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Rhythmic beat perception in a Down's syndrome population: A computerized measure of beat accuracy and beat interval response

Freeman, Isabel Autry, Ed.D.

The University of North Carolina at Greensboro, 1986

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RHYTHMIC BEAT PERCEPTION IN A DOWN'S SYNDROME POPULATION: A COMPUTERIZED MEASURE OF BEAT ACCURACY AND BEAT INTERVAL RESPONSE

by

Isabel A. Freeman

A Dissertation Submitted to
the Faculty of the Graduate School at
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Approved by

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APPROVAL PAGE

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The purpose of this investigation was to explore the manner in which 15 individuals with Down's syndrome deviated in rhythmic beat responses from a musical stimulus produced by a computer. Subjects ranged in age from 17-46 and had a mean WAIS Full Scale IQ of 57. A reference group of five non-retarded individuals provided comparison data.

Measured were: (1) the anticipation and delay of the time interval between beat responses; (2) the interval of time between each beat response in relation to the tempo of the musical example; and (3) a subject's beat intervals (demonstration of tempo) in relation to that subject's beat deviations from the computer beat. A custom-designed Commodore-64 computer program was utilized which contained components for music-editing, timing of the musical stimulus, recording of subject response, and plotting of derived interval and beat deviation data.

Under two conditions of a conducted visual cue and no cue offered, subjects were instructed to tap a steady beat on a button-press in response to an original three-voice composition. Recorded data identified subjects in three categories according to a mean beat interval accuracy. Also recorded was time occurring in milliseconds between the subject's beat placement and the computer's beat placement.

Results indicated significant differences between the reference group who exhibited more prebeat responses and the subjects who exhibited more postbeat responses under both conditions. Subjects with mean beat intervals similar in accuracy to that of the reference group did not demonstrate absolute beat deviations significantly different from the reference group during the cue condition, although significant differences were found between these groups when the cue was ceased. Results imply that an accurate tempo can be perceived, executed, yet be consistently delayed. The relevance of this for the music educator is the importance of beat performance evaluation and exaggerated visual cuing.

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Several people have graciously assisted in the completion of this investigation and the preparation of this document. I would like to acknowledge the fine efforts and dedication of those individuals who participated as subjects. Much appreciation goes to the devoted parents and group-home leaders who were very helpful by providing their time and cooperation. Also, gratitude is extended to Dr. James Sherbon, my advisor and chairman of the dissertation committee, whose interest in this study, continual guidance, and unwavering support were a motivating force in the progress of this investigation. Gratefully appreciated is the expert counsel and many hours of dedicated reading and advice-giving offered by other committee members: Mrs. Barbara Bair, Dr. Arthur Hunkins, Dr. Patricia Sink, Dr. Jacqueline Strong, and especially Dr. Jack Bardon who was a consistent source of encouragement.

A very special note of recognition, thanks, and love goes to my husband, Frank, whose custom-designed and developed computer programs enabled this study to be implemented and completed. His many abilities--scholarship, intuitive caring, editing, patience (indeed, tolerance!)--were gifts to an investigation he, too, found important in furthering knowledge about our friends with Down's syndrome.

Thank you and bless you my children: Audrie, Mickey, Steve, Shelley, Chris, Cathy, and Val for valuable assistance offered in various ways, from active participation in early experimental trials, to proofreading, to housekeeping. And last, but not least, a sincere thank you to my parents, Audrienne and Murchison Autry whose support was vital in all my educational endeavors.

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CHAPTER 1

INTRODUCTION AND PROBLEM

Few studies have been conducted dealing with the rhythmic performance of an adolescent or adult Down's syndrome population. Where there have been investigations of this kind, researchers have often employed methods that utilize only institutionalized individuals, or mixed samples of Down's syndrome and brain-damaged persons. Many procedures appear to ignore the need for objective measurement and rely heavily on subjective observations or conclusions derived from faulty procedures (e.g., an individual being credited with a poor performance when instructions were unclear).

Considering the subjectivity of much of the available data, this investigation objectively explored an observation by this investigator that these individuals, while very attentive to music, often present problems related to rhythmic beat performance. Subjectively noticed and subsequently explored in a pilot study was that in music ensemble settings Down's syndrome subjects provided rhythmic responses that occasionally seemed to be definable in terms of a delayed beat response. Observations on several subjects participating in individual or group rhythm trials indicated that these subjects frequently demonstrated an even, steady beat that was synchronized with, but occurred after, the "real beat" within the music. Other subjective evaluations of the investigated rhythmic performance under various conditions generated the following observations: (1) All rhythmic trials were improved when introducing the visual aid of a conductor maintaining a strong, steady beat. (2) When a conductor was not involved, visual cues were instrumental in a subject's changing a correct beat to an incorrect beat while observing a neighbor clapping an unsteady beat. (3) A steady beat was more easily maintained at moderate tempi (metronome marking of ♩=96) with music familiar to the subject, especially if the subject sang the familiar music while clapping. 4) The more body gestures implemented by the conductor to emphasize beat placement, and the more the subject employed bilateral body motion, the more accurate the performance. 5) No subject maintained a consistently steady beat on all selections, and none appropriately accelerated in tempo as the music accelerated. There was an indication that a "catch-up" period of time was required to accommodate the transition.

Therefore, the primary research questions were: In what manner would the beat responses of Down's syndrome individuals deviate from a stimulus produced by a computer? Would these responses be ahead, behind, or consistent with the stimulus? What would be the interval of time between each subject's beat, and would this interval of time deviate from the interval of time between each computer beat? If a

Down's syndrome subject were to demonstrate a beat delay (compared with a computer beat), but exhibit an interval of time between beats that was consistently accurate (compared with the interval of time between beats on a computer), it might then be assumed that perception of the beat was as accurate as that of a normal individual, but a problem existed between the perception of the stimulus and the execution of the response.

Also examined were, (1) the degree to which a visual cue of a conductor demonstrating tempo was related to performance; and (2) the study of possible relationships between the accuracy of the Down's syndrome individual's rhythmic performance and various subtests of the Wechsler Adult Intelligence Scale (WAIS [Wechsler, 1955]).

According to Gibson (1978), motor studies regarding Down's syndrome subjects have not yet offered a clear demonstration of the relationship between recognition of a stimulus (such as musical tempo) and the execution of a motor performance (such as clapping), or the relationship between the recognition of that stimulus and those counterparts necessary to initiate a movement. Considering the need for knowledge in this area, coupled with the need for assisting this particular group in creating an improved musical performance, this investigation attempted to demonstrate rhythmic response behaviors that could be measured and to explore possibilities for programming improvement. With this data implications could be drawn for enhancing the overall musical effectiveness of an ensemble to which these individuals belong, as well as increasing self-esteem--an important characteristic for motivating general productivity.

Refining the methodology for assessing beat placement was an important part of this study since interpretation of results would need to be in terms of an accepted standard that is more precise than a theoretical beat placement. For purposes of this investigation, accuracy of a beat was defined as a determined measurement on a graphic scale where possible beat deviations produced by Down's syndrome subjects were compared with a computer's programmed beat. The computer's beat was a programmed response synchronized in timing with the tempo of the musical stimulus. This computer beat was the standard against which the subject's responses were compared. The main objective of this computer methodology was to offer the capability of accurately comparing a rhythmic response with the computer's programmed beat response. However, an aurally accepted standard for an appropriate beat placement was considered likely to deviate from the computer standard, since the computer might provide accuracy beyond what any population sample approximates. The computer could not account for the split-second addition of time taken for sound to travel from the computer-produced stimulus to the subject's ear, nor could it account for the individual differences in the decoding and encoding processes of the person producing beat placement variations. This latter problem was deemed significant in the rhythmic performance patterns or capabilities of any individual, and perhaps especially so of Down's syndrome individuals. For the above reasons, a non-Down's-syndrome reference group was also recorded by the computer. Their responses were then compared with the Down's syndrome subjects' responses to determine whether the computer's beat was consistently ahead or behind an accepted standard for a rhythmic response.

Perhaps there is a problem measuring a Down's syndrome individual's perceptual abilities related to music due to difficulties preparing and/or executing a response. In order to initiate and maintain a steady beat to a piece of music, each beat response requires a process whereby an individual must perceive the stimulus, then select or prepare the response, then execute that response in the form of motor behavior.

Investigations of Down's syndrome subjects often present contradictory evidence regarding the nature of their inferior motor performance. For example, it is clinically observable that these individuals often exhibit clumsiness. However, the relationship between recognition of a stimulus and the execution of the motor response is not clearly indicated in the literature. Anwar (1981) stated that motor learning theories relate the time taken to prepare or select a response, called "response programming time" to the sequencing of movement components prior to a response movement execution. He further stated that:

> Auditory-motor perceptual integration is at a greater disadvantage than visual-motor integration....What is still not clear is whether delays in the time to react are due to the programming time prior to the onset of movement (response preparation) or due to response execution. The former would involve decisions of sequencing, direction extent, and torque of movement (p. 113).

Anwar's broad conclusion was that the development of motor set, drive potentials and motor impulsivity difference contribute to Down's syndrome subjects having longer reaction times.

The literature regarding perceptual-motor functions in these subjects has generally shown less impairment in visual perception tasks and increased difficulties in tasks involving auditory stimuli. Berkson (1960), and Frith and Frith (1974) noted in their investigations that mental age is not related to certain impairments of motor skill performance. Berkson observed that the length of time required for a visual stimulus to be exposed for recognition was not related to intellectual functioning, as he attempted to isolate perceptual, central and motor phases of reaction time. He found that mental age was related to the initiation and execution of a movement response. The speed of Down's syndrome subjects on both simple and complex movements was significantly slower than that of other mentally subnormal subjects. He concluded that even when IQ was controlled, the condition of Down's syndrome tended to correlate with response time. Frith and Frith revealed in a rotary pursuit tracking and finger tapping task that low mental age was not a sufficient condition for the impaired motor skill performance of his Down's syndrome sample. Gibson (1978) suggested that the Friths' study implied a dependence on immediate visual and kinesthetic feedback, and this is a compensation for the inability to evoke or express motor sequences.

There are other studies which indicate that auditory-motor integration is more impaired in Down's syndrome individuals than is the recognition of a visual stimulus. Hermelin (1964) found that Down's syndrome subjects, in contrast to epileptic and other retarded individuals, reacted faster to a light than to a sound signal. For the non-Down's syndrome retarded and the epileptic group, reaction time was faster to sound than to light. For the Down's syndrome group, a visual warning before the auditory signal resulted in a significantly faster reaction time.

There is a general post-mortem anatomical finding that the Down's syndrome cerebellum is disproportionately smaller than the remainder of the brain, as well as smaller than the cerebellum of those without Down's syndrome. According to some investigators this is an indication that peripheral physiology is more critical than auditory perception in the performance of motor skills related to auditory behavior. O'Connor and Hermelin (1961) concluded that reaction time and the quality of attention time is related to immaturity of the cerebellum.

In a study on auditory-evoked responses in Down's syndrome and idiopathic mental retardation, Straumanis, Shagass, and Overton (cited in Gibson, 1978) found that Down's syndrome subjects indicated a significantly greater first peak amplitude than did a comparison sample of college students. An attention-inhibition deficit associated with an auditory circuiting function was thought to be a cause for the longer first peak latency. These authors also indicated that the conduction system is only initially faulty.

Comparisons between scores on the Wechsler scales and other measures with Down's syndrome subjects are difficult to find. In fact, very few studies have been reported in which a Down's syndrome population has had intellectual functioning assessed with the Wechsler scales. When these scales were used, often little or no attention was focused on subtest-level performance, and the population studied was most often institutionalized children and adolescents. Frequently, there appeared to have been overgeneralizing from results that had been obtained. This, coupled with a lack of well-controlled studies, could have influenced those investigators who view Down's syndrome individuals as having severely limited intelligence. Such a view has possibly precluded attempting investigations that might link certain facets of intellectual functioning with another variable.

A question which emerged in consideration of the above findings and related to this study was: Are certain perceptual abilities intact, yet not accurately interpreted by the casual observer or researcher since overt expressive difficulties in the condition of Down's syndrome could be primarily related to motor behavior?

This study was based on an interest in accurately measuring the execution of a response or a series of responses (e.g., tapping a steady beat) and finding if that response is accurate--occurring regularly within a given time frame--yet consistently delayed (therefore, likely not perceived by an observer to be correct). The accurate measurement of a Down's syndrome individual's beat response to a musical stimulus provided by a computer could indicate that a steady beat was being tapped by that person. The computer measurement could also indicate the beat to be consistent with the beat tapped by a musically sophisticated "beat-tapper." However, the execution of that beat might be consistently delayed.

This investigation could have implications for a choral or band director in understanding the way in which to gain the best rhythmic response from an individual with Down's syndrome. Implications for psychologists interested in perception studies with Down's syndrome individuals could also be drawn.

CHAPTER 2

REVIEW OF LITERATURE

This review of literature is organized into sections which offer an overview of the condition of Down's syndrome. This condition is viewed by the investigator to be the most important component of the study. While hundreds of rhythmic investigations have been conducted, none has specifically and objectively addressed the issue of rhythmic performance by this population with attention to the psychological and physiological problems the condition itself presents. Objective quantification of beat placement for these individuals does not appear to exist in the traditional music or Down's syndrome literature.

The purpose of the format of this presentation is to cite investigations pertaining to characteristics of the Down's syndrome individual who may exhibit normal as well as aberrant functioning in several areas. It is to demonstrate that these persons may or may not vary greatly in a particular characteristic from normally functioning individuals, yet may vary greatly among themselves. While it is important to understand that stereotyping those with Down's syndrome can only relegate them to areas of unfair assessments, it is also important to understand that the motor behavior domain is an area of apparent across-theboard deficit. Motor behavior being implicated in the performance of any rhythmic response effort is therefore being treated as an integral part of this review.

The foundation for this investigation is an integration of multidisciplinary studies which lend impetus to an attempt at further defining and isolating rhythmic performance variables. An appreciation of the research complications that Down's syndrome presents is critical for designing a study that: (1) offers an objective methodology for examining the behavioral variable of beat accuracy; (2) has remedial implications for use by the music educator; (3) provides relevance for continued investigation.

Since this investigation is exploratory in nature and will demonstrate several observations, the material contained within the review is meant to assist in substantiating meaningful interpretations. Known facts regarding the syndrome as well as positions of tenuous hypotheses requiring further testing will be presented. In so doing, the investigator, as well as the reader, is prepared for increased discrimination between what is syndrome specific and what is not.

Substantive areas included in this chapter are the history, etiology, incidence, anatomical findings, neuropathologic indications, intellectual assessment, and perceptual-motor function of Down's syndrome. Concluding the review is material pertaining to the assessment of rhythmic potential in Down's syndrome individuals.

A Brief History Of The Down's syndrome Diagnosis

Some of the earliest documented descriptions of individuals with Down's syndrome appeared in the writings of Esquirol in 1838 and Seguin in 1846 (cited in Pueschel and Thuline, 1983). However, the first step in the research of this condition has been credited to Langdon Down, a London physician who, in 1866, described a disease picture which he referred to as "mongolian idiocy." While his description of features is considered by those in the medical profession to be classic, offering an excellent method of clinical diagnosis, his explanation of the syndrome as a racial deviation is unfounded (Warkany, Lemire, and Cohen, 1981).

The desire to force the Down's syndrome condition into Mendelian rules resulted in many etiological explanations. Some of these were based on observation and some on speculation, until the cytogenetic studies of Lejeune which were published in 1959 offered evidence that extra genetic material was associated with Down's syndrome. At a 1959 conference on the etiology of Down's syndrome, Lejeune, Gauthier, and Turpin (cited in Warkany, 1975) announced that they had obtained cells from tissue cultures of nine phenotypic children, all of whom had the genotype of 47 chromosomes in each cell. The extra chromosome was found to be morphologically similar to the two pairs of G group chromosomes (pairs 21 and 22) and was finally identified as being an extra number 21 chromosome (Donnell, Alfi, Rublee, and Koch, 1975).

In 1960, Polani, Briggs, Ford, Clarke, and Berg described a case where a phenotypic Down's syndrome female had 46 chromosomes with extra material being translocated to the 15th pair of chromosomes at the D group. In 1961, Clarke, Edwards, and Smallpiece described a condition known as mosaicism. An intelligent child with clinical mongoloid features (the phenotype, based on a clinical diagnosis) was found to have a substantial minority of cells with 47 chromosomes, and the majority of cells with 46 chromosomes (the genotype or karyotype based on cytogenetic study).

Etiology

Whether or not an individual is diagnosed as Down's syndrome generally depends on first establishing the clinical diagnosis, based on phenotype, then substantiating this with cytogenetic studies to determine the genotype. Following are descriptions of the genotypes trisomy 21, translocation Down's syndrome, and mosaicism.

Trisomy 21

The chromosome analysis of Down's syndrome individuals reveals that 90%-95% have a supernumerary chromosome in the g group with the 21st pair. This constitutes 47 chromosomes in each cell with the extra one being a number 21 (Pueschel and Thuline, 1983), and is the basis for the descriptive term for Down's syndrome being trisomy 21 (Nadler and Burton, 1980). The occurrence of this extra chromosome is due to nondisjunction, an event taking place when two members of a chromosome pair fail to segregate appropriately during the first or second stage of meiotic divisions in the formation of the egg or sperm. Causes of nondisjunction are hypothesized to be related to familial predisposition, aging of the ovum, and environmental factors (Donnell et al., 1975).

Translocation Down's syndrome

While trisomy 21 and Down's syndrome are often used interchangeably, Hook (1981) states that the terms should be reserved for a genotype and phenotype diagnosis, respectively (de la Cruz and Gerald, 1981). Approximately 4%-6% of Down's syndrome incidences are of the translocation type (Pueschel and Thuline, 1983) and may be due to environmental causes or familial predisposition, but are not maternal-age dependent (Warkany et al., 1981).

Typically, the Down's syndrome individual has the extra chromosome attached to another chromosome. The so-called "packaging" of the extra chromosomal material is different from trisomy 21, but the condition is clinically indistinguishable from the trisomic type (Nadler and Burton, 1980). In such cases approximately one-third are found to have a parent with 45 chromosomes and a balanced translocation of one of the 21st pair attaching to a D-group chromosome or another G-group chromosome. The parent would not have been afflicted with the disorder since an appropriate amount of chromosomal material was present. According to Hook (1981),

> The inclusion of translocation genotypes that will unknowingly occur in phenotypic surveys will contribute a small amount of "noise" which for the most part will not seriously distort inferences concerning 47,+21 that may be drawn from these studies (p.7).

However, Lilienfield and Benesch (1969), cite a report that trisomy 21 Down's syndrome individuals have higher levels of several enzymes than do translocation Down's syndrome individuals, reflecting a genetic overdose from the additional chromosome.

Mosaicism Down's syndrome

Approximately 1%-2% of Down's syndrome individuals are mosaic (Pueschel and Thuline, 1983), with occurrence due to a normal zygote and nondisjunction during mitosis, or due to a trisomic zygote that loses an extra chromosome during mitosis. Thus, mosaicism is exhibited by certain types of cells containing an extra chromosome and the remaining cells containing the normal number (Lilienfield and Benesch, 1969). There may be much variability, depending on the proportion of trisomic cells in the whole body or in a particular tissue. The phenotype may vary from a typically affected Down's syndrome appearance to a normal appearance (Donnell et al., 1975). It was estimated by Penrose and

Smith (1966, cited in Donnell et al., 1975) that approximately 10% of normal appearing mothers of Down's syndrome offspring are chromosomal mosaics. Hsu, Gertner, Leiter, and Hirshhorn (1971, cited in Donnell et al., 1975) describe finding mosaicism in fathers, also. However, Smith and Berg (1976, cited in Hook, 1981) estimate that not more than 1% of fathers are mosaics. Interestingly, Hamerton (1981) notes that it is theoretically impossible to rule out the presence of a second cell line in any study. Therefore, true incidence of mosaicism frequency becomes very difficult, if not impossible to establish.

Conclusion

Gibson (1978) notes that thousands of scientific investigations have been performed, and that they have offered explanations of causal factors and treatment strategies. However, why nondisjunction, translocation, and mosaicism of chromosomes occur is not yet understood. He also states that chromosomes are important in our under standing of evolution, and justifies his premise with the statement,

> Aneuploids advance evolution by adding genetic material through a process of nondisjunction and attachment, the initially surplus genetic load undergoing adaptive mutation more readily than established gene clusters. . . . Down's syndrome represents a research population which might advance our understanding of chromosomal dynamics. (p. 5)

Incidence

There is very little definitive information available on the incidence rates of Down's syndrome for many ethnic groups. However, Lilienfield and Benesch (1969) declare that all countries and races have reported the occurrence of the disorder. Nadler and Burton (1980), report that Down's syndrome occurs in the general population with an incidence of 1 in 700 live births, and is marked by increased incidence with increased maternal age. At age 25, the incidence is about 1 in 2000; at 35, 1 in 250-300; at 40, 1 in 100, and by 45, 1 in 40. According to Pueschel and Thuline (1983), approximately 75% to 85% of trisomy 21 embryos are thought to be spontaneously aborted.

While it has been shown that the risk of having a Down's syndrome child increases sharply with maternal age being between 30 and 45, Hara and Sasaki (1975, cited in Trunca, 1980) state that cytogenetically informative families indicate that paternal nondisjunction accounts for 40% of Down's syndrome cases.

Of special interest regarding the maternal age effect of producing a child with Down's syndrome are the following postulations from Lilienfield and Benesch's reports on epidemiology (1969):

(1) The uterus becomes less selective with age; therefore, would be more likely to implant a trisomic fertilized ovum.

(2) Nondisjunction is dependent on chemical or physical

processes associated with age, the meiotic division becoming irregular after an accumulation of independent accidents in these processes. (3) Older women would have a tendency for oocytes to be fertilized after several hours as opposed to younger women being more prone to having more immediate fertilization. (4) There is a cumulative effect of environmental agents such as viruses, radiation and chemicals.

