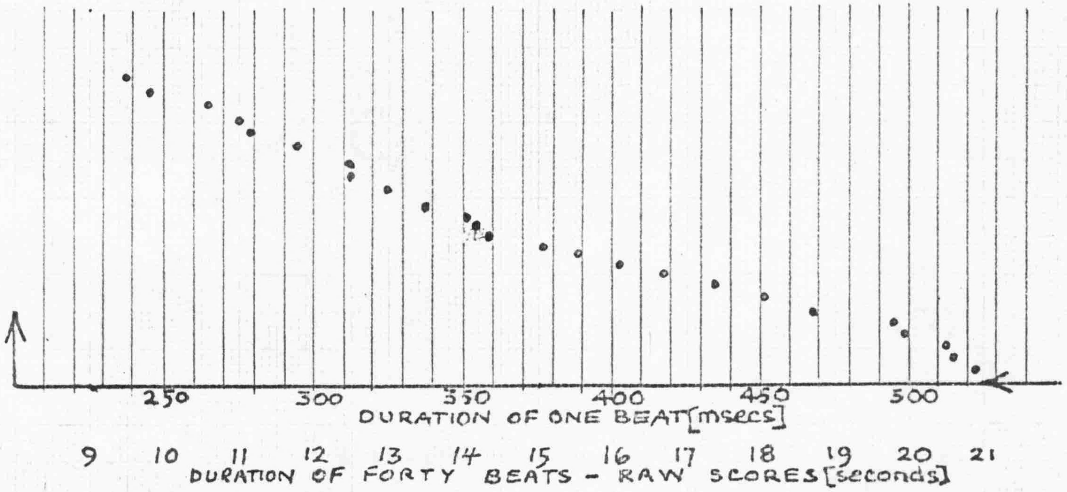
(a) Cumulations

PB

25 attempts
I 1/10/76, II 2/10/76
Lounge-Blüthner Grand



(II) Sequence: 'Natural' → Slower



(I) Sequence: Faster ← 'Natural'

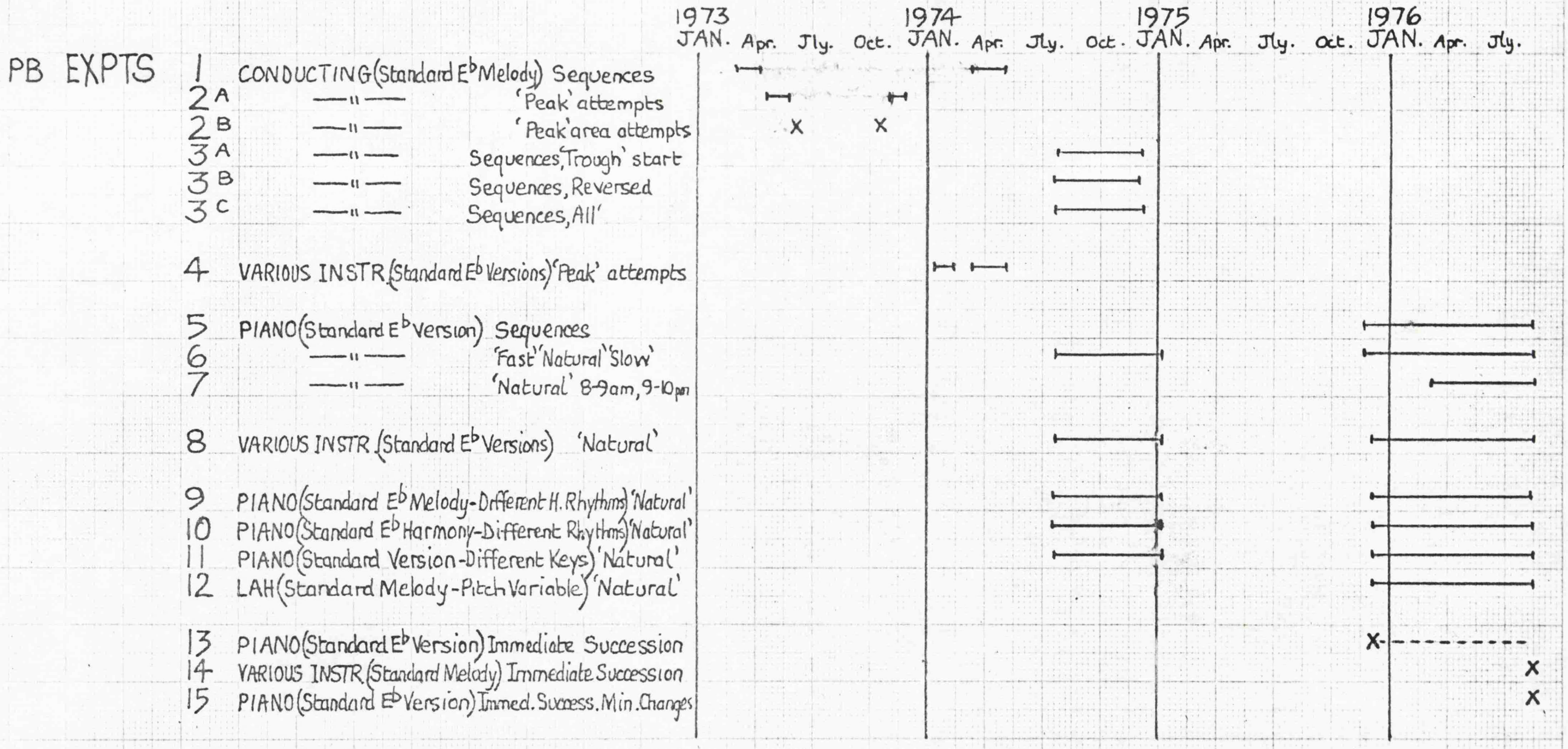
sequences respectively, and the comparative absence of more than one attempt within any single standard scale interval of 10 msecs. With regard to the former, although the absolute differences are not incremental, they do appear to approximate to some proportional or logarithmic relationship. This was noticed in connection with the earlier sequential experiments and generally supports the so-called Weber-Fechner law. The difference limen of the order of 2-4 per cent also accords well with the tempo discrimination literature in Chapter 1. That each standard scale interval rarely contains more than one performance is surprising, but further confirms its appropriateness for the presentation of Main Experimental Programme data.

A comparison with the tempo differences occurring in the Experiment 1, 3 and 5 sequences (Figs 1-8, 3-3 and 5-2), shows a very general tendency for the tempo differences in Expt 15 to be two to three times as small (in relation to beat duration) as those observed in the freer requirements of the earlier experiments. The writer is quite clear, from introspection during this experiment, that smaller tempo differences were impossible. Indeed, there was an occasion in both sequences when the identical raw score was obtained in two successive attempts. As in the case of Expt 3^B, the only tempo reversal occurred in the fast-slow sequence - and in the slow 800 msecs area where confusion was considered less likely. The writer suspects that the changes of tempo effected in Expt 15 were rather smaller than the conscious changes made in real performing situations to satisfy even the most subtle changes in interpretative intention. The last few performances of Sequence II were so slow that they were not only unmusical for such slight material but also required gross performing movements to accomplish a steady tempo. Finally, it is interesting that the four performances after the initial one in Sequence II also felt very uncomfortable.

This concludes the complete experimental programme. Fig 16 gives the chronological period of all PB experiments in the Main Programme, showing their temporal interrelationships. As far as can be ascertained, the tempi for any given experiment or performing method were not influenced by another preceding or concurrent one. To this end, interaction was minimised by ensuring that the various methods for the same or coincident experiments were alternated in random order, with rarely any similar-type performances given on the same day.

FIG 16 MAIN EXPERIMENTAL PROGRAMME

CHRONOLOGICAL PERIOD OF PB EXPERIMENTS SHOWING INTERRELATIONSHIPS



CHAPTER NINE

Summary and Conclusions

As any final observations must be made in the light of the undoubted weaknesses attending an investigation of this type, those weaknesses must first be enumerated:-

Weaknesses of the Experimental Programme

Although not primarily a psychophysical investigation, the experiments come within the general scope of the criticisms levelled by Roederer (1973) against all such work. Briefly, as they have already been detailed at the beginning of Chapter 1, they concern the effects of learning, conditioning and the subject's free will when repeated measurements of the same kind are made - particularly when only one subject is used. The application of this to these experiments is only too clear. Only one principal S was used and also just one basic piece of music - although good reasons have previously been advanced for both of these limitations. However, the possibility of unconscious tempo learning was always present, although the cumulations shown suggest that no anchor effect or learning took place. In addition, the writer knew both the desired results and the general direction of the results as they accumulated. Fortunately, the data from some supporting Ss, who certainly knew nothing of either, is more significant than the writer's in some cases. A further possible weakness suggested itself from introspection during the later series. It seemed that the "natural" speed attempts when a factor was varied were not always independent "natural" tempi, but instead were sometimes subjectively the same as those of the Standard E flat Version; the attempts apparently modified or confused by the differing musical or instrumental circumstances. If this is too severe a retrospective criticism, it is nevertheless possible that a rather similar unconscious attitude, arising from the memory of all previous experimental performances, often affected the writer's "natural" speeds. Although the attempt to repeat tempi deliberately was inhibited, the writer is not sure whether his actual attitude to tempo selection did not in fact produce the same undesirable effect. This attitude became clear enough to put into words only when all the experiments had been completed. It centred on a desire to avoid gross tempo differences with the tempo area first established as being "natural". Thus, quite different tempi that may well have been "natural" are possibly excluded from the data. Unfortunately, it is impossible to ascertain the validity of the above criticism. Certainly the generally unimodal and normal-type tempo distributions produced by the writer testify either to its validity or to the reality of a single "natural" preferential tempo in the situations employed.

The next major concern must be the unnaturalness of the performing requirements - inevitable in psychophysical research, but also in musical experiments of this type. Repeated performances of the same music under the same conditions rarely occur normally. In order to have both controlled conditions and a sufficient number of observations, an artificial programme will always be necessary. Not only were the experimental performances unlike those in real-life situations, there was also the disturbing effect of timing apparatus and procedures. Further, as in true natural performance the conscious attempt at a "natural" tempo is never required, the extra degree of self-consciousness and concern for the tempo may have prevented the achievement of the very quality desired. Indeed, both BB and the writer realised at the end of the programme that they often sought to satisfy physical rather than musical criteria. The basic music, too, was an additional source of artificiality. It had to be both short and of a bland quality, and capable of generating a series of different versions, each one artificially consistent with respect to the particular musical variable investigated. It was thus far removed both in scale and complexity from most music played in genuine performance situations.

Perhaps the most suspect aspect of the programme concerns the sequence experiments. The possibility that sequence data is a function of the type of sequence employed has already been discussed in detail in connection with the relevant experiments. Nevertheless, although a sequential performance at different tempi is the ultimate in artificial requirements, the writer saw no alternative way to obtain the data required.

With regard to the assumptions associated with the timing method, the writer is aware that all results may only be truly said to relate to average beat duration or total duration and not necessarily to tempo. The assumption of tempo steadiness within the total duration of forty beats may be defended on the grounds that, although rubato is a performing reality, musical movement is less concerned with the duration of individual beats than with the progression towards a longer-term musical "goal". Therefore, the duration of a unit longer than the beat, and even the bar, is a more accurate index of true tempo. In any case, the experimental measurement of single beat durations by means of kymograph is not only less accurate but also requires more disturbing apparatus. With the wisdom of hindsight, it was probably an error to base all the experiments on triple metre music, when duple metre is probably more condusive to a rigid tempo.

Certain other statistical matters may also be mentioned. Because so many different experiments were considered necessary, and also because of the great demands of each on time, not only were there comparatively few supporting subjects, but test retest procedures were also insufficiently applied in the case of the writer, and never in the case of other Ss. Further, many desirable additional and confirmatory experiments had to be abandoned. The control of the variables not being investigated also posed problems. For example Experiment 11, ostensibly concerned only with change of key/pitch, inevitably also involved changes in instrumental "feel" and touch.

Alternative interpretations of the data are also possible. A broad "peak" area in a sequence distribution could suggest several possibilities. For example:-

(i) A neutral area where many tempi are equally possible.

(ii) A broad area where a changing single "preference" occurs.

(iii) Inability to differentiate tempi within it.

Indeed, when more than one attempt in a sequence falls within the same broad "peak" area, reference to a singular "preference" area cannot legitimately be made. In addition, the use of an interval scale and histograms in the data presentation inevitably exaggerated any tendency for the distributions to assume the clear cut single or multimodal character required to support the hypothesis.