There are many studies which indicate incidences of Down's syndrome vary periodically and with regard to geographic location and environmental factors. Haubold (1959, cited in Benda, 1960) suggests there is evidence that geographic differences and environmental factors, such as hepatitis or nutritional deficiencies are positively correlated with increased incidence of Down's syndrome. Hansen, Belmont, and Stein (1980) state that nonrandomness of Down's syndrome occurrence cannot be ruled out. However, the major difficulties in ascertaining the effects of viruses from the epidemiologic literature are discrepancies in study design and also the lack of a specific model that is being tested.

Distinctive Signs and Anatomical Findings

The ten most common signs of Down's syndrome found in the newborn are hypotonia, poor Moro reflex, hyperextensibility of joints, loose skin on posterior of neck, upslanting palpebral fissures, flat facial profile, short ears with overhanging helices, clinodactyly of the fifth fingers, simian creases, and dysplastic pelvis (Hall, 1964, cited in Warkany et al., 1981).

According to a detailed study of 50 Down's syndrome children (Levinson et al., 1955), no development characteristics or physical features were found to be constant. There was variability with regard to the extent and degree of the characteristics and in the frequency of their occurrence. Also, phenotypic features have been found to change with time. Pueschel and Thuline (1983) note that some stigmata may become more apparent as other physical findings become less evident.

While most Down's syndrome individuals can be readily recognized by their facial features, the appearance at birth may be typical. Ninety-five percent of all newborn Down's syndrome cases are diagnosed on the basis of hypotonia (Nadler and Burton, 1980). With later development, other common signs begin to be exhibited and include mental retardation, cardiovascular anomalies, and gastrointestinal malformations. Other pertinent anatomical and physiological findings are a reduced size of the cerebellum and brain stem, an underdeveloped thyroid gland, specific deficits in auditory sequencing, color retention, voice articulation, visual-motor tasks, and language development.

Many structural factors are related to the speech disorders associated with Down's syndrome. Gibson (1978), in reviewing the literature on delayed and defective speech in these cases cites the following problems: (1) phyaryngealization (raspy, gravel-voiced articulation), especially associated with ages four to fourteen; (2) a small and shortened buccal cavity which distorts vocal tract configuration from lips to pharynx, and may not offer enough room for the tongue which begins to protrude; (3) an edematous tongue which is fissured, not allowing for a distinction between the sounds of sh and s; and (4) a larynx high in the neck and with a thickening of fibrotic mucosa. According to Sanger (1975, cited in de la Cruz, 1977) the maxillary complex is lacking in a forward or frontal development, while the mandible exhibits normal growth. In addition to speech difficulties associated with oral cavity problems is the communication problem caused by the frequently found hearing loss in the Down's syndrome population. Rigrodsky, Prunty, and Glovsky (1961, cited in Gibson, 1978) found that 60% of his Down's syndrome sample displayed a hearing loss.

Warkany et al. (1981) report that early causes of death related to Down's syndrome are frequently associated with cardiovascular anomalies (20%), lower respiratory infections (8%), acute leukemia (1%) and gastrointestinal malformations (8%). Whereas a 50% mortality rate used to be common for young Down's syndrome children, early mortality has now been reduced to 30% due to improved medical techniques. (Gibson, 1978).

The life expectancy for those with Down's syndrome has changed greatly since the 1920's. According to Benda (1969), if an infant survived the first year of life, he could be expected to survive to age nine. By 1945, life expectancy had increased to 12-15 years of age. In 1964, a Down's syndrome individual residing in an institution had a life expectancy of 36 years, if surviving the first five years of life. Smith (1975) reports that life expectancy continues to improve for those with Down's syndrome. Many are now surviving into the sixth and seventh decade of life, a fact which perhaps accounts for why fewer investigations have been performed on this adult population.

As medical skills improve, not the least to be mentioned is that of constructive surgery to aid in a Down's syndrome individual's being more accepted by peers. An example of this is a six-year-old child who was scheduled to undergo surgery to remove epicanthal folds, lift the bridge of the nose, correct the eyelids,and reconstruct the chin with an inlay (Kousseff 1978).

Neuropathologic Indications

According to Crome, Cowie, and Slater (1966), a disproportionate and extreme diminution of brain stem and cerebellum weight was determined for Down's syndrome subjects. The average total brain weight was 76% of what would be considered normal. The weight of the brain stem and cerebellum was only 66% of what is considered to be normal. Not only were the brain stem and the cerebellum found to be smaller and weigh less than normal, but were smaller and weighed less as compared with other parts of the Down's syndrome brain. Crome et al. considered the degree of hypotonia experienced by a Down's syndrome individual to be associated with the small cerebellum and brain stem. Another finding specific to the brain anatomy and pertinent to findings of this investigator (Freeman, 1981), noting aphasic-type responses on the Wechsler Adult Intelligence Scale (WAIS), is the relative development of the frontal lobes being less than normal (Levi, 1936, cited in Benda, 1969).

A study regarding receptive language processing and ear advantage of Down's syndrome children has indicated that there is right-brain hemispheric dominance for this population (Hartley, 1985). This dominance appears to be related to the condition of Down's syndrome and not to retardation in general. Rather than the typical right ear advantage demonstrated by most individuals, the Down's syndrome children exhibited a left ear advantage for linguistic, serially-processed auditory stimuli, such as common objects and digits. According to Hartley, the right hemisphere is characterized by parallel, holistic, simultaneous processing. The left hemisphere is characterized by serial, analytic, sequential processing. The performance of the

Down's syndrome children implies that either the less efficient hemisphere is being used for linguistic processing or the right hemisphere is being used predominantly. The latter would seem to be a better opinion since Down's syndrome persons show deficits in sequential processing tasks, but not tasks of simultaneous processing.

With many Down's syndrome persons now experiencing a longer life span, there are studies to document pathologic observations of the brain in older individuals. The atrophic changes of Alzheimer's disease are often reported. A recent pathological study on transmitter deficits in the Down's syndrome brain of six persons over age 50 offered evidence of numerous senile plaques and neurofibrillary tangles within the cerebral cortex and hippocampus (Mann, Yates, Marcyniuk, and Ravinda, 1985). The one subject who was 31 years of age did not show these changes.

While Gibson (1978) states that neuropathologists have found Alzheimer changes in the Down's syndrome brain in all subjects over 35, other investigators not involved in morbidity studies have found that many older Down's syndrome subjects do not indicate early signs of senile dementia. Mittler (1977) found that in 5 of the 11 Down's syndrome population over 40 years of age that he studied, neuropathology showed progressive improvement. Owens, Dawson, and Losin (1971) report having found several subjects over age 35 with Down's syndrome to exhibit clinical dementia indicating Alzheimer's disease. In three of these subjects there was a greater abnormality in object identification, snout reflex, Babinski sign, and pulmomental sign.

According to Gunnarson (1945, cited in Gibson, 1978) who compared the electrocortical studies of Down's syndrome and non-Down's syndrome subjects, a slower alpha rhythm was found to be present with the Down's syndrome sample. Also noting the diffuse slow EEG activity of those with Down's syndrome, Warkany et al. (1981) reported the incidence of seizures in Down's syndrome to vary from less than 1% to nearly 10% of cases. This wide variation is likely due to differences in diagnostic criteria and various age ranges studied. The older population with evidencing cerebral changes would likely be more prone to having seizures.

Intellectual Assessment

As opposed to the earlier findings regarding Down's syndrome individuals being severely retarded, recent researchers have found that most function in the mild to moderate range of mental retardation, with a small number functioning in the borderline to low average range (Pueschel and Thuline, 1983).

Kousseff (1978) offers a case report of a six-year-old female with trisomy 21 and low average intelligence. This child had a karyotype of an extra chromosome in all 62 mitoses counted, therefore was presumed unlikely to be mosaic. Both parents and eight healthy siblings exposed her to intensive stimulation at home. She was placed in a program for children with psychomotor delay when she was nine months old. By age five years, nine months she had attained a Verbal IQ of 82, Performance IQ of 85, and a Full Scale IQ of 83 on the Wechsler Preschool and Primary Scale of Intelligence. There was average functioning on three of the subtests assumed to be academic predictors: Information, Vocabulary, and Arithmetic. Concurrent speech evaluations indicated results corresponding to intellectual performance.

Rosecrans (1971) also reports on a relatively high functioning Down's syndrome individual. This male subject was a translocation Down's syndrome who obtained a Verbal IQ of 86, a Performance IQ of 68, and a Full Scale IQ of 75 on the Wechsler Intelligence Scale for Children. This was considered by Rosecrans to be unusually high intellectual development.

Fishler (1975) found in a study of 255 Down's syndrome children that there was a leveling off of intellectual development by age four or five, with an expected scatter of 30 to 50 IQ points (instrument used and residential setting not stated).

Gibson (1978), however, reports a schema on 303 hospitalized Down's syndrome subjects, ages birth to 44, and found a plateau of intellectual functioning occurring at ages 4-5.5, 8.5-10.5, and 12.5-17. His report is based on mental age only. (The instrument and the IQ attained are not mentioned.) One important problem inherent in the testing of Down's syndrome individuals that Gibson recognizes is that test standardization literature assumes intellectual maturation to be the same for Down's syndrome as for most normals. The Down's syndrome population refutes this with their various central nervous system anomalies. (This is an excellent justification for use of the Wechsler scales with adult Down's syndrome individuals. The subtest levels offer valuable diagnostic criteria, and the concept of mental age is not used.) According to Gibson, who reviewed the literature on psychometric studies on Down's syndrome, there are many contradictions in findings pertaining to: (1) the degree of cognitive homogeneity for Down's syndrome over other discrete clinical entities of mental retardation; (2) language lag becoming more evident with increasing chronological age for Down's syndrome than for non-Down's syndrome samples; (3) number sense; and (4) intact or only slightly impaired rote memory.

With regard to sex differences in mental and motor measures for young Down's syndrome children, Harris (1983) found that there was no significant between-group differences for 9 females and eleven males when tested with the Bayley Scales of Infant Development. While previous research has shown slight superior performance on the part of Down's syndrome females as compared with males, Ramsey and Piper (1980), supporting Harris (1983), showed that females and males, age 3-30 months, performed similarly on the Griffiths Mental Development Scale and the Bayley Scales of Infant Development.

Warkany et al. (1981) and Fishler (1975) state that the mean IQ for mosaic Down's syndrome individuals is higher than for trisomy 21. However, Fishler, in comparing the IQ levels with percentage of normal cells in 15 mosaic Down's syndrome individuals, was unable to make valid conclusions about the complement of abnormal cells and intellectual status.

Psychometric findings in the literature are varied. It is the opinion of this investigator that some of the discrepancies reported may be due to sampling procedures. Warkany et al. (1981) note that home-reared subjects perform at a consistently higher level of intellectual functioning than their institutionalized counterparts. While this view is supported by several other investigators (Smith and Berg, 1976; Gibson, 1978; Kousseff, 1978), there are still many authors of texts who cite generalized IQ's without regard to the instrument used for assessment, where the individual resides, or the age of the population studied.

Perceptual-Motor Function

Theory

According to Anwar (1981), reaction time (RT) tasks are the most frequently used of all paradigms for assessing motor control. Information processing during voluntary movements lends itself easily to an experimental situation where a subject must respond with rapid short movements to an external stimulus. The subject, who encodes and associates the stimulus with tasks requirements, makes a number of decisions about how a movement will be selected and executed. Schmidt (1977) concludes that once an individual has identified the stimulus and selected the response, translating the abstract idea of a response into a set of muscular actions is required.

The first RT stage is stimulus-identification where the environment first communicates with the individual. The variables affecting it are input variables, and these affect the nature of the stimulus given to the system. Next is the "response-initiation stage" or "response-programming stage". In this stage the individual is called upon to perform complex events in the following order: recalling a program of action from the performer's memory, readying the program for activation, readying the motor system for the program, and initiating the movement. The variables affecting this stage are called output variables, and these affect the nature of the movement produced. This is the final set of processes allowing the individual to communicate with the environment.

Anwar (1981) states that presumably the sequencing of movement components takes place centrally in the central nervous system. The response-selection stage is responsible for associating a particular stimulus input with the appropriate output, and is a translation between the input and the output. It is thought that response selection and response preparation entails decision-making which requires time that covaries with complexity of the task (Klapp, 1976, cited in Anwar). Henry and Rogers (1960, cited in Anwar) affirm that a fast initiation time does not predict a fast movement time or execution time. Anwar's review of literature has led him to point out that within a given task, initiation time and movement time are not highly correlated. Yet, in Down's syndrome studies, the index of RT is generally considered to be the movement initiation and execution times combined.

While the above discussion focuses on movement, the following will briefly present Schmidt's (1982) accounting of how information is processed. He proposes a framework of memory systems to be thought of as a series of hypothetical "boxes." Items are placed into these boxes, and information transfers from box to box when certain kinds of information-processing operations are performed. Short-term sensory store (STSS), short-term memory (STM), and long-term memory (LTM) are the labels given to these boxes.

According to Schmidt (1982), the STSS memory system serves to hold massive amounts of information presented to it for a brief period of time. It accepts information presented with very little recoding. As new information comes forth, the old information is thought to fade with the passage of time. "Such a system can be proposed for each of the stimulus modalities--vision, touch, audition, kinesthesis, and so on" (p.115). Two features of the STSS are that of involving literal storage of information in terms of spatial location and form, and simple transformation of literal information received. The former feature is considered to be occurring in the stimulus-identification stage in motor behavior. The latter feature is thought to be associated with "analyzers" which interpret certain forms immediately before being stored, such as verticality or roughness. Many analyses can then be simultaneously performed, and interpretations can be simultaneously stored in STSS.

STM receives information from STSS or LTM. This "box" is characterized by having a limited capacity, a relatively short duration, and being a processing "workspace." The information processing activities which are practiced are in some way transferred from STM to LTM, the only difference between STM and LTM being the amount of time that information can be stored (Schmidt, 1982).

Related Down's syndrome Investigations

Gibson (1978) asserts that, "Proper separation of the influences of central, expressive and receptive variables will be required for a fuller appreciation of the developmental processes peculiar to Down's syndrome" (p.17). In addition, he states that while limiting explanations to the peripheral system is potentially hazardous, exclusive centralist hypotheses to explain psychomotor behavior are not satisfactory. This is because of the possibility that cognitive outputs for Down's syndrome are corrupted by difficulties with muscle tone, activation lability, modality strength, conduction latency, or coordination skill.

Anwar's review (1981) of current literature on motor function indicates that most mentally retarded persons have impaired kinesthetic or proprioceptive systems. Studies have indicated that when compared with a control group of normal children matched for mental age, there is usually a high correlation between mental age and motor proficiency. Down's syndrome subjects, however, present an exception to this rule by tending to show greater abnormalities on perceptual-motor tasks than do other mentally retarded individuals with whom the Down's syndrome subjects are matched for mental age. Anwar suggests that the information system may not be as deficient as was once assumed, and it may be that Down's syndrome individuals are unable to utilize motor programs efficiently. He cites one of the problems in assessing motor deficiency as being psychometric measures which have been developed and standardized on normal children. Such tests cannot have possibly taken into account the neuromotor deficits of Down's syndrome subjects.

Berkson (1960), and Frith and Frith (1974) appear to have been somewhat successful in isolating perceptual, central and motor phases of RT for Down's syndrome subjects in their respective investigations (referred to in Chapter I). Berkson considered response selection to be intact and the initiation and execution of a response to be a deficit when measuring visual threshold effects. Frith and Frith, investigating pursuit rotor tracking and finger tapping, found that, "Neither the level of mental development nor the degree of general mental retardation can account for these deficits" (p.300).

Further support for perception being intact on specific tasks comes from Dodd (unpublished manuscript, cited in Schiefelbusch and Lloyd, 1974). She compared ten normal and ten Down's syndrome children matched for mental age and social background, on phonological rules. She found that both groups used the same phonological rules, but the Down's syndrome children did so inconsistently, and phonological rules could not account for many of the errors. However, non-Down's syndrome mentally retarded children matched for mental age with normal children performed similarly to the normal group. In accounting for the differences in children with Down's syndrome, Schiefelbusch suggests that their performance may be a function of the failure of long-term motor programs. It is likely that since these children can be trained to offer a correct response in the appropriate context, "they can perceive the morphological differences and can abstract the appropriate rule" (p.256).

Several investigations have been undertaken to assess auditory and visuo-motor functioning, and most results have indicated the greater weakness to be in the auditory mode. Belmont (1971) states that present research concludes that Down's syndrome individuals are deficient in auditory-vocal processing relative to their own alternative channels and to the auditory-vocal processing of other retarded persons. "Perceptual and associative processing varies within the mongoloid population, and Down's syndrome are more or less capable than other retarded, depending upon which input-output channels are being considered" (p.74). According to him, indications are that the visuo-motor system is the strongest, and perhaps stronger than it is for other retarded.

Anwar (1981) also supports the theory that auditory-motor perceptual integration is inferior to the visuo-motor. However, he acknowledges that there is uncertainty as to whether delays in reaction are because of response preparation or response execution. His assertion based on many pertinent studies is that the development of motor set, drive potentials and motor impulsivity difference are contributing to the longer RTs in Down's syndrome. He also alludes to a study by McDonald and MacKay (1974) that reports a proactive interference of an auditory stimulus on recall. Because these studies indicate lowered auditory thresholds, he concludes there must be factors other than delays in perceiving the signal which play a part in the earlier reported longer RTs for an auditory stimulus.

Anwar (1981) believes that regardless of the experimental parameters used, there is evidence that slower times occur with a visual and auditory evoked stimulus, and the slowness is unlikely due to raised thresholds for these two modalities. "It is suggested that the information processing system required to make the discrete response is at fault. Within this context auditory-motor perceptual integration is at a greater disadvantage than visual-motor integration" (p.113).

Bilovski and Share (1965) found deficits in auditory-vocal channels on automatic-sequence levels for a Down's syndrome group of subjects who were tested by the Illinois Test of Psycholinguistic Abilities (ITPA). All subjects were compared with their own language-age norms as to the deviation from the norm on all of the subtests. The auditory channel indicated the greatest relative deficit within each process on the ITPA. Motor encoding was a strength, representing an ability to gesture ideas rather than vocalize them. Another strength was visual decoding, representing an ability to understand pictures when little or no vocal demands are offered. "Where the mode of reception is visual or where the mode of expression is motor, the subjects of this study perform well above their language norm" (p.81-82).

Precortical auditory information processing and brainstem-evoked potentials were investigated by Karrer, Nelson, and Galbraith (1979). They compared Down's syndrome, mixed mentally retarded, and normal adults. The Down's syndrome subjects showed the smallest amplitudes of evoked potentials for components recorded within the first ten milliseconds after auditory stimulation. Karrer et al. suggest that this might account for the slower recovery time, decreased excitatory processes or greater latency variability for Down's syndrome individuals. There were shorter latencies for all components except the acoustic nerve.

While Gibson (1978) states that some investigators claim that a reduced attention span and depressed arousal potential serve to inhibit learning efficiency in Down's syndrome, he offers the conjecture that the Down's syndrome clinical stereotype confuses this issue. There is a linguistic environment that is different from that of normal children due to a low verbal expectation. The verbal environment is not nurtured and may even be depleted. Accordingly, there are investigators who propose that many communication problems might be in the eyes of the beholder.

There is incomplete, but promising evidence supporting a specific mentation for Down's syndrome in visual, tactile, and auditory motor efficiency, according to Gibson (1978). He believes that mediation and locus of control are issues relegated to the province of experimental literature.

Assessment of Rhythmic Potential in Down's Syndrome

In general, the investigations concerning "musical sensitivity," rhythmic performance, pitch discrimination, or any musical undertaking by Down's syndrome subjects have yielded results primarily based on subjective interpretation. Sophisticated instrumentation for assessing any sort of musical endeavor has not been found to be utilized with this population.

A TAP MASTER was utilized by Kaplan (1977) to assess normal and educable mentally retarded children in a Test of Rhythmic Responsiveness. Correct tapping responses to beat, tempo change, metric accent, durational pattern, and ostinato were tabulated by a digital counter on a cassette player. Musical examples were tape recorded, and a wood-block stimulus pattern was superimposed on the taped examples. The children being tested listened to the stimulus through earphones and tapped according to the stimulus pattern. While there is no indication that responses occurring with the beat could be objectively assessed via this method, or that close approximations could be given credit, the investigator could evaluate certain types of responses. She found that there were significantly different degrees of success between the two groups in echo-tapping. The normal subjects were superior at this task.

An interesting technique for analyzing rhythmic drum responses was conducted by Henson, Parks, and Cotte (1977). They compared rhythmic musical responses of six normal and six retarded adults with an apparatus which included two microphones, two amplifiers, and a multiple pen event recorder. One pen recorded the investigator's standard beat to which the subjects' responses were compared. The other recorded the subjects' responses. The musical stimulus required the subject to respond with a steady beat. Results indicated that the normal group responded with an off-beat 20% of the time, and the retarded group responded as such 10% of the time. The retarded subjects also beat a standard 4/4 time approximately 25% more often than did the normals. Henson et al. did not attempt to measure the accuracy of the beat, nor the interval of time between beats.

Blacketer-Simmonds (1953) is cited by Gibson (1978) as performing the first sample-based research on rhythmic and musical abilities in Down's syndrome persons. A review of these studies as reported by Gibson indicates to this investigator that very little objective data was yielded from studies which based results on "expert" observation. Timing was judged by the ability to march in line and perform body bends to a musical accompaniment. Enjoyment of music was judged by observing sustained attention and facial expressions. The groups were also judged on ability to hum or sing simple melodies, and to imitate drum beat patterns presented by the instructor. The subjective results indicated that 43% and 33% of the Down's syndrome and non-Down's syndrome subjects, respectively, were good timekeepers. Enjoyment of music was thought to be similar in both groups. No individual was thought to be able to approximate a tune.