The final and perhaps most serious problem concerning data interpretation involves the possibility of circadian and longer-term variations in any tempi preference. However, as the effect of these would have been to broaden the distribution features or even obscure any precise but changing preference, the significant results that remain are even more noteworthy. In making comparisons, circadian variation may be discounted as the attempts by all Ss normally took place at random times during the day. The time of day was always recorded to ensure an adequate variety of times.

A number of more general criticisms remain to be made. Firstly, although all the student Ss could play the required music adequately, a greater fluency and corresponding faster tempi could be observed in some of the later piano performances. With further regard to this, the relationship between a subject's musical/rhythmic ability and tempo preference or distribution profile was never considered. Also, the effect of sex differences had to be ignored, as a fair comparison could not be made between PB, BB and the far less experienced female student musicians.

It is evident that only tentative general observations may be made from data principally obtained from one subject. In addition, it is clear that the writer performed at all reasonable tempi on occasions during the years of the experimental programme, at least within the degree of differential sensitivity defined by the 10 msecs scale interval. Therefore there appear to be no tempi that are not possible at some time or other. Despite the adherence to a strictly objective view of preference, where speeds actually performed are the only criterion, the writer was often preoccupied with the thought of all the alternative speeds that presumably could have been performed on each occasion. Another speculation often present concerned the impossibility of ever exactly repeating a total performing situation. Apart from circadian or other variations in biological parameters, the precise mood or attitude towards a performance can never be replicated. Thus, an ideal experiment can never be devised, and perhaps, because of the constant changing of so many personal variables, the concept of preference can only truly be applied to any one given occasion.

The above actual and potential weaknesses of both the experiments and any interpretation of the results must therefore correspondingly weaken any final Conclusions. Bearing in mind the small number of subjects employed, particular reservations must apply to any general or universal statements. However, most of the above particular criticisms are only applicable to the question of absolute preferences. As most of the significant data to be commented on later concern comparative preference or the effect on tempo of a change of musical circumstances, any Conclusions in this area have greater validity.

The Results as a Whole

Because of the lengthy and detailed discussion of each experiment already included in Chapter 8, this summary will concern principally those preference or tempo trends and characteristics that are a general feature of the results.

Discrete Preferences

The possibility of there being a range of discrete preferential tempi or areas remains likely. Surprisingly, the most convincing evidence does not come from the sequence experiments designed expressly for that purpose. However, there are suggestions from these that quite close and precise discrete "preferences" exist at the fast end of the tempo spectrum, with much broader preference areas elsewhere. Although the sequence distribution profiles may have been a function of the type of sequence employed, some confirmation of their absolute validity was obtained from the relationship of these profiles to the distributions for single "fast", "natural" and "slow" attempts. It is possible that the "peaks" observed in the sequence data and in the generally unimodal single attempt distributions were rendered less precise by long-term changes in tempo behaviour of the type noted in some early experiments. However, more convincing and unsolicited support for a discrete preference hypothesis comes from the data for Expts 13-15. It will however be more appropriate to discuss this fully later in relation to the writer's model for the generation of tempi. It will be shown that there is a distinct possibility that discrete preferences in performing situations may rest on the foundation of much more finely differentiated discretely available movement speeds.

Consistent Tempo Change with Change of Musical Situation

Significant differences or trends were invariably observed in the intra-subject tempi distributions for different instruments or music. Of the variables tested in Expts 8-11, changes in harmonic rhythm caused the greatest tempo differences, while key/pitch change, although consistent in its effect, made the smallest difference to tempo. No consistent significant tempo differences were observed when the writer performed the same experiment during the same chronological period, but using a different piano and room.

Although the results of the one subject to repeat the various experiments (PB) show a very consistent inter-method tempi relationship, that relationship was never consistently reflected in the two methods performed by the supporting Ss in Expts 8-11. Thus, the change of instrument, harmonic rhythm, melodic rhythm or key, while consistently affecting tempo for any individual, does not necessarily affect it in the same direction for all musicians. This is particularly true for those more subtle changes in a musical variable where a preconceived notion of its effect is less possible. The writer's own tempo trends were amply confirmed in Expt 14, where the experimental situation eliminated all the criticisms levelled in the first section.

The above concerns the comparative preferences of a subject for different tempi when the musical situation is changed. Comparative preferences also exist between different subjects performing the same music in the same way. Here again, significant tempi differences were invariably obtained. These two aspects of comparative preference confirm that no common tempo was generated either by the subject in different music, or by the instruments or music for different subjects.

With regard to the degree of absolute "preference" observed in any given individual musical situation, although no distribution was ever literally contained within the 20 msecs limits defined as the experimental "same tempo", the latter was a realistic ideal usually not too far removed from the actual data. Inasmuch as any distribution approaches this 20 msecs interval, so it may be said to be a preferred tempo.

One possible physical explanation for the precision of many "natural" speed distributions arises from the analysis of the Expt 1 conducting sequences. The "change of gear" tempo, present in both the PB and BB slow-fast conducting sequences has already been referred to in this respect. Although it was only positively identified in the PB conducting sequences, both subjects were aware of it in the Standard E flat Version sequences of Expt 5, and also of a corresponding and similar subjective "feel" about many of the single "natural" speed performances elsewhere. That the 400 msecs area conducting "change of gear" tempo has significance outside the context of sequential performances has been shown by the ease with which it can be reproduced in single attempt experiments. Whether every total physical performing situation produces its own particular "change of gear" tempo, different also for each musician, and whether that tempo corresponds to the "preferred" or "natural" tempo for each respective situation must however remain a matter for conjecture. For further elucidation, it would certainly be necessary, at the very least, to conduct sequence experiments using each of the instrumental and musical versions employed in this investigation.

Circadian or Long-Term Variation

Evidence for a long-term variation in the writer's tempi was given in the early experiments, where a sudden and consistent shift towards faster speeds was observed. However, in Expts 8-11, the relationship between the distributions for each Series 1 and the two later series shows no consistent trend either way. With regard to Circadian Variation, although the evidence is limited and inconclusive, Expt 7 suggests that mean tempi and possibly also their distribution may be affected by time of day. It was in fact found that the evening performances were the closest to the 20 msecs "same tempo" ideal obtained throughout the complete main programme. Whether that increased consistency was due to a corresponding consistency in body temperature or other physiological parameter cannot be answered by this investigation.