Peters (1970) investigated the basic musical sensitivity of normal and Down's syndrome children. Interested in assessing the capacity for developing musical skills of those with Down's syndrome, he examined the results of videotapes of subjects clapping hands in response to musical stimuli. Two graduate music students used a numerical scale, ranging from zero to four, to rate the subjects' responses. Findings indicated that an ability to perceive musical sounds and patterns, to synthesize, memorize and repeat them was at the level of young normal children, and responses to stimuli were not as accurate as those of the younger and older normal children.

Somewhat conflicting evidence is offered in a study performed by Stratford and Ching (1983) who were interested in assessing rhythm and time in the perception of Down's syndrome children. Subjects were ten Down's syndrome, ten non-Down's syndrome mentally retarded, and ten normal children matched in mental ages ranging from 31-61 months. The chronological ages for the Down's syndrome and non-Down's syndrome mentally retarded ranged from 9 to 17, and the chronological ages of the normal children ranged from 4 to 5. The task required attending to and shadowing rhythms by tapping them simultaneously with the stimuli. Three increasingly complex rhythms were used. Responses were collected from a tapping device, and then recorded on a computer. Normal and Down's syndrome children offered similar performances, whereas the non-Down's syndrome mentally retarded were weaker. Stratford and Ching suggest that at this level rhythmic discrimination is similar for Down's syndrome and normal individuals. One of the interesting points raised by the investigators is that when rhythmic performance is objectively measured in microseconds, not even skilled musicians can be perfectly accurate, although results sound so to the human ear.

Statement of Research Purpose

While the above rhythmic studies provide important clues regarding rhythmic behaviors, only the latter includes objective measures of performance; and alternatives for further objectifying the research are seldom considered. Developing objective methodology to study these behaviors effectively should be important in more accurately investigating certain inferences concerning rhythmic beat perception, then quantifying areas for programming improved rhythmic performance.

The purpose of this investigation was to explore the manner in which the rhythmic beat response of Down's syndrome individuals deviated from a musical stimulus produced by a computer, and considered the following research questions:

1. Will there be a measurable anticipation or delay of the beat response that is consistent or variable?
2. How will the interval of time between each beat response of the subject relate to the tempo of a musical example?
3. In what ways do these intervals of time that represent the subject's perception of tempo relate to the deviations of the subject's beats from the computer's standard?

With data compiled that relates to these measurements, there would be implications advanced for the music educator in increasing the overall musical effectiveness of the Down's syndrome individual demonstrating guided talents and increasing self-esteem. Also such data would be expected to provide inferences regarding auditory perceptual processes in the condition of Down's syndrome.

CHAPTER 3

PROCEDURES

The procedures for determining selection of subjects, measurement techniques, and analysis of data were structured to ensure a comprehensive assessment of beat placement perception in a Down's syndrome population. Behaviors both as a group and as individuals within that group were investigated with reference to (1) the interval of time occurring between a subject's own beat placements (the mean beat interval), (2) the interval of time occurring as a deviation between a subject's beat placement and a computer's beat placement (the computer beat deviation), and (3) the relationship of these temporal intervals to present intellectual functioning as measured by the Wechsler Adult Intelligence Scale (WAIS). A custom music program for the Commodore-64 (C-64) was written specifically for this investigation to assess beat placement data (Freeman, 1985) which was produced by a subject's tapping a "steady beat" response to a computer-generated musical example.

Subjects

Eight male and seven female Down's syndrome individuals, ranging in age from 17 to 46, served as subjects for this study. Their place of residence was in a noninstitutional setting, either with immediate family or in a small community-based group home. Twelve of these subjects were participants in a choral ensemble that assembled to rehearse one hour weekly at a local church, with performances in public concerts at least once each month. Subject participation in this ensemble ranged from a minimum of five to a maximum twelve years. In addition, there were two female subjects who had been members of the ensemble for three years prior to 1983, and one male subject who was a new member, joining the ensemble five months before the investigation began. These three subjects were included in the study to explore behaviors that could possibly be related to recency of membership. The selection of the other twelve subjects was intended for purposes of increasing the chances of securing a substantial degree of homogeneity in the population. All subjects were known by the investigator to possess a somewhat similar degree of "musical sophistication" that likely precluded certain contaminating factors that could exist in a randomly chosen Down's syndrome population: (1) The stability achieved from the homogeneous grouping ensured the ability of the subjects' comprehension of the instructions, e.g., a subject's ability to understand what was meant by a request to keep a steady beat. (2) Prior knowledge of the subjects' previous exposure to various types of musical experiences served as a control in that it was assumed any results from the study regarding certain deficits in this Down's syndrome population--whether musical or intellectual--would not be attributed to misunderstanding directions, unfamiliarity with the examiner, or inability of the examiner to know what was needed for tasks to be a pleasant endeavor.

Materials and Apparatus

Prior to testing, the investigator explained the nature of this investigation to all subjects and to interested parents and guardians of the subjects. It was requested that two forms be completed. One was a signed consent to participate (see Appendix A); the other was a brief personal history to be completed with the assistance of a parent or guardian (see Appendix B).

The WAIS was used for assessing intellectual functioning of the 15 subjects. It was decided not to administer the revised form of the WAIS (WAIS-R) since most of these subjects had previously been administered the WAIS in 1981 as part of the pilot study for this project. It was determined that more meaningful comparisons of the data could be available by retaining the same form.

The custom music program written for the purpose of obtaining objective measurement for this study had various components. Entitled MUSICBEAT (Freeman, 1985), the first component was written in BASIC computer language. This provided for easy entry, editing, and printing of the original three-voice compositions utilized as the musical examples (see Appendix E for manuscript of example, and Appendix C for the same example in computer format). Included in this component were menus for entering and editing of a triangle, square, sawtooth, or pulse waveform. The attack, decay, sustain, and release of the tones could be manipulated, along with tempo, intensity, filtering, and ring modulation settings.

Written in machine language, the second component had two main functions. First, it produced the musical example. It also recorded both a computer-derived "beat" and the beat of the subject who, while listening to the composition, responded by tapping a steady beat on a button-press device connected to the C-64 via the "joystick" port. This interface device was a black, eight-inch-square console unit with a red one-inch diameter button. The tapping device transformed each subject's mechanical rhythmic response to an electrical signal for purposes of recording the response.

Machine language was necessary so that the playing/ beat-recording phase could provide the required speed and accuracy needed to produce meaningful data. Rather than use the so-called "Jiffy Timer" available in the C-64, the built-in timer in the Complex Interface Adaptor chip was used. This provided a much higher resolution timer which measured temporal intervals in microseconds. With this configuration, accuracy could be obtained at about +/-1 ms, the time required for the program to "cycle" all start/stop times, compute intervals, set note values, check for a button tap, etc. Therefore, both the playing of a musical example and the recording of the computer and subject's beats were accomplished with extreme accuracy.

After each musical example was played, a recording of the computer and subject's beats were saved to disk for subsequent analysis. The program, BEATPLOT (Freeman, 1985), was used for plotting and displaying beat intervals and deviations (see Appendix D).

Testing Procedures

Practice Session

In a first practice session the 15 Down's syndrome subjects were assembled as a group. They were told that they would be clapping a steady beat to two original musical examples played by the C-64. The procedure involved listening (via a six-inch acoustic suspension speaker), clapping a steady beat when the investigator began conducting a steady beat as a visual cue, and continuing the clapping until the completion of the musical example. When it became apparent that this was understood, the group practice session started. Four seconds after stimulus onset, the investigator began conducting a steady beat as a visual cue. The visual cue continued for an additional ten seconds, then ceased as the subjects continued to clap until the end of the musical example. At the completion of this example, a second example was presented, and the subjects followed the same procedure. The subjects were then told that they would hear these examples again and have fun keeping a steady beat by tapping a button on a box attached to the computer. At this point the subjects were shown the computer which would provide the musical example, the table at which they would be seated, a button-press box, and a pillow on which to rest the arm so that comfortable alignment of the hand with the button could be achieved.

The second stage of the practice session involved each subject's assuming a comfortable position in front of the button-press and practicing a tapping motion at different speeds. The subject was then told that a musical example would be played, that tapping should begin as soon as the investigator began to conduct, and that tapping should continue after the conducting ceased until the end of the example. When the subject demonstrated readiness and understanding, the individual practice session started. As in the group practice session, four seconds after stimulus onset the investigator began conducting a steady beat as a visual cue and withdrew this cue after ten seconds. The subject followed the instructions, tapping a steady beat throughout the example. At the completion of this example, another example was played with the subject following the same procedure.

Experimental Session

A second session, held at a later time, served as the experimental situation where each subject met individually with the investigator. As in the practice session, each subject was seated at a table as described previously. The pillow was adjusted for maximum comfort and arm alignment with the button-press box which was approximately ten inches from the table's edge closest to the subject. The speaker from which the musical example was heard was also on the table and placed approximately 30 inches from the subject. The subject was put at ease with a few moments of conversation, then questioned about recollection of the group meeting where everyone had joined together to learn how to tap a steady beat at the computer. (This elicited a positive response from each subject when recalling the practice session.)

The following directions were then offered as the subject prepared for the testing situation:

> You will hear four different musical examples played on the computer. For each example, you will have a practice time. Ask me any questions you wish before and after each example. But don't ask anything during the playing of each example. Do you have any questions now? (time allowed for this). Okay, you are about to hear the computer play an example. You will begin by listening. Then, you will see me give you a cue as we did in the practice session. What do you do? Right, you tap. Remember that when I give the cue, you start tapping a steady beat on the button. (Investigator demonstrates with the subject's hand on the button.) I will keep conducting for awhile, and then I'm going to drop out. What do you do when I drop out? That's right, you keep on tapping. Ready? Okay, remember this time is for practice.

After the practice example, the subject was asked if there were any questions. When assured that the procedure was understood, the second trial using the same example was presented and recorded. Next, as a second treatment condition, the trial was presented with no conducting cue ever offered. Only an initial cue for the subject to begin tapping was given. This method of presentation continued for each of the four examples which had tempo markings ranging from 𝅗𝅥=58 to 𝅗𝅥=132. Three of the examples were written in a 4/4 meter, and the fourth began in 6/8, changing to 4/4 with the 𝅗𝅥.=𝅗𝅥 at the ninth measure.

Due to the voluminous data which were retrieved for the 15 subjects completing four rhythm trials (75 pages per subject), it was obvious that an attempt should be made to select a single best musical example for the investigation. After examining representative output from all four examples, the third example, T.I.C., was selected for analysis (see Appendix E). With an unchanging tempo of 𝅗𝅥=132 and a straightforward bass line of steady quarter notes, this composition elicited less erratic response than the other three compositions. In the second, and slowest, musical example some subjects tapped the quarter note value and others tapped the eighth note value. Also in this composition, erratic responses were frequently demonstrated, possibly due to more psychomotor decisions being available regarding the slower tempo. For the forth example in 6/8 time some subjects tapped the eighth note value while others tapped the quarter note or the dotted-quarter note value. The first musical example resulted in rhythmic responses that were similar to those demonstrated on the third example. However, this example was not selected for analysis since it was of shorter duration and contained the additional variable of syncopation. Finally, a secondary reason for selecting T.I.C. was the obvious enjoyment and interest the subjects displayed when responding to this piece; the humorous harmonies elicited smiles from most subjects as they performed the trial.

After all Down's syndrome subjects completed the experimental testing, five non-Down's syndrome individuals having had a minimum of two years of formal musical training were asked to follow the same procedure. They acted as a reference group to provide data for comparisons. Since there was no norm with which the individual subject's beats could be compared, this reference group's mean beat interval and computer beat deviation were compared with the C-64's theoretical standard beat to establish a reference point for subsequent comparisons. The investigator also performed the experimental task (no conducting cue variable presented) to ensure that the conducted visual cue presented to the subjects was as accurate as the beat demonstrated by the reference group.

Analysis of the Data

The method for objectively evaluating the data of the recorded rhythmic responses was to compare each subject's beat response on one original musical composition to the corresponding computer's beat (the theoretical standard), and to the beat responses of the reference group. Data were gathered for two conditions of presentation: (1) the investigator's providing a conducted visual cue on the first half of the composition as the subject tapped a button-press; and (2) the investigator's withdrawing the conducted cue on the second half of the composition as the subject continued tapping a steady beat on the button-press. Responses were graphed, and times and intervals were recorded on a computer printout which enabled the investigator to retrieve information in several areas.

A mean beat interval was first determined. This term was used to describe the amount of time in milliseconds for a subject to proceed from one beat to the next, and was indicative of the subject's perception of tempo. The investigator, recognizing that the mean beat interval could imply accuracy that might not be present, examined each profile to determine if any subjects demonstrated erratic beat lengths that when averaged produced an accurate beat interval. A standard deviation of this beat interval was calculated, then examined for a better understanding of the mean beat interval.

The next factor to be considered was the subject's magnitude of beat deviation from the computer's beat placement. The number of prebeat and postbeat deviations were recorded, as were the mean amount of prebeat, postbeat, and absolute deviation in milliseconds. Standard deviations of these three deviations were then computed. Also calculated was the range of each subject's computer beat deviations.

Subjects were then placed into one of three categories according to beat interval performance. Subjects who, during the conducted cue, had a mean beat interval within a range of +/- 2.5 ms of the computer beat interval of 450.55 ms were placed in Category I. Category II contained subjects whose mean beat interval during the cue condition was less than 443 ms. Category III contained those subjects whose mean beat interval during the cue condition was greater than 467 ms. There were eight subjects in Category I, four in Category II, and three in Category III. Although mean beat interval data and computer beat deviation data were also derived from beat performances of both the reference group and the investigator, no category assignment was made for them. Data from these individuals originally was intended to provide information concerning variability of the so-called "normal performance" in relation to the consistency of the computer. This information was acquired;

also observed among these individuals was a similarity of temporal contiguity with the computer standard beat. This provided the investigator with more opportunities for subsequent statistical comparisons than had at first been considered (see Chapter IV).

A Chi square was computed on the frequencies of prebeat and postbeat deviations for all subjects and the reference group, and between each category and the reference group. This was completed for the two conditions of cue and no cue.

To determine significant differences between each of the groups with regard to beat accuracy, $\underline{t}$ tests were performed on the mean absolute beat deviations. Under the cue condition and the no cue condition, $\underline{t}$ values were computed for differences between each category, and between each category and the reference group.

Pearson product-moment correlation coefficients were computed between the WAIS variables of Full Scale, Performance, and Verbal IQ; between the six subtest scaled scores of the Verbal section and the Verbal and Full-Scale IQs; between the five subtest scaled scores of the Performance section and the Performance and Full-Scale IQs; and between beat accuracy of the subjects and their attained Verbal, Performance, and Full Scale IQs.

As a supplement to the aforementioned statistical treatments, many observations were recorded for descriptive analysis. This multidimensional treatment of the data allowed interpretations to be developed regarding the original questions concerning a delayed and temporally accurate beat response for this Down's syndrome population. It also allowed for more subjective conclusions to be drawn for further study.

CHAPTER 4

RESULTS

Accuracy of beat placement in this Down's syndrome population was based on data obtained from two behavioral measures. The first to be identified was the interval of time in milliseconds occurring between the subject's own beat placements. This was referred to as a mean beat interval, and indicated the subject's demonstration of tempo. The second behavior to be explored was the interval of time in milliseconds occurring between the subject's beat placement and the computer's beat placement. This was referred to as the computer beat deviation, and indicated the subject's temporal accuracy in relation to the computer-generated beat.

An additional classification was used to isolate subjects' responses, and consisted of two conditions, cue and no cue. For purposes of comparisons of those subjects who were performing an accurate tempo with those subjects whose tempo was sufficiently inaccurate to yield beat deviations that were erratic, all subjects were placed into one of three categories. Category I contained those subjects whose mean beat interval during the cue condition was within +/-2.5 ms of the computer beat interval set at 450.56 ms (equivalent to the tempo of the musical example).

Category II contained subjects whose mean beat interval during the cue condition was of lesser magnitude than this accuracy (subjects whose mean beat intervals were a width of 367.6, 387.4, 405.4, 442.2, respectively). Category III contained those subjects whose mean beat interval during the cue condition was of greater magnitude than this accuracy (subjects whose mean beat intervals were a width of 467, 517.1, and 538.5, respectively). A reference group contained individuals each of whom demonstrated a mean beat interval that was within one millisecond of the computer beat interval regardless of cue condition.

Data were compiled on each subject and classified according to cue condition with regard to the following: (1) mean beat interval and standard deviation of the mean beat interval (see Table 1); (2) the total number of prebeat deviations (the subject's button-press response occurring prior to the computer beat), and the mean and standard deviation in milliseconds of the prebeat deviations; (3) the total number of postbeat deviations (the subject's button-press response occurring after the computer beat), and the mean and standard deviation in milliseconds of the postbeat deviations; and (4) the number of absolute deviations (deviation from the computer beat without regard to the whether the subject's beat occurred before or after the computer beat), and the mean and standard deviation in

TABLE 1

Mean Beat Interval and Standard Deviation in Milliseconds For Three Categories of Subjects

CATEGORY	SUBJ	CONDITION	MEAN BEAT INTERVAL	STANDARD DEVIATION
I	01	CUE	449.4	13.4
		NO CUE	450.6	17.4
	05	CUE	449.4	23.3
		NO CUE	450.9	14.5
	07	CUE	448.4	17.3
		NO CUE	449.2	17.5
	09	CUE	448.3	26.2
		NO CUE	456.3	43.9
	02	CUE	450.6	26.4
		NO CUE	436.1	32.9
	15	CUE	450.9	25.3
		NO CUE	453.8	26.6
	11	CUE	451.3	28.1
		NO CUE	456.6	50.3
	04	CUE	449.9	31.3
		NO CUE	451.6	29.1
II	12	CUE	442.2	26.3
		NO CUE	452.5	31.0
	03	CUE	405.4	32.9
		NO CUE	385.8	21.5
	06	CUE	387.4	29.7
		NO CUE	411.1	29.0
	13	CUE	367.6	39.5
		NO CUE	368.6	17.8
III	10	CUE	467.0	43.3
		NO CUE	444.9	47.3
	08	CUE	517.1	28.5
		NO CUE	499.6	52.2
	14	CUE	538.5	42.3
		NO CUE	533.9	50.1

TABLE 2

Deviations From Computer Beat in Milliseconds for Category I Subjects

		PREBEAT DEV.			POSTBEAT DEV.			ABSOLUTE DEV.		
SUBJ	CONDTN	NO.	MEAN	S.D.	NO.	MEAN	S.D.	NO.	MEAN	S.D.
01	CUE	6	10.4	2.5	30	21.6	11.5	36	19.7	11.4
	NO CUE	13	13.2	10.7	28	20.5	13.7	41	18.2	13.3
05	CUE	9	14.7	10.2	27	14.1	9.9	36	14.3	10.0
	NO CUE	10	9.6	4.7	31	15.1	6.7	41	13.7	6.7
07	CUE	17	18.9	15.4	29	27.6	12.9	36	25.9	13.9
	NO CUE	11	22.2	16.7	30	51.8	30.1	41	43.9	30.2
09	CUE	6	8.6	6.3	34	38.1	17.4	40	33.6	14.4
	NO CUE	5	48.6	68.7	35	30.3	21.4	40	32.6	32.1
02	CUE	12	21.1	21.8	24	23.2	9.9	36	22.5	15.0
	NO CUE	24	52.0	46.3	18	44.8	57.5	42	49.0	51.5
15	CUE	8	27.4	19.0	28	44.2	30.9	36	40.5	29.5
	NO CUE	3	9.7	1.4	41	44.0	33.0	44	41.7	33.0
11	CUE	6	12.4	7.7	30	47.8	29.9	36	41.8	30.4
	NO CUE	2	94.2	90.2	38	63.2	32.2	40	64.8	37.9
04	CUE	0	-	-	36	71.3	27.3	36	71.3	27.3
	NO CUE	7	21.4	15.7	34	29.0	20.0	41	27.7	20.4

milliseconds of the absolute deviations (see Tables 2, 3, and 4).

The mean beat interval performance and the beat deviation performance of the five individuals in the reference group were computed for the two conditions of cue and no cue (see Tables 5 and 6). The mean beat interval performance and the computer beat deviation performance of

TABLE 3

Deviations From Computer Beat in Milliseconds for Category II Subjects

		PREBEAT DEV.			POSTBEAT DEV.			ABSOLUTE DEV.		
SUBJ	CONDTN	NO.	MEAN	S.D.	NO.	MEAN	S.D.	NO.	MEAN	S.D.
12	CUE	17	38.0	54.4	20	55.0	63.2	37	47.2	59.9
	NO CUE	12	25.6	18.8	29	61.3	38.5	41	50.9	37.6
03	CUE	23	76.2	67.5	17	100.1	65.5	40	86.4	67.7
	NO CUE	24	109.3	68.2	24	120.0	67.4	48	114.6	67.7
06	CUE	22	114.9	58.0	20	115.4	67.7	42	115.2	62.8
	NO CUE	25	105.5	55.7	19	90.6	64.8	44	99.1	60.3
13	CUE	22	116.0	64.4	22	103.2	64.0	44	110.0	64.5
	NO CUE	27	105.1	67.7	23	107.7	64.7	50	106.3	66.3

TABLE 4

Deviations From Computer Beat in Milliseconds for Category III Subjects

		PREBEAT DEV.			POSTBEAT DEV.			ABSOLUTE DEV.		
SUBJ	CONDTN	NO.	MEAN	S.D.	NO.	MEAN	S.D.	NO.	MEAN	S.D.
10	CUE	9	106.3	71.7	26	94.7	59.6	35	97.7	63.1
	NO CUE	24	63.0	45.4	17	48.0	44.1	41	56.8	45.5
08	CUE	13	109.0	70.0	19	110.0	64.1	32	109.6	66.6
	NO CUE	11	119.2	62.1	26	106.9	55.1	37	110.6	57.6
14	CUE	10	112.8	64.2	20	121.7	63.2	30	118.8	63.7
	NO CUE	17	116.6	70.9	17	105.0	49.7	34	110.8	61.5

TABLE 5

Mean Beat Interval and Standard Deviation in Milliseconds for Reference Group

ID NO.	CONDITION	MEAN BEAT INTERVAL	STANDARD DEVIATION
01	CUE	450.5	20.0
	NO CUE	450.9	23.8
02	CUE	450.9	20.0
	NO CUE	450.0	19.8
03	CUE	451.1	16.4
	NO CUE	450.0	17.7
04	CUE	450.2	18.6
	NO CUE	451.1	13.0
05	CUE	451.2	36.9
	NO CUE	450.5	26.6

TABLE 6

Deviations from Computer Beat in Milliseconds For Reference Group

		PREBEAT		POSTBEAT		ABSOLUTE	
ID NO.	CONDTN	NO.	MEAN	NO.	MEAN	NO.	MEAN
01	Cue	15	17.8	21	22.2	36	20.4
	No Cue	11	15.1	30	21.6	41	19.9
02	Cue	16	12.3	20	13.2	36	12.9
	No Cue	22	19.2	19	12.3	41	16.0
03	Cue	36	39.4	0	-	36	39.4
	No Cue	28	14.4	13	10.8	41	13.2
04	Cue	36	63.9	0	-	36	63.9
	No Cue	31	22.2	10	15.8	41	20.7
05	Cue	12	28.5	24	22.3	36	24.4
	No Cue	25	20.0	16	16.7	41	18.7

the investigator were also calculated. Since the condition for all subjects and the reference group had been provided by the investigator, there was no equivalent cue condition available for the investigator. Therefore, for purposes of further control and to obtain a comparison, the investigator provided data without cue on the entire musical example, and reported data in the same manner and with the same two divisions of the musical example as was equivalent to the divisions of cue condition and no cue condition, respectively, for each of the subjects (see Tables 7 and 8).

TABLE 7

Mean Beat Interval and Standard Deviation in Milliseconds for Investigator

CONDITION	MEAN BEAT INTERVAL	STANDARD DEVIATION
CUE[a]	450.1	14.2
NO-CUE	450.0	13.6

a. This was the section of the musical example that was the stimulus for the cue condition. There was no cue provided the investigator.

Chi-Square Analyses of Deviation Frequencies

Eight chi-square analyses were computed on the total number of prebeat and postbeat deviations that each subject and each individual in the reference group had demonstrated. These comparison data were placed in two groups according to prebeat and postbeat number of deviations for the cue and no cue conditions. Groups were paired as follows: reference group with all subjects, reference group with Category I subjects, reference group with Category II subjects, reference group with Category III subjects.

TABLE 8

Deviations from Computer Beat in Milliseconds for Investigator

CONDITION	PREBEAT		POSTBEAT		ABSOLUTE	
	NO.	MEAN	NO.	MEAN	NO.	MEAN
CUE[a]	25	12.4	11	15.0	36	13.8
NO-CUE	30	15.6	11	9.6	41	13.9

a. This was the section of the musical example that was the stimulus for the cue condition. There was no cue provided the investigator.

A significant difference between the reference group and all subjects was found with regard to the number of prebeat and postbeat deviations. Chi-square values of 61.135 and 32.127, $p<.001$, were obtained for the cue and no cue conditions, respectively. The subjects exhibited more postbeat deviations and the reference group more prebeat deviations (see Table 9).

When compared with the reference group, Category I subjects also differed significantly with regard to the number of prebeat and postbeat deviations. The chi-square

TABLE 9

Frequency of Prebeat and Postbeat Deviations for Reference Group vs. All Subjects

	CUE		NO CUE	
GROUP	PREBEAT	POSTBEAT	PREBEAT	POSTBEAT
REFERENCE	115	65	117	88
SUBJECTS	170	382	215	410

TABLE 10

Frequency of Prebeat & Postbeat Deviations for Reference Group vs. Category I Subjects

	CUE		NO CUE	
	PREBEAT	POSTBEAT	PREBEAT	POSTBEAT
REFERENCE	115	65	117	88
CATEGORY I	54	238	75	255

values of 97.87 and 63.34, p .001, were computed for the cue condition and the no cue condition, respectively. Category I subjects had three times more postbeat deviations than prebeat deviations, regardless of the presence or absence of the cue condition (see Table 10).

For Category II subjects the number of prebeat and postbeat deviations were more equally divided. Under the cue condition there was a significant difference between these subjects and the reference group on prebeat and postbeat deviation behavior. The chi-square value was 4.86, p<.03. However, there was no significant difference between these subjects and the reference group in the absence of the cue condition where a chi-square value of 2.78, p>.05, was noted (see Table 11). Since Category II subjects had mean beat intervals that were smaller than those of their Category I counterparts (therefore less synchronized with the set tempo), it would be expected that deviations would occur more erratically, thus demonstrated on either the plus or minus side of the computer-placed beat.

TABLE 11

Frequency of Prebeat and Postbeat Deviations for Reference Group vs. Category II Subjects

	CUE		NO CUE	
GROUP	PREBEAT	POSTBEAT	PREBEAT	POSTBEAT
REFERENCE	115	65	117	88
CATEGORY II	84	79	88	95

Subjects in Category III had postbeat deviations numbering twice as many as the prebeat deviations during the cue condition. There was a significant difference noted between the reference group and Category III with regard to the frequency of prebeat and postbeat deviations during the cue condition. A chi-square value of 22.94, p<.002 was derived. No significant difference occurred between these two groups under the no cue condition (chi-square value of 2.88, p>.05).

Those differences in performance between the conditions of cue and no cue for both Category II and Category III when compared with the reference group might have been the result of an individual subject's attempting to "beat" as soon as possible after visually noting the conductor's beat. This would not necessarily create the appearance of more postbeat deviations; rather, create the beginning and completion of beat intervals that were influenced by confusing auditory and visual stimuli. Perhaps if tempo perception was sufficiently different from that of the conductor, interference with processing time was occurring as these subjects attempted accommodation with the conductor's beat (see Table 12).

TABLE 12

Frequency of Prebeat & Postbeat Deviations for Reference Group vs. Category III Subjects

	CUE		NO CUE	
	PREBEAT	POSTBEAT	PREBEAT	POSTBEAT
REFERENCE	115	65	117	88
CATEGORY III	32	65	52	60

Group Differences in Beat Deviations

The temporal accuracy of the subjects' beats in terms of milliseconds deviation from the computer's standard beat was analyzed for the three categories of subjects. Prebeat and postbeat deviations were computed as were the absolute deviations. The mean absolute deviation was considered to be the best measure of beat placement deviation for each subject. When t tests were computed between all subjects and the reference group, and between the individual categories and the reference group, the following results were found (see Tables 13 and 14).

Table 13

Mean Absolute Beat Deviations and Standard Deviations in Milliseconds: t Test Results for Cue Condition

GROUPS COMPARED	MEAN	STANDARD DEVIATION	t SCORE
REFERENCE	29.1	19.6	
CATEGORY I	33.7	18.1	0.14 (p .05)
REFERENCE	29.1	19.6	
CATEGORY II	89.6	30.9	3.37 (p .02)
REFERENCE	29.1	19.6	
CATEGORY III	108.7	10.6	5.96 (p .001)
CATEGORY I	33.7	18.1	
CATEGORY II	89.6	30.9	4.02 (p .002)
CATEGORY I	33.7	18.1	
CATEGORY III	108.7	10.6	6.60 (p .001)
CATEGORY II	89.6	30.9	
CATEGORY III	108.7	10.6	1.01 (p .05)

(1) During the cue condition, the reference group did not exhibit a mean absolute beat deviation that was significantly different from that of Category I (M = 29.227 and M = 33.713; t = .142, $p>.05$). However, for the same comparisons there was a significant difference between the mean and the absolute deviations of those in the reference group and Category II subjects (M = 29.117 and M = 89.575, t = 3.37, $p<.02$); and between the reference group and Category III subjects (M = 29.117 and M = 108., t = 5.96, $p<.001$). This supports findings regarding the frequency of prebeat and postbeat deviations. Subjects whose numbers of

Table 14

Mean Absolute Beat Deviations and Standard Deviations in Milliseconds: t Test Results for No-Cue Condition

GROUPS COMPARED	MEAN	STANDARD DEVIATION	t SCORE
REFERENCE	17.1	3.2	
CATEGORY I	36.4	16.8	2.76 (p .02)
REFERENCE	17.1	3.2	
CATEGORY II	92.7	28.6	6.62 (p .002)
REFERENCE	17.1	3.2	
CATEGORY III	92.7	31.1	6.35 (p .01)
CATEGORY I	36.4	16.8	
CATEGORY II	92.7	28.6	4.36 (p .001)
CATEGORY I	36.4	16.8	
CATEGORY III	92.7	31.1	3.98 (p .004)
CATEGORY II	92.7	28.6	
CATEGORY III	92.7	31.1	.0003 (p .05)

deviations were equally on either side of the computer standard, and whose mean beat interval indicated a tempo less accurate than that of a reference group, would be expected to reflect beat deviations that were significantly different from that reference group, as beats would be synchronized at points greater or less than the beat interval submitted by the reference group (see Appendix F and G for examples of subjects with mean beat interval of 538.86 ms and 387.41 ms, respectively). Where a mean beat interval was accurate and similar to that of the reference group, yet postbeat frequencies were significantly different (such as with Category I subjects), then beats were synchronized at points of relative temporal accuracy (see Appendix H for example of subject with mean beat interval of 448.4 ms). These points, while occurring somewhat consistently after the computer beat, did not necessarily deviate significantly in milliseconds from the reference group whose beats deviated to either side of the computer standard, but preceding it with greater frequency.

(2) During the condition of no cue, Category I subjects exhibited a greater mean absolute beat deviation than they had during the cue condition. There was a significant difference between the reference group's absolute beat deviation and Category I ($\underline{M}$ = 17.067 and $\underline{M}$ = 36.441, respectively; $\underline{t}$ = 2.76, $p < .02$). It was noted that four of the Category I subjects did not maintain an accurate mean

beat interval after cue as previously demonstrated during the cue (each subject demonstrating a cued mean beat interval that was within +/- 2.5 milliseconds of the computer's beat interval). Although the data from these four subjects did not present statistical evidence for forming conclusions regarding a visual cue, the observation is made that some subjects were assisted by the cue in maintaining a substantially accurate mean beat interval. Without the cue condition the subjects in Categories II and III maintained a similar performance inaccuracy as demonstrated with cue. There was a significant difference between the mean absolute beat deviations of the reference group and Category II ($\underline{M}$ = 17.067 and $\underline{M}$ = 92.725, respectively; $\underline{t}$ = 6.62, $p<.01$). There was also a significantly different mean absolute beat deviation between the reference group and Category III ($\underline{M}$ = 17.067 and $\underline{M}$ = 92.733, respectively; $\underline{t}$ = 6.35, $p<.01$). A clinical observation was that the more the mean beat interval differed from the computer standard the greater was the absolute mean beat deviation. If the perceived tempo was not initially accurate with the cue condition, the beat deviated further from the standard. Conversely, if subjects demonstrated beat interval accuracy with the cue condition, they had indicated tendencies for dependence on the continuation of that cue.

(3) When the cue condition was presented, there was a significant difference between the mean absolute beat

deviation of those subjects in Category I and those in Category II ($M = 33.73$ and $M = 89.575$, respectively; $t = 4.02$, p .002), and between Category I and Category III ($M = 33.713$, $M = 108.7$; $t = 6.6$, $p < .001$). This supports similarities demonstrated between Category I subjects and the reference group (where no significant difference was demonstrated with regard to mean absolute beat deviation). It further supports the premise that while Category I subjects have an accurate tempo perception as well as a deviation that does not differ greatly in milliseconds from the reference group, they may differ in place of deviation occurrence.

4) During the condition of no cue, there was a significant difference between Category I and Category II subjects with regard to the mean absolute beat deviation ($M = 36.441$ and $M = 92.725$, respectively; $t = 4.36$, $p < .001$). For this condition there was also a significant difference between Categories I and III on the same measure ($M = 36.441$ and $M = 92.733$, respectively; $t = 3.98$, $p < .004$).

5) When Category II was compared with Category III there was no significant difference between the mean absolute beat deviations either with presence of cue ($M = 89.575$ and $M = 108.7$; $t = 1.01$, $p > .05$) or absence of cue ($M = 92.725$ and $M = 92.733$; $t = .0003$, $p > .05$). Due to the erratic and inaccurate beat behavior among each of these subjects in both of these categories, differences would not

be expected between the two groups. Any significant difference would have implied that one of these categories contained subjects whose beat deviations were very small.

Observations on Influence of Musical Instruction

Although not subjected to measurement, it was observed that music instruction appeared to be a factor in the subject's ability to demonstrate a perceived beat interval similar to that which was cued by the investigator and/or presented by the computer standard. Two subjects in Category III had not been members of the choral ensemble during the past two years. One subject had been a member for only five months prior to this study, and the remaining four subjects in Categories II and III had been members of the same choral ensemble for at least five consecutive years. All eight subjects in Category I had been in the ensemble for at least five years; three of those subjects had, in addition, received individual musical instruction for at least one year. While four of the Category I subjects' mean beat intervals were adversely affected by the absence of a cue condition, three of the four whose intervals remained uninfluenced were the same subjects who had received individual instruction. For this Down's syndrome population, there was strong subjective evidence that the extent of musical instruction was related to beat performance.

An Observation on Postbeat Delay of Response

Results from the data received indicate that while the perception of tempo may be "intact" and beat deviations may be accurate to a point within a standard set by a reference group, there may also be demonstrated a postbeat delay of response. When the differences that existed between the reference group's anticipatory beat responses and the Category I subjects' delayed beat responses were considered, there was evidence to support the observation that such delays on the part of the subject might be perceived as even greater to an individual in the reference group.

Intellectual Functioning and Beat Accuracy Measures

Each of the 15 subjects was administered the Wechsler Adult Intelligence Scale (WAIS) for purposes of determining areas of intellectual strengths and weaknesses as demonstrated by performance on the 11 various subtests. Next, it was considered important to determine if any relationships existed between intellectual functioning as exhibited by the Verbal, Performance, and Full Scale IQs, and beat accuracy as defined in this investigation.

The mean IQs of all subjects on the Verbal, Performance, and Full Scale Sections were 56.2, 60.3, and 56.6, respectively. The Full Scale mean, however, reflects the performance of 14 of the subjects, since one subject (#12) did not present sufficiently high scale scores to yield a

Full Scale IQ. (The Verbal and Performance IQs were 45 and 39, respectively.) This subject was not included when statistically treating any data regarding the Full Scale IQ. The greatest difference between the Verbal and Performance IQs was demonstrated by subject #6 who obtained a Verbal IQ of 42, a Performance IQ of 69 (close to Borderline range of functioning), and a Full Scale IQ of 51. Neither the Verbal nor Full Scale IQ is considered to represent that subject's best functioning. This subject was raised in a bilingual environment where there would be unknown influence on tasks requiring verbal responses. Therefore, the Performance IQ is probably the better indicator of this subject's true potential. Thus, the mean Verbal and Full Scale IQs for all subjects are less meaningful due to these considerations.

The mean Verbal Scale score for all subjects was 2.5, and the mean Performance Scale score for all subjects was 3.7. Highest scores were on Picture Completion and Object Assembly where mean subtest scale scores were 4.9 and 4.1, respectively. Therefore, relative strengths were found to be in tasks requiring visual organization and concentration, ability to differentiate essential from non-essential details in the environment, alertness, and recognition of familiar patterns (Groth, ed., 1971). Lowest scores were on Arithmetic and Digit Span where mean subtest scale scores were 1.8 and 1.1, respectively. Relative weaknesses were in areas requiring auditory attention and concentration, and arithmetical reasoning ability (Groth). See Figure 1 and Appendix I.

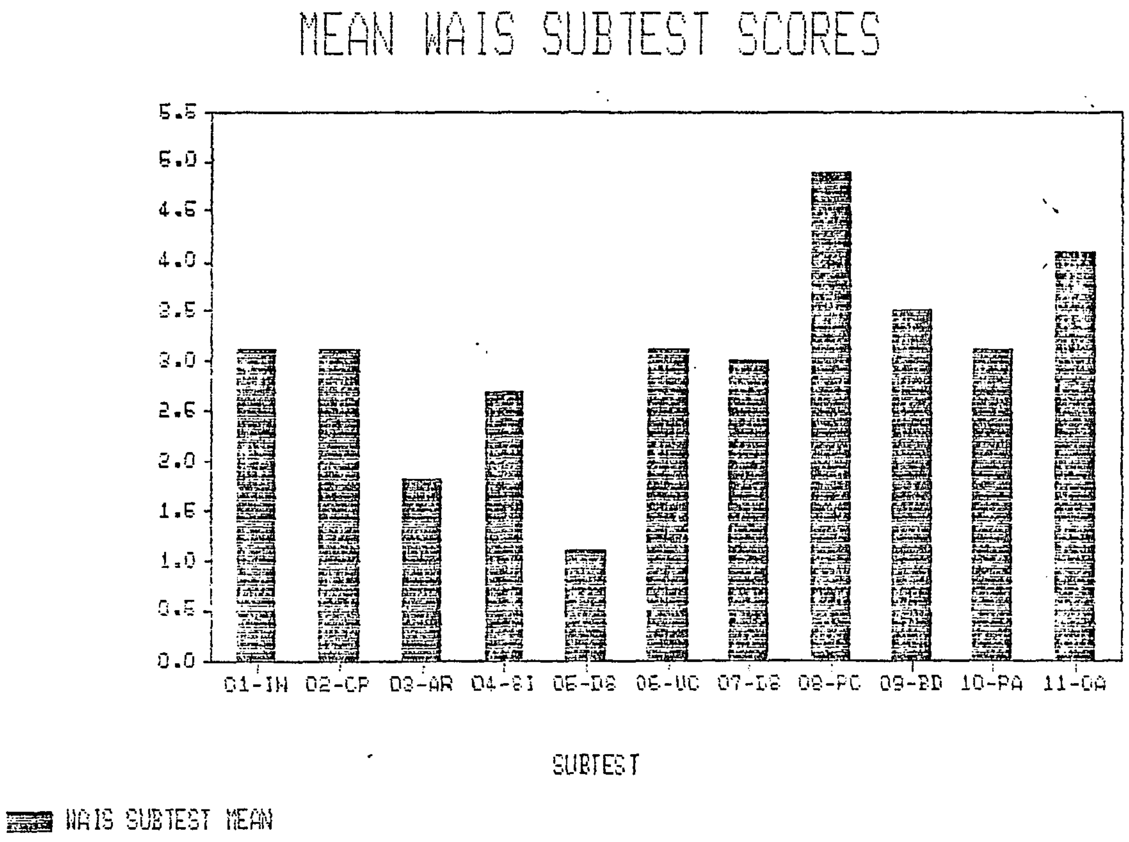

Figure 1--Mean Wais Subtest Scores

Pearson product-moment correlation coefficients were computed between the variables of the various measures of beat accuracy, and the obtained Verbal, Performance, and Full Scale IQs of the WAIS. No significant relationship was found between any of these measures, indicating that for this population intellectual functioning was independent of both tempo perception and beat placement with a computer standard.

CHAPTER 5

SUMMARY AND CONCLUSION

This study was conducted to assess objectively the beat accuracy of Down's syndrome individuals. The investigator had observed several Down's syndrome adolescents and adults seated together in a choral ensemble setting (comprised of heterogeneous mentally retarded individuals) who were clapping beats that yielded two forms of beat accuracy. First, these beats appeared to be steady and synchronized. Secondly, the beats occurred as delayed or behind a conducted cue and chordal guitar accompaniment.

These two rhythmic behaviors provided an incentive for developing a methodology involving the use of a Commodore-64 computer. The computer would be capable of refined measurement of both a beat interval response (time in milliseconds between beats) and a beat deviation (temporal accuracy in relation to a computer-generated beat). The premise was: If a measured performance of beat interval accuracy and beat deviation were to be elicited from a population of Down's syndrome adolescent and adult subjects as they each tapped a response to a musical composition, objective data would be available for isolating and identifying rhythmic beat behaviors. For example, it might be documented that an individual who was providing a beat interval that was accurate, was also providing a response occurring later than a standard. This would then be an indication of accurately perceived tempo and delayed beat response execution.

The primary focus of the investigation was to explore the manner in which a Down's syndrome population's beat responses to a musical stimulus produced and recorded by a computer deviated from a standard beat that also was set by that computer. Would these subjects demonstrate a perceived tempo that would approximate a computer standard or a standard as set by a reference group? Would beat responses precede, follow, or be synchronized with the musical stimulus provided by the computer?

Fifteen Down's syndrome adolescent and adult individuals from the same choral ensemble served as subjects. Comparisons were made between these subjects, who were divided into three categories according to mean beat interval performance. Comparisons also were made between a reference group (the norm) and the three categories. Data were compiled and treated statistically. All observations were considered under two conditions of presentation as each subject tapped a "steady beat" response to the musical example: (1) the condition of visual exposure to a steady beat cue conducted by the investigator; and (2) a condition of no visual cue.

The computer program utilized for these proceedings was written for entering and editing three-voice compositions which would serve as musical examples, generating a timedbeat interval synchronized with the example, recording a subject's beat response as data input, and providing a graph exhibiting the subject's interval deviation and its proximity to the computer beat (Freeman, 1985). This instrumentation allowed for documentation of the subject's perception of tempo (called the mean beat interval), and temporal proximity to the computer beat (beat deviation).

Discussion

The more interesting of the findings from this investigation are that: (1) This particular population of Down's syndrome individuals had only four of the fifteen subjects maintaining an accurate beat (within 2.5 ms of the computer standard) during both the cue and no cue conditions. (2) With a presented visual conducted cue, however, eight of the fifteen subjects maintained the accurate beat. (3) Although an accurate tempo was being tapped during the cue condition by these eight subjects, they were presenting a response after the computer standard significantly more often than was the reference group.