Finally, the results generally confirm the appropriateness of the chosen scale interval and the associated experimental definitions of "same speed" and "preference". Rarely did successive performances in a sequence occupy the same 10 msecs scale interval, even in Expt 15 where minimal tempo changes were required. In addition, Expt 13 confirmed that a realistic relationship existed in the relevant "natural" tempo area between a subjective "same speed" and the study's empirical definition as being those tempi occurring within two adjacent 10 msecs scale intervals.

Relationship of Results to the Literature and Possible Tempo Origins

In this section both the above results as a whole and some more specific data will be discussed in relation to the Literature and Speculation in Chapters 1-5. The chapters will be taken in order and only those aspects directly related to the writer's results will be mentioned.

Chapter 1: Time and Rhythm Psychology

Unitary Duration

Neither the 700 msecs unitary pulses of subjective time nor the 100 msecs lower limit appear to be reflected in the data, either as a single "preference" or in the form of a periodicity.

Duration and Tempo Indifference Intervals

With much of the Literature again referring to values of the order of 750 and 100 msecs there is clearly no relationship with the writer's results. The former figure remains interesting as it is the duration equivalent of the so-called "normal" or "just" tempo of MM 80. The sensitivity limen generally reported however are of interest. The limen associated with duration estimation, being in the 5-12 per cent range is roughly commensurate with the tempi differences observed in the normal sequence experiments, while the smaller 2-3 per cent limen generally given in the literature for multiple stimuli or tempo approximates to the minimal tempo differences obtained in Expt 15. There seems no obvious logical explanation for these correspondences but they remain interesting phenomena.

Weber Law

A Weber-Fechner type ratio generally exists between the absolute value of the tempo and the difference between adjacent tempi in the given sequential situations (Provided tempo is considered in terms of the duration of one beat. This will be questioned shortly). Thus, tempo sensitivity in performance appears to have similar characteristics to sensitivity in the passive comparison situations devised by the psychophysicists.

Tempo Absolute Indifference Interval

Apart from noting that this is the tempo with which all others are compared as being subjectively "fast" or "slow", and therefore the psychophysical equivalent of the "normal" tempo, little more need be said. Once again the 750 msecs area appears frequently in the literature. Surprisingly enough, it is only the writer's "slow" tempi that tend to accumulate in this area.

Duration and Tempo Estimation Factors

Although the writer believes many of these factors are relevant with regard to musical tempo performance and estimation, only two are directly related to the factors varied in the experiments. In both cases the results in the psychophysical field may be positively associated with the experimental data. Firstly, the tendency for higher sounds to appear longer is reflected in the faster tempi for higher keys. Although there may also be other than psychophysical factors contributing to this relationship, it is likely, for reasons explained in Chapter 3, that the higher sounds are played faster to compensate for their apparent longer duration. Secondly, the observation that evenly divided durations seem longer than irregularly divided ones agrees with the writer's faster tempi for ♫ compared with ♪.♬ beat subdivision.

Preferred Tapping Rates (By Comparison)

The broad agreement in the literature that the 500 msecs area represents the preferred tempo in a passive listening situation is certainly of interest. The only experimental evidence of some degree of common "preference", namely the combined subject distribution for the Standard E flat Version at a "natural" tempo, is centred on this 500 msecs value (Fig 6-2). The writer's performances in particular, when using this particular method, were always at around this figure. Nevertheless, this may just be a chance relationship, as the Standard E flat Version in no way represents an absolute musical or performing standard, being merely an arbitrary norm for the purposes of the experiments. It is therefore almost certain that other music would not have produced a similar combined subject mean tempo.

Rhythmic Imagery

The literature here is of considerable interest, not in direct relation to the results, but to the very necessary "mental" rehearsal that must precede any kind of performance, real or experimental. If the tempo of a performance is basically set before initiation and not modified extensively afterwards, then the vital necessity of a vivid "mental rehearsal" before initiation, with the rhythmic features often accompanied by some form of kinaesthesis, is beyond question. Only then can the potential tempo take into sufficient account the various tempo-affecting factors before they make their actual effect. Because of the nature of the experiments, the large number of performances given, the focus on tempo and the associated introspection, the writer was able to make some analysis of the "mental" and kinaesthetic events leading to tempo initiation. In addition to the various implicit movements associated with the imminent performance, there was invariably an intake of breath and upward movement of the shoulders immediately prior to commencement. Introspection at the time also strongly suggested that these preliminary actions absolutely decided the essential tempo. There is therefore a case for asserting that whatever follows, probably even an unsuspected heavy instrumental action, will have comparatively little effect on the actual performing tempo.

Chapter 2: Physiology, Personality and Movement Speeds

Fundamental Physiological Periodicities, Circadian and Other Variations

There is no evidence from either the sequential or single tempo distributions that the origin of tempi is the frequency of a known fundamental nervous periodicity. It could be argued that if a tempo quantum exists, the sequence analyses would have shown an incremental rather than a proportional relationship between adjacent tempi (but see below under

Chapter 4). Nevertheless, the possibility remains. Any changes due to the various biological rhythms and other factors operating over a long experimental period could have effectively masked the quantum generating the tempi at any given time.

With regard to a Circadian Variation in tempo there is a suggestion that the mean tempo,and possibly also the distribution profile,may be affected by time of day. There is also evidence that tempo may undergo longer-term changes. Unfortunately, as noted above, any short or longer-term variation has the effect of rendering less precise or explicit the data supporting any absolute preferences or trends that may exist in each situation.

The most recent work with regard to any relationship between pulse rate and movement speeds has detected no link, and this accords with the results from the writer's rather limited Pilot Experiments.

Universal Tempo Preference

This is the Movement equivalent of the musician's "normal" or "just" tempo and indeed, as in the case of many of the previously considered psychophysical parameters, the MM 60-80 area frequently occurs. Unfortunately, no such general preference can be observed in the writer's results.

Individual Preferred Tapping Rates (By Performing)

The general consensus from the literature is that individuals often have a "preference", but that wide individual differences exist. The experiments make it clear that a similar state of affairs exists in the world of musical tempi.

Individual Personal Tempi

As significant differences were observed between the various "natural" tempi distributions of the same subject, it is evident that the concept of one "Personal Tempo" is untenable, even restricting it to musical performance. Many writers in the literature also reject a monistic view of "Personal Tempo", some postulating group factors of speed as an alternative. The one really relevant aspect of this literature is the general agreement concerning intra-individual consistency in any given movement. This consistency is also one of the most obvious features of the writer's results.

Movement Analysis

Of particular interest in the literature here is the ballistic movement mentioned in connection with the actions of beating time. It appears that the duration of this down beat movement is surprisingly uniform and independent of both the tempo of the beating or the length of the stroke. Further, an obstacle interposed during this ballistic movement does not affect the tempo of the beating, suggesting again that the tempo of a series of movements is fixed before initiation and cannot easily be changed, even when subsequent external conditions such as an obstacle or increased loading are not anticipated. All this supports the writer's speculation concerning musical tempo initiation. In addition, it possibly explains why no change in mean "natural" tempo occurred when a different piano was used. Not only was the tempo "rehearsal" presumably unaffected by the different room/piano, but any subsequent unanticipated differences of action were not able to change the initiated speed to any great extent. However, Expt 14 has shown that very small modifications to the tempo probably did in fact occur, although requiring the impossible criterion of immediately successive performances in two different places, together with the use of a finer scale interval, for their detection.

The writer also asserts that the "change of gear" tempo in conducting sequences represents the first ballistic-type movements after the smoothly flowing actions of the slower tempi. Although all the faster tempi also required ballistic movements, there is the possibility that the actual "change of gear" point has a special movement significance. If so, it may also be the tempo most easily remembered or performed, and thus be a "preference" for that reason alone. Finally, it is interesting that the writer's "fast" performances in Expt 6, unlike the "natural" and "slow" ones, were affected by change of instrument. Perhaps the different instrumental actions became critical where facility for comfortable rapid movements was concerned.

Movement Training and Memory

If, as some writers have asserted, tempo plays an integral part in the learning of any skill or movement sequence, there are possible implications for the experimental results, and indeed all musical performance. There can of course be no suggestion that the slower tempi often used when practising a technical difficulty are necessarily related to the final performing tempo. Nevertheless, there is the possibility of a relationship between movements and their tempo that is integral rather than arbitrary. Whether this is merely a restatement of the general tendency towards intra-individual tempo consistency in any one physical movement or not, the results lend some credence to a proposition of this kind.

As far as unintentional learning of a tempo is concerned, there is no evidence of it from the writer's data. The first and last performances in a temporally-spaced series were equally likely to produce both modal and extreme values.

Chapter 3: Musical and Performing Factors

Standardisation of the Beat

As few subjects and only one arbitrarily-chosen piece of music were concerned in the experiments, general statements about the present validity of a "normal" tempo of MM 80 cannot be made. Nevertheless, this tempo has no apparent significance in relation to the data obtained, either directly, or in any mathematical relationship.

Harmony and Harmonic Rhythm

The relationship between mean tempo and harmonic rhythm is as predicted. The more frequent or more interesting the chords, the slower the tempo tends to be.

Melodic Rhythm

Significant tempo differences between the different versions employed were also obtained, but the differences were generally smaller than those between the harmonic rhythms tested.

Touch

An extremely significant tempo difference was obtained in the one series in which a comparison between legato and staccato piano playing was possible. As anticipated, the staccato performances were much faster.

Mode

Although the traditional major/minor-faster/slower relationship was confirmed in the writer's results, the data from the one student S concerned gave an insignificant trend in the opposite direction.

General Pitch Level and Key

A very interesting and consistent trend was observed in the writer's results positively relating a discrete series of progressively higher keys with gradually faster general tempi. Both the psychophysical literature and the mechanical and acoustical factors concerned support the observed tendency. However, somewhat contradictory student data suggests that even here, as in the other factors varied, individual response to a change in a variable, although consistent, may be in a different direction.

Conducting Movements

The contention that conducting is a genuine method of musical performance, and an expression of an "ideal" musical tempo has been made earlier. Indeed, introspection suggested that the experimental conducting tempi were those desired from imaginary performers. However when real sounds are heard, the feedback and other additional factors involved may well change a conductor's attitude to any theoretical ideal. There is certainly no indication from the experiments that the writer's conducting tempi were in any way related to the speeds at which the various other versions of the music were performed. Further, it was always difficult to eliminate the implicit vocal aspect of performance when beating time.

Type of Instrument

Quite clearly, a change of instrument type encourages consistently different tempi. Also clear is that any change of mean tempo may be in opposite directions for different subjects. It is interesting that the breath-based performances, as a group, tended to produce the more homogeneous tempi.

Action and Touch

Although a change of piano affected "fast" tempi, the writer's "natural" and "slow" speeds were apparently unaffected by changing to another piano (and room). This was unexpected, but as mentioned earlier, possibly attributable to the difficulty experienced in changing a speed once the initiatory movements have been "thrown". However, if the touch had been substantially different on the second instrument, the writer would have realised this and taken it into account before tempo initiation. There is thus no necessary conflict with the view that a stiffer mechanical action often necessitates a slower tempo.

Acoustics

The different performing room dimensions apparently made no consistent difference to the speeds. In any case, as neither room was comparable in size to a normal performing hall, their respective acoustical parameters were not likely to be of the order where an effect on tempo was to be expected.

Chapter 4: Possible Tempo Origins

As indicated previously, one particular model from those outlined in Chapter 4 now best explains the experimental results, at least in the case of the writer. This does not invalidate the possibility that alternative mechanisms or priorities may take precedence for other musicians, or indeed for the writer in different musical circumstances.

Firstly, there seems no reason to doubt that the writer's range of acceptable tempi or aesthetic judgement in each experimental situation was in fact determined by the relevant Broad Range factors enumerated in Chapter 3. It is then asserted that each precise tempo actually performed was dependent upon the available movement speeds within that range. The possibility of those movement speeds being discrete rather than continuous received considerable experimental support, as did the likelihood of there being different tempi available in each total physical/mechanical situation. Finally, there is the additional possibility that certain biological rhythms may have caused parallel fluctuations in movement speeds and/or tempo estimation. It is of course beyond the brief of this study to comment further here as to the fundamental generating source of these movement tempi.