Mean Beat Interval Measurement

An indication of a subject's perception of tempo was rendered through the measurement in milliseconds of one button-press tap to another. As could be noted from the graphic printout (as an example, see Appendix H), a subject in Category I maintained beat intervals that were relatively stable at about 450 ms. This beat behavior was similar to that of individuals in the reference group (as an example see Appendix D). When the investigation began, it was obvious that a mean beat interval representing a subject's overall performance could be misleading. For example, it would be possible for a 450 ms mean beat interval to result from a subject's tapping an erratic beat length of several intervals representing 300 ms and 600 ms. After analyzing the data it was found, however, that this did not occur. Subjects in this category had small standard deviations (ranging from 13.4 ms to 31.3 ms during the cue condition), similar to those of the reference group (standard deviations ranging from 20 ms to 36.9 ms during the cue condition); thus the mean beat interval indicated a steadiness that was retained throughout the cue condition portion of the musical example.

For subjects producing mean beat intervals of 442.2 ms or less and 467.0 ms or more during the cue condition--a performance which placed them in Category II or III, respectively--there were somewhat greater standard deviations (ranging from 26.3 ms to 39.5 ms, and 33.1 ms to 35.4 ms, respectively). Subjective examination indicated that some of these performance patterns were not as consistent as were those in Category I. An investigation could arise from this observed phenomenon. Replicating this study with a similar and larger population might yield results indicating that individuals performing a mean beat interval that falls within a small range of the computer standard (e.g., 2.5 ms) maintain a consistently spaced interval. Then questions to follow would be: (1) At what millisecond range would a mean beat interval be considered accurate, and what would be the acceptable standard deviation for placement in this category? (2) What would be the rhythmic beat behavior of those in the other categories, and what millisecond range would determine their placement? (3) Would the beat behavior demonstrate individual patterns that were similar to those of Category II and III where some subjects, for example, moved in an incremental fashion from small to large, then suddenly back to small, beginning the pattern once again?

The overall beat pattern performance of subjects in Category II and Category III subjectively supports the concept that individuals may have predispositions for certain beat patterns. That these patterns are influenced by the two conditions of cue and no cue also is supported by the data analysis. The steady beat behavior of four of the subjects in Category I was likely influenced by the steady beat of the conducted cue. When not performing under this condition, these subjects moved outside Category I to the smaller or greater interval width--intervals which became 436.1 ms, 453.8 ms, 456.3 ms, and 456.6 ms, respectively. This finding supports several investigations, including those of Anwar (1981), Gibson (1978), and Belmont (1971), all of whom cite evidence for the premise that the visual-motor system is superior to auditory-motor integration in Down's syndrome individuals. For this investigation there was evidence that the cue condition provided a strength that directed the beat interval toward accuracy.

Strength of the visual-motor system also could be associated with influences of the cue condition upon Category II and III. In no instance did the cue appear to assist with establishing an accurate mean beat interval for subjects in these categories. In some individual cases there was slight movement toward 450 ms (the computer's tempo) after the cue condition ceased. One possible interpretation is that the lack of cue interfered less with the subject's own "internal" beat, allowing the beat to be at those points comfortable to the subject, thereby moving more toward the accurate tempo.

Computer Beat Deviation Measurement

The frequencies of prebeat and postbeat deviation, and the deviation in milliseconds from the computer's standard beat were two measurements producing helpful ways of examining beat behavior. Due to frequency differences between the reference group and Category I in anticipation and delay of response, there were implications that individuals who would frequently demonstrate prebeat behavior could view postbeat behavior as more delayed than should be warranted. This might also be worthy of investigation.

Certainly, postbeat behavior would appear even more delayed to a "prebeat-preferenced" individual than to an individual who might theoretically perform at the computer's standard (no prebeat and postbeat behavior). This point is readily made by observing the reference group's prebeat behavior as being almost twice as frequent as the postbeat during the cue condition. Under the same condition Category I had more than four times as many postbeat responses as prebeat responses. These frequencies are important for understanding what the definition of a beat really is. It could be conjectured that if most musically sophisticated persons were prebeat oriented, they would not be capable of subjective evaluation of the "correctness" of the postbeat oriented person. The individual demonstrating equal frequencies on either side of the computer standard would likely evaluate that "correctness" differently. Certainly, the individual performing accurate interval responses that were primarily postbeat would not subjectively evaluate the prebeat oriented individual's beat as "correct."

Another measurement that needs consideration is the deviation of the individual's beat from that of the standard. Such information yields data that are indicative of the temporal accuracy of an individual's beat. For this investigation such a measurement was critical for more clearly analyzing beat behavior. If absolute deviations were small and a mean beat interval was accurate, this would imply a high degree of accuracy with regard to all measures of beat performance. If a mean beat interval appeared accurate and absolute deviations were relatively large, then beat behavior would occur as mostly random button pressing. Therefore, when examined with the mean beat interval, the amount of deviation and the frequencies of prebeat or postbeat deviations became an integral part of making interpretations of beat behavior.

When it was observed that a mean beat interval was accurate, that deviations were small, and that postbeat frequencies were greater than prebeat, then it could be strongly implied that tempo was accurately perceived and was consistently occurring toward the delayed side of the computer standard. Such was the behavior of Category I subjects. As an example, subject #1 (from Category I) during the cue condition had a mean beat interval of 450.5 ms (computer standard set at 450.56 ms!), a mean absolute beat deviation of 19.7 ms, and postbeat frequencies that were five times greater than prebeat (30 ms and 6 ms respectively). This could be compared with the beat behavior of the investigator who demonstrated a mean beat interval of 450.1 ms a mean absolute beat deviation of 13.8 ms and prebeat frequencies that were more than twice as many as the postbeat (25 ms and 11 ms respectively). It would be realistic to assume that the investigator could perceive this subject as being accurate in tempo and delayed in beat placement. The beat behavior of all Category I subjects during cue condition was similar to that of subject #1. Thus, it becomes even more clear how the initially observed rhythmic beat behavior of those Down's syndrome individuals sitting together and attempting to clap a steady beat were indeed keeping an even steady beat that was interpreted by the investigator as being consistently behind.

Relative Importance of Music Instruction

The extent of sustained music instruction obviously had an influence upon beat behavior in that eight of the twelve subjects who had been in the choral ensemble for the last five years were in Category I. Two of the seven subjects in Category I and Category III had not been in this or any other music ensemble during the past two years. One of the subjects in Category II had only been with the ensemble for five months. Of particular interest is that none of these three were in Category I. Conversely, four of the Category I subjects who deviated to a greater extent when the cue condition was not provided, had not received any specialized music instruction. Three of the four who had remained in Category I while performing under both conditions had received individual music instruction for at least one year during the past five. This instruction consisted of 30-minute private piano lessons once each week. Competency at the keyboard was not stressed as much as was ear-training exercises involving rhythmic patterning and pitch discrimination. Also stressed was improvisation and performance.

Providing experimental control for studies of this type could be difficult. For example, individuals from ensembles similar to the one from which these subjects came could be compared in beat accuracy performance with those who had not received any special instruction. This, however, would present several control problems. First, there are few music ensembles for this population that would offer a sustained period of membership. Also, it would be difficult to determine the type and degree of musical instruction for individuals outside the ensemble.

Single-case studies where a music educator could provide a sustained music environment (complete with love and understanding of the student) and a continuing log of teacher/student interactions with special note of observations regarding all areas of development would perhaps be the most effective form of helpful research. The teacher's knowledge of the importance of the influence of visual explanation, and many times even tactual explanation (e.g., patting a desired rhythm on a student's hand) could offer many valuable suggestions and implications for furthering research methodology with these challenging individuals.

Implications of the WAIS for Further Investigation

The relatively low scale score of the Digit Span and high scale score of the Picture Completion subtests lends further support to the aforementioned investigators finding that auditory-motor function represents more of a deficit in the Down's syndrome condition than does the visual-motor. An implied investigation that evolves from both the results of the WAIS and rhythmic beat accuracy is one that would attempt to draw further relationships between a possible auditory-motor circuiting lag and delayed beat response. A non-Down's syndrome population also could be tested on the WAIS (a population presenting similar IQs) and be subjected to the same beat accuracy measures as was this group of subjects. Individuals with accurate beat perception could be found and placed in a Category I situation. If they did not exhibit the delay of beat that the subjects for this study demonstrated, and if they did not exhibit a relative deficit on the Digit Span subtest that was comparable to the scores of those subjects in this study, then another population of subjects could be gathered for comparisons. This population would be one that does demonstrate a severe deficit on the Digit Span, but not on any other subtest. If some of these persons could be placed in a Category I situation based on mean beat interval, then be found that they, too, exhibited a consistent postbeat deviation, it could be implied from data on the three groups of subjects that Digit Span or auditory-attention span is related to execution of the beat, or a postbeat deviation. This might further isolate components of perception that need investigating.

Other Implications for Further Study and Problem Investigation

The implications from this study appear to support a premise that Down's syndrome individuals may be demonstrating accurate tempo perception while executing a beat that is occurring as delayed. This reinforces the notion of Gibson (1978) that cognitive outputs for Down's syndrome individuals are subject to interference by difficulties with muscle tone, modality strength, conduction latency, or coordination skill. As Schmidt (1982) concluded, once an individual identifies a stimulus and selects the response, that individual must then translate the abstract idea of a response into a set of muscular actions. The response translation may be the point of deficit in the Down's syndrome population studied. Likewise, this investigation also supports Dodd's study (1974) which indicated that in learning phonological rules, Down's syndrome individuals exhibit inferior performances related to long-term motor programs. It may be that they are perceiving the morphological differences and abstracting the appropriate rule.

There is one important area that merits consideration, and is based on demonstration of performance by these subjects. It is becoming increasingly evident that one cannot adequately judge perceptual response (at the signal level) as being characteristically inferior in a Down's syndrome population when that judgment is based on adequacy of response. The execution of the response is possibly an entity about which much further research is needed. Perception cannot be judged by its execution, though perception possibly may be judged by measuring execution (e.g., beat delays versus tempo accuracy). This clinical stereotype (Down's syndrome) confuses the issue about learning efficiency (Gibson, 1978).

More questions appear to be raised by this investigation than are answers given. Certainly one major question emerging from this study regarding Down's syndrome is the meaning of an accurate beat. An operational definition of beat accuracy may be isolated to a demonstration of appropriate tempo. However, as this study shows, the additional component of accuracy should also take into consideration where that beat occurs. Implied here is that tempo perception may be accurate for two groups of individuals displaying two entirely different behaviors--one presenting most beats as anticipatory to that of the standard, and the other presenting most beats as delays that occur after the standard. One must ask if there is a "true" beat, and if so where should it be judged as properly placed? Although a computer standard has been immensely important in securing measurable types of data, there is a question as to whether it is helpful in deciding omnipotence of beat placement. Perhaps a true beat is not a mechanical placement at all; rather, a perceived anticipated or delayed variable.

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APPENDIX A

CONSENT FORM

CONSENT FORM

I offer consent for (my daughter, son, self) ____________ ____________________, to participate in a research project involving the study of beat accuracy. Incorporated into this study will be an assessment of intellectual functioning via the Wechsler Adult Intelligence Scale. The assessment of beat performance will be through use of a computer which produces musical examples and measures the beat response of an individual who taps a button "in time" with the music.

It is understood that I (my daughter, son) may withdraw from this study at any time. All results will be held in confidence with subjects being identified by number only.

Any parent so desiring may obtain information regarding his/her son/daughter's individual performance in this study. Any one else requesting the same information would be required to obtain a signed release of such information.

Signature (self) ________________________________ Date: __________

Signature (parent/guardian) ________________________ Date: __________

APPENDIX B

PERSONAL DATA SHEET

PERSONAL DATA

Identification #__________ D.O.B.__________________ Age________

Mother's D.O.B.___________________ Father's D.O.B.____________________

Educational Data (including dates when possible):

Public School____

Private School____

Special Instruction (individual or group):

Speech Therapy____

Tutoring in any area (specify)________________________________

Music____

Recreation (Special Olympics, etc.)____________________________

Work History____

____

____

____

Community Activities____

____

____

Hobbies____

Disinterests____

Medical Findings or Physical Problems:

Cytology________________

Heart________________

Lung________________

Vision________________

Audition________________

Allergies________________

Other________________

____

____

Other Findings (I.Q., Achievement)_______________________________

____

APPENDIX C

THREE-VOICE COMPOSITION AS ENTERED IN THE C-64 COMPUTER

```
MEASURE   1
    V 1 : R/1
    V 2 : R/4 G2 R G
    V 3 : C2/4 F# C F#

MEASURE   2
    V 1 : R/1
    V 2 : R/4 F#3 R F#
    V 3 : C3/4 E C E

MEASURE   3
    V 1 : R/4 E4 C/4. C/8
    V 2 : R/4 G3 R G
    V 3 : C3/4 E C E

MEASURE   4
    V 1 : C4/8 C C/4 C/8 C/4.
    V 2 : R/4 G3 R G
    V 3 : C3/4 E C E

MEASURE   5
    V 1 : R/4 E4 R E
    V 2 : R/4 D#4 R D#
    V 3 : C3/4 G C A

MEASURE   6
    V 1 : R/4 E3 R E
    V 2 : R/4 D#4 R D#
    V 3 : C3/4 B C A

MEASURE   7
    V 1 : R/4 F4 D/4. D/8
    V 2 : R/4 A3 R A
    V 3 : D3/4 F D D

MEASURE   8
    V 1 : D4/8 D D/4 D/8 D/4.
    V 2 : R/4 A3 R A
    V 3 : D3/4 F D F

MEASURE   9
    V 1 : R/4 F4 R F
    V 2 : R/4 A3 R B
    V 3 : D3/4 G# D A#

MEASURE   10
    V 1 : R/4 F4 R F
    V 2 : R/4 A3 R B
    V 3 : D3/4 G# D A#

MEASURE   11
    V 1 : G4/4 E E E/8 E
    V 2 : R/4 A3 R A
    V 3 : C3/4 G C G

MEASURE   12
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MEASURE  12
    V 1 : E4/8 E E/4 E/2
    V 2 : R/4 A3 R A
    V 3 : C3/4 G C G

MEASURE  13
    V 1 : R/4 B4 E/8 B/4.
    V 2 : R/4 A3 D#4 A3
    V 3 : C3/4 G C G

MEASURE  14
    V 1 : E4/8 B/4 E/8 E/2
    V 2 : D#4/4 A3/8 D#4/4. A3/4
    V 3 : C3/4 G C G

MEASURE  15
    V 1 : A4/8 F F/4 F/4. F/8
    V 2 : R/4 A3 R A
    V 3 : D3/4 F D F

MEASURE  16
    V 1 : F4/8 F F F F/2
    V 2 : R/4 A3 R B
    V 3 : D3/4 F D G

MEASURE  17
    V 1 : R/4 A4 F/8 A/4.
    V 2 : R/4 A3 C#4 A3
    V 3 : D3/4 F D F

MEASURE  18
    V 1 : F4/8 A/4 F/8 F/2
    V 2 : C#4/4 A3/8 C#4/4. A3/4
    V 3 : D3/4 F D F

MEASURE  19
    V 1 : G4/8 F F/4 F F/8 F
    V 2 : B3/2 C4
    V 3 : G3/2 A

MEASURE  20
    V 1 : A4/8 F F/4 F/4. A/8
    V 2 : F3/4 C4 B3/2
    V 3 : D3/4 A G/2

MEASURE  21
    V 1 : C5/8 A4 A/4 A C5/8 C
    V 2 : A3/2 F
    V 3 : F3/2 D

MEASURE  22
    V 1 : E5/4 C A4/8 E C A3
    V 2 : B3/4 A/2 F/4
    V 3 : C3/2 E/4 D

MEASURE  23
    V 1 : E3/4. G A/4
    V 2 : A2/4. G F/4
    V 3 : F2/4. E D/4

MEASURE  24
    V 1 : R/4 A#4 R C5
    V 2 : R/4 G3 R G
    V 3 : C3/4 F# C F#
```

```
  WAVESET DATA
  ************



WAVESET # 1
===========


V 1 WF (T,S,P,N):   P
   P.W. (1-4095):   2000
   ATTACK (0-15):   4
    DECAY (0-15):   3
  SUSTAIN (0-15):   11
  RELEASE (0-15):   0

V 2 WF (T,S,P,N):   P
   P.W. (1-4095):   2000
   ATTACK (0-15):   4
    DECAY (0-15):   3
  SUSTAIN (0-15):   11
  RELEASE (0-15):   0

V 3 WF (T,S,P,N):   P
   P.W. (1-4095):   2000
   ATTACK (0-15):   4
    DECAY (0-15):   3
  SUSTAIN (0-15):   11
  RELEASE (0-15):   0


FILTER FREQ: 0
 V 1 FILT IS OFF
 V 2 FILT IS OFF
 V 3 FILT IS OFF
FILTER RESONANCE: 0
FILT PASS MODE: NOT SET

VOLUME: 15
TEMPO: 120


      V 1 RING MOD IS OFF      V 2 RING MOD IS OFF      V 3 RING MOD IS OFF
        SYNC (VOICE 1 & 3) IS OFF---
        VOICE 3 OUTPUT IS NOW: ON
```

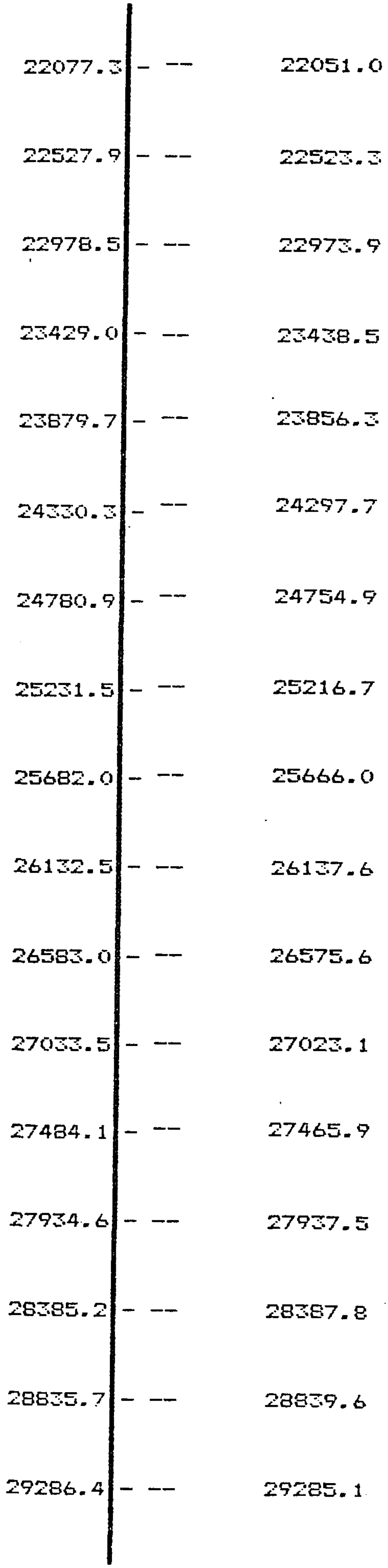
APPENDIX D

PROTOCOL OF BEAT PERFORMANCE OF MEMBER OF REFERENCE GROUP WITH A MEAN BEAT INTERVAL OF 451 ms WITH CUE AND 450 ms WITHOUT CUE

```
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: FF
CONDITION CODE: 1

START: 5180      END: 21401

  COMP -    SUBJ --           SUBJ BEAT INTV        C/S DEVIAT
   MSEC
0-----------------------------------------------------------------0
        |
 450.55.0.-
        |
  901.0|-
        |
 1351.6|-
        |
 1802.1|-
        |
 2252.8|-
        |
 2703.4|-
        |
 3154.0|-
        |
 3604.6|-
        |
 4055.1|- --      4103.4
        |
 4505.6|- --      4520.7
        |
 4956.1|- --      4949.7
        |
 5406.6|- --      5378.8       0      - 27.7500019
        |
 5857.2|- --      5809.1        430.300001     - 47.9500008
```

6307.7	--	6275.5	466.4	- 32.1499996
6758.3	--	6711.0	435.5	- 47.1499996
7208.8	--	7165.1	454.099999	- 43.6500015
7659.4	--	7607.2	442.100001	- 52.0500012
8110.0	--	8054.0	446.800001	- 55.8500004
8560.6	--	8504.3	450.299999	- 56.1500015
9011.2	--	8988.1	483.799999	- 22.9500008
9461.7	--	9426.4	438.299999	- 35.2500038
9912.2	--	9884.1	457.700001	- 28.0500031
10362.8	--	10324.7	440.600002	- 37.9500008
10813.3	--	10781.1	456.399998	- 32.1500015
11263.9	--	11214.5	433.400002	- 49.25
11714.5	--	11673.3	458.799999	- 41.0499993
12165.0	--	12088.3	415	- 76.6500015
12615.5	--	12542.7	454.400002	- 72.75
13066.1	--	12968.7	426	- 97.25
13516.7	--	13454.5	485.799999	- 62.0499992

13967.3	- --	13914.1	459.599999	- 53.0499992
14417.8	- --	14391.2	477.099999	- 26.5500031
14868.4	- --	14818.0	426.800003	- 50.25
15319.0	- --	15261.9	443.899998	- 56.9500008
15769.5	- --	15738.3	476.400002	- 31.1500015
16220.0	- --	16204.8	466.5	- 15.1500015
16670.6	- --	16642.8	437.999996	- 27.6500015
17121.2	- --	17092.6	449.800003	- 28.449997
17571.8	- --	17537.7	445.099999	- 33.949997
18022.4	- --	17986.5	448.800003	- 35.7499924
18472.9	- --	18436.6	450.099999	- 36.25
18923.5	- --	18898.1	461.5	- 25.25
19374.0	- --	19346.4	448.300003	- 27.5499954
19824.5	- --	19804.6	458.199997	- 19.8499985
20275.1	- --	20253.1	448.5	- 21.8499985
20725.6	- --	20725.5	472.400002	- .0999984741
21176.2	- --	21165.8	440.299995	- 10.25
21626.7	- --	21625.8		