The detailed argument in support of the above model now follows. Although many experiments made a general contribution, the writer's reasoning is principally based on a study and comparison of the very interesting results from Expts 13, 14 and 15; these experiments, all involving performances in immediate succession, were not designed for this express purpose. Particularly germane are the consistent tempo differences and trends observed in Expt 14. The same basic argument may be made from two starting points:-

It is clear from Expt 14 that different music and performing methods can very consistently change a subjectively identical tempo; this experiment at the same time indirectly generally confirming what has already been observed in Expts 8-11 regarding the relative potency of the factors tested, whether affecting tempo choice, tempo estimation or both. As the Expt 14 tempo changes for each performing method were not due to any intentional artistic tempo modification, they were most likely caused either by tempo judgement being affected by the changing musical circumstances or by different movement tempi being available each time. It is difficult to conceive of any tempo sensitivity, conscious or otherwise, as fine as the differences observed in Expt 14 so the latter view seems the more likely. Further, the data also indicates that the tempi differences that occurred in Expt 14 were generally smaller than the conscious minimal tempo changes in the 500 msecs area of Expt 15, where the performing method was not varied. The evidence is not conclusive but at least suggests that the different Expt 14 tempi were not the result of adjacent speeds being performed from the same discrete series. On the other hand, neither are the differences of the order of the even smaller fluctuations observed in Expt 13, where the immediately successive attempts at a "natural" tempo produced much more accurate tempo repetitions. However, it is interesting that the visual mean deviation for each separate method in Expt 14 approximates to the Expt 13 deviations, where all the performances were also of the same music and method. This order of deviation must represent the random and unaccountable element present in all the experiments, no doubt partly attributable to timing inaccuracy. The general precision of the writer's Expt 13 "natural" tempo attempts does in fact contribute to the argument more directly. A repetition accuracy of the order noted is much more readily attributable to a physical control of tempo rather than pure judgement. If any performer had to assess identity of tempo on the basis of the subjective duration of each beat in isolation, the smallest directionally consistent deviation from absolute accuracy would multiply according to the number of beats concerned. In this instance the forty beat error would have given much less consistent raw score durations than those actually obtained in Expt 13. One is therefore left with the likely conclusion that precise tempo has a physical basis and that the consistent small speed changes in Expt 14 associated with the different musical and instrumental conditions were due to parallel changes in the available movement tempi. However, the rather greater BB "natural" tempo fluctuations in Expt 13 necessitate a repetition of the reservation made elsewhere that the writer's data may not have universal validity in every respect in this or any other experiment.

Or again, from a slightly different point of view, as there were no gross tempo differences in any of the Expt 14 series, the general tempo area around 500 msecs was at least accessible for all the music and methods used. If a continuum of speeds had been available for each performing situation, it would surely have been theoretically possible to perform the mixed method sequences with the same accuracy as that observed in the single method sequences of Expt 13. We are now back to the argument advanced in the previous exposition of the writer's case. As the order of aesthetic or estimation sensitivity required to produce the consistent deviations in the Expt 14 data is both beyond that reported in the literature and inconsistent with the other results, the alternative possibility remains the viable one. That is, that the precise tempo performed each time was the available movement speed closest to that aimed for: the available movement speeds changing by the amount observed in each successive performing situation. Apart from philosophical objections to any assumptions of "what might have been", it is inconceivable that only one tempo is ever available at any given time. We thus return to the proposition that a musician, although unaware of the restriction, initiates one of the tempi available from the discrete series fixed by the total movement situation. That total situation must also include the temporal dimension. It is possibly due to the changing phases of the various biological rhythms, different moods and other personal factors that most temporally-spaced experimental attempts produced more diffused distributions, thus masking any more precise single or multiple modes representative of the true state of affairs at any given time. Nevertheless, the slow-fast sequence experiments primarily intended to investigate this very question also give a little further qualified support for the discrete preference hypothesis, - or perhaps, more accurately, the hypothesis of available discrete tempi.

However, care must be taken that the tempo differences within each slow-fast sequence are not automatically equated with the tempo differences between modal values in the distributions they produced. The former are a specific indication of tempo discrimination while the latter, although having some relevance in this connection, primarily represent differences between varying degrees of "preference".

The main argument detailed above does however require to be reconciled with a feature of the data apparently inconsistent with it. Although the visual evidence from the sequential analyses indicates that the tempi differences, both minimal and gross, always approximate to some kind of proportional relationship, the basic requirement for discretely available movement speeds of the kind postulated would seem to be a micro tempo generating constant incremental tempo differences. The difficulty may almost certainly be resolved by questioning two tacit assumptions. These assumptions unavoidably present to some degree in the writer's thinking throughout the study, are the too literal equating of tempo discrimination with tempo availability on the one hand, and beat duration with tempo movement on the other.

With regard to the former, although tempi differences in sequential situations were unequivocally proportional as presented in terms of duration, it does not necessarily follow that they were the only tempi physically available at each session. Every successive faster or slower tempo may well have been judged using the same discriminatory system associated in the psychophysical literature with passive listening experiments, but it is perhaps incorrect, however, to assume that other intermediate speeds were not physically available, particularly between the slower tempi. Thus, even if minimal tempo change is proportional and determined by tempo judgement, theoretical tempo availability could still be incremental. Indeed, it is this very possibility that made it necessary to refer to inconclusive evidence in connection with other speculation in an earlier paragraph.

Fortunately, however, this speculation need not be invalidated as the writer at present is inclined to continue asserting the soundness of this first assumption, believing the integrity of the second to be much more questionable.

Because of the method used in measuring tempo, and of the adoption of a linear beat duration scale in the data presentation, the writer has always had some concern that the duration of single beats would not be too literally equated with the movement tempi they purport to represent, and which is the investigations true concern. This error has not always been avoided. For example, the percentage duration differences quoted have always been termed "tempo" differences. Although beat duration represents tempo, it is not an exact equivalent. If a linear tempo scale or logarithmic scale of the kind rejected early in the study had been adopted, instead of a linear one based on beat duration, the visual sequential tempi differences would in fact have approximated to constant rather than proportional increments and correspondingly have changed the quoted percentage "tempo" differences.

Thus, the data is not necessarily at variance with the writer's model of tempo availability. Reconciliation of the discrete movement tempi hypothesis with the apparent non-incremental character of the "tempo" differences is achieved either by admitting the availability of intermediate non-performed speeds or by using a linear tempo and not a linear beat duration scale in the data presentation.

Whether any micro tempo would in fact produce a constant incremental range of speeds in terms of tempo rather than beat duration is beyond the writer's competence to pursue further. Indeed, the hypothesis is not invalidated even if it is subsequently shown that the steps are not incremental in any way. The term discrete does not necessarily imply equal steps of any kind.