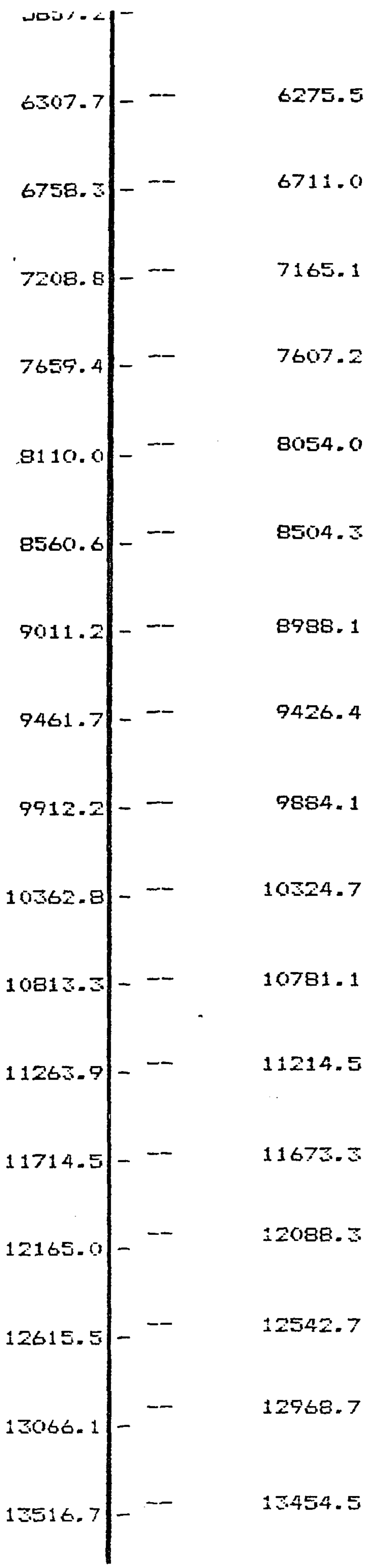

22077.3 22051.0
22527.9 22523.3
22978.5 22973.9
23429.0 23438.5
23879.7 23856.3
24330.3 24297.7
24780.9 24754.9
25231.5 25216.7
25682.0 25666.0
26132.5 26137.6
26583.0 26575.6
27033.5 27023.1
27484.1 27465.9
27934.6 27937.5
28385.2 28387.8
28835.7 28839.6
29286.4 29285.1

29737.0	29734.4
30187.6	30195.2
30638.2	30637.8
31088.7	31084.2
31539.2	31525.6
31989.7	31980.8
32440.2	32431.6
32890.9	32859.3
33341.5	33336.5
33792.1	33810.6
34242.8	34236.6
34693.3	34686.7
35143.8	35148.2
35594.3	35614.9
36044.8	36028.4
36495.3	36467.2
36945.9	36953.8
37396.4	37389.3

```
37847.0|- --       37824.7
       |
38297.5|- --       38283.2
       |
38748.1|- --       38730.7
       |
39198.6|- --       39168.5
       |
39649.1|- --       39629.0
       |
40099.8|- --       40129.5
       |
40550.4|- --       40569.8
       |
41001.0|- --       41009.1
       |
41451.6|- --       41440.0
       |
       |  --       41865.4
       |
       |  --       42323.9
       |
       |  --       42785.7
       |
       |  --       43238.9

INTERVALS RECORDED:  35
MEAN:  451.057143

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 20.7571416
 15.3428569
 15.5571427
 3.04285574
 8.95714236
 4.25714159
 .757143497
 32.7428565
 12.7571435
 6.64285803
 10.4571404
 5.34285498
```

```
  17.8571412
  7.7428565
  36.0571427
  3.34285879
  25.0571427
  34.7428565
  8.54285574
  26.0428557
  24.2571397
  7.15714502
  25.3428588
  15.4428573
  13.0571465
  1.25713968
  5.95714426
  2.25713968
  .95714426
  10.4428573
  2.75713968
  7.14285422
  2.55714273
  21.3428588
  10.7571473


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  12.7567344



SD: 16.4333617


SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 36 AVERAGE: 39.3902778


SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 0 AVERAGE: 0


SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 36 AVERAGE: 39.3902778
```

```
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: FF
CONDITION CODE: 2

START: 23203      END: 41676

  COMP -   SUBJ --            SUBJ BEAT INTV       C/S DEVIAT
   MSEC
0-------------------------------------------------------------0
                |
                |
  450.55.0.-
                |
                |
     901.0|-
                |
                |
    1351.6|-
                |
                |
    1802.1|-
                |
                |
    2252.8|-
                |
                |
    2703.4|-
                |
                |
    3154.0|-
                |
                |
    3604.6|-
                |
                |
    4055.1|-  --          4103.4
                |
                |
    4505.6|-  --          4520.7
                |
                |
    4956.1|-  --          4949.7
                |
                |
    5406.6|-  --          5378.8
                |
                |
          |   --          5809.1
```


6307.7
6275.5
6758.3
6711.0
7208.8
7165.1
7659.4
7607.2
8110.0
8054.0
8560.6
8504.3
9011.2
8988.1
9461.7
9426.4
9912.2
9884.1
10362.8
10324.7
10813.3
10781.1
11263.9
11214.5
11714.5
11673.3
12165.0
12088.3
12615.5
12542.7
13066.1
12968.7
13516.7
13454.5

13967.3	13914.1
14417.8	14391.2
14868.4	14818.0
15319.0	15261.9
15769.5	15738.3
16220.0	16204.8
16670.6	16642.8
17121.2	17092.6
17571.8	17537.7
18022.4	17986.5
18472.9	18436.6
18923.5	18898.1
19374.0	19346.4
19824.5	19804.6
20275.1	20253.1
20725.6	20725.5
21176.2	21165.8
21626.7	21625.8

22077.3	- --	22051.0		
22527.9	- --	22523.3		
22978.5	- --	22973.9		
23429.0	- --	23438.5	0	+ 9.5
23879.7	- --	23856.3	417.799995	- 23.1500015
24330.3	- --	24297.7	441.400002	- 32.449997
24780.9	- --	24754.9	457.200005	- 25.8499909
25231.5	- --	25216.7	461.799995	- 14.6500015
25682.0	- --	25666.0	449.300003	- 15.9499969
26132.5	- --	26137.6	471.599999	+ 5.09999848
26583.0	- --	26575.6	438	- 7.34999848
27033.5	- --	27023.1	447.5	- 10.3499985
27484.1	- --	27465.9	442.799995	- 18.0500031
27934.6	- --	27937.5	471.600006	+ 2.90000153
28385.2	- --	28387.8	450.299995	+ 2.59999848
28835.7	- --	28839.6	451.800003	+ 3.90000153
29286.4	- --	29285.1	445.5	- 1.29999542

```
29737.0|- --    29734.4    449.299995    - 2.6000061

30187.6|- --    30195.2    460.800003    + 7.59999848

30638.2|- --    30637.8    442.599999    - .400001526

31088.7|- --    31084.2    446.400002    - 4.5

31539.2|- --    31525.6    441.400002    - 13.5499954

31989.7|- --    31980.8    455.199997    - 8.90000153

32440.2|- --    32431.6    450.800003    - 8.54999542

32890.9|- --    32859.3    427.700005    - 31.3499909

33341.5|- --    33336.5    477.199997    - 4.84999085

33792.1|- --    33810.6    474.099991    + 18.5

34242.8|- --    34236.6    426           - 5.94999695

34693.3|- --    34686.7    450.100006    - 6.55000305

35143.8|- --    35148.2    461.5         + 4.3999939

35594.3|- --    35614.9    466.699997    + 20.5999908

36044.8|- --    36028.4    413.5         - 16.3500061

36495.3|- --    36467.2    438.800003    - 28.0500031

36945.9|- --    36953.8    486.600006    + 7.90000916

37396.4|- --    37389.3    435.5         - 7.04998779
```

```
37847.0|- --      37824.7     435.399994   - 22.1499939

38297.5|- --      38283.2     458.5        - 14.25

38748.1|- --      38730.7     447.5        - 17.25

39198.6|- --      39168.5     437.800003   - 30.0499878

39649.1|- --      39629.0     460.5        - 20.0499878

40099.8|- --      40129.5     500.5        + 29.699997

40550.4|- --      40569.8     440.300003   + 19.4000092

41001.0|- --      41009.1     439.299988   + 8.09999085

41451.6|- --      41440.0     430.900009   - 11.4499969

       |  --      41865.4

       |  --      42323.9

       |  --      42785.7

       |  --      43238.9

INTERVALS RECORDED:  40
MEAN:  450.0375

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 32.2375046
 8.6374985
 7.16250456
 11.7624954
 .737496972
 21.5624985
 12.0375
 2.53750002
 7.2375046
 21.5625061
 .262495399
 1.76250303
```

```
 4.53750003
 .737504601
 10.762503
 7.43750155
 3.6374985
 8.6374985
 5.16249693
 .762503028
 22.3374955
 27.1624969
 24.0624908
 24.0375
 .0625060797
 11.4625
 16.6624969
 36.5375
 11.237497
 36.5625061
 14.5375
 14.6375061
 8.46249998
 2.53750002
 12.237497
 10.4625
 50.4625
 9.73749697
 10.7375122
 19.1374909


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  13.3062502



SD: 17.7117773


SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 28 AVERAGE: 14.3910689


SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 13 AVERAGE: 10.7846146


SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 41 AVERAGE: 13.247559
```

APPENDIX E

MANUSCRIPT FORM OF EXAMPLE PROVIDING MUSICAL STIMULUS

E

I. L. C.

♩ = 133 m.m. (or 450.56 milliseconds)

3 Subject begins beat

4 Recording of Subject's beat begins for calibration

13 Conductor drops cue, and subject's beat is disregarded for calibration

14 Calibration of Subject's beat resumes.

24 Subject's beat is disregarded for calibration

Freeman

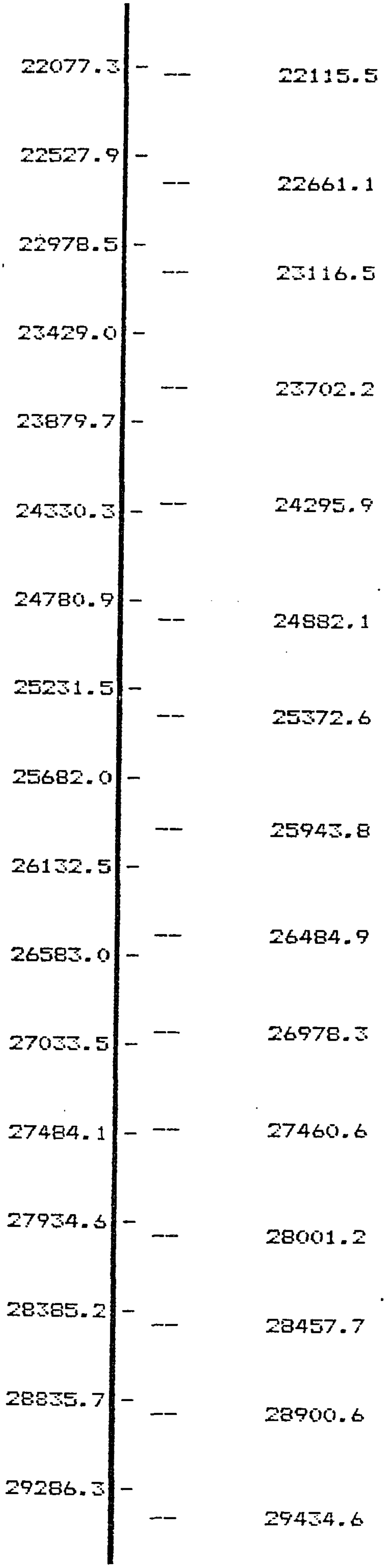
APPENDIX F

PROTOCOL OF BEAT PERFORMANCE OF SUBJECT IN CATEGORY III WITH A MEAN BEAT INTERVAL OF 538 ms WITH CUE AND 533 ms WITHOUT CUE

```
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: 14
CONDITION CODE: 1

START: 5181      END: 21401

  COMP -    SUBJ --            SUBJ BEAT INTV        C/S DEVIAT
   MSEC
0----------------------------------------------------------------0
              |
     450.6   |-
              |
     901.1   |-
              |
    1351.7   |-
              |
    1802.3   |-
              |
    2252.8   |-
              |
    2703.3   |-
              |
    3153.8   |-
              |
    3604.3   |-
              |
    4054.9   |-
                --        4267.2
    4505.5   |-
                --        4802.0
    4956.1   |-
              |
    5406.6   |- --        5431.2        0     + 24.5999985
              |
    5857.2   |-
```

```
          |  --     6018.5      587.300001   + 161.300001
   6307.7 | -
          |  --     6581.5      563          - 176.699999
   6758.3 | -
   7208.8 | - --    7180.5      599          - 28.2999993
   7659.4 | - --    7695.1      514.599999   + 35.6999989
   8110.0 | -
          |  --     8212.4      517.299999   + 102.399998
   8560.6 | -
          |  --     8721.1      508.700001   + 160.5
   9011.2 | -
          |  --     9273.6      552.5        - 188.100002
   9461.7 | -
   9912.2 | - --    9888.5      614.900002   - 23.7000008
  10362.8 | - --   10418.9      530.399998   + 56.0999985
  10813.3 | -
          |  --    11009.0      590.100002   + 195.700001
  11263.9 | -
          |  --    11536.8      527.799999   - 177.599999
  11714.5 | -
  12165.0 | - --   12110.8      574          - 54.2000008
  12615.5 | - --   12653.0      542.200001   + 37.5
  13066.2 | -
          |  --    13175.0      522          + 108.799999
  13516.8 | -
          |  --    13716.7      541.699997   + 199.899998
```

```
13967.4 | -
        |     --      14235.1      518.400002      - 182.799999
14418.0 | -

14868.5 | -   --      14816.0      580.900002      - 52.5

15319.0 | -
        |     --      15392.5      576.5           + 73.5

15769.5 | -
        |     --      15921.1      528.599999      + 151.599998
16220.0 | -
        |     --      16407.2      486.099999      + 187.199997
16670.6 | -
        |     --      16883.9      476.700005      + 213.300003
17121.2 | -

        |     --      17454.8      570.899994      - 116.900002
17571.8 | -


18022.4 | -   --      18064.1      609.300003      + 41.699997

18472.9 | -   --      18545.6      481.5           + 72.699997

18923.5 | -
        |     --      19026.6      481             + 103.099998

19374.0 | -
        |     --      19504.8      478.199997      + 130.799995

19824.5 | -
        |     --      19979.7      474.900002      + 155.199997

20275.1 | -
        |     --      20498.4      518.700005      + 223.300003
20725.6 | -

        |     --      21048.5      550.099999      - 127.599998
21176.2 | -


21626.7 | - --        21619.2
```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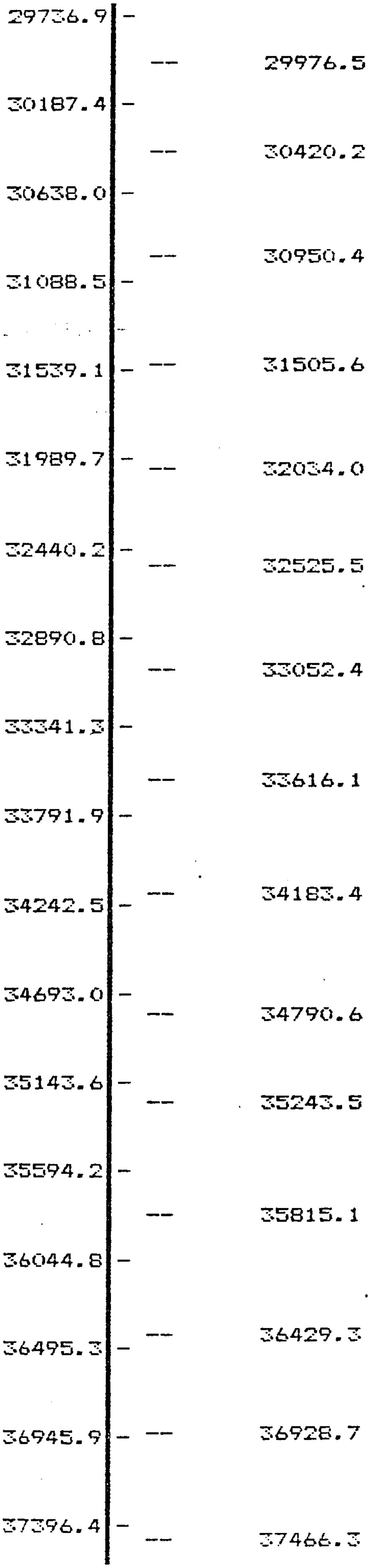
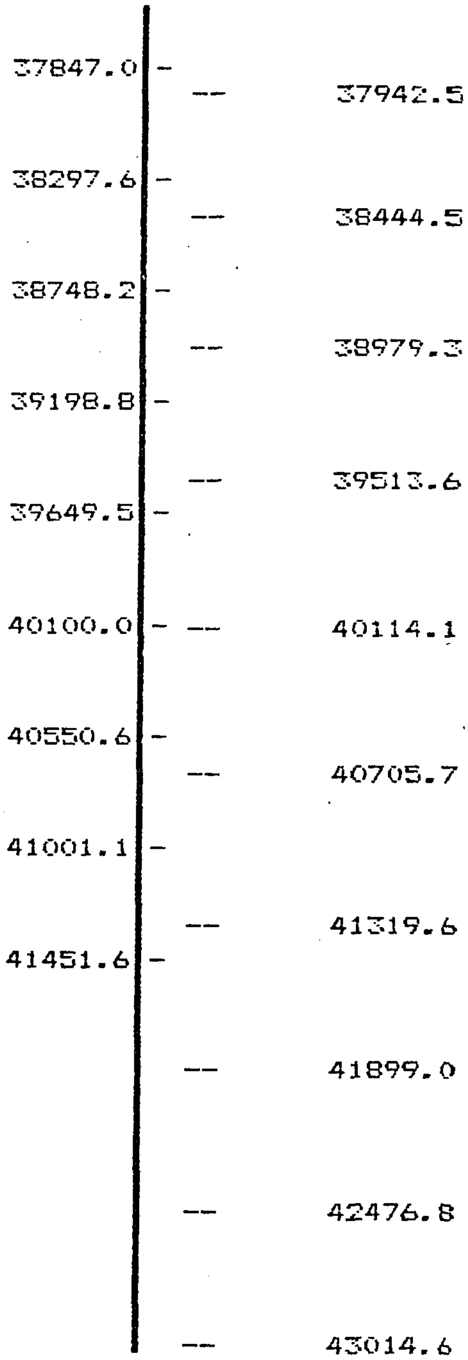
22115.5
22527.9
22661.1
22978.5
23116.5
23429.0
23702.2
23879.7
24330.3
24295.9
24780.9
24882.1
25231.5
25372.6
25682.0
25943.8
26132.5
26484.9
26583.0
27033.5
26978.3
27484.1
27460.6
27934.6
28001.2
28385.2
28457.7
28835.7
28900.6
29286.3
29434.6


29736.9
29976.5
30187.4
30420.2
30638.0
30950.4
31088.5
31539.1
31505.6
31989.7
32034.0
32440.2
32525.5
32890.8
33052.4
33341.3
33616.1
33791.9
34242.5
34183.4
34693.0
34790.6
35143.6
35243.5
35594.2
35815.1
36044.8
36495.3
36429.3
36945.9
36928.7
37396.4
37466.3



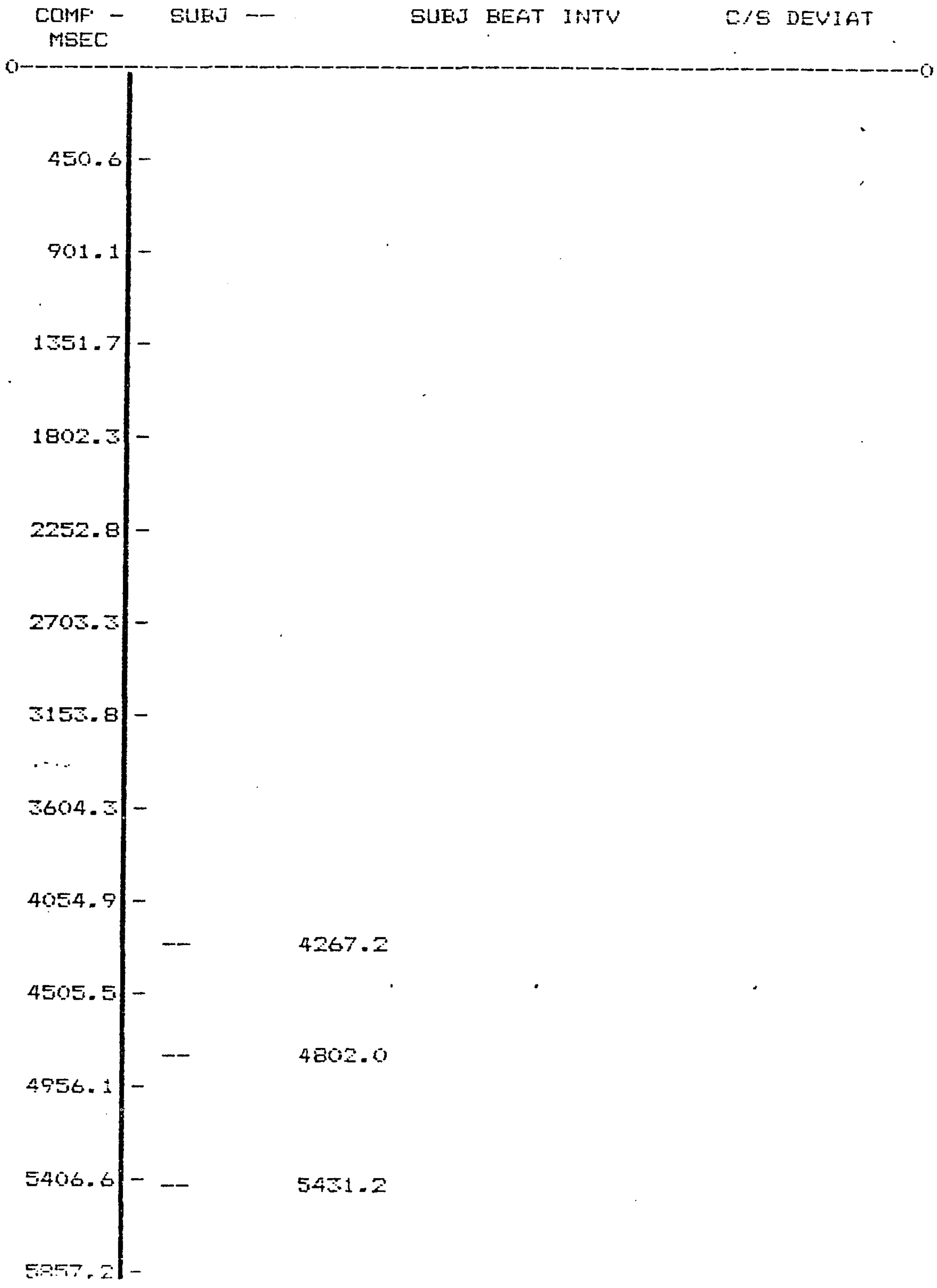
```
INTERVALS RECORDED:   29
MEAN:   538.527586

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 48.7724149
 24.4724138
 60.4724138
 23.9275877
 21.227587
 29.8275855
 13.9724138
 76.3724153
 8.12758851
 51.5724161
 10.727587
 35.4724138
 3.67241454
 16.5275862
```