We now come to an important point that has only had brief mention before. Namely, that the discrete preference hypothesis exists at two levels. In its most fundamental form it refers to the theoretical availability of very finely differentiated discrete movement speeds in every performing situation. At the practical level in real musical performance and in Expts 1-12, it refers to the selection of those discrete movement speeds that are performed more often, producing the observed broader but still discrete "preferences". Expt 15, and indeed the raw scores of all experiments, clearly show that within the restrictions of a very fine discrete movement system, "all" tempi are theoretically available for selection and can occasionally be performed, especially in situations designed to produce minimal tempo changes. Thus, those speeds that are in fact performed a significantly greater number of times may truly be said to be "preferred" in relation to the other available tempi less often performed.

One final objection can be levelled at the writer's discrete tempo availability hypothesis; in particular at the concept of tempo origin and control being based on a fundamental nervous periodicity or associated micro tempo. The autonomy of the individual beat or its tempo equivalent in controlling musical movement appears to be at variance with the type of longer-term tempo control also frequently postulated by the writer. Reconciliation is nevertheless possible. That same control of the single beat could also exercise a similar function over longer periods, explaining why the raw score total durations were so consistent in some experiments. Attributing consistent tempi to the duration control of longer musical periods is thus misleading, as it denies that a more fundamental mechanism may actually control both. What then could be the particular functions of the bar, phrase and longer periods in relation to tempo? One function is likely to be the overriding of any rubato so that the total phrase duration is unchanged, - a possible solution of the problem of rubato in relation to a discrete speed hypothesis is mentioned briefly at the end of this section.

Perhaps other functions have less to do directly with tempo than with musical phrasing and progression towards musical "goals" that are fixed in time because of the basic common control of both tempo and "goal". Indeed, whether the "goal" controls the tempo or vice versa, or whether, as suggested here they are dependent upon a common time-keeper, is yet a further question that can have no final answer in this study. Whatever the true situation however, having rhythmic "goals", both short and long-term, undoubtedly affects a performer's musical attitude between them.

Perhaps the final confirmation that the decisive factor in both tempo production and judgement is physiological and/or physical comes from the common experience of feeling discomfort when performing or listening to music. As that discomfort can usually be relieved by a very minor change in the tempo, it is unlikely that aesthetic criteria underly it. Further, not even eminent musicians are always affected in the same way, as evidenced by the disagreement over tempi among critics and reviewers. Thus, tempo is both an individual and very subtle matter, both in performance and appreciative response.

Finally, the problem of the synchronisation of individually different discretely available tempi in an ensemble situation may easily be overcome. If different total situations produce different available speeds, then an unconscious change of movement amplitude or other controllable performing variable would enable a musician to perform at any tempo. A similar mechanism could also be involved during the continuous tempo changes of rubato. This successfully reconciles the inescapable phenomena of rubato and all gradual tempo changes with the discrete tempi hypothesis and solves what might otherwise have been an intractable problem. Any theoretical account of tempo must satisfy the realities of everyday musical performance as well as experimental results.

Chapter 5: Specific Literature and General Views

Preferential Tempi by Performance

The relationship of the relevant literature to the writer's data need not be discussed as earlier work has been very limited in scope and method.

Tempo-Affecting Factors

The Elgar tempi studied by Turner (1938), where a slight change was noted with every change of theme within the same MM mark, can now be seen in the light of Expt 14. Although in the latter case it was not the theme that was changed, the principle of unconscious tempo modification in response to a change of performing or musical circumstances remains the same.

Longer-Term Duration Control

The interesting examples of overall timing consistency or unconscious control given in this section, although probably exceptional, further the case for musical durations longer than the beat contributing to or even controlling tempo. As mentioned above in connection with Chapter 4, this view has to be opposed to, or reconciled with, certain aspects of the proposed model of tempo availability. From introspection during performances, the writer was always conscious of the progression towards a rhythmic "goal", with a corresponding comparative unconcern for the placing of the intermediate beats performed on the way. In this connection there was also a ♩ ⁞ 𝅗𝅥 "up down" rhythmic feeling in each bar - the arsis and thesis of the tactus. Perhaps, any long-term duration control over whole movements or longer periods is of a different kind from the shorter-term rhythmic "goals" associated with the bar and phrase.

Relationship of Results to the Writer's Hypothesis:-

> Within the broad range of speeds appropriate for any total musical situation, a musician has one or more relatively precise discrete preferences. These change consistently when any individual, musical or performing factors are varied.

It is very difficult to separate the related concepts of absolute preference and preference change with changing musical circumstances. Quite clearly unchanging individual absolute preferences do not exist, and even when the musical and performing circumstances are apparently identical, circadian and other individual variations will always tend to increase the range of different tempi performed. However, a degree of absolute tempo preference for any given musical situation appears to be a reality for many of the musicians employed in the experimental programme. This becomes much more apparent when considered in relation to relative preference, as shown by a comparison of the tempi distributions for different instrumental or musical situations. Here the comparative preferences for different tempo areas are usually well marked, with statistically significant mean differences being recorded in many cases.

With regard to the sole availability of discretely separate movement tempi in any total situation, the argument for this has just been given. The general theoretical model of tempo origin and availability, first advanced in Chapter 4 and further developed in this chapter in the light of the experiments, remains the writer's position. However, the true nature of the fundamental origin of tempo, the physiological mechanisms involved, together with the precise characteristics of any discrete tempo differential must remain a matter for workers in other fields. In musical experiments, the limits of the scale interval, the accuracy of the timing procedure, still more the operation of short or long-term biological variations will always disguise the real situation. Further, we have to face the impossibility of ever knowing what other speeds could have been performed at any given time.

Thus, although the first part of the hypothesis must still remain a speculative area, it is clear that the results amply confirm the acceptance of the second part. Where gross differences in musical variables are concerned musicians would probably have accepted it without question in any case. What has been shown is that even very small changes in total musical circumstances consistently affect an individual's mean tempo.

Conclusions

Neither the literature nor the experiments support the possibility of there being one universal tempo favoured above all others. The old concept of a "normal" tempo bears no relation to contemporary practice - everyday musical experience testifying to the wide range of speeds possible both withinand between individuals. Neither can beat subdivision or any other arithmetic procedure relate general performing practice or the experimental tempi to one essential rate of musical movement. There is also little evidence that a given piece of music generates a similar tempo for different musicians, although a more interesting and complex musical situation than those employed in the experiments may have suggested otherwise.

The very considerable measure of support for the hypothesis has been noted above. Most subjects exhibited a degree of absolute tempo preference in each situation, although single distributions rarely approached the 20 msecs interval deemed to represent the experimental limits of "same tempo". What is more important however is that each individual's mean tempi invariably changed significantly in different musical circumstances. In addition, although intra-individual relative preferences were internally consistent, different subjects sometimes reacted in different ways to the same change in an instrumental or musical variable. It is evident, too, that the factors affecting tempo production almost certainly have a corresponding implication for tempo estimation. In this respect there is considerable evidence that the factors that can change tempo preference and which also vary during any given piece, may imperceptibly and perhaps continuously modify a performing tempo.

The results from several experiments also give encouragement to the likelihood of performing speeds being available from a discrete series rather than a continuum. They further suggest that any such series changes with changing musical circumstances, and also most likely with the different phases of circadian or longer-term biological rhythms. This availability of fixed tempi would thus be the final and decisive factor governing the precise tempo performed on any occasion.

Summing up, although the writer is reluctant to make general statements from the data for comparatively few musicians, and must in any case assume that the experiments typify genuine musical performance, one such can surely be made. Namely, musicians are likely to have consistent intra-individual tempo trends and characteristics, while showing great inter-individual diversity in both absolute and comparative tempo preferences.

Implications for Musical Practice and Education

The first clear implication of the writer's work, particularly arising from the helpful views of the musicians contributing to Chapter 5, is of the prime importance of Tempo in musical performance. Although the precise tempo initiated is possibly controlled by physical availability, its choice is dictated by many important criteria. The final tempo decision must be based on the resultant of many factors - sometimes quite contrary in their effect. Adequate "mental" preparation involving anticipation of the forthcoming music and implicit kinaesthetic "rehearsal" are necessary if a proper account is to be taken of them. It is also very evident that the requisites for successful tempo initiation should include an awareness of the factors that could confuse tempo judgement. The sequence experiments also suggest that musicians may find it harder to adjust to a slightly slower tempo than to a faster one, particularly when at the fast end of the tempo spectrum.

Implications for tempo memory, too, may be drawn from both literature and experiments. The confusion of tempo estimation or performance by a change in some factor, referred to above, is likely to affect short-term memory, and consequently cause tempi to change unconsciously when general pitch level, volume, orchestration or other variable changes during the same performance. Further, short and long-term variation in a musician's "internal clock" may also correspondingly affect tempi or estimation. Indeed, it is probably influences such as these that lead to the tempo miscalculations in record and radio studios of the kind referred to by the responding record and radio producers.

The study may also have some relevance to certain problems of ensemble and teaching. Any difficulty found in reconciling individual movement "preferences" in an instrumental ensemble situation, if not solved naturally, may possibly be overcome by the conscious modification of movement amplitude or other performing parameter, thus changing the tempi naturally available. Teachers, too, need to be made aware that individuals not only react differently to the various tempo criteria, but may also have their personal available performing movement tempi. A conflict could therefore be experienced when an attempt is made to impose a tempo on a pupil. Apart from any technical difficulties involved, an uncomfortable performance may result from such a procedure.

Finally, much of the above is true for the teaching of movement as well as musical skills. Indeed, it seems that the two subjects are related not just because of the traditional pairing of "Music and Movement" as commonly understood, or because of the factors common to the various classical dance steps and routines and the functional and artistic music associated with them, but also at the deeper level of human movement origins and characteristics.

This completes the Investigation. Although the writer is satisfied that the background has now been classified and established, only a very small portion of the experimental work necessary for a proper understanding of both general and individual tempo characteristics has thus far been attempted. Not only do the experiments described require repeating with more subjects, very many further lines of enquiry suggested by the literature, speculation and the results, remain for the writer and any subsequent workers in this field. It therefore remains for posterity to discover which aspects of the speculative background to tempo and its origins truly contribute to the performing tempi of musicians, and which experimental findings have an application beyond the limited procedures outlined herein.

Finally, as hinted in the Introduction and again at the end of Part A, the whole subject is so complex that many of its aspects may well remain forever a mystery. At the end of a study in which an attempt has been made to catalogue and measure what is possibly both indefinable and immeasurable, it is appropriate to let a philosopher have the last word. Although the concluding quotation was originally intended to apply to music generally, if applied to musical tempo in particular, it not only hints at the mystery, but is also a pre-echo of the present writer's speculation concerning a longer than one beat duration control over tempo, of which one is unaware:-

> Music is 'an unconscious exercise in arithmetic in which
> the mind does not know it is counting.'
> (Leibnitz)

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An Investigation into the Possible Origins and Nature of any Preferential Tempi in Musical Performance

Peter J.L. Brown. Summary of Ph.D. dissertation. University of Leicester, 1977.

In PART A an attempt was made to outline the total Background to performing tempi. The possible relevant areas of Time and Rhythm Psychology, Physiology, Personality and Movement Speeds, together with the many musical factors concerned, were detailed, and the literature reviewed. It was noted that multiples and fractions of 750 msecs frequently occurred in connection with the psychophysical parameters of discrimination and preference, and further that this figure is the duration equivalent of the traditional "normal" tempo of c. MM 80. Tempo origins and availability were discussed, together with the definitions of "choice" and "preference". Finally, the limited directly related experimental literature was supplemented by general views and answers to a questionnaire.

The experimental work in PART B was designed to test the following hypothesis:-

> Within the broad range of speeds appropriate for any total musical situation, a musician has one or more relatively precise discrete preferences. These change consistently when any individual, musical or performing factors are varied.

Because of the inevitable artificiality of the musical circumstances and the emphasis on one principal subject (the writer), conclusions must be tentative and preclude automatic universal application:-

1) The Hypothesis was generally supported. Individual mean tempi were significantly changed when the selected musical, instrumental or performing factors were varied. However, although intra-subject relative tempo preferences were consistent, not all subjects reacted in the same way to any given change. Several experiments supported the view that tempo choice is limited to different discretely available movement tempi in each total performing situation.

2) Factors affecting tempo production may have a corresponding implication for tempo estimation.

3) MM 80, the "normal" tempo, had no significance in relation to the experimental performances; neither could any other single tempo be associated unconditionally with one or more subjects, nor with any given musical circumstances.