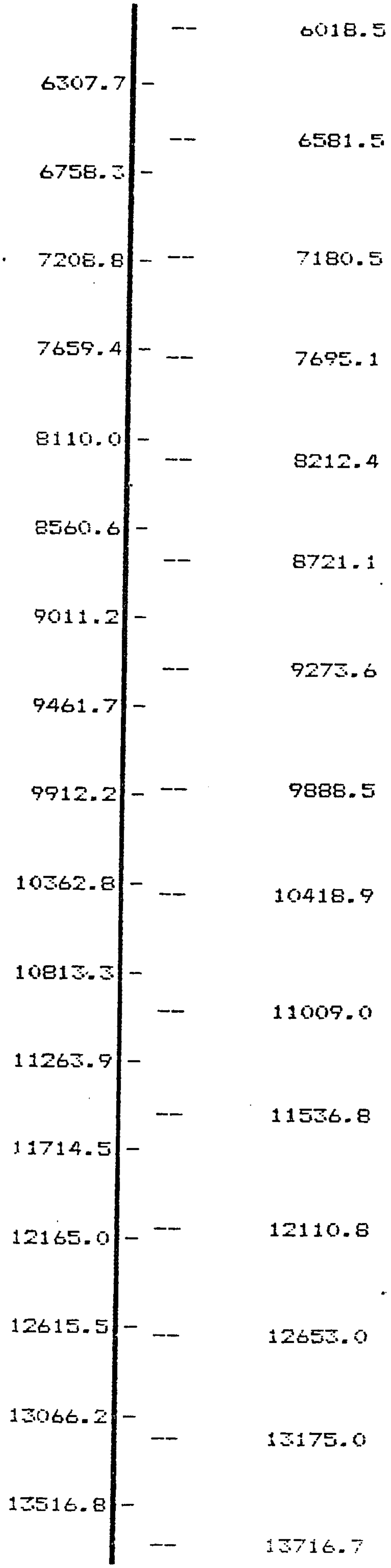
```
 3.17241073
 20.1275847
 42.3724153
 37.9724138
 9.92758775
 52.4275878
 61.8275816
 32.3724077
 70.7724168
 57.0275862
 57.5275862
 60.3275893
 63.6275847
 19.8275816
 11.5724123


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  35.3802615



SD: 42.3070166


SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 10 AVERAGE: 112.84


SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 20 AVERAGE: 121.744999


SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 30 AVERAGE: 118.776666
```

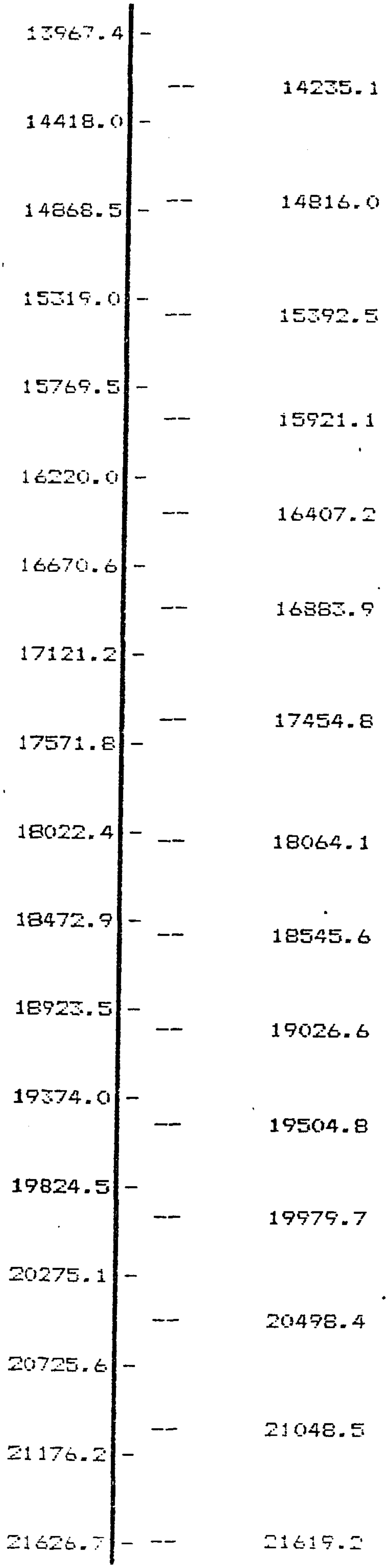
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: 14
CONDITION CODE: 2

START: 23203 END: 41676




6018.5
6307.7
6581.5
6758.3
7208.8
7180.5
7659.4
7695.1
8110.0
8212.4
8560.6
8721.1
9011.2
9273.6
9461.7
9912.2
9888.5
10362.8
10418.9
10813.3
11009.0
11263.9
11536.8
11714.5
12165.0
12110.8
12615.5
12653.0
13066.2
13175.0
13516.8
13716.7


13967.4
14235.1
14418.0
14868.5
14816.0
15319.0
15392.5
15769.5
15921.1
16220.0
16407.2
16670.6
16883.9
17121.2
17454.8
17571.8
18022.4
18064.1
18472.9
18545.6
18923.5
19026.6
19374.0
19504.8
19824.5
19979.7
20275.1
20498.4
20725.6
21048.5
21176.2
21626.7
21619.2

```
22077.3 | -  --    22115.5

22527.9 | -
           --    22661.1

22978.5 | -
           --    23116.5

23429.0 | -

           --    23702.2     0      - 177.300003
23879.7 | -

24330.3 | -  --    24295.9     593.700005     - 34.2999954

24780.9 | -
           --    24882.1     586.199997     + 101.199997

25231.5 | -
           --    25372.6     490.5          + 141.099998

25682.0 | -

           --    25943.8     571.199997     - 188.700005
26132.5 | -

           --    26484.9     541.099999     - 98.1000061
26583.0 | -

27033.5 | -  --    26978.3     493.400002     - 55.2000046

27484.1 | -  --    27460.6     482.300003     - 23.4000015

27934.6 | -
           --    28001.2     540.599999     + 66.5999985

28385.2 | -
           --    28457.7     456.5          + 72.5

28835.7 | -
           --    28900.6     442.900002     + 64.9000015

29286.3 | -
           --    29434.6     534            + 148.300003
```

```
29736.9 |-
        |   --      29976.5      541.900002      - 210.899994
30187.4 |-
        |   --      30420.2      443.699997      - 217.699997
30638.0 |-
        |   --      30950.4      530.199997      - 138.100006
31088.5 |-

31539.1 |-  --      31505.6      555.200005      - 33.4000015

31989.7 |-  --      32034.0      528.400002      + 44.300003

32440.2 |-
        |   --      32525.5      491.5           + 85.3000031
32890.8 |-
        |   --      33052.4      526.899994      + 161.599991
33341.3 |-
        |   --      33616.1      563.699997      - 175.700012
33791.9 |-

34242.5 |-  --      34183.4      567.300003      - 59

34693.0 |-
        |   --      34790.6      607.199997      + 97.5999909
35143.6 |-
        |   --      35243.5      452.900009      + 99.9000092
35594.2 |-
        |   --      35815.1      571.599991      + 220.899994
36044.8 |-

36495.3 |-  --      36429.3      614.200012      - 66

36945.9 |-  --      36928.7      499.399994      - 17.1000061
```

```
37847.0 | -
        |    --      37942.5      476.199997     + 95.5
        |
38297.6 | -
        |    --      38444.5      502            + 146.900009
        |
38748.2 | -
        |
        |    --      38979.3      534.800003     - 219.399994
        |
39198.8 | -
        |
        |    --      39513.6      534.299988     - 135.700012
39649.5 | -
        |
        |
40100.0 | - --       40114.1      600.5          + 14.0999908
        |
        |
40550.6 | -
        |    --      40705.7      591.600006     + 155.100006
        |
41001.1 | -
        |
        |    --      41319.6      613.899994     - 132
41451.6 | -
        |
        |
        |    --      41899.0
        |
        |
        |
        |    --      42476.8
        |
        |
        |
        |    --      43014.6

INTERVALS RECORDED:  33
MEAN:  533.860606

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 59.8393986
 52.339391
 43.360606
 37.339391
 7.23939252
 40.4606044
 51.5606029
 6.73939252
 77.360606
 90.9606045
```

```
 21.3393986
 5.46060443
 42.360606
 6.96061206
 29.839391
 33.4393971
 73.339391
 80.9605968
 37.7393849
 80.3394063
 34.4606121
 3.73940015
 57.660609
 31.860606
 .939397097
 .439381838
 66.639394
 57.7394002
 80.0393879


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  39.8332417


SD: 50.1015838


SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 17 AVERAGE: 116.588238

SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 17 AVERAGE: 105.041177

SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 34 AVERAGE: 110.814707
```

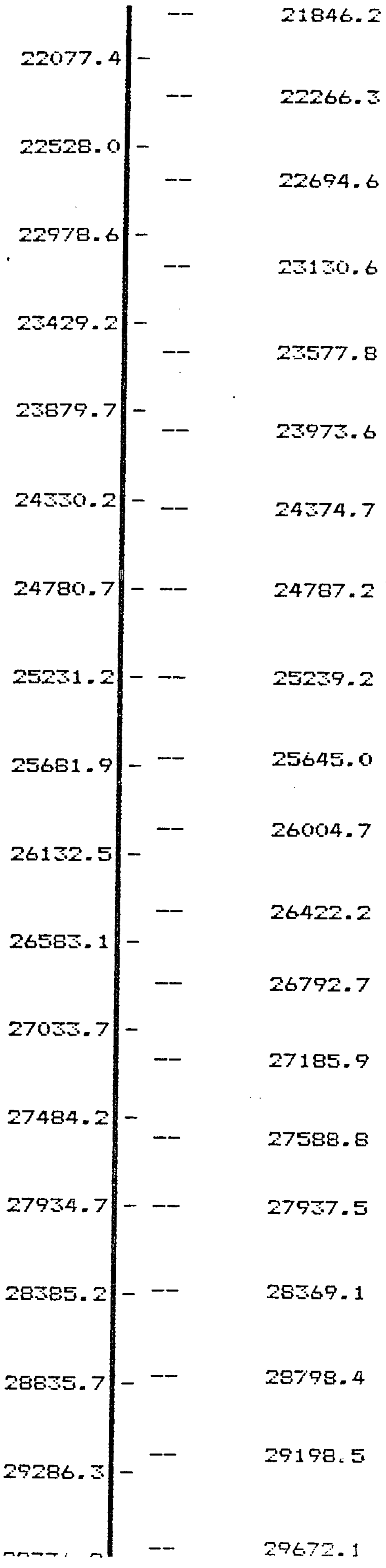
APPENDIX G

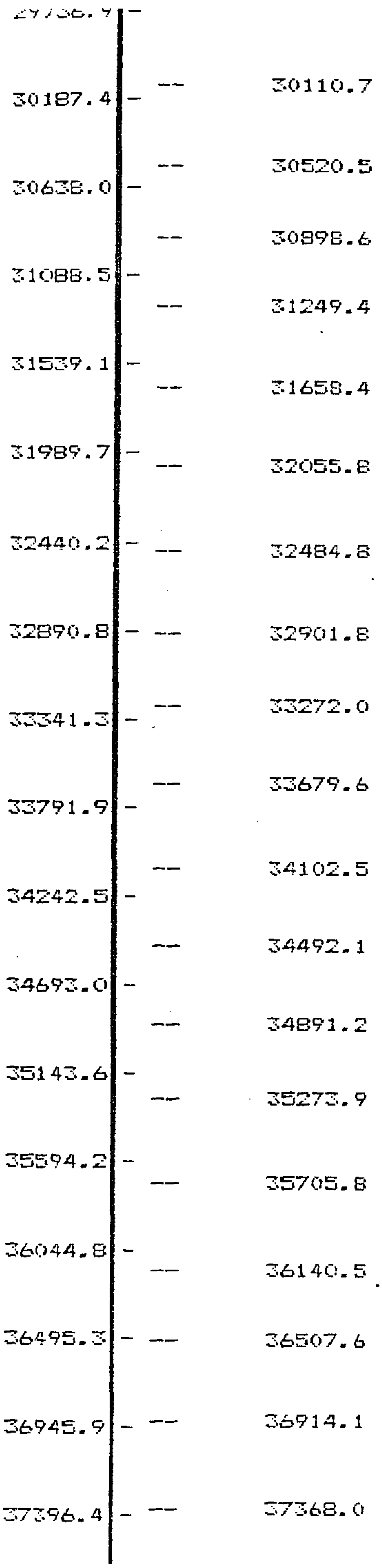
PROTOCOL OF BEAT PERFORMANCE OF SUBJECT IN CATEGORY II WITH MEAN BEAT INTERVAL OF 387 ms WITH CUE AND 411 ms WITHOUT CUE

```
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: 6
CONDITION CODE: 1


START: 5181      END: 21401

  COMP -   SUBJ --            SUBJ BEAT INTV        C/S DEVIAT
   MSEC
0------------------------------------------------------------0
            |
   450.6    |-
            |
   901.1    |-
            |
  1351.7    |-
            |
  1802.3    |-
            |
  2252.8    |-
            |
  2703.3    |-
            |
  3153.8    |-
            |
  3604.3    |-
            |
  4055.0    |-  --       4119.5
            |
  4505.6    |-  --       4486.4
            |
            |   --       4835.8
  4956.2    |-
            |   --       5196.8       0     - 209.9
  5406.8    |-
            |   --       5566.9       370.1           + 160.1
  5857.3    |-
            |   --       5935.1       368.200001      + 77.8000012
```

```
        |
 6307.8 | -  --     6254.8     319.699999     - 53
        |    --     6660.6     405.799999     - 97.7000008
 6758.3 | -
        |    --     7057.9     397.300001     - 150.9
 7208.8 | -
        |    --     7453.1     395.199999     - 206.200001
 7659.4 | -
        |    --     7890.9     437.800001     - 219
 8110.0 | -
        |    --     8244.9     353.999998     + 134.899998
 8560.6 | -
        |    --     8631.5     386.600002     + 70.9000015
 9011.2 | -  --     8962.3     330.799999     - 48.7999992
        |    --     9305.6     343.299999     - 156.100002
 9461.7 | -
        |    --     9676.5     370.900002     + 214.799999
 9912.2 | -
        |    --    10054.1     377.599999     + 141.899998
10362.8 | -  --    10428.1     374            + 65.2999992
10813.3 | -  --    10833.6     405.5          + 20.2999992
        |    --    11166.2     332.600002     - 97.5999985
11263.9 | -
        |    --    11559.1     392.899998     - 155.299999
11714.5 | -
        |    --    11937.7     378.600002     + 223.200001
12165.0 | -
        |    --    12323.8     386.099999     + 158.799999
12615.5 | -  --    12674.3     350.5          + 58.7999992
13066.1 | -  --    13072.1     397.799999     + 6
13516.7 | -  --    13453.5     381.400002     - 63.0999985
        |
```

	[illegible]	[illegible]	[illegible]
13967.3			
	14257.9	381.200001	- 159.900002
14417.8			
	14635.5	377.600002	+ 217.700001
14868.4			
	15051.7	416.199997	+ 183.299999
15319.0			
	15407.6	355.900002	+ 88.5999985
15769.5			
	15830.0	422.400002	+ 60.5
16220.0	16200.7	370.699997	- 19.3000031
	16607.7	407	- 62.800003
16670.6			
	17040.1	432.400002	- 81
17121.2			
	17473.5	433.400002	- 98.199997
17571.8			
	17923.0	449.5	- 99.2999954
18022.4			
	18333.6	410.599999	- 139.300003
18473.0			
	18731.7	398.099999	- 191.800003
18923.5			
	19116.5	384.800003	+ 193
19374.1			
	19497.4	380.900002	+ 123.300003
19824.7			
	19917.0	419.599999	+ 92.3000031
20275.2	20292.3	375.299995	+ 17.0999985
20725.7	20692.2	399.900002	- 33.5
	21080.8	388.599999	- 95.4000015
21176.2			
	21422.8		
21626.7			

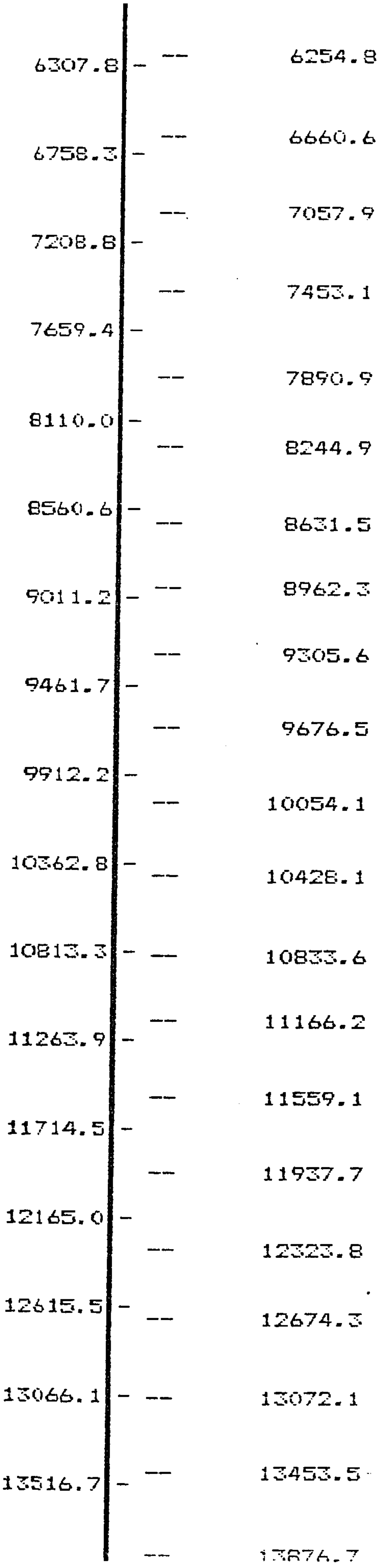

21846.2
22077.4
22266.3
22528.0
22694.6
22978.6
23130.6
23429.2
23577.8
23879.7
23973.6
24330.2
24374.7
24780.7
24787.2
25231.2
25239.2
25681.9
25645.0
26004.7
26132.5
26422.2
26583.1
26792.7
27033.7
27185.9
27484.2
27588.8
27934.7
27937.5
28385.2
28369.1
28835.7
28798.4
29198.5
29286.3
29672.1

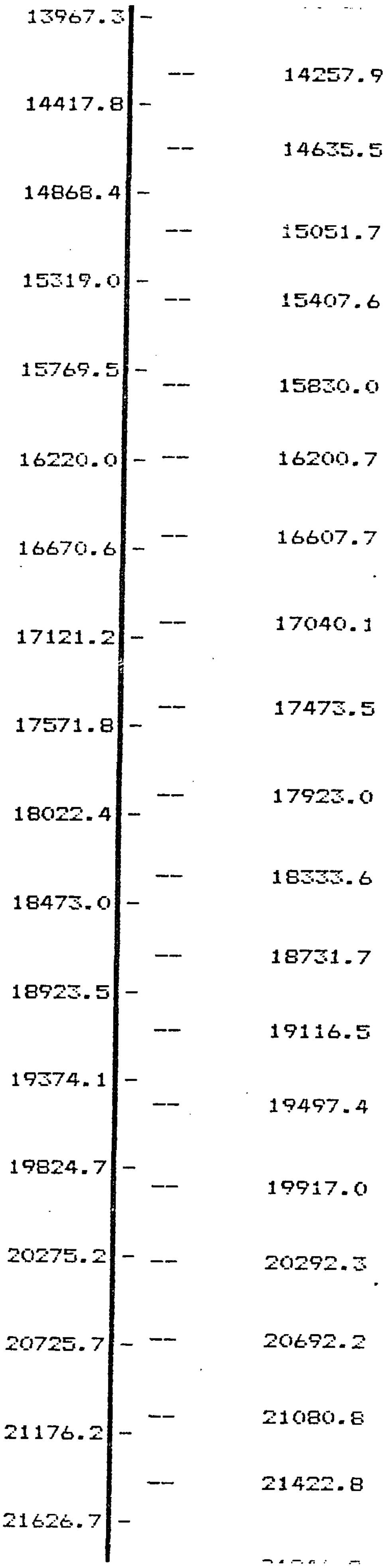

30187.4
30638.0
31088.5
31539.1
31989.7
32440.2
32890.8
33341.3
33791.9
34242.5
34693.0
35143.6
35594.2
36044.8
36495.3
36945.9
37396.4
30110.7
30520.5
30898.6
31249.4
31658.4
32055.8
32484.8
32901.8
33272.0
33679.6
34102.5
34492.1
34891.2
35273.9
35705.8
36140.5
36507.6
36914.1
37368.0

```
                    | --      37794.0
  37847.0 |-
                    | --      38205.6
  38297.5 |-
                    | --      38662.9
  38748.1 |-
                    | --      39104.2
  39198.6 |-
                    | --      39524.8
  39649.1 |-
                    | --      39958.0
  40099.7 |-
                    | --      40373.7
  40550.3 |-
                    | --      40822.5
  41000.9 |-
                    | --      41255.6
  41451.5 |-
                    | --      41711.6
                    | --      42119.4
                    | --      42571.7
                    | --      42947.3

INTERVALS RECORDED:   41
MEAN:   387.414634

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 17.3146337
 19.2146334
 67.7146353
 18.3853651
 9.88536703
 7.78536475
 50.385367
 33.414636
 .81463182
 56.6146349
 44.1146349
 16.5146326
 9.81463564
 13.4146341
 18.0853659
```

```
54.8146318
5.4853636
8.81463182
1.31463563
36.9146341
10.3853651
6.01463258
35.7853628
6.21463335
9.81463182
28.7853628
31.5146326
34.9853674
16.7146372
19.5853659
44.9853674
45.9853674
62.0853659
23.1853644
10.6853644
2.61463106
6.51463258
32.1853644
12.1146387
12.4853674
1.18536437


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  23.0400949


SD: 29.6702499


SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 22 AVERAGE: 114.936364


SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 20 AVERAGE: 115.43


SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 42 AVERAGE: 115.171429
```

```
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: 6
CONDITION CODE: 1

START: 23203      END: 41676

 COMP -- SUBJ --            SUBJ BEAT INTV        C/S DEVIAT
 MSEC
0-------------------------------------------------------------0
          |
   450.6  |-
          |
   901.1  |-
          |
  1351.7  |-
          |
  1802.3  |-
          |
  2252.8  |-
          |
  2703.3  |-
          |
  3153.8  |-
          |
  3604.3  |-
          |
  4055.0  |-  --          4119.5
          |
  4505.6  |-  --          4486.4
          |
          |   --          4835.8
  4956.2  |-
          |   --          5196.8
  5406.8  |-
          |   --          5566.9
  5857.3  |-  --          5935.1
```


6254.8
6307.8
6660.6
6758.3
7057.9
7208.8
7453.1
7659.4
7890.9
8110.0
8244.9
8560.6
8631.5
8962.3
9011.2
9305.6
9461.7
9676.5
9912.2
10054.1
10362.8
10428.1
10813.3
10833.6
11166.2
11263.9
11559.1
11714.5
11937.7
12165.0
12323.8
12615.5
12674.3
13066.1
13072.1
13453.5
13516.7
13876.7


13967.3
14257.9
14417.8
14635.5
14868.4
15051.7
15319.0
15407.6
15769.5
15830.0
16220.0
16200.7
16670.6
16607.7
17121.2
17040.1
17571.8
17473.5
18022.4
17923.0
18473.0
18333.6
18923.5
18731.7
19116.5
19374.1
19497.4
19824.7
19917.0
20275.2
20292.3
20725.7
20692.2
21176.2
21080.8
21422.8
21626.7

```
         |  --   21846.2
22077.4  | -
         |  --   22266.3
22528.0  | -
         |  --   22694.6
22978.6  | -
         |  --   23130.6
23429.2  | -
         |  --   23577.8     0            + 148.599998
23879.7  | -
         |  --   23973.6     395.800003   + 93.9000015
24330.2  | - --  24374.7     401.099999   + 44.5
24780.7  | - --  24787.2     412.5        + 6.5
25231.2  | - --  25239.2     452          + 8
25681.9  | -  -- 25645.0     405.800003   - 36.699997
         |  --   26004.7     359.699997   - 127.700005
26132.5  | -
         |  --   26422.2     417.5        - 160.800003
26583.1  | -
         |  --   26792.7     370.5        + 209.599999
27033.7  | -
         |  --   27185.9     393.199997   + 152.199997
27484.2  | -
         |  --   27588.8     402.900002   + 104.599998
27934.7  | - --  27937.5     348.700005   + 2.80000305
28385.2  | - --  28369.1     431.599999   - 16.0999985
28835.7  | - --  28798.4     429.299995   - 37.3000031
         |  --   29198.5     400.100006   - 87.699997
29286.3  | -
29736.8  | - --  29672.1     473.599999   - 64.699997
```

```
                --        30110.7       438.599999       - 76.699997
30187.4 |-
                --        30520.5       409.800003       - 117.399994
30638.0 |-
                --        30898.6       378.099999       - 189.900001
31088.5 |-
                --        31249.4       350.799995       + 160.899994
31539.1 |-
                --        31658.4       409              + 119.299995
31989.7 |-
                --        32055.8       397.400002       + 66.0999985
32440.2 |-      --        32484.8       429              + 44.5999985
32890.8 |-      --        32901.8       417.000008       + 11
                --        33272.0       370.199997       - 69.3000031
33341.3 |-
                --        33679.6       407.599991       - 112.200012
33791.9 |-
                --        34102.5       422.900009       - 139.899994
34242.5 |-
                --        34492.1       389.599991       - 200.900009
34693.0 |-
                --        34891.2       399.100006       + 198.199997
35143.6 |-
                --        35273.9       382.699997       + 130.300003
35594.2 |-
                --        35705.8       431.900009       + 111.600006
36044.8 |-
                --        36140.5       434.699997       + 95.699997
36495.3 |-      --        36507.6       367.099991       + 12.2999878
36945.9 |-      --        36914.1       406.5            - 31.7000122
37396.4 |-      --        37368.0       453.900009       - 28.3999939
```

```
 37847.0| -  --     37794.0     426          - 52.8999939

             --     38205.6     411.599991   - 91.9000092
 38297.5| -

             --     38662.9     457.300003   - 85.1000061
 38748.1| -

             --     39104.2     441.300003   - 94.3999939
 39198.6| -

             --     39524.8     420.600006   - 124.299988
 39649.1| -

             --     39958.0     433.199997   - 141.599991
 40099.7| -

             --     40373.7     415.699997   - 176.5
 40550.3| -

             --     40822.5     448.800003   - 178.300003
 41000.9| -

             --     41255.6     433.099991   - 195.800003
 41451.5| -

             --     41711.6

             --     42119.4

             --     42571.7

             --     42947.3

INTERVALS RECORDED:  43
MEAN:   411.111628

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 15.3116248
 10.0116293
 1.38837218
 40.8883722
 5.31162477
 51.4116309
 6.38837218
 40.6116278
 17.9116309
 8.21162629
 62.4116233
 20.4883707
 18.1883676
 11.0116217
 62.4883707
```

```
 27.4883707
 1.31162477
 33.0116293
 60.3116324
 2.11162782
 13.7116263
 17.8883722
 5.88837981
 40.9116309
 3.51163697
 11.7883813
 21.511637
 12.0116217
 28.4116309
 20.7883813
 23.5883691
 44.011637
 4.61162782
 42.7883813
 14.8883722
 .488363028
 46.1883753
 30.1883752
 9.48837829
 22.0883691
 4.58836913
 37.6883752
 21.988363


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  22.6811257



SD: 28.9697236



SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 25 AVERAGE: 105.528


SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 19 AVERAGE: 90.5631565


SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 44 AVERAGE: 99.0659086
```

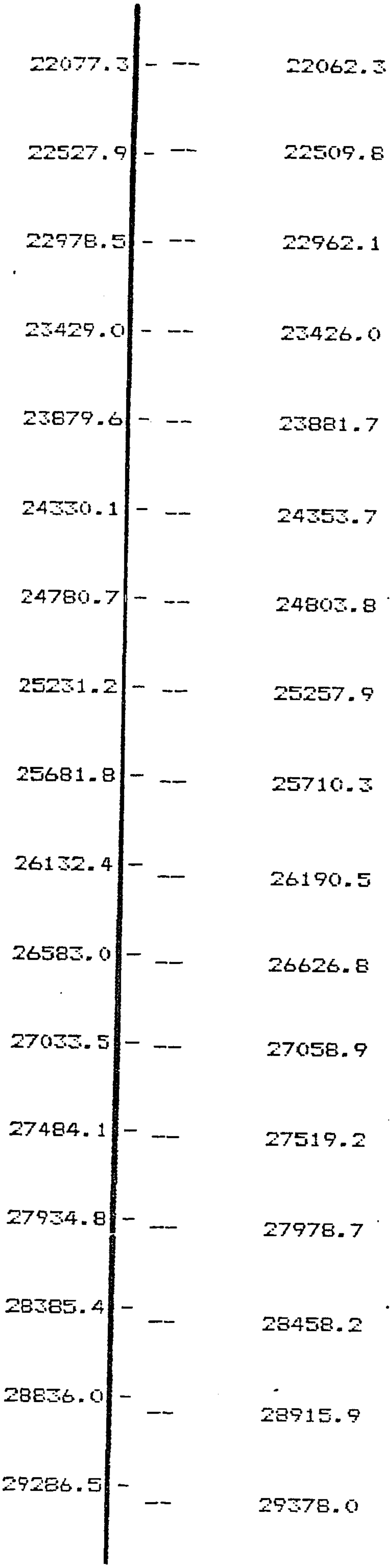
APPENDIX H

PROTOCOL OF BEAT PERFORMANCE OF SUBJECT IN CATEGORY I WITH MEAN BEAT INTERVAL OF 448 ms WITH CUE AND 449 ms WITHOUT CUE

```
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: 7
CONDITION CODE: 1

START: 5181     END: 21401

  COMP -    SUBJ --          SUBJ BEAT INTV       C/S DEVIAT
   MSEC
0---------------------------------------------------------------0
          |
          |
   450.6  | -
          |
   901.1  | -
          |
  1351.7  | -
          |
  1802.3  | -
          |
  2252.9  | -
          |
  2703.5  | -
          |
  3154.1  | -
          |
  3604.6  | -
          |
  4055.1  | -  --       4095.4
          |
  4505.6  | -  --       4528.1
          |
  4956.1  | -  --       4970.7
          |
  5406.6  | -  --       5434.3      0     + 27.6999989
          |
  5857.2  | -  --       5877.7      443.4          + 20.5
```

```
  6307.7 |- --    6357.2    479.5        + 49.5
  6758.3 |- --    6788.8    431.600001   + 30.5
  7208.8 |- --    7255.2    466.4        + 46.3999996
  7659.4 |- --    7683.5    428.300001   + 24.1000004
  8110.0 |- --    8114.9    431.4        + 4.89999962
  8560.6 |- --    8585.2    470.300001   + 24.6000023
  9011.2 |- --    9045.2    460          + 34
  9461.7 |- --    9508.8    463.599999   + 47.0999985
  9912.2 |- --    9918.4    409.599999   + 6.19999695
 10362.8 |- --   10368.2    449.800003   + 5.40000153
 10813.3 |- --   10798.3    430.099999   - 15
 11263.9 |- --   11258.1    459.799999   - 5.70000076
 11714.5 |- --   11740.6    482.5        + 26.0999985
 12165.0 |- --   12203.0    462.400002   + 38
 12615.5 |- --   12664.5    461.5        + 49
 13066.1 |- --   13111.0    446.5        + 44.9000015
 13516.7 |- --   13547.7    436.699997   + 31
```

```
13967.3 | - --    13993.2    445.5         + 25.8999577

14417.8 | - --    14448.1    454.900002    + 30.2999993

14868.4 | - --    14879.2    431.099999    + 10.7999992

15319.0 | - --    15304.4    425.200001    - 14.5

15769.5 | - --    15761.4    457           - 8.10000229

16220.0 | - --    16236.2    474.799999    + 16.1999969

16670.7 | - --    16692.7    456.5         + 22

17121.3 | - --    17151.4    458.700005    + 30.1000061

17571.9 | - --    17608.4    457           + 36.5

18022.5 | - --    18049.5    441.099999    + 27

18473.0 | - --    18501.6    452.099999    + 28.5999985

18923.5 | - --    18960.3    458.699997    + 36.7999954

19374.0 | - --    19393.2    432.900002    + 19.1999969

19824.5 | - --    19830.2    437           + 5.69999695

20275.1 | - --    20269.5    439.300003    - 5.5

20725.6 | - --    20691.9    422.400002    - 33.699997

21176.2 | - --    21126.6    434.699997    - 49.5

21626.7 | - --    21601.7
```


22077.3
22062.3
22527.9
22509.8
22978.5
22962.1
23429.0
23426.0
23879.6
23881.7
24330.1
24353.7
24780.7
24803.8
25231.2
25257.9
25681.8
25710.3
26132.4
26190.5
26583.0
26626.8
27033.5
27058.9
27484.1
27519.2
27934.8
27978.7
28385.4
28458.2
28836.0
28915.9
29286.5
29378.0

29737.0	29804.8
30187.5	30253.8
30638.0	30721.7
31088.5	31157.2
31539.1	31618.5
31989.7	32086.0
32440.2	32542.7
32890.8	32980.2
33341.3	33427.4
33791.9	33862.4
34242.5	34316.0
34693.0	34729.4
35143.6	35176.9
35594.2	35615.7
36044.8	36047.8
36495.4	36469.2
36946.0	36922.1
37396.6	37364.4

```
  37847.1 | -  --      37815.2

  38297.6 | -  --      38296.8

  38748.1 | -  --      38751.2

  39198.6 | -  --      39178.4

  39649.1 | -  --      39647.4

  40099.7 | -  --      40116.7

  40550.3 | -  --      40541.1

  41000.9 | -  --      40962.3

  41451.5 | -  --      41394.9

          |    --      41816.0

          |    --      42243.5

          |    --      42691.3

          |    --      43140.6

INTERVALS RECORDED:   35
MEAN:  448.351429

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 4.95142889
 31.1485715
 16.7514281
 18.0485711
 20.0514274
 16.9514289
 21.9485726
 11.6485715
 15.24857
 38.75143
 1.44857454
 18.25143
 11.4485707
```

```
34.1485715
14.048573
13.1485715
1.85142851
11.6514316
2.85142851
6.54857302
17.25143
23.1514278
8.64857149
26.4485707
8.14857149
10.3485761
8.64857149
7.25143004
3.74856997
10.3485684
15.451427
11.3514285
9.05142546
25.951427
13.6514316


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  14.581388



SD: 17.2986787


SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 7 AVERAGE: 18.8571429

SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 29 AVERAGE: 27.5517236

SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 36 AVERAGE: 25.8611107
```

```
BEAT TIMING CHART

COMPOSITION NAME: TIC
SUBJECT NUMBER: 7
CONDITION CODE: 1


START: 23203     END: 41676

  COMP -    SUBJ --            SUBJ BEAT INTV        C/S DEVIAT
   MSEC
0------------------------------------------------------------------0
          |
          |
    450.6 | -
          |
    901.1 | -
          |
   1351.7 | -
          |
   1802.3 | -
          |
   2252.9 | -
          |
   2703.5 | -
          |
   3154.1 | -
          |
   3604.6 | -
          |
   4055.1 | -  --        4095.4
          |
   4505.6 | -  --        4528.1
          |
   4956.1 | -  --        4970.7
          |
   5406.6 | -  --        5434.3
          |
   5857.2 | -  --        5877.7
```

6307.7	6357.2
6758.3	6788.8
7208.8	7255.2
7659.4	7683.5
8110.0	8114.9
8560.6	8585.2
9011.2	9045.2
9461.7	9508.8
9912.2	9918.4
10362.8	10368.2
10813.3	10798.3
11263.9	11258.1
11714.5	11740.6
12165.0	12203.0
12615.5	12664.5
13066.1	13111.0
13516.7	13547.7

13967.3	13993.2
14417.8	14448.1
14868.4	14879.2
15319.0	15304.4
15769.5	15761.4
16220.0	16236.2
16670.7	16692.7
17121.3	17151.4
17571.9	17608.4
18022.5	18049.5
18473.0	18501.6
18923.5	18960.3
19374.0	19393.2
19824.5	19830.2
20275.1	20269.5
20725.6	20691.9
21176.2	21126.6
21626.7	21601.7

22077.3	22062.3		
22527.9	22509.8		
22978.5	22962.1		
23429.0	23426.0	482.300003	- 3
23879.6	23881.7	455.699997	+ 2.09999848
24330.1	24353.7	472	+ 23.5999985
24780.7	24803.8	450.099999	+ 23.0999985
25231.2	25257.9	454.100006	+ 26.7000046
25681.8	25710.3	452.399994	+ 28.5
26132.4	26190.5	480.200005	+ 58.0999985
26583.0	26626.8	436.299995	+ 43.7999954
27033.5	27058.9	432.099999	+ 25.3999939
27484.1	27519.2	460.300003	+ 35.0999985
27934.8	27978.7	459.5	+ 43.9000015
28385.4	28458.2	479.5	+ 72.8000031
28836.0	28915.9	457.699997	+ 79.8999939
29286.5	29378.0	462.100006	+ 91.5

```
29737.0 |-  --    29804.8    426.799995    + 67.7999954

30187.5 |-  --    30253.8    449           + 66.2999954

30638.0 |-  --    30721.7    467.900002    + 83.699997

31088.5 |-  --    31157.2    435.5         + 68.699997

31539.1 |-  --    31618.5    461.300003    + 79.4000015

31989.7 |-  --    32086.0    467.5         + 96.3000031

32440.2 |-  --    32542.7    456.699997    + 102.5

32890.8 |-  --    32980.2    437.5         + 89.3999939

33341.3 |-  --    33427.4    447.199997    + 86.0999909

33791.9 |-  --    33862.4    435           + 70.5

34242.5 |-  --    34316.0    453.600006    + 73.5

34693.0 |-  --    34729.4    413.399994    + 36.3999939

35143.6 |-  --    35176.9    447.5         + 33.3000031

35594.2 |-  --    35615.7    438.800003    + 21.5

36044.8 |-  --    36047.8    432.100006    + 3

36495.4 |-  --    36469.2    421.399994    - 26.1000061

36946.0 |-  --    36922.1    452.899994    - 23.8000031

37396.6 |-  --    37364.4    442.300003    - 32.1000061
```

```
 37847.1|- --     37815.2      450.800003     - 31.8999939

 38297.6|- --     38296.8      481.600006     - .799987793

 38748.1|- --     38751.2      454.399994     + 3.1000061

 39198.6|- --     39178.4      427.199997     - 20.1999969

 39649.1|- --     39647.4      469            - 1.69999695

 40099.7|- --     40116.7      469.300003     + 17

 40550.3|- --     40541.1      424.399994     - 9.10000611

 41000.9|- --     40962.3      421.200012     - 38.5

 41451.5|- --     41394.9      432.599991     - 56.5

        |  --     41816.0

        |  --     42243.5

        |  --     42691.3

        |  --     43140.6

INTERVALS RECORDED:  40
MEAN:  449.2225

DEVIATION FROM SUBJ OWN AVERAGE BEAT INTERVAL:
 6.4774971
 22.7775002
 .877498627
 4.87750626
 3.17749405
 30.9775047
 12.9225044
 17.1225014
 11.0775032
 10.2775002
 30.2775002
 8.4774971
 12.8775063
```

```
 22.4225044
 .222499847
 18.6775017
 13.7224998
 12.0775032
 18.2775001
 7.4774971
 11.7224998
 2.0225029
 14.2224998
 4.37750626
 35.822506
 1.72249985
 10.4224968
 17.1224937
 27.822506
 3.67749405
 6.9224968
 1.5775032
 32.3775063
 5.17749405
 22.0225029
 19.7775001
 20.0775032
 24.8225059
 28.0224876
 16.622509


AVERAGE DEVIATION FROM SUBJ AVG BEAT:  14.2852509



SD: 17.464156



SUBJECT PRE-BEAT DEVIATIONS:
NUMBER: 11 AVERAGE: 22.1545452


SUBJECT POST-BEAT DEVIATIONS:
NUMBER: 30 AVERAGE: 51.7666654


SUBJECT ABSOLUTE DEVIATIONS:
NUMBER: 41 AVERAGE: 43.8219502
```

APPENDIX I

WAIS SUBTEST SCALE SCORES, VERBAL IQ, PERFORMANCE IQ, FULL SCALE IQ ON EACH SUBJECT, AND DERIVED MEANS

WAIS SUBTEST SCALE SCORES, VERBAL IQ, PERFORMANCE IQ, FULL SCALE IQ ON EACH SUBJECT AND DERIVED MEANS[a]

SUBJECT	AGE	INFO	COMPREHEN	ARITH	SIMILAR	DIGIT SPN	VOCAB	DIGIT SYM	PICT COMP	BLOCK DES	PICT ARR	OBJ ASSM	VERB IQ	PERF IQ	FULL SC
03	34	9	5	3	0	2	9	4	8	5	7	7	66	76	68
07	17	4	3	2	8	6	3	5	4	6	2	7	72	68	68
10	28	4	7	2	10	1	7	3	6	5	4	5	71	65	66
15	34	4	5	4	3	2	4	6	6	4	5	4	62	68	62
02	41	3	4	2	0	0	5	5	4	3	5	4	54	67	58
14	29	4	4	2	2	4	5	3	6	3	4	3	61	60	58
11	30	1	4	2	3	1	4	3	6	5	2	7	55	65	57
08	24	3	3	1	2	0	4	5	5	3	2	5	54	60	54
05	18	2	0	1	3	0	0	4	5	3	4	5	49	63	53
01	18	2	4	1	2	0	4	0	3	2	4	3	56	51	51
06	22	1	0	0	0	0	0	4	6	7	5	5	42	69	51
04	46	1	4	2	2	0	0	0	3	1	0	0	52	52	49
09	24	3	1	1	6	0	0	0	3	3	2	5	52	51	49
13	24	3	3	2	0	1	2	3	7	1	0	1	52	50	48
12	29	3	0	2	0	0	0	0	1	1	0	1	45	39	—
AVG:	28	3.1	3.1	1.8	2.7	1.1	3.1	3	4.9	3.5	3.1	4.1	56.2	60.3	56.6

a. The Full Scale IQ for Subject 12 could not be derived. Therefore, this subject was not considered in the reporting of the mean Full Scale score of 56.6